REPORT
87

Department of
Industry and Resources

STRUCTURE AND PETROLEUM PROSPECTIVITY OF THE GASCOYNE PLATFORM WESTERN AUSTRALIA

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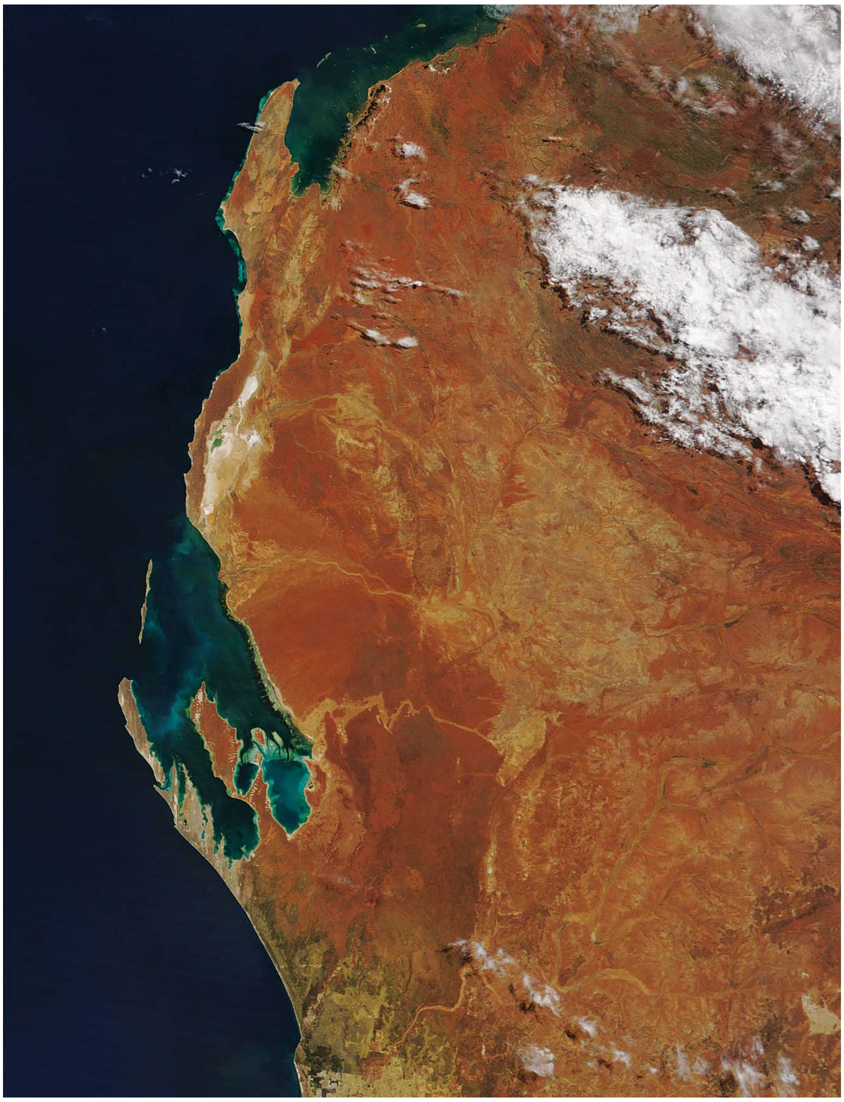

Geological Survey of Western Australia

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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STRUCTURE AND PETROLEUM PROSPECTIVITY OF THE GASCOYNE PLATFORM, WESTERN AUSTRALIA

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True-colour MODIS (Moderate Resolution Imaging Spectroradiometer) image of the Southern Carnarvon Basin, from the NASA/GSFC (Goddard Space Flight Centre) *Terra* satellite

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Structure and petroleum prospectivity of the Gascoyne Platform, Western Australia

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Abstract

The Gascoyne Platform is a poorly explored, structurally elevated part of the Southern Carnarvon Basin, with only one new-field wildcat per 12 000 km^2, and is a frontier region for petroleum exploration in Western Australaia. It contains up to 5000 m of ?Cambrian–Triassic strata with a thin Cretaceous–Cainozoic cover. Depocentres initially formed in the southern part of the platform, but the focus of deposition shifted to the north in the Late Devonian. During most of the mid-Carboniferous to earliest Cretaceous the platform was a positive structural feature, which diverted sediments mainly to the north and west. The onshore central part of the platform contains a north-trending elongate trough that shallows abruptly to the east and south, and gradually to the west and north towards the Cape Range peninsula. Along its eastern margin, the Wandagee and Ajana Ridges form the boundary with Permian depocentres. To the west, the platform rises towards the Bernier Ridge. In the southwest, the Geelvink Fault System and its northern extension forms a hinge zone that separates the platform from the Abrolhos, Houtman, and Exmouth Sub-basins.

Five tectonic episodes have affected the Gascoyne Platform during the: Early Ordovician, Late Carboniferous – Early Permian, mid- to Late Permian, Late Jurassic – Early Cretaceous, and Miocene. All pre-Cretaceous tectonic episodes produced normal, extensional faults and the Early Cretaceous breakup event overprinted older structures. Many of these faults were reactivated with reverse movement during Miocene compression. Pre-Cretaceous structural trends on the Gascoyne Platform are oriented north-northeasterly in the north, northwesterly in the centre, northeasterly in the south, and northerly in the east.

The main petroleum source rocks known within the Gascoyne Platform are from the Silurian Coburn and Devonian Gneudna Formations, which are mostly early mature to mature. The main objective for petroleum exploration has been the Birdrong Sandstone sealed by the Muderong Shale within Miocene anticlinal structures, but with no success. Additional plays that have not been investigated in structurally valid positions include faulted traps with objectives such as the Tumblagooda Sandstone sealed by the Kockatea Shale in the southwest, and reefal carbonate facies within the Gneudna Formation to the north. Peak hydrocarbon expulsion for Palaeozoic sources was during the Late Permian to Middle Jurassic. Long-range hydrocarbon migration from the Triassic Kockatea Shale in the adjacent Abrolhos Sub-basin is also possible, but trap formation post-dates peak hydrocarbon expulsion for this source during the Late Jurassic. Although post-Palaeozoic traps are unlikely to be effective, secondary migration is possible.

KEYWORDS: geological structures, stratigraphy, seismic interpretation, gravity anomalies, magnetic anomalies, source rock, petroleum potential, Gascoyne Platform, Southern Carnarvon Basin, Western Australia.

Introduction

The Gascoyne Platform covers an area of about 120 000 km^2 in the central Southern Carnarvon Basin, extending from south of Kalbarri to north of Coral Bay, and is approximately equally divided between onshore and offshore (Fig. 1). It was first referred to as the Gascoyne Sub-basin by Condon (1954) and was later split into the northern and southern Gascoyne Basins by Geary (1970), but that division has not been adopted elsewhere. It was renamed the Gascoyne Platform by Hocking (1994). The area is regarded as a structurally elevated platform, south of the Cardabia transfer fault zone (Fig. 1), where Ordovician to lowermost Permian strata subcrop below Cretaceous–Cainozoic cover. Quaife et al. (1994) considered that the 'Edel Province' (previously the 'Edel Platform'; Smith and Cowley, 1987) was the southern extension of the Southern Carnarvon Basin depositional system. The 'Edel Terrace' (Hocking, 1994) has a similar structural configuration to the Gascoyne Platform and is no longer differentiated. Seismic and limited well data indicate a thin Triassic section above Ordovician strata within parts of the former 'Edel Terrace', which is consistent with the thin Triassic section in the coastal cliffs south of Kalbarri. In the southwest, the Geelvink Fault System ('Geelvink Fault' of Marshall and Lee, 1988) separates the Gascoyne Platform from the Abrolhos Sub-

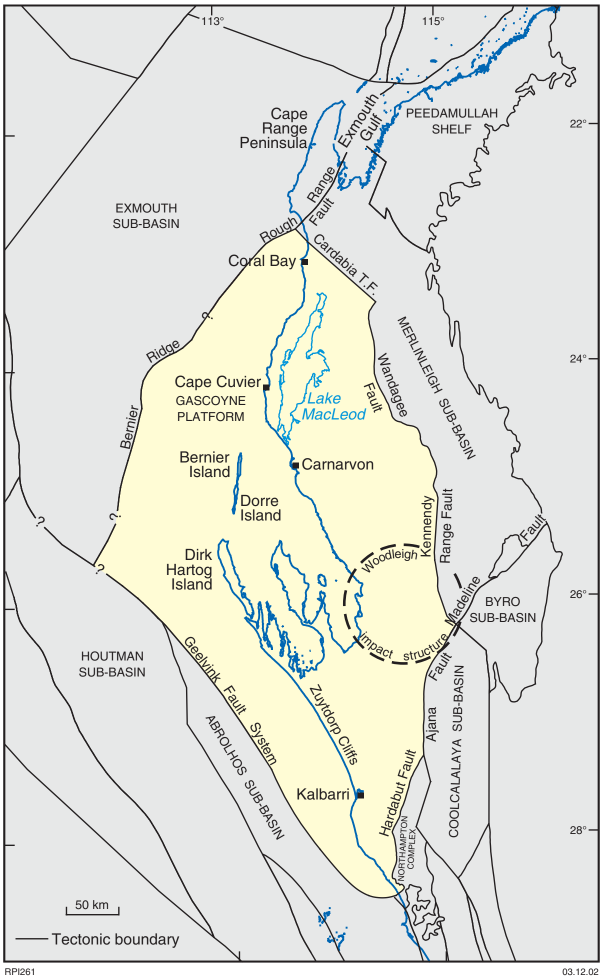


Figure 1. Location of the Gascoyne Platform showing the regional tectonic framework

basin (Bradshaw et al., in prep.). The northwestern boundary of the Gascoyne Platform is along a basement high (Bernier Ridge; Lockwood and D'Ercole, in prep.). The eastern boundary, defined by the Wandagee, Kennedy Range, and Ajana Fault Systems (Fig. 1), separates the platform from the Carboniferous–Permian depocentres of the Merlinleigh, Byro, and Coolcalalaya Sub-basins, below which the lower to mid-Palaeozoic succession was buried by up to 5 km. The southern boundary with the Northampton Complex is along the Hardabut Fault (Fig. 1).

The onshore part of the Gascoyne Platform is poorly explored, with only eight onshore petroleum exploration wells (new-field wildcats), 22 stratigraphic tests (Appendix 1), and 16 wells drilled on Dirk Hartog Island to define an anticlinal structure. Only 2622 line-kilometres of seismic data have been acquired onshore (Appendix 2), of which about 25% are of too poor quality to interpret. About 18 000 line-kilometres of seismic data were acquired in the offshore part of the platform from the 1960s to early 1990s. The only wells in the offshore part of the Gascoyne Platform are Pendock 1 and Edel 1.

The area mapped for this Report extends south from the Rough Range Fault to immediately southwest of the Geelvink Fault System (Fig. 1), and thereby includes the northeastern segment of the Abrolhos Sub-basin. The Abrolhos Sub-basin contains a Permian and Triassic sedimentary succession typical of the Perth Basin, and an Ordovician–Carboniferous, Cretaceous, and younger section characteristic of the Carnarvon Basin (Crostella, 2001). Only a brief account of the Permian–Triassic stratigraphy of the Abrolhos Sub-basin is included in this Report.

Previous investigations

Exploration of the onshore Gascoyne Platform began in 1902 with the drilling of the first artesian bore, Pelican Hill 1 (Maitland, 1909). Subsequent artesian bores were also used in early evaluations of the region (Clapp, 1926; Condit, 1935; Hobson, 1936), but only 31 of these provide stratigraphic information for the Palaeozoic succession, because the majority terminated in the Cretaceous Birdrong Sandstone aquifer (Iasky and Mory, 1999). The results from many of these bores are difficult to interpret because only drillers' records are available (Playford and Chase, 1955). For example, many of them penetrate a red to brown sandstone below the base Cretaceous unconformity that may be either the Lower Devonian Kopke Sandstone or Ordovician Tumblagooda Sandstone.

Mapping of surface anticlines in the northern onshore Gascoyne Platform began in the 1930s (Raggatt, 1936), and the Bureau of Mineral Resources (BMR, now Geoscience Australia) commenced outcrop mapping in 1948, followed by systematic, regional aeromagnetic and radiometric surveys in the 1950s, and regional helicopter gravity surveys in the late 1960s. In the early 1950s, Western Australian Petroleum Pty Ltd (WAPET) began petroleum exploration in the Carnarvon Basin by drilling wells on anticlinal features and topographic highs. In 1953 the company made the first oil discovery in Western Australia with its first well on the Rough Range anticline, Rough Range 1, thereby prompting further exploration of the basin, but without success onshore. Of the 40 follow-up wells drilled on the Cape Range peninsula, only Roberts Hill 1 and Parrot Hill 1 recovered significant hydrocarbons. Farther south WAPET drilled four shallow stratigraphic tests in the northern Gascoyne Platform (Grierson 1–3 and Cape Cuvier 1) and a new-field wildcat, Warroora 1, on an anticline in the Lake MacLeod area. This well was drilled to a total depth (TD) of 1826 m, but was dry. Between 1955 and 1957, WAPET drilled 16 shallow stratigraphic wells on Dirk Hartog Island to define an anticlinal structure, and tested its Cretaceous culmination with Dirk Hartog 17B, which was drilled to a TD of 1523 m just below the top of the Tumblagooda Sandstone. The company continued its stratigraphic drilling on the Wandagee Ridge with Wandagee 1 and Wandagee Coreholes 1 and 3 in 1962. At that time, Continental Oil Company (Conoco) began exploration in the central onshore Gascoyne Platform and conducted a regional seismic survey, which led to the drilling of Yaringa 1 in 1966. In 1967, WAPET tested two other anticlines north of Lake MacLeod (Chargoo 1 and

Gnaraloo 1), and in 1968, Magellan Petroleum Pty drilled Hamelin Pool 1 and 2 to investigate the evaporite rocks of the Dirk Hartog Group and the petroleum potential of the Shark Bay area (Continental Oil Company of Australia Ltd, 1968).

Petroleum exploration in the offshore part of the Gascoyne Platform began in 1965 when Tasman Oil and Conoco carried out regional aeromagnetic and seismic surveys respectively. This was followed up by WAPET with a regional seismic survey in 1966 and a regional aeromagnetic survey in 1969. Canadian Superior Oil Australia also took an active interest in this offshore region and carried out several seismic surveys between 1967 and 1973 before Genoa Oil NL farmed in and drilled the first offshore well (Pendock 1) in the Southern Carnarvon Basin in 1969. The well was drilled on a seismically defined anticline mapped at the base of the Cretaceous section (Geary, 1970), but there were only minor hydrocarbon shows from the Silurian and Devonian succession. In the southern Gascoyne Platform, formerly the 'Edel Terrace', Ocean Ventures carried out several seismic surveys before drilling Edel 1 in 1972 on an anticline mapped at a presumed Jurassic or Triassic horizon, but no hydrocarbons were found. The well intersected Cainozoic strata overlying Tumblagooda Sandstone intercalated with volcanic rocks (Crostella, 2001). In the early 1970s WAPET, Conoco, and Oceania also conducted regional seismic and gravity surveys, and Oceania drilled Tamala 1 as a stratigraphic test in the onshore Shark Bay area in 1973.

With the exception of Conoco, who retained an interest in the southern offshore Gascoyne Platform and conducted seismic surveys in 1978 and 1980 in that area, petroleum exploration in the Southern Carnarvon Basin almost ceased by the mid- to late 1970s. In 1981, Eagle Corporation Ltd investigated a gravity anomaly and drilled two holes to test for mineralization within carbonate rocks of the Dirk Hartog Group and shallow Permian coal (Layton and Associates, 1981), and unknowingly drilled into the Woodleigh impact structure (Iasky et al., 2001). Around the same time, CRA Exploration tested the eastern margin of the Gascoyne Platform (Devlin, 1982a,b) while exploring for Permian coal in the Merlinleigh, Byro, and Coolcalalaya Sub-basins.

In the mid-1980s Canada North West acquired seismic data in the central onshore Gascoyne Platform before drilling Quobba 1. This well tested an anticlinal structure at the Birdrong Sandstone level and was terminated in the Dirk Hartog Group at 1718 m as a stratigraphic test. Three holes were drilled by BHP for Cu–Pb mineralization in the southern part of the onshore Gascoyne Platform in the early 1990s (Edgar, 1994), and at this time there was also renewed interest in the offshore part of the platform. Mobil Exploration carried out a seismic survey near Pendock 1 in 1992, and Enterprise Oil and Seafield Resources carried out seismic surveys in the southern Gascoyne Platform in 1992, 1993, and 1997. As a result of the earlier survey, Seafield Resources drilled Livet 1 in the Abrolhos Sub-basin in 1996.

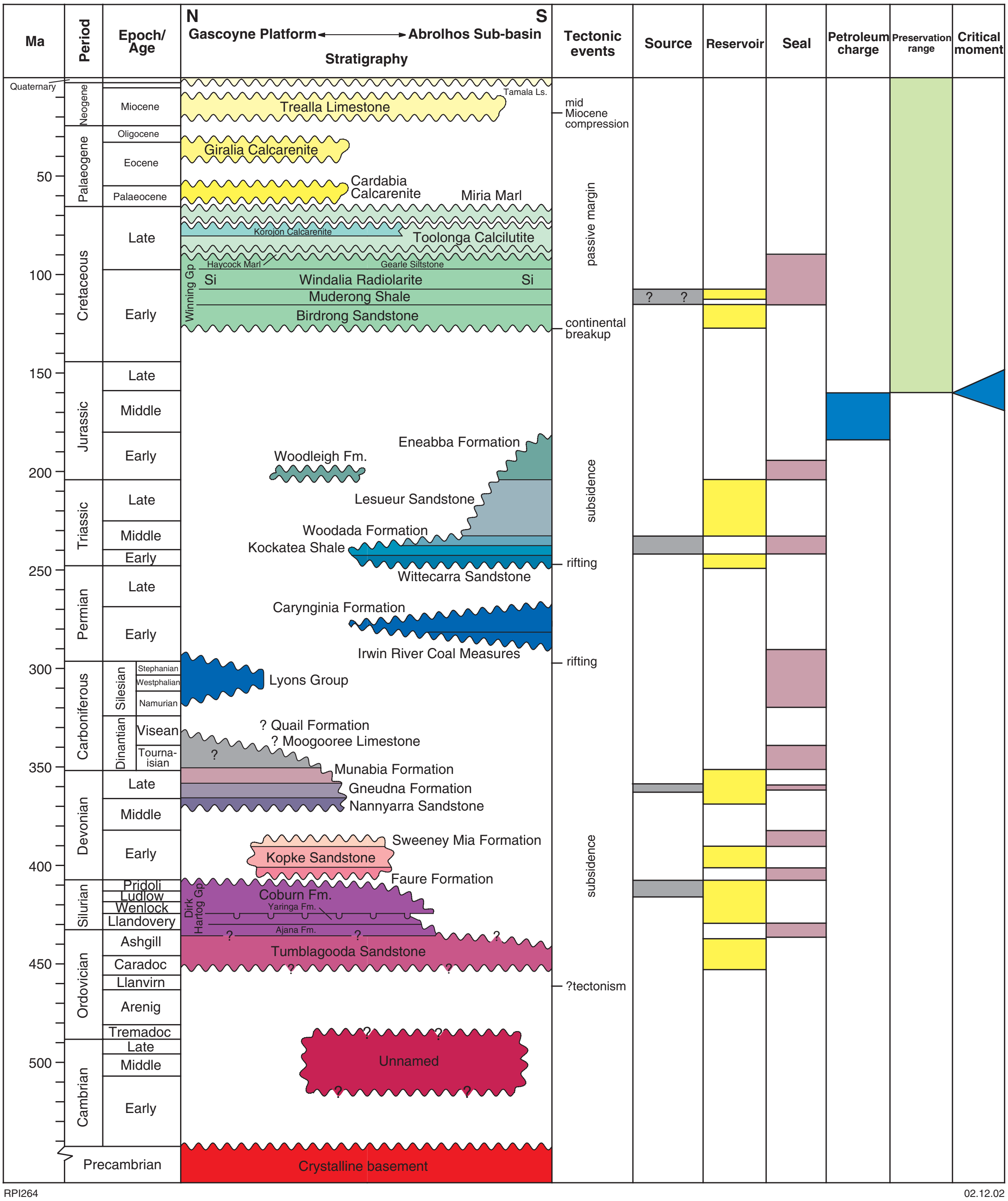
In an attempt to gain additional stratigraphic knowledge across the platform, the Geological Survey of Western Australia (GSWA) drilled a series of shallow, fully cored stratigraphic tests in 1996 (GSWA Barrabiddy 1A and GSWA Mooka 1), 1999 (GSWA Woodleigh 1 and GSWA Woodleigh 2/2A), and 2001 (GSWA Boologooro 1, GSWA Edaggee 1, and GSWA Yinni 1), and also participated in the drilling of stratigraphic tests by Pace Petroleum (Yaringa East 1) and Knight Industries (Coburn 1) in 1997. Of these wells only Barrabiddy 1A can be regarded as having seismic control.

In 2001–02, Shell Australia and Woodside Energy Ltd were awarded exploration permits across the boundary between the Gascoyne Platform and the Exmouth Sub-basin. Their activities included aeromagnetic and seismic surveys (Partington et al., 2003). In 2002, Empire Oil and Gas NL drilled Carlston 1 to test a reefal Devonian unit (Point Maud Member of the Gneudna Formation) based on the Carlston and Carlston Detail seismic surveys acquired in 1994. Carlston 1 was terminated at 1003 m without finding the objective, because the seismic data were misinterpreted. At the southwestern margin of the Gascoyne Platform, Origin Energy Developments Pty Ltd drilled Morangie 1 in 2002 to test sandstone below the Lower Triassic Kockatea Shale. The objective was water saturated and the well was terminated at 2188 m. Woodside Energy Ltd drilled Herdsman 1 in 2003 west of the Rough Range Fault in the Exmouth Sub-basin. A new permit in the southern part of the Gascoyne Platform has been issued to Chimelle Petroleum Ltd, who were planning a regional seismic survey at the time of writing (March 2003).

Present study

This Report expands on the work of Iasky and Mory (1999) by extending the structural interpretation into the offshore Gascoyne Platform and evaluating the petroleum prospectivity of the pre- and post-breakup sedimentary succession. The structural interpretation was conducted on a regional scale using a total of 7654 line-kilometres of offshore and 580 line-kilometres of onshore seismic data (Appendix 3; Plate 1). Gravity and magnetic data were used qualitatively to complement the interpretation in areas where the seismic-data coverage is poor. Seven horizons were mapped in two-way time (Miocene unconformity, Plate 2; base Cretaceous unconformity, Plate 3; top Kockatea Shale, Plate 4; mid- to Late Permian unconformity, Plate 5; base Gneudna Formation, Plate 6; top Tumblagooda Sandstone, Plate 7; and near-basement unconformity, Plate 8), but were not depth converted because of the limited offshore well control. Isopach maps for six selected sections were derived from two-way-time maps, using interval velocities from well data, in order to understand the evolution of the region. Isopach maps for four main sequences within the Cretaceous succession were determined from petroleum exploration and stratigraphic wells, water bores, mineral holes, and outcrop data (Appendices 4 and 5).

Thermal maturity of source rock was modelled using BasinMod on petroleum exploration and stratigraphic wells, together with 'pseudo wells' (interpreted stratigraphy at selected shotpoints along seismic sections), to create a maturity map of the effective Palaeozoic source rocks.



Si Siliceous
Fm. Formation
Gp Group
Unconformity

Figure 2. Stratigraphy and petroleum-system elements of the Gascoyne Platform and northern part of the Abrolhos Sub-basin (modified from Iasky and Mory, 1999)

Stratigraphy

The Gascoyne Platform contains a ?Cambrian–Triassic succession underlying a thin Cretaceous–Cainozoic section. The following review of the stratigraphy (Fig. 2) onshore is based on well data, as discussed by Iasky and Mory (1999), whereas offshore it is based largely on seismic mapping because of the scarcity of offshore wells. The Permian and Triassic succession, as mapped in the western Abrolhos Sub-basin, is also discussed. More extensive lithological descriptions and a historical perspective of the stratigraphy are found in Hocking et al. (1987), Gorter et al. (1994, 1998), Mory et al. (1998), and Iasky and Mory (1999). Two-way-time differences between interpreted seismic horizons were converted into approximate thicknesses using a single interval velocity (Appendix 6) derived from the seven wells for which velocity surveys were conducted.

?Cambrian to earliest Ordovician

An unnamed unit below the Tumblagooda Sandstone (Fig. 2) appears to be widespread throughout the southern offshore Gascoyne Platform (south of latitude 26°30'S). Evidence for this is based on a high-amplitude seismic reflection, interpreted as an unconformity at the base of the Tumblagooda Sandstone (Fig. 3; Plate 8), overlying a package of high-amplitude, continuous, parallel reflectors. The amplitude and continuity of these reflections are greatest near Edel 1, and decrease to the south; the northern extent of the unit is unclear because of the poor data quality north of Edel 1 (Fig. 4). The unit spans up to 650 milliseconds on seismic sections, which is equivalent to about 2000 m using a generalized velocity function (Fig. 5; Appendix 7). The seismic character implies consistent bedding, possibly due to upward-coarsening cycles similar to those in outcrop of the overlying Tumblagooda Sandstone (Hocking, 1991). Although there is no clear seismic reflection at the contact between the unnamed unit and basement, in places there is a distinct change from parallel reflections to a more chaotic seismic character, which may be attributed to crystalline basement.

The unnamed unit beneath the Tumblagooda Sandstone must be Ordovician or older. The unit may correlate with the ?Cambrian–Ordovician siliciclastic section (399–1073 m) in Wandagee 1 (Fig. 6, Plate 9) in which earliest Ordovician conodonts were extracted from core 5 (704–708 m; Mory et al., 1998; Iasky and Mory, 1999). If the conodont fauna was in situ, the carbonate and underlying sandstone may be older than the Tumblagooda Sandstone. Laminated, silty redbed facies from core 7 (874–877 m) in this well show no sign of bioturbation and are atypical of the Tumblagooda Sandstone. An alternative but less likely interpretation is that the Tumblagooda Sandstone is Cambrian in age, with a break (of up to 60 m.y.) between it and the overlying Dirk Hartog Group in the southern part of the Gascoyne Platform.

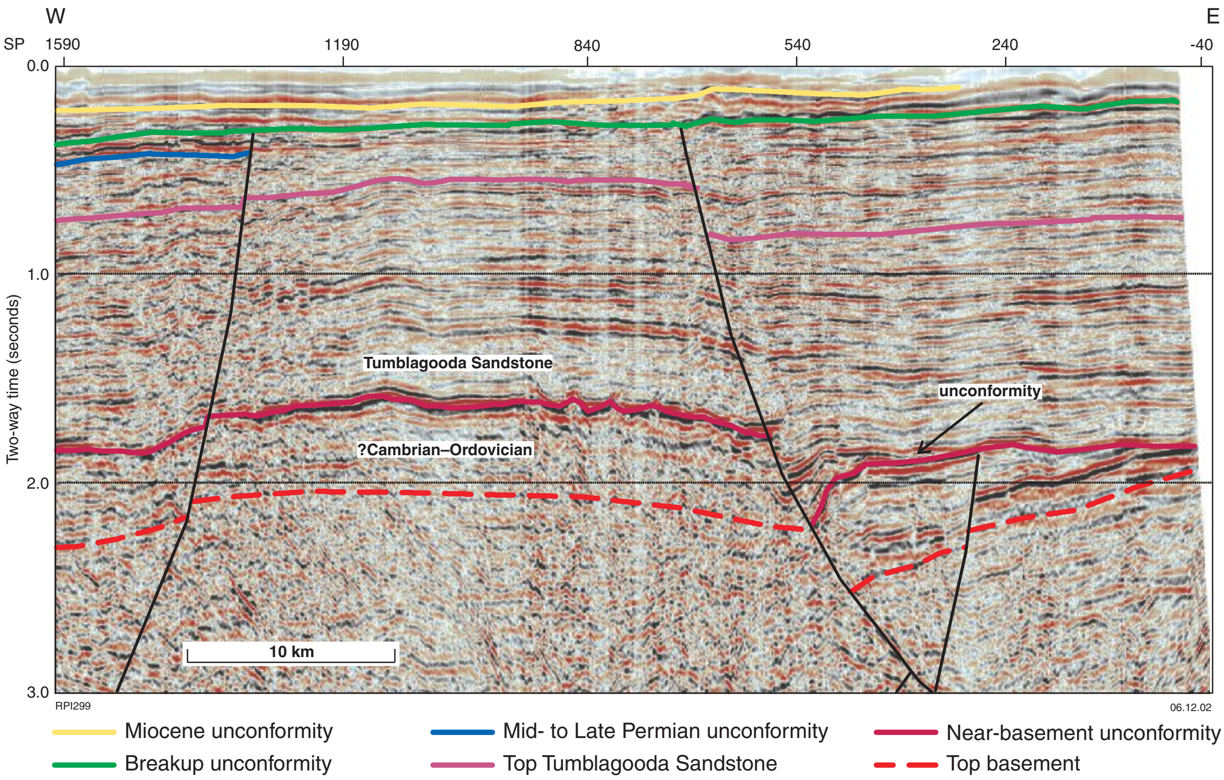


Figure 3. Eastern end of seismic line H78-122 (SP 0–1600) showing the unconformity at the base of the Tumblagooda Sandstone and the underlying unit. Note the growth on the fault at SP 540 during early deposition of the Tumblagooda Sandstone

There is a possibility that the unnamed unit correlates with the uppermost part of the Badgeradda Group, which consists of sandstone and siltstone in the Badgeradda Range, Woodrarrung Range, and Errabiddy Hills, just east of the Coolcalalaya Sub-basin. Leiospheres (*Leiosphaeridia* sp.) and filaments taken from the lower part of the Badgeradda Group indicate a late Mesoproterozoic to Neoproterozoic age (c. 1200–750 Ma; Grey, K., 2003, written comm.). However, current crescents illustrated by Perry and Dickins (1960, plate 4) from the Yarrawolya Formation at the top of the group may be imprints of arthropod cephalons elongated somewhat by currents. If so, this implies a maximum age of earliest Cambrian for the uppermost part of the Badgeradda Group and a possible correlation with the redbed section below the Early Ordovician conodont fauna in Wandagee 1. If the pre-Tumblagooda Sandstone unit correlates with the Badgeradda Group, it implies Cambrian deposition was widespread in the onshore and offshore northern Perth and Southern Carnarvon Basins, and extended onto the Yilgarn Craton.

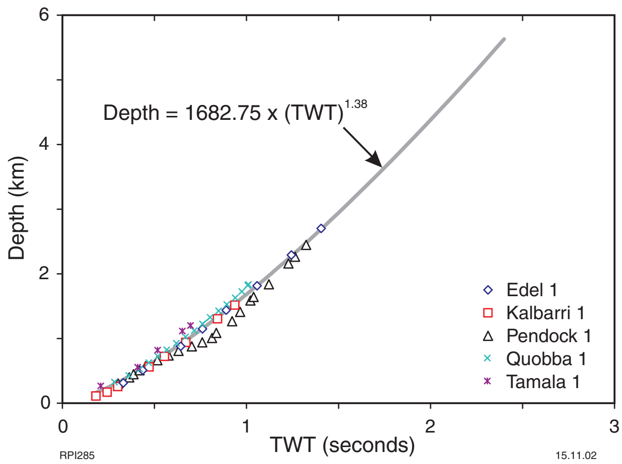


Figure 5. Average velocity function for the Gascoyne Platform

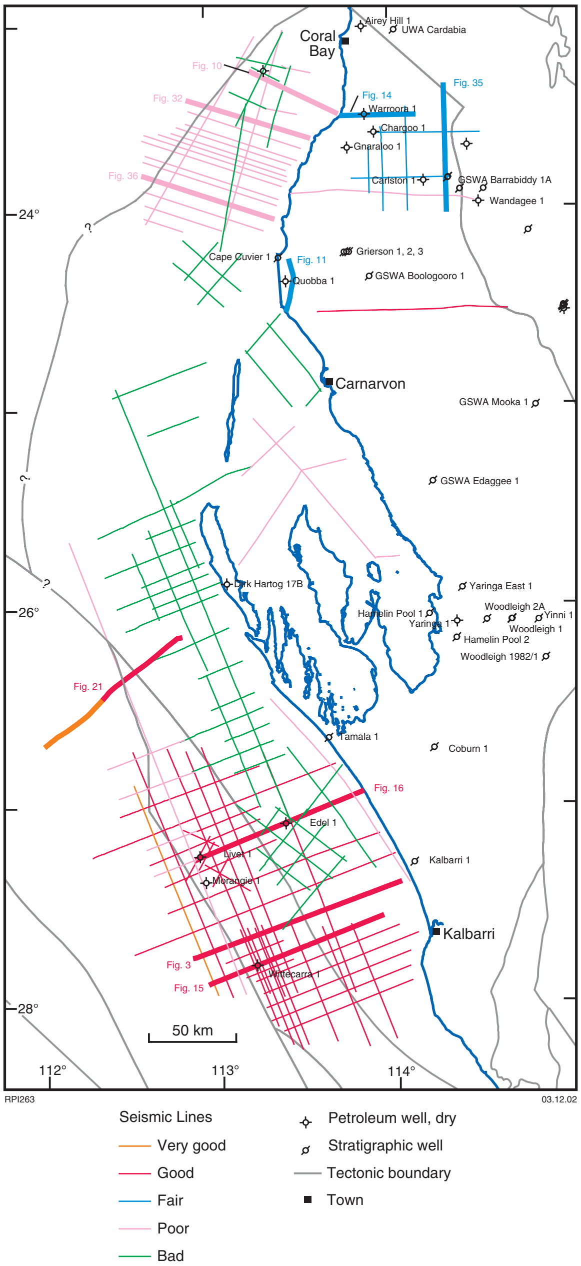


Figure 4. Seismic lines used for the interpretation. Colours indicate quality of the seismic data

Ordovician

The Tumblagooda Sandstone (Clarke and Teichert, 1948) consists predominantly of classic coarse-grained redbed facies, with only minor amounts of siltstone and mudstone, deposited in a braided fluvial to coastal setting (Hocking, 1991) or mixed fluvial and eolian sandsheet environment (Trewin, 1993a,b). The age of the formation appears to be Ordovician based on the Llandovery (Early Silurian) conodont faunas identified in the overlying Ajana Formation of the Dirk Hartog Group in the central part of the Gascoyne Platform (Mory et al., 1998). However, the age of the Tumblagooda Sandstone may extend from Cambrian to Early Ordovician, based on its similarity to the redbed facies in Wandagee 1 (811–1073 m).

The seismic character of the Tumblagooda Sandstone is dominated by low- to high-amplitude, parallel reflections (Fig. 3) similar to the underlying unnamed unit. In places, the base of the Tumblagooda Sandstone can be resolved in the seismic data by a high-amplitude reflection, indicating a sudden change in acoustic impedance, characteristic of unconformities (Fig. 3). The top of the formation does not display a distinct reflection, implying similar acoustic impedance to the overlying units, which are Permian to Triassic in the southern part of the area, and Silurian farther north near Shark Bay. In some areas, minor faults appear to truncate at, or near, this contact (Plate 10, section CC').

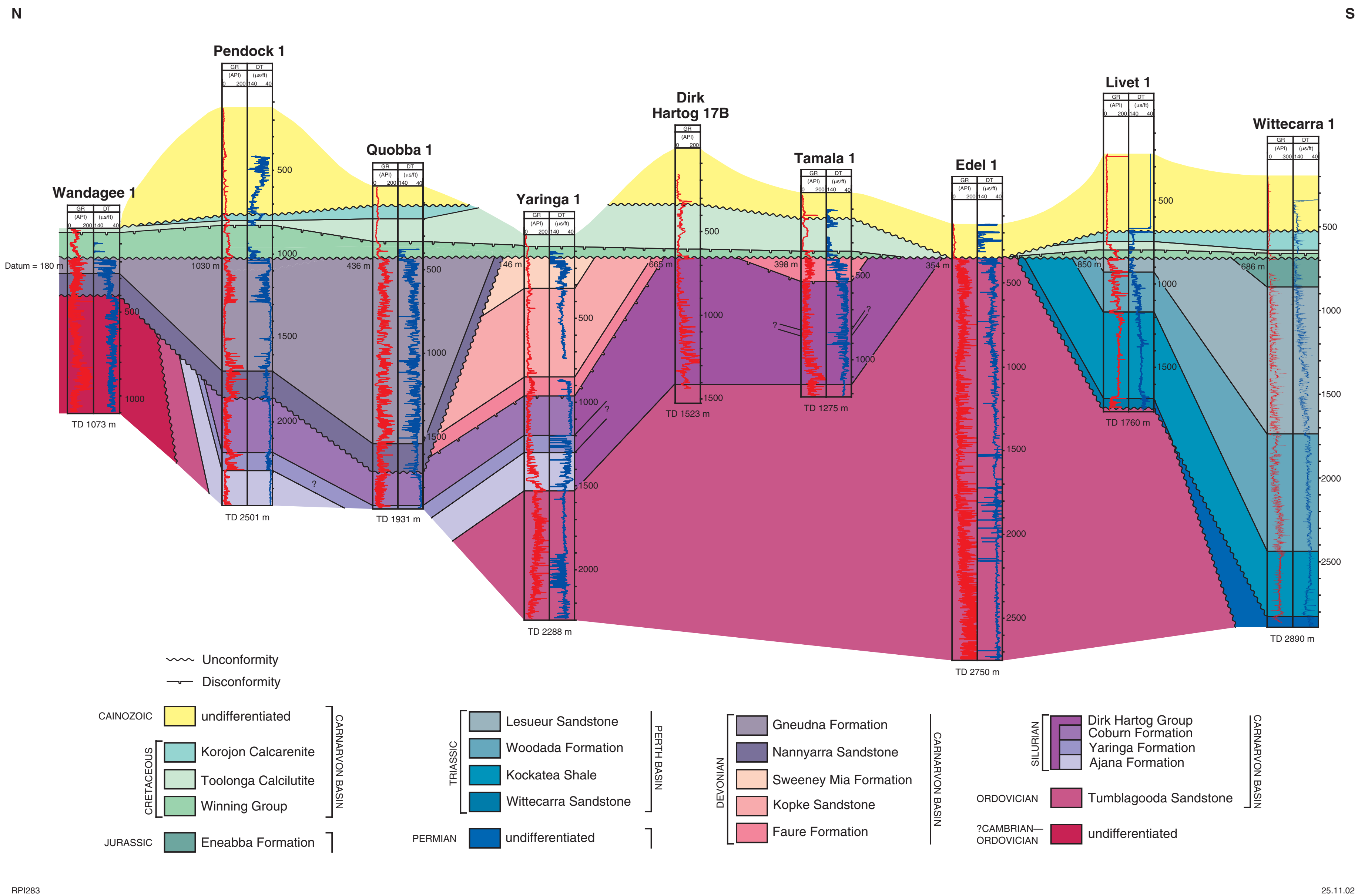


Figure 6. Simplified north–south well correlation. Datum is the base Cretaceous (breakup) unconformity. Refer also Plate 9

The top of the Tumblagooda Sandstone was mapped in two-way time throughout the study area (Fig. 7; Plate 7), but the base of the unit could only be identified in the southern and central part of the study area, thereby limiting the extent of isopachs for this unit. The isopach map (Fig. 8) shows that the formation is thicker in the southern part of the offshore Gascoyne Platform. This is consistent with onshore well and outcrop data (Hocking, 1991), which indicate a maximum thickness of about 3500 m near the Ajana Ridge. The average thickness in the mapped area is about 2000 m, although there is some local thickening at latitude 27°S and a general thickening towards the Murchison River at Kalbarri (Fig. 8).

?Ordovician to Silurian

The Dirk Hartog Group conformably, or possibly disconformably, overlies the Tumblagooda Sandstone. The group is absent in the southern part of the Gascoyne Platform (Fig. 9). Hocking (1991) considered that part of the Tumblagooda Sandstone section east of the Northampton Complex might correlate with the lower part of the Dirk Hartog Group. The group was deposited in a relatively restricted marine environment, with brief connections with an open-marine environment throughout the Silurian. It has been subdivided into the Ajana, Yaringa, and Coburn Formations (Mory et al., 1998).

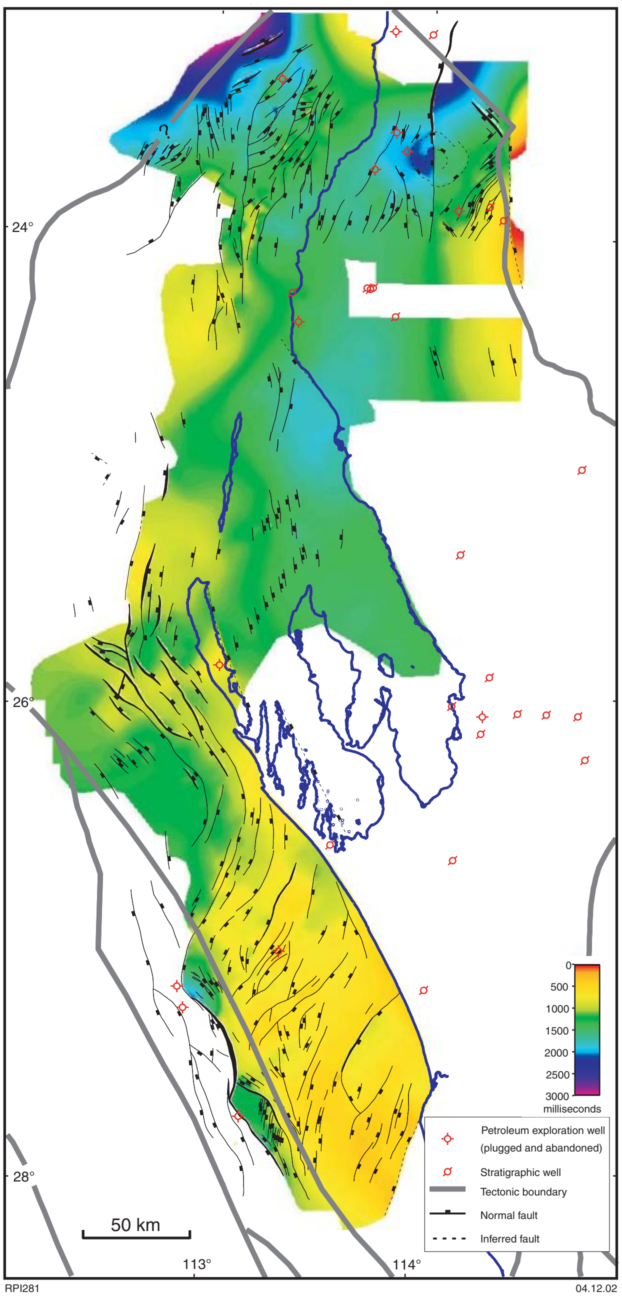


Figure 7. Two-way time structure map of the top Tumblagooda Sandstone

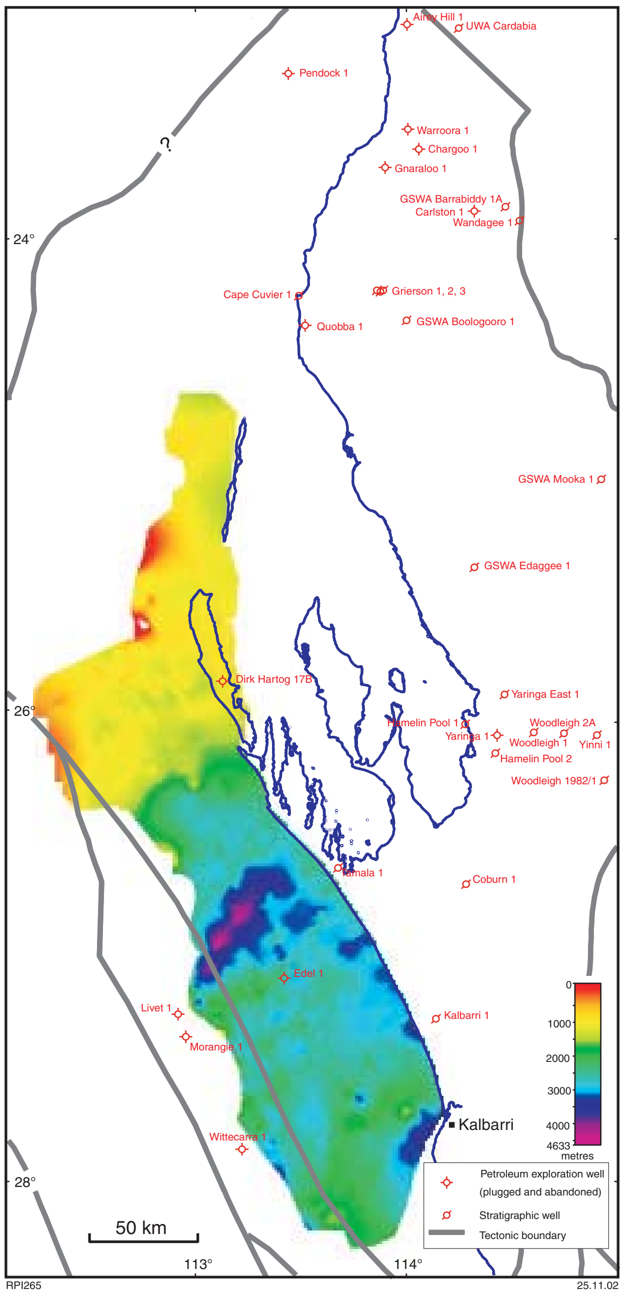


Figure 8. Tumblagooda Sandstone isopach map. Extent of isopach is limited by the seismic interpretation of the base of the unit

Dolomitic carbonate in Wandagee 1, similar to that of the Dirk Hartog Group, yielded an Early Ordovician conodont fauna (Mory et al., 1998), but from seismic data it is unclear whether this section is continuous with the Dirk Hartog Group, and therefore part of it, or as preferred here, a separate, older unit (Fig. 6).

The Ajana Formation, at the base of the Dirk Hartog Group, shows shoaling-up cycles (Gorter et al., 1994) of grey sandy mudstone, laminated dolomitic mudstone, and wackestone. Oxidized siltstone at the base of the formation (Marron Member; Mory et al., 1998) may represent a transitional facies between the Dirk Hartog Group and the Tumblagooda Sandstone. The Yaringa Formation, overlying the Ajana Formation, consists mainly of dolomite and evaporite rocks, although it is tentatively correlated with a predominantly sandstone interval in Pendock 1 (Fig. 6; Plate 9). The Coburn Formation mainly consists of dolomitic carbonate, and since it lies disconformably on the Marron Member along the eastern margin of the Gascoyne Platform (Iasky and Mory, 1999), it probably paraconformably overlies the Yaringa Formation to the west.

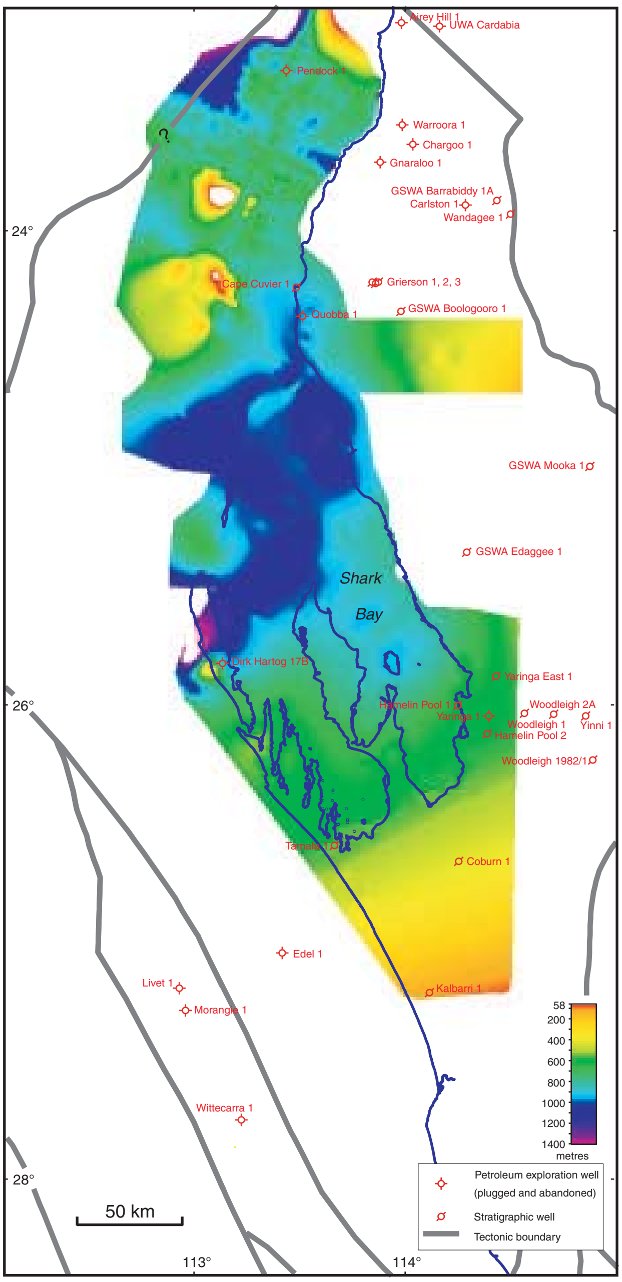


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Figure 9. Dirk Hartog Group isopach map

The Dirk Hartog Group has an indistinct seismic character (Fig. 10) and neither the top nor bottom of the group displays a distinct reflection. The thickness of the group cannot be estimated in most of the onshore area as there are insufficient data. The thickest known section is 740 m in Dirk Hartog 17B, but the isopachs (Fig. 9) show thickening to about 1100 m to the north of Shark Bay. Apparent thickening of the group in the northwest may be an artefact produced by inadequate data. The group thins to the east and south and is absent in Edel 1, presumably due to post-Silurian erosion. The hiatus between the Dirk Hartog Group and Lower and Upper Devonian units (Fig. 2) shown by Gorter et al. (1994) is not evident on seismic data (Fig. 10).

Devonian

The Lower Devonian succession is separated from a Middle–Upper Devonian succession by a mid-Devonian hiatus (Iasky and Mory, 1999). The Faure Formation (base), Kopke Sandstone, and Sweeney Mia Formation (top) constitute the lower succession, and the Nannyarra Sandstone, Gneudna Formation, and Munabia Formation form the upper succession (Fig. 2).

The Lower Devonian Faure Formation consists of mudstone, dolomite, and fine-grained sandstone and is disconformable on the Dirk Hartog Group (Gorter et al., 1994). Deposition was in a low-energy, saline to hypersaline, shallow-water environment under arid conditions (Yasin and Mory, 1999a). The formation is only present in the southern part of Gascoyne Platform, and ranges in thickness from 72 to 149 m in the four wells in which it has been identified (Coburn 1, Hamelin Pool 1, Tamala 1, and Yaringa 1). The Kopke Sandstone conformably overlies the Faure Formation and is an upward-coarsening, sandstone-dominated unit with minor amounts of dolomite and siltstone, deposited in deltaic to fluvial environments (Yasin and Mory, 1999a). The unit has been identified in the central-southern part of the Gascoyne Platform, with a maximum known thickness of 496 m in Yaringa 1 (Fig. 6; Plate 9). The Sweeney Mia Formation conformably overlies the Kopke Sandstone, and consists of oxidized, mixed carbonate and siliciclastic rocks with minor evaporitic beds, deposited in reducing, lagoonal to supratidal environments. The formation is known only in the central part of the Gascoyne Platform, where the maximum known thickness is 192 m in Yaringa East 1.

The Nannyarra Sandstone marks the beginning of the mid- to Upper Devonian succession and is interpreted as a major marine transgression that commenced in the Emsian (late Early Devonian; Mory et al., 2003) or

Eifelian (Middle Devonian; Iasky and Mory, 1999). The unit unconformably overlies Lower Devonian or older rocks, although there is no angularity at the contact based on seismic data. The unit consists predominantly of sandstone, with minor amounts of siltstone, and was deposited in a low-energy, shallow-marine, intertidal environment. The maximum known thickness of the Nannyarra Sandstone is 190 m in Quobba 1 (Fig. 6; Plate 9). Well data indicate that the unit is widespread in the northern Gascoyne Platform and thins to the south, where it progressively oversteps older units (Iasky and Mory, 1999). Along the eastern margin of the Merlinleigh Sub-basin the unit overlies granitic basement. Lithologically, the Nannyarra Sandstone grades into the overlying Gneudna Formation, which consists of interbedded carbonate rocks and siltstone with minor amounts of evaporite, deposited in a nearshore to restricted, shallow-marine environment. The Gneudna Formation has a maximum known thickness of 1092 m in Quobba 1 (Fig. 6; Plate 9). A massive dolomite of probable reefal or shoal origin (Point Maud Member) within the Gneudna Formation has its thickest known section (331 m) in GSWA Barrabiddy 1A (Mory and Yasin, 1999). On seismic sections, the Gneudna Formation is difficult to differentiate from the underlying and overlying strata, and was interpolated from the limited well control (Fig. 11). The Munabia Formation conformably overlies and interfingers with the Gneudna Formation, and consists of sandstone with minor amounts of claystone, conglomerate, and dolomite, deposited in a barrier-complex environment during the Frasnian (Hocking, 2000).

The top and base (Fig. 12; Plate 6) of the Gneudna Formation were mapped where possible from seismic data, although neither horizon displays a distinctive reflection (Figs 10 and 11). Well data indicate that it does not extend south of the central part of the Gascoyne Platform, where the Cretaceous succession rests directly on the Lower Devonian succession. The Gneudna Formation is only partially eroded in the western and central parts of the

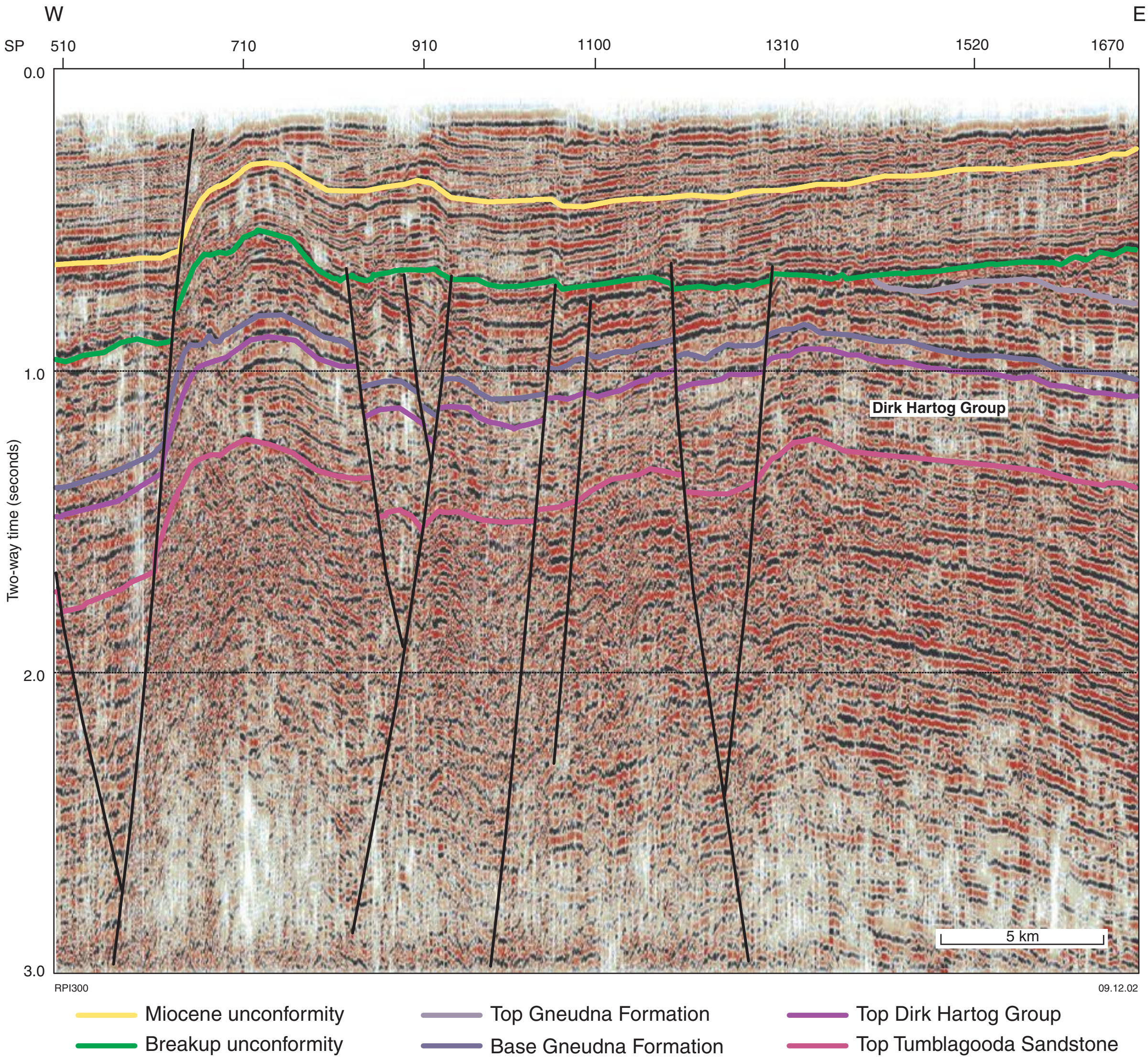


Figure 10. Seismic line CE82-03M (SP 500–1700) showing the seismic character of the Dirk Hartog Group. Note the reverse movement on some of the normal faults at the Miocene level

Gascoyne Platform and an uneroded succession is present to the north, where progressively younger units subcrop the Cretaceous succession. Isopachs for the formation (Fig. 13) show a relatively thick succession crossing the present-day coastline between latitudes 24°S and 25°S, and a thinner eroded succession towards the northwestern and northeastern margins of the platform. This suggests that these areas were relatively higher. The maximum thickness is between 1100 and 1600 m, which may have been the average thickness of the formation before erosion at the platform margins, presumably during the Permian to Jurassic.

Carboniferous to Permian

The Carboniferous succession consists of inferred Lower Carboniferous strata that are overlain, probably unconformably, by a mid-Carboniferous to Lower Permian succession. The Lower Carboniferous succession interpreted from seismic data in the northern part of the Gascoyne Platform is presumed to consist of limestone (Moogooree Limestone) and overlying sandstone and siltstone (Quail Formation) based on the succession in the Merlinleigh Sub-basin. The overlying succession, intersected in Airey Hill 1, Chargoo 1, Gnaraloo 1, and Warroora 1, is restricted to the northernmost part of the Gascoyne Platform, and consists predominantly of shale and sandstone deposited in a glaciomarine environment (Lyons Group; Hocking et al., 1987).

Seismic data indicate that a significant thickness of Carboniferous strata is present in the northern part of the platform (Fig. 14; Plate 10). Near Warroora 1 the Lyons Group is more than 1500 m thick, and overlies up to 1000 m of Lower Carboniferous strata. However, the Lyons Group is absent in Quobba 1 and Pendock 1, indicating that, to the south and west of this thick succession, the

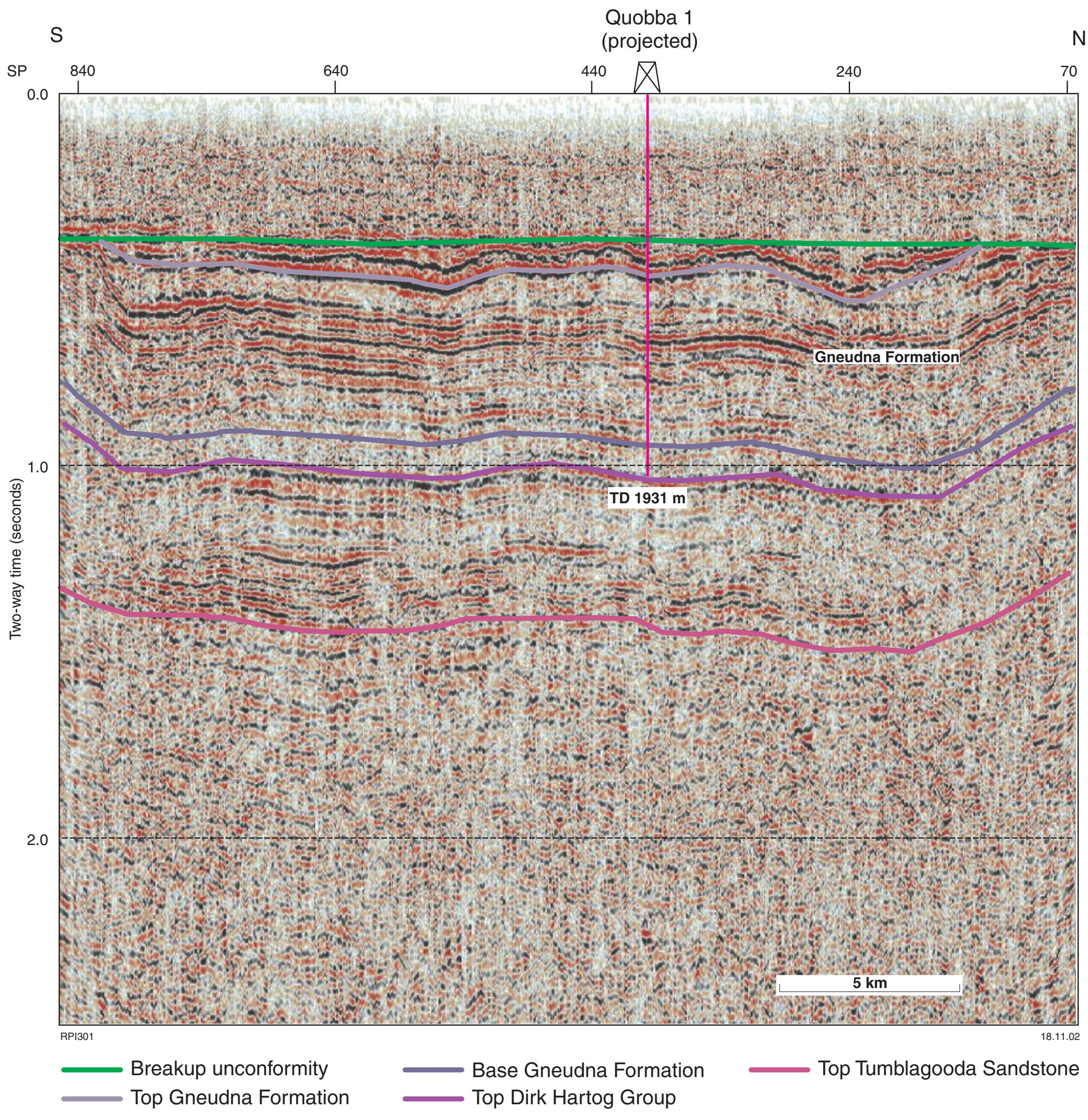


Figure 11. Seismic line CG83-09L showing the seismic character of the Gneudna Formation

Lyons Group has been totally removed by erosion prior to deposition of the Lower Cretaceous Winning Group, or was not deposited. In the Merlinleigh Sub-basin the group is Late Carboniferous to Permian in age, and up to 3000 m thick (Iasky et al., 1998; N. Eyles et al., 2002; C. H. Eyles et al., 2003). The relationship between the Carboniferous succession and the underlying Munabia Formation can only be seen in seismic sections, and appears to be conformable (Figs 11 and 14).

Of the Lower Permian to Upper Carboniferous succession in the Perth Basin, only the Irwin River Coal Measures and Carynginia Formation (Playford et al., 1976; Mory and Iasky, 1996) are known in the Abrolhos Sub-basin (Crostella, 2001). The Lower Permian Carynginia Formation was intersected in Wittecarra 1, immediately below the mid- to Late Permian unconformity (Plate 5; Smith and Cowley, 1987; Marshall et al., 1989), and consists of interbedded siltstone and sandstone with minor amounts of shale. Based on seismic data it overlies a few-hundred metres of undifferentiated Lower Permian strata, which probably extend onto the western margin of the Gascoyne Platform (former Edel Terrace) and directly overlies the Tumblagooda Sandstone (Fig. 15). A comparable stratigraphic relationship is observed in the onshore northern Perth Basin east of the Northampton Complex

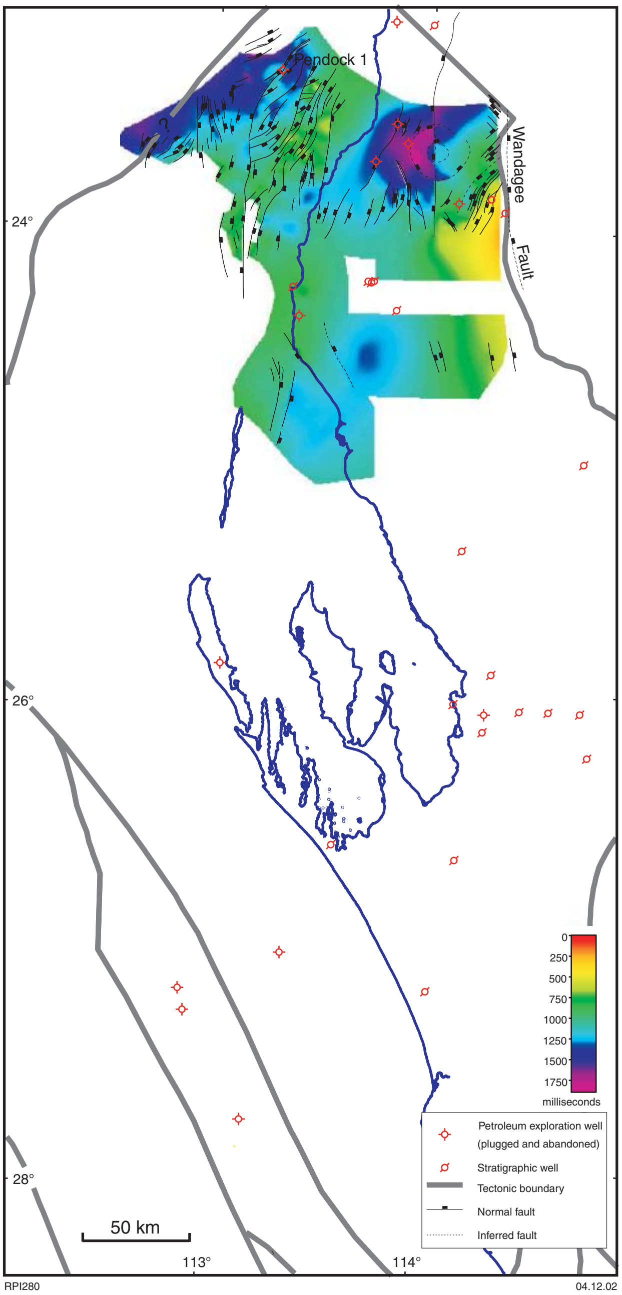


Figure 12. Two-way time structure map of the base Gneudna Formation

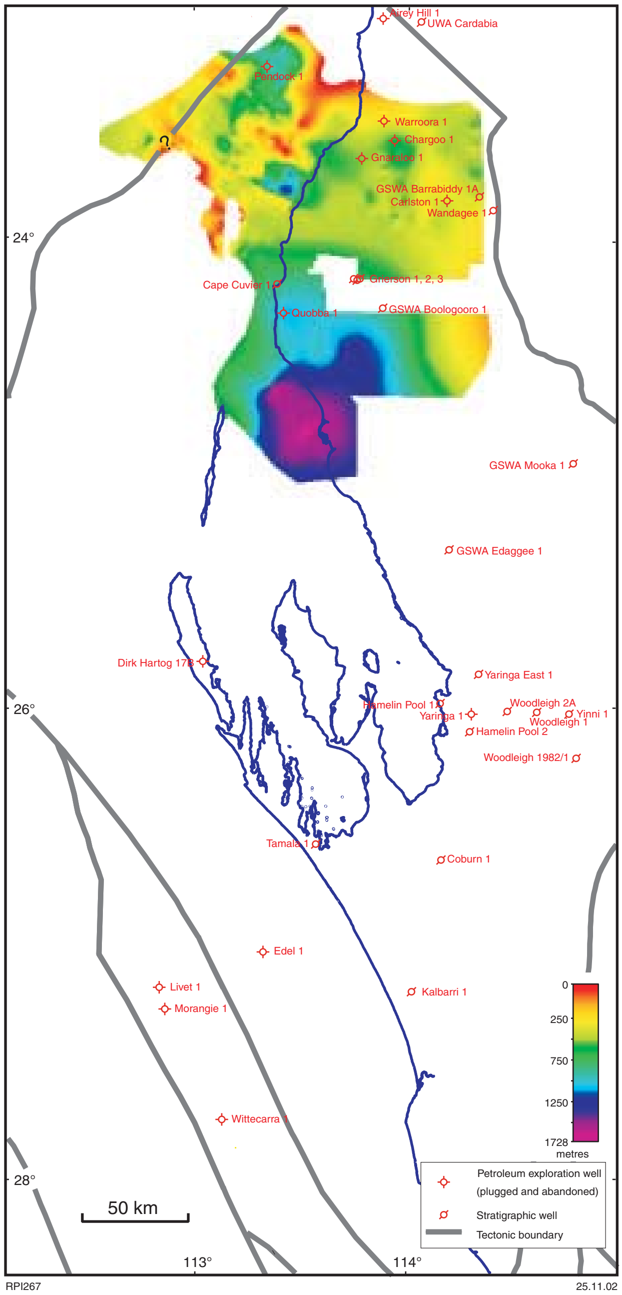


Figure 13. Gneudna Formation isopach map

(Playford et al., 1976), and may be implied south of Livet 1, in which the Lower Triassic Wittecarra Sandstone directly overlies the Tumblagooda Sandstone. There is a possibility, however, that westerly dipping Lower Permian strata at Wittecarra 1 (Fig. 15) are truncated by the mid- to Late Permian unconformity (Plate 5) somewhere east of the well, and that strata beneath the unconformity on the platform are Silurian–Carboniferous. There is no record of the Upper Permian succession in the study area; the 'Wagina Formation' recognized in Morangie 1 (Origin Energy Developments Pty Ltd, in prep.) is here assigned to the Lower Triassic Wittecarra Sandstone.

Triassic

A Triassic succession has been intersected in Wittecarra 1 (Fig. 15) and Livet 1 (Fig. 16) on the eastern margin of the Abrolhos Sub-basin, above the mid- to Late Permian unconformity (Crostella, 2001). The units penetrated in these two wells include, in ascending order, the Wittecarra Sandstone, Kockatea Shale, Woodada Formation, and Lesueur Sandstone. They are part of the northern Perth Basin succession, which post-dates mid- to Late Permian uplift and erosion. Basal transgressive sands (Wittecarra Sandstone) were followed by deposition of marine fine-grained sediment (Kockatea Shale), coarsening up into interbedded sand and silts (Woodada Formation), and finally Middle–Upper Triassic continental sands (Lesueur Sandstone), forming an overall regressive episode.

The Triassic succession dips steeply to the west towards the Abrolhos Sub-basin, and on the Gascoyne Platform is truncated by the base Cretaceous breakup unconformity (Plate 3; Fig. 17). On seismic sections the Kockatea Shale corresponds to a uniform zone of low-amplitude reflections. This zone is easily distinguishable from overlying, higher-amplitude reflections of the Woodada Formation and Lesueur Sandstone, and the high-amplitude reflection from the mid- to Late Permian unconformity at its base (Figs 15 and 16; Plate 10). A thin section of the Kockatea Shale extends into the

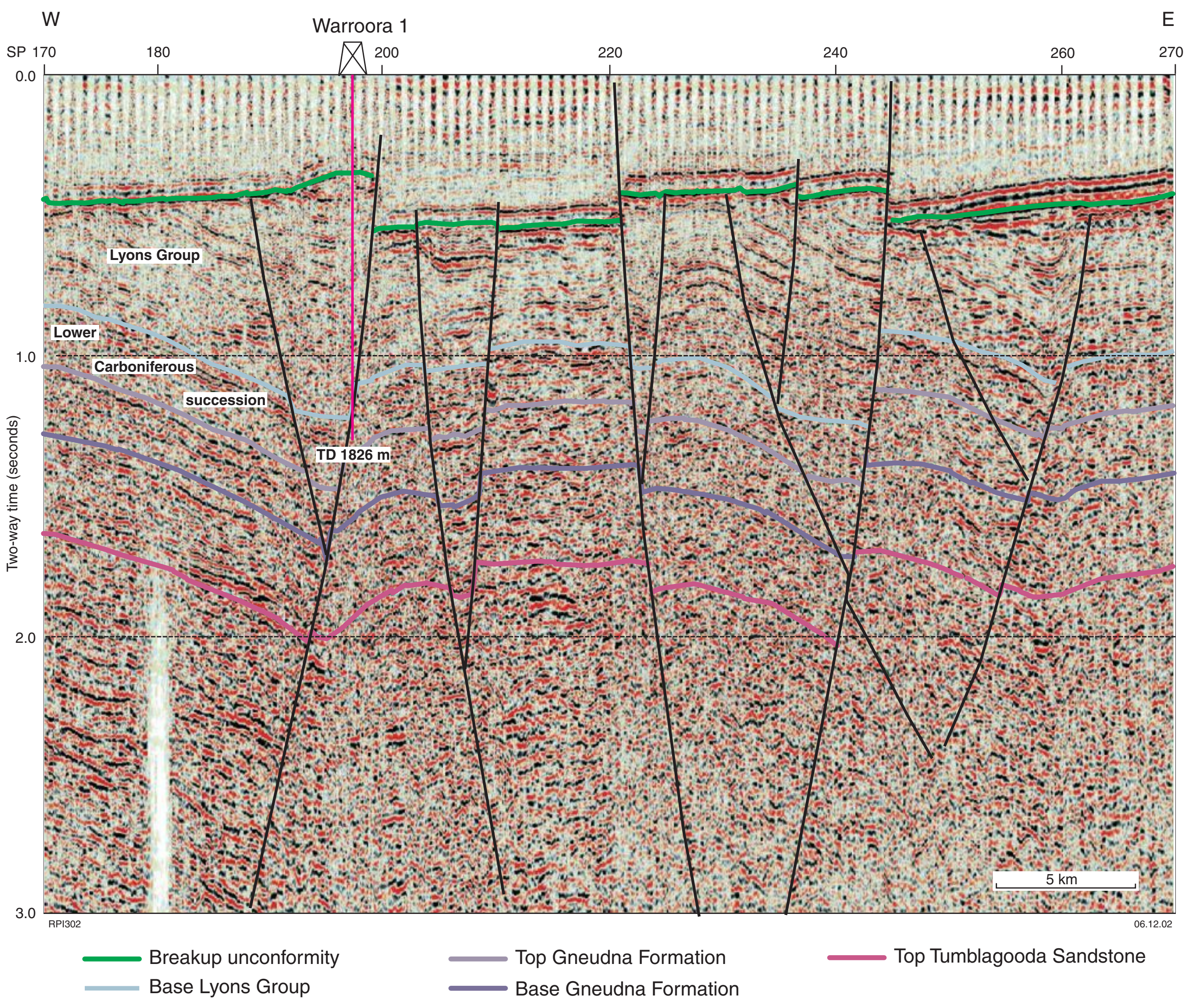


Figure 14. Seismic line SR62-C-L showing the Carboniferous succession

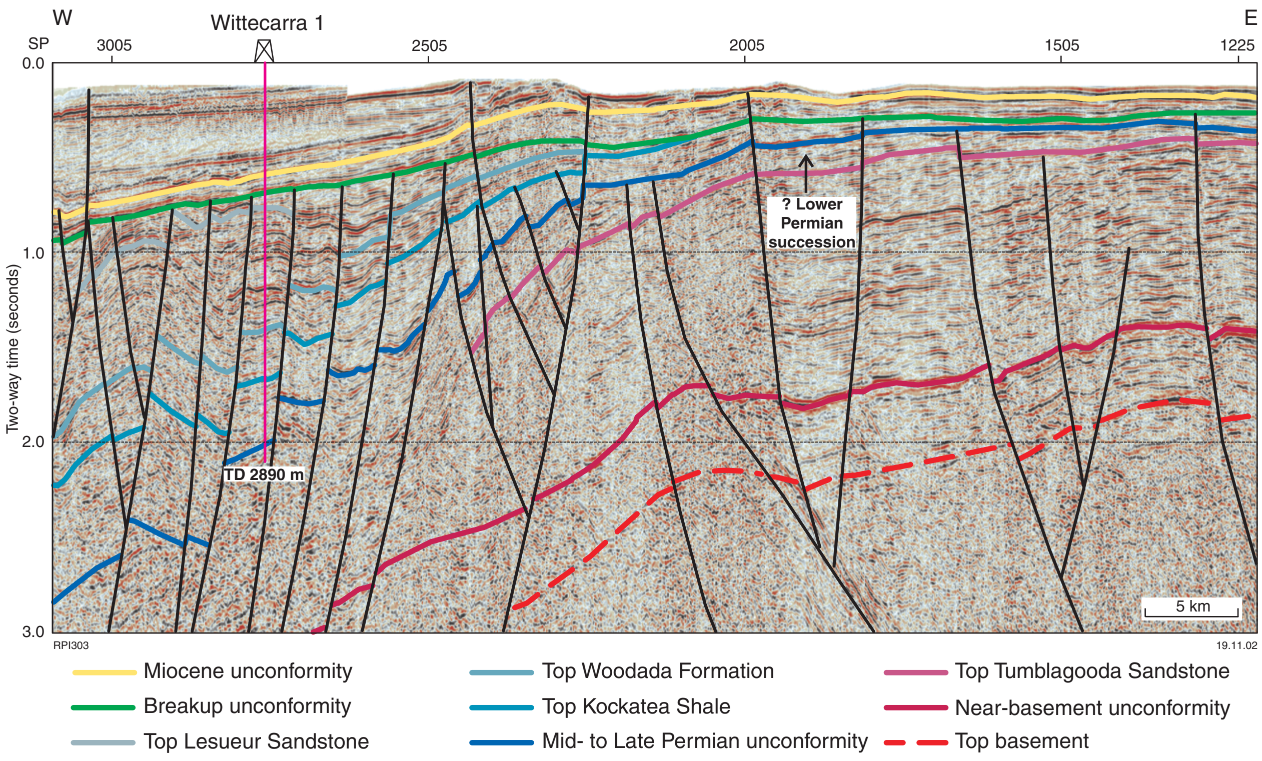


Figure 15. Seismic line H78-124B showing the mid- to Late Permian unconformity and possible underlying succession

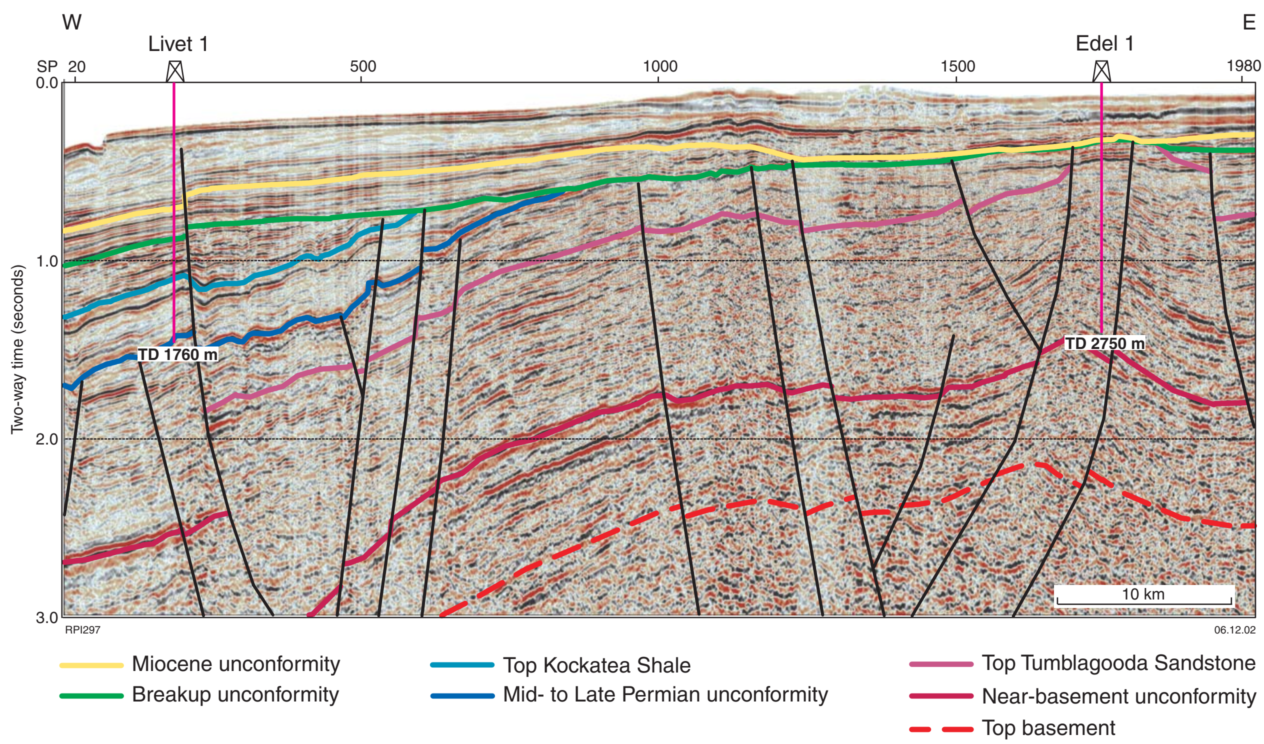


Figure 16. Seismic line H78-110/100A (SP 0-200) showing the base Cretaceous and Miocene unconformities. The high-amplitude reflections from Cainozoic reefs at around SP 1200 mask the underlying Miocene unconformity

southern Gascoyne Platform, where it overlies the mid- to Late Permian unconformity (Fig. 18) and is truncated by the Early Cretaceous unconformity (Figs 15 and 16). This is consistent with the coastal cliffs at Shell House, south of Kalbarri, where the Kockatea Shale conformably overlies the 11 m-thick type section of the Wittecarra Sandstone, which is disconformable on the Tumblagooda Sandstone.

Isopachs for the Kockatea Shale are shown only where the top of the unit can be mapped from seismic data (Fig. 19; Plate 4), and exclude the eroded sections in the southern Gascoyne Platform. Thicknesses range from 300 m on the western edge of the Gascoyne Platform to 1000 m in the Abrolhos Sub-basin, implying syn-depositional faulting along the Geelvink Fault System. Thicknesses greater than 1400 m on Figure 19 may be an artefact of the gridding process and are therefore unrealistic.

Jurassic

The only confirmed Jurassic unit on the Gascoyne Platform is the Woodleigh Formation (Fig. 2), which consists of interbedded shale and sandstone of lacustrine

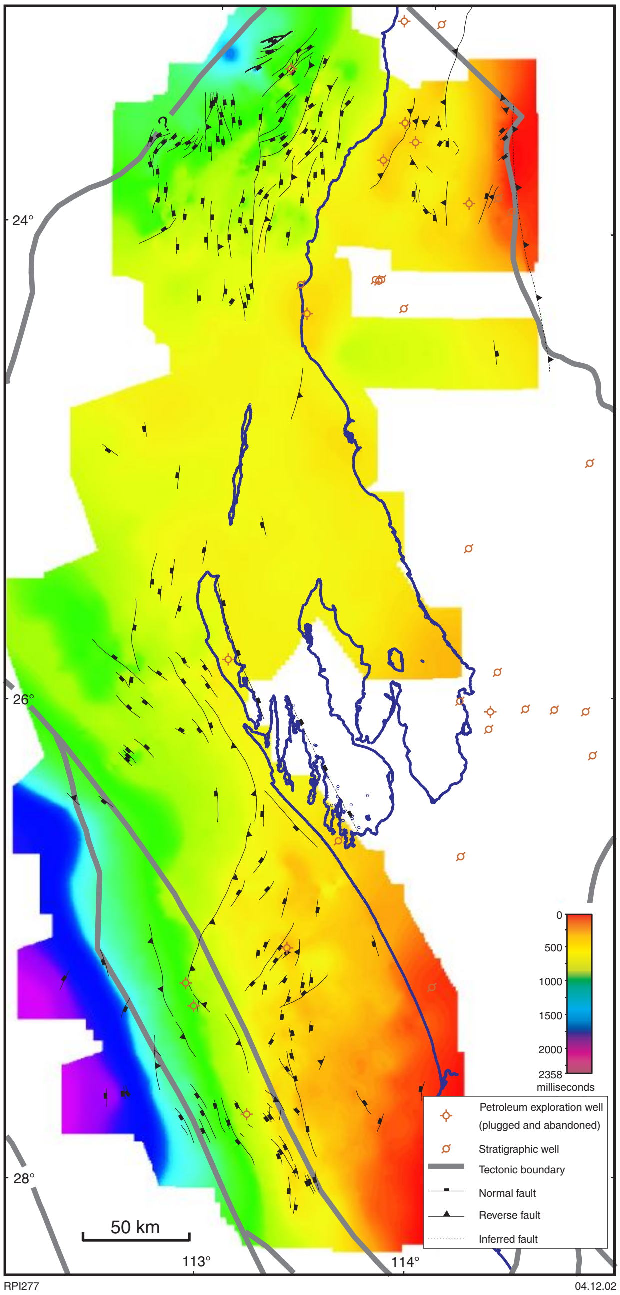


Figure 17. Two-way time structure map of the base Cretaceous unconformity

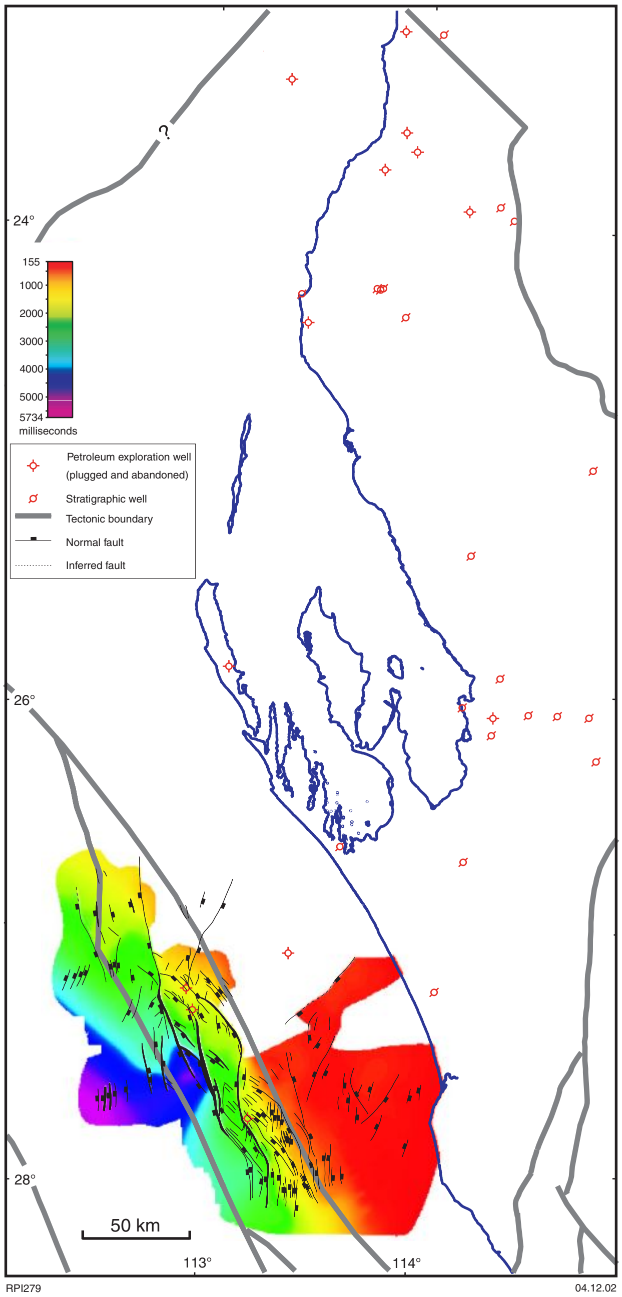


Figure 18. Two-way time structure map of the mid- to Late Permian unconformity

origin within the Woodleigh impact structure (Fig. 1; Iasky and Mory, 1999; Mory et al., 2000a). The unit has been dated at Early Jurassic from abundant spores and pollen (McWhae et al., 1958). The increasing numbers of Early Permian palynomorphs towards the base of the unit are interpreted as reworked (Mory et al., 2001). The greatest known thickness of the unit is 286 m in GSWA Woodleigh 2A. Apatite fission-track analyses (AFTA) of the unit in GSWA Woodleigh 2A imply an original thickness of about 1100 m, before uplift and erosion, associated with breakup, removed about 700 m of strata (Gibson et al., 2000). Although the Woodleigh impact structure has been interpreted to be 120 km in diameter (Mory et al., 2000a,b; Uysal et al., 2002), the farthest proven extent of the Woodleigh Formation from the centre of the structure is in Woodleigh water bore 9, 25 km to the east-southeast (Iasky et al, 2001).

The mid-Jurassic age of bivalves and algae reported by Teichert (1940) from sandstone next to the Minilya River on Wandagee Station (23°45'10"S, 114°23'40"E) has not been confirmed. On stratigraphic and lithological grounds, however, the sandstone is more likely to be Cretaceous.

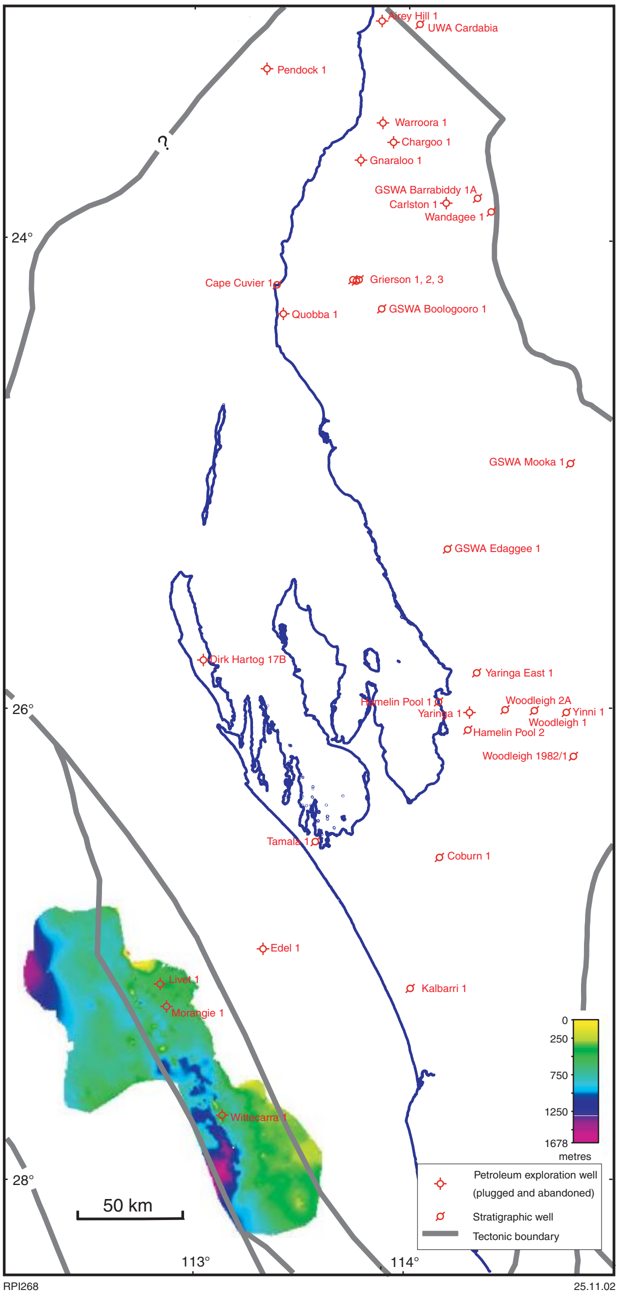


Figure 19. Kockatea Shale isopach map. Extent of map is limited to where the top of the unit can be mapped from seismic data

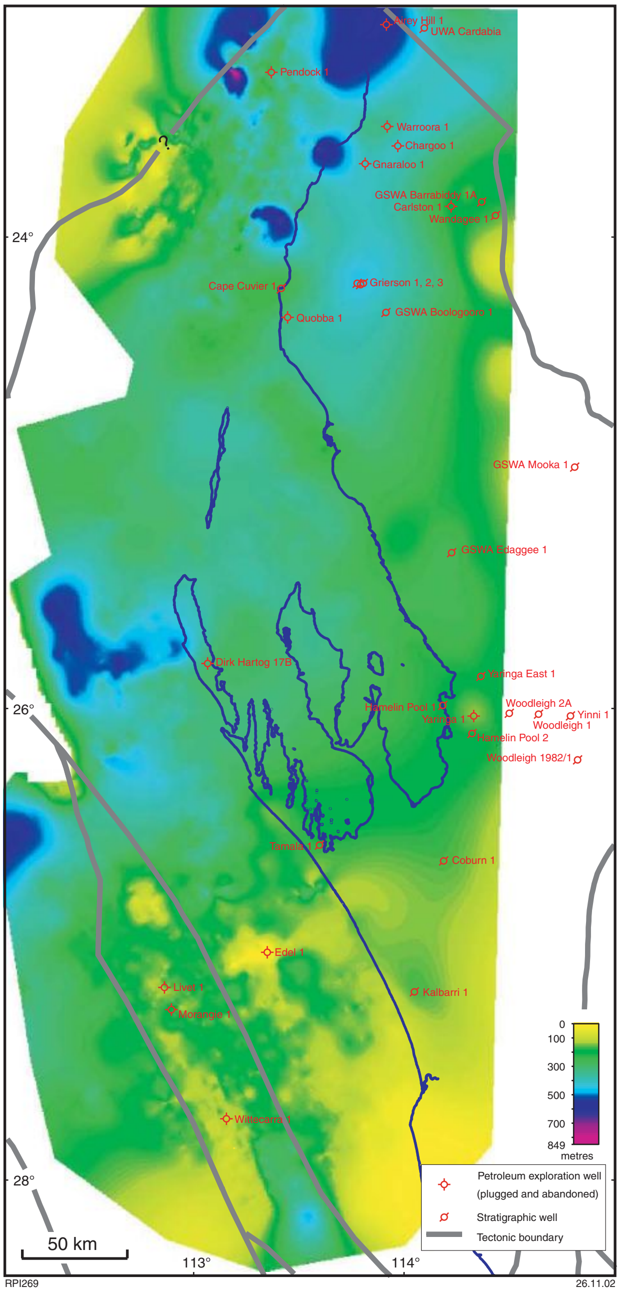


Figure 20. Cretaceous succession isopach map

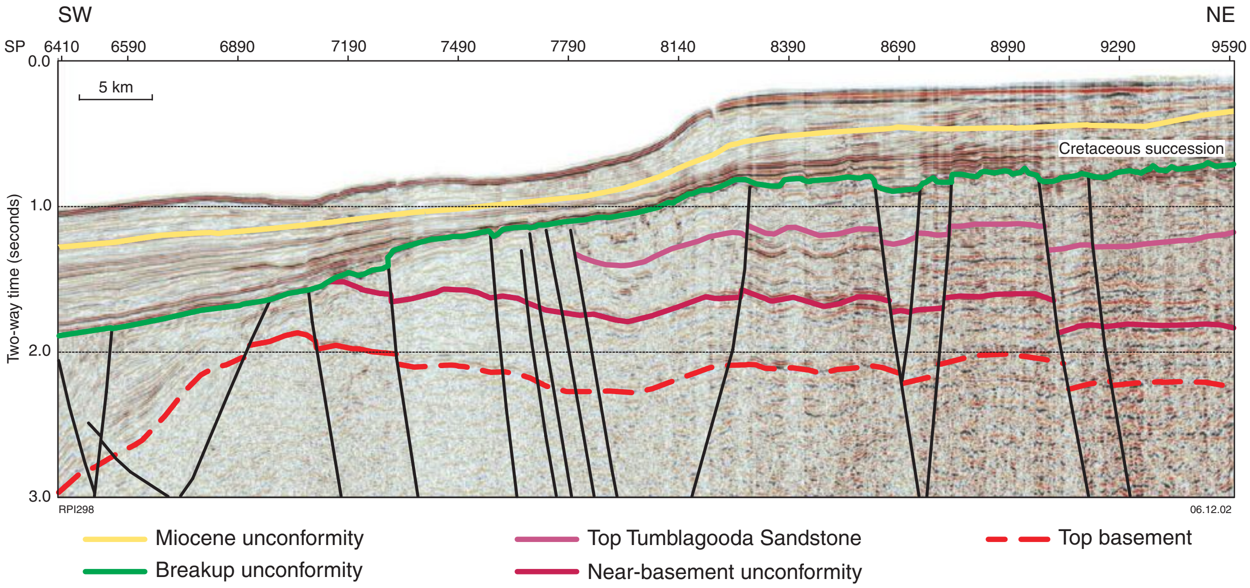


Figure 21. Seismic line 057-13 (SP 6400–9600) showing varying thickness of Cretaceous succession

Cretaceous

The Cretaceous succession consists of, in ascending order, the Winning Group, Haycock Marl, Toolonga Calcilutite, Korojon Calcarenite, and Miria Formation, and extends along most of the North West Shelf and across the Gascoyne Platform. The unconformity separating the Cretaceous succession from older rocks marks the breakup of Australia from Greater India in the Early Cretaceous (Plate 3). Pre-Cretaceous units are commonly truncated at an angle to the overlying Cretaceous units (Fig. 16), but in some areas the relationship is less obvious (Plate 10). The average thickness of the Cretaceous succession on the Gascoyne Platform (Fig. 20) is about 300 m, with strata thickening north towards the Exmouth Sub-basin and Peedamullah Shelf. There is a local Cretaceous trough immediately west of Dirk Hartog Island (Figs 20 and 21), but the succession thins onto the Bernier Ridge to the northwest (Fig. 20).

The Winning Group represents a period of widespread transgression over the Carnarvon Basin that continued throughout the Early Cretaceous. The group consists of a basal transgressive sandstone (Birdrong Sandstone) overlain by low-energy marine shale (Muderong Shale), in turn overlain by low-energy marine, silica-rich, fine-grained clastic rocks (Windalia Radiolarite) and glauconitic siltstone (Gearle Siltstone or Alinga Formation). The most prominent sequence boundaries within the Winning Group are at the tops of the Muderong Shale and Windalia Radiolarite (Westphal and Aigner, 1997; Mory and Yasin, 1999). Locally there is a break of up to 15 m.y. within the Gearle Siltstone (Dixon et al., 2003). Overlying the Winning Group, with a minor break, are marine carbonaceous claystone and bioturbated calcilutite of Turonian age (Haycock Marl). The Winning Group does not display a distinctive seismic character except for the top of the Muderong Shale, which is characterized by a prominent high-amplitude reflection. The group is easily identified, as it overlies the breakup unconformity (Figs 15, 16, and 21). The Mardie Greensand is a partial lateral equivalent of the Birdrong Sandstone, known mostly in the Northern Carnarvon Basin, but it may extend into the northern part of the Gascoyne Platform.

An isopach map of the combined Birdrong Sandstone and Mardie Greensand (Fig. 22) shows that these units are thickest (about 60 m) along a north-northeasterly trending trough that roughly coincides with the coastline between Cape Cuvier and Coral Bay, and extends up to the eastern coastline of the Exmouth Gulf. Additional local depocentres for these units are within the Woodleigh impact structure, where a depression appears to have formed over Lower Jurassic lake deposits, and west of the Rough Range Fault in the Exmouth Sub-basin (Fig. 22). The combined Muderong Shale and Windalia Radiolarite isopach map (Fig. 23) shows overall thickening to the north, from less than 25 m in the southern Gascoyne Platform to over 250 m in the northern Exmouth Sub-basin. The combined Gearle Siltstone and Haycock Marl isopach map (Fig. 24) shows that, on the Gascoyne Platform, thicknesses range from 0 m (absent) at Edel 1 to 200 m near Airey Hill 1. As with the Muderong Shale and Windalia Radiolarite, the Gearle Siltstone and Haycock Marl increase in thickness to the north, but these thicknesses increase dramatically north of the Rough Range Fault and Peedamullah Shelf, implying significant movement along the Rough Range Fault during the Albian to Turonian. Both isopach maps show a slight increase in thickness over the Woodleigh impact structure (Figs 23 and 24).

The Toolonga Calcilutite is a widespread unit on the Gascoyne Platform, and disconformably overlies the Winning Group. The unit consists of fossiliferous calcilutite and calcisiltite deposited in a low-energy, inner- to middle-shelf marine environment. The isopach map for the unit (Fig. 25) shows a depocentre with a maximum thickness of over 300 m over Shark Bay. The unit thins to the east towards the Wandagee and Ajana Ridges, where it has been removed by erosion. In the northern Gascoyne Platform the Toolonga Calcilutite grades up into the overlying Korojon Calcarenite, which consists of silty calcarenite and calcisiltite deposited in a moderate-energy marine environment. The maximum known thickness of the Korojon Calcarenite (80 m) is in Quobba 1, but the unit is absent in the southern Gascoyne Platform. The Miria Formation consists of calcarenite and calcisiltite deposited in a low- to medium-energy, marine-shelf environment. The formation disconformably overlies the Korojon Calcarenite and Toolonga Calcilutite, and ranges in thickness from 0.6 to 2.1 m in outcrop (Hocking et al., 1987) to 95 m in Airey Hill 1, which is the the only well that penetrates the unit on the Gascoyne Platform.

Cainozoic

The Cainozoic succession in the Gascoyne Platform is predominantly flat lying and consists of shallow-marine carbonate rocks (Cardabia and Giralia Calcarenites and Trealla Limestone; Hocking et al., 1987). However, the succession progrades to the west along the western margin of the study area (Plate 10). The Cardabia Calcarenite disconformably overlies Cretaceous rocks, and outcrops in the Giralia, Marrilla, Chargoo, Warroora, and Gnargoo anticlines. It covers most of the northwestern part of the platform and extends to the east as far as the Giralia Range and south as far as the Lake MacLeod anticlines (Hocking et al., 1987). The maximum known thickness of the unit is 77 m at Toothawarra Creek (MGA 820660E 7473835N; Condon et al., 1956). The Giralia Calcarenite lies disconformably on the Cardabia Calcarenite and has a maximum drilled thickness of 78 m in Edel 1.

Isopachs of the Cainozoic section (Fig. 26) were calculated from onshore well data and offshore seismic data using an average interval velocity (Appendix 6). The Cainozoic section is thin over most of the onshore Gascoyne Platform, compared to the offshore part of the platform, where it is mostly 200–400 m thick. However, to the west of the study area the Cainozoic section thickens rapidly to a maximum of about 800 m (Fig. 26).

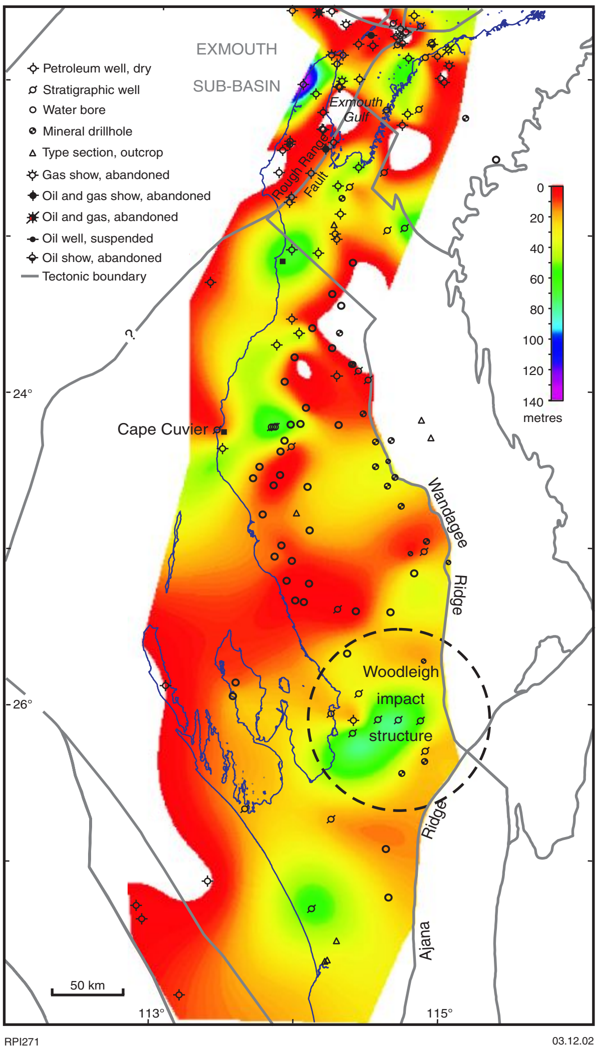


Figure 22. Birdrong Sandstone and Mardie Greensand isopach map

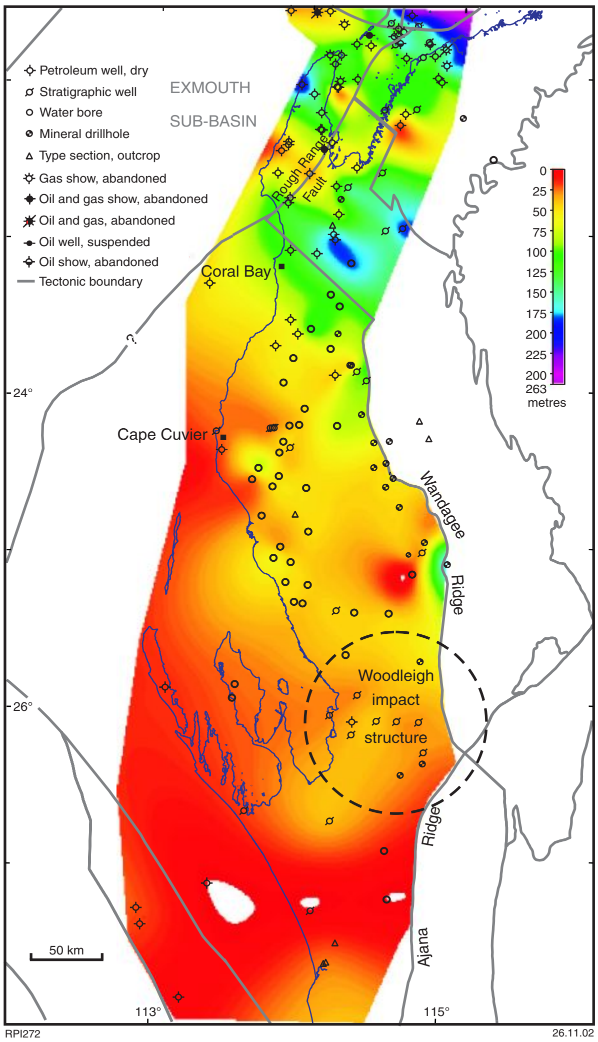


Figure 23. Muderong Shale and Windalia Radiolarite isopach map

Structure

Gravity data

Onshore gravity coverage over the Gascoyne Platform includes surveys conducted by WAPET, Oceania Petroleum, and Barewa Oil in the late 1950s and early 1970s (Appendix 2). Stations are widely and irregularly spaced from 500 to 1500 m along traverses. The accuracy of the readings for the surveys is about ±0.5 μm/s². The offshore gravity observations, which comprise estimates of the gravitational potential from satellite altimetry (Sandwell and Smith, 1997) constrained by ship-borne measurements, have a spatial resolution of about 25 km and a probable error of about ±40–50 μm/s². The isostatic residual gravity image (Fig. 27) shows the effect of gravity due to density variation in the crust and was calculated by joining the onshore Bouguer gravity with the Bouguer-corrected offshore free-air gravity (Lockwood and D'Ercole, in prep.). The calculations required removing the regional gravity field from the Bouguer-corrected gravity. For offshore satellite data, the Bouguer correction was calculated by replacing the effect of gravity due to water with that due to a crustal layer. The regional field was obtained by modelling crustal thickness assuming isostatic equilibrium for the area (Lockwood and D'Ercole, in prep.).

Interpretation

Regional structural trends and tectonic units of the area can be easily identified from the gravity data (Fig. 27). Lockwood and D'Ercole (in prep.) calculated the thickness of the sedimentary section above crystalline basement (Fig. 28) by applying the inversion technique of Pilkington and Crossley (1986) over the calculated isostatic residual gravity. The image derived from the inversion shows that the Gascoyne Platform has a central onshore trough, with sections thinning east towards the Wandagee and Ajana Ridges and west towards the offshore basement ridge (Bernier Ridge). The gravity high at the southern margin of the Gascoyne Platform corresponds to the Northampton Complex and its offshore extension. The northern margin

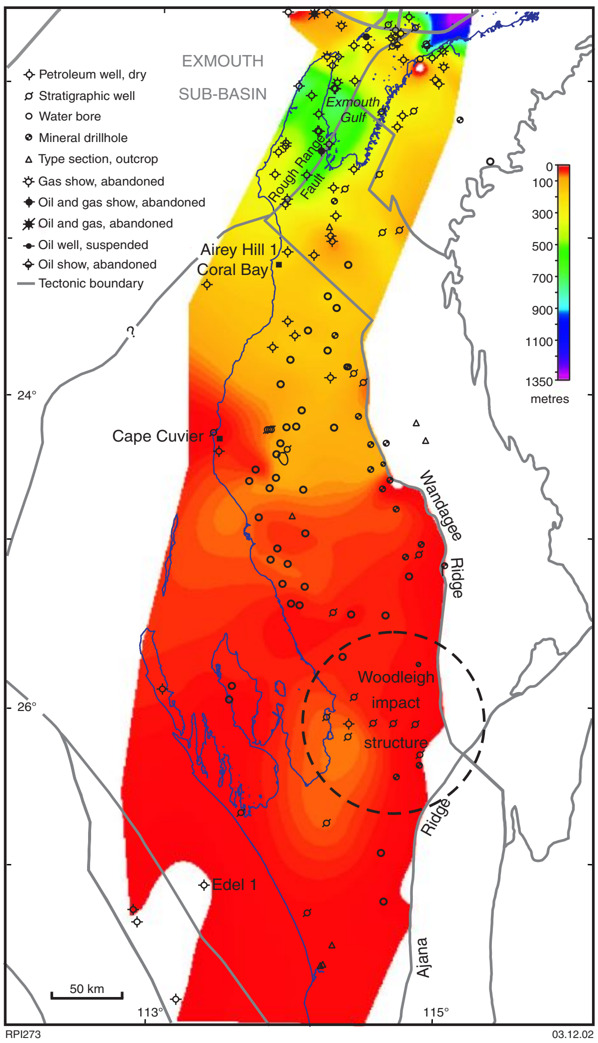


Figure 24. Gearle Siltstone and Haycock Marl isopach

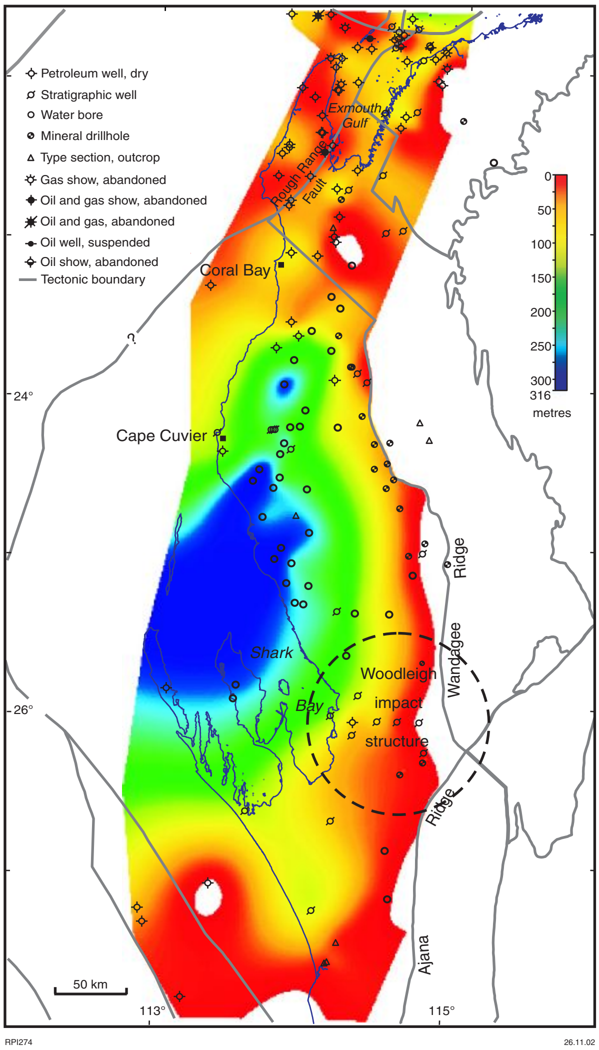


Figure 25. Toolonga Calcilutite isopach map

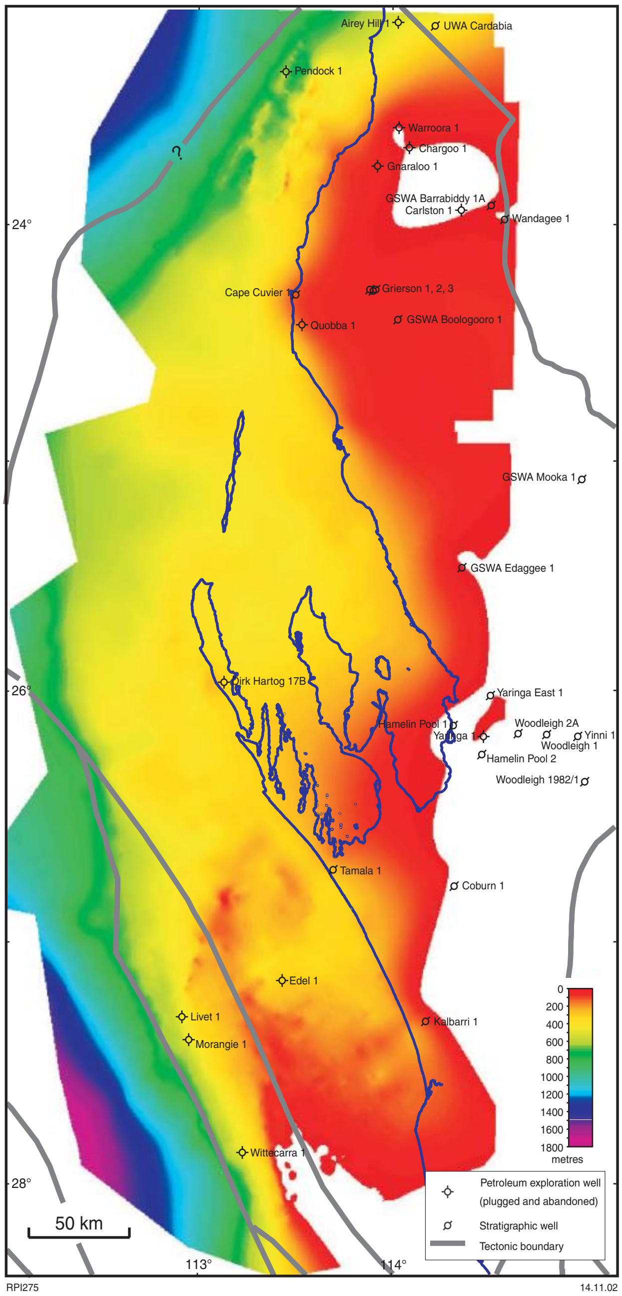


Figure 26. Approximate thickness of Cainozoic strata

of the platform, defined by the Cardabia Transfer Fault Zone (Fig. 27; Crostella and Iasky, 1997), coincides with a distinct gravity lineament (Iasky et al., 1998), and the gravity data indicate a gradual shallowing of basement to the north over this lineament. The gravity high in the northernmost Gascoyne Platform (Fig. 27) extends north of the study area and over the Cape Range peninsula (Iasky et al., 2001, figure 11), and is interpreted as an area of basement uplift, implying a limited thickness of the Phanerozoic succession. However, drilling on the peninsula shows a relatively thick Upper Carboniferous – Jurassic section (Crostella, 1996; Crostella and Iasky, 1997), which is mostly missing on the Gascoyne Platform, indicating that the Ordovician – Lower Carboniferous succession probably thins or is missing over this basement high.

Gravity data indicate shallow basement along the western margin of the offshore Gascoyne Platform, beyond which the sedimentary succession thickens rapidly into the Abrolhos and Houtman Sub-basins to the southwest and Exmouth Sub-basin to the northwest (Figs 27 and 28). This interpretation is consistent with the seismic data, which show a thin section of mainly Tumblagooda Sandstone in the southern Gascoyne Platform, and a much thicker and younger basin fill in the adjacent Abrolhos Sub-basin (Plate 10). The western margin of the northern Gascoyne Platform is defined by a basement ridge below the Cretaceous (Bernier Ridge) that is recognized on both gravity and seismic data. These data indicate a fault system similar to the Geelvink Fault System, which separates a Mesozoic depocentre from the western side of the Bernier Ridge (Lockwood and D'Ercole, in prep.).

The eastern margin of the Gascoyne Platform is defined by northerly trending gravity highs corresponding to the Wandagee and Ajana Ridges. Northwesterly and southwesterly trending lineaments within the platform are probably related to zones of weakness within basement that were reactivated as transfer faults at basement level, and associated fault systems within the sedimentary section (Iasky and Mory, 1999). The Wandagee and Ajana Ridges are truncated abruptly by the Woodleigh impact structure, which overprinted the existing structure in the Late Devonian (Uysal et al., 2001). In the southern Gascoyne Platform, the offshore parts of two prominent, southwesterly trending lineaments (*swa* and *swb* in Fig. 27) correspond to faults mapped from seismic data (Fig. 29). On the margins of the platform, two prominent northwest-trending lineaments (*nwa* and *nwb* in Fig. 27) are similarly aligned with major structural features: lineament *nwa* is aligned with the southern edge of the Wandagee Ridge and divides the Byro and Coolcalalaya Sub-basins; and lineament *nwb* appears to be an extension of the Urella Fault (Mory and Iasky, 1996), which extends into the Northampton Complex and converges with the Yandanooka – Cape Riche Lineament (Everingham, 1968) — the focus of recent seismic activity in the Yilgarn Craton (Doyle, 1971; Dentith et al., 1994).

Magnetic data

The magnetic data coverage over the Gascoyne Platform includes three surveys flown by BMR in the mid- to late 1950s, a survey by Tasman Oil in 1965 (Tasman Oil Pty Ltd, 1965), and one by WAPET in 1969 (Appendix 2). The early BMR surveys were flown at 150 m above the ground with lines 1600 m apart, the WAPET survey was flown at 200 m above the ground with lines 2400 m apart, and the Tasman Oil survey was flown at 460 m above the ground in groups of three lines 1600 m apart every 12 800 m. All surveys are included in the Geoscience Australia national data grid except for the Tasman Oil survey, which was digitized and merged with the rest of the data to provide a regional magnetic image of the platform (Fig. 30). The poor resolution of the image can be attributed to the broad acquisition parameters.

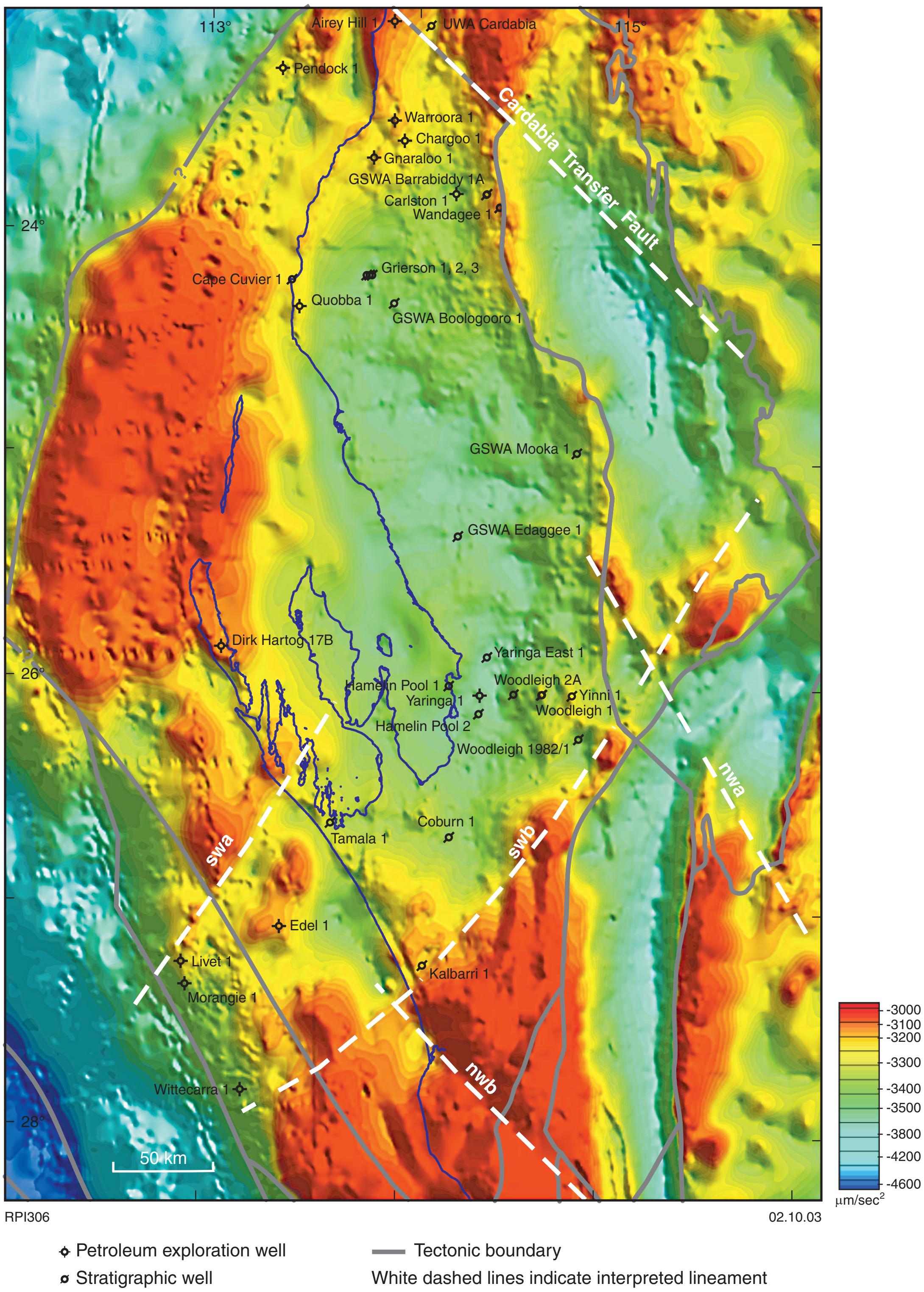


Figure 27. Isostatic residual gravity image of the Gascoyne Platform (after Lockwood and D'Ercole, in prep.). White dashed lines are interpreted lineaments

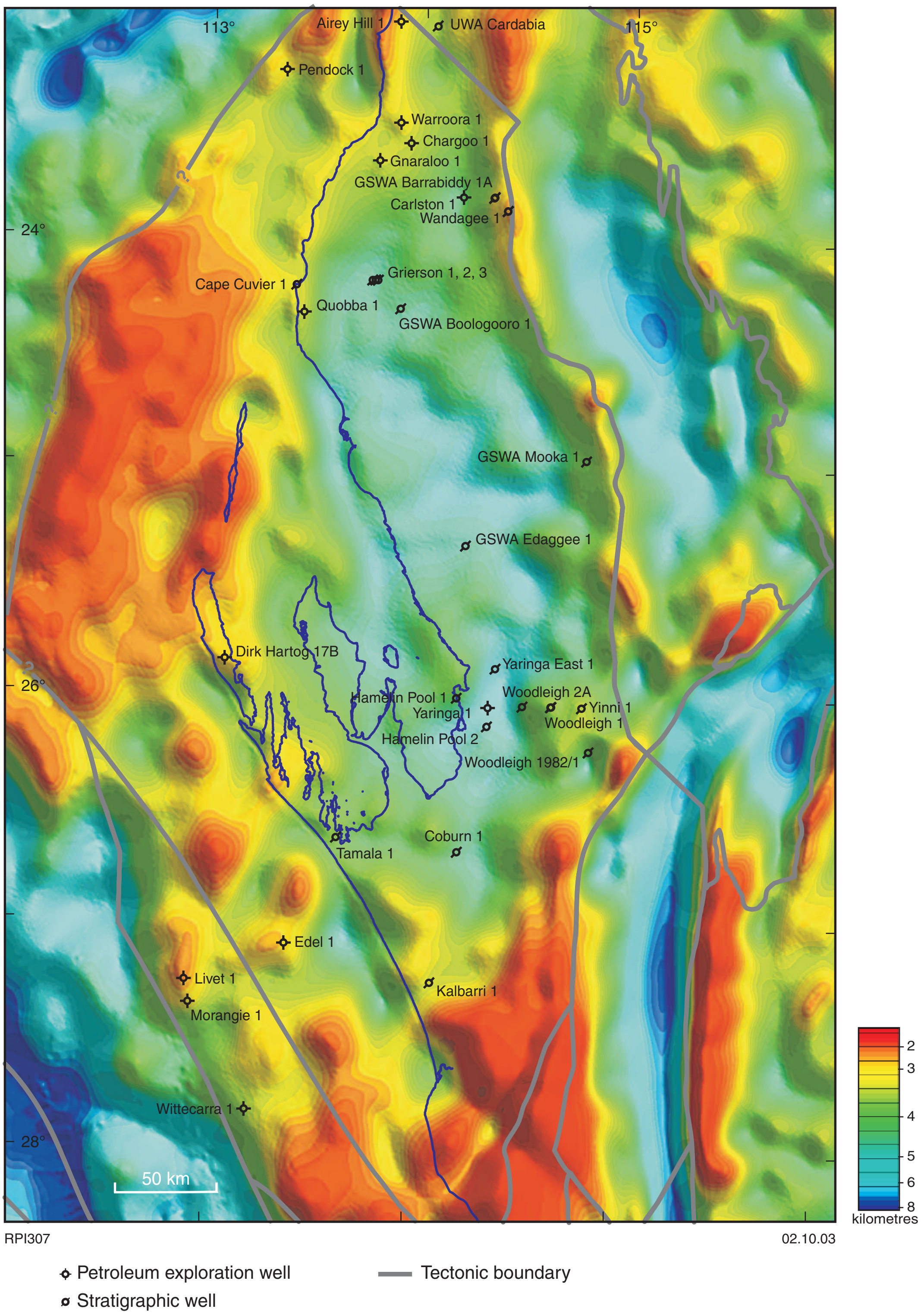


Figure 28. Depth to basement modelled from gravity data (after Lockwood and D'Ercole, in prep.)

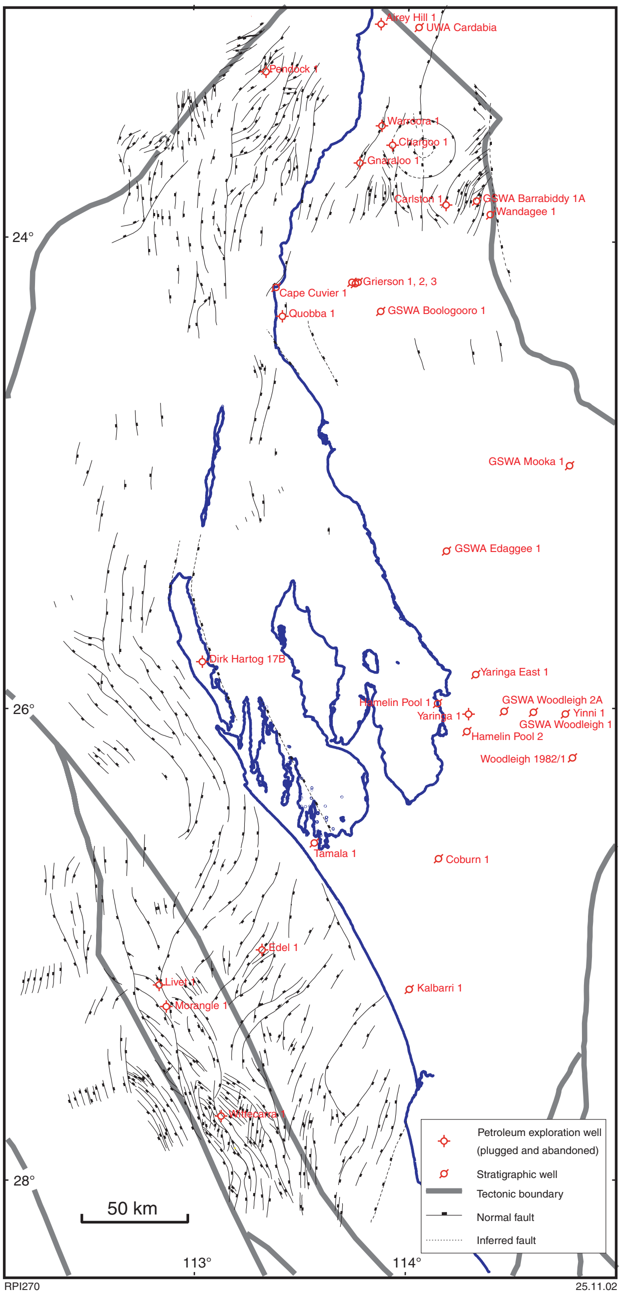


Figure 29. Faults interpreted from seismic data extrapolated to the base Cretaceous unconformity

Interpretation

The total magnetic intensity image (Fig. 30) displays low-frequency anomalies in the Southern Carnarvon Basin in contrast to the high-frequency anomalies over the Gascoyne Complex and Yilgarn Craton. There is generally a poor correlation between gravity and magnetic anomalies (e.g. over the Northampton Complex and Bernier Ridge). However, there is a similarity between gravity and magnetic lineament trends. There are several southwest-trending, high-frequency, high-amplitude magnetic lineaments in the Northampton Complex that correspond to near-surface dykes. This trend is also evident on the gravity image (*swb* on Fig. 27). The trend of a high-frequency magnetic lineament (*nwc* in Fig. 30) along the Zuytdorp Cliffs is similar to the trend of a gravity lineament (*nwb* in Fig. 27) to the south of the cliffs. The frequency of this magnetic anomaly indicates a shallow origin, probably representing activity along the fault that controlled the development of the cliffs. The high-frequency, northwest-trending magnetic lineament to the east (*nwd* in Fig. 30) has a similar trend, and probably represents a fault related to the same tectonic episode.

The magnetic anomaly at Edel 1 is probably due to phonolite, lamprophyre, and trachyte volcanic rocks (of a continental-margin origin) that were intersected below 260 m of flat-lying Cainozoic strata (Killar, 1972). The seismic data at this location indicate an anticline over a deep intrusion (Crostella, 2001; Gorter and Deighton, 2002; Plate 10, section GG'). Age dating of these volcanic rocks in Edel 1 (Killar, 1972) indicates a Late Permian – Early Triassic intrusion. Magnetic anomaly *mb* (Fig. 30) to the north has a similar frequency and amplitude, and may represent a similar feature to that at Edel 1. Other low-frequency magnetic anomalies within the Gascoyne Platform possibly correspond to similar igneous intrusive bodies within basement (Lockwood and D'Ercole, in prep.).

Seismic data

The seismic data used for this study consist of 153 lines from 25 surveys, amounting to 8234 line-km (Appendix 3), and these data provide a regional coverage over the platform (Plate 1). The northern and southern parts of the Gascoyne Platform have reasonable seismic coverage, but as there are only a few lines over the central part of the platform near Shark Bay (Fig. 31), correlation between the northern and southern portions is difficult. The vintages of the surveys range from 1962 to 1997. The quality of the original processed lines is typically poor, but the quality of some lines from 1970s regional surveys was considerably improved by reprocessing in the late 1990s (Appendix 3).

The level of confidence in the seismic interpretation is dependent on the quality of the data, which have been rated as bad, poor, fair, good, and very good (Fig. 4; Appendix 3). Bad-quality lines have poor resolution and are difficult to interpret, whereas complex structures can be resolved in very good quality lines. The highest-quality data are mostly along the southern and western margins of the Gascoyne Platform, whereas the rest of the platform is represented mostly by poor-quality data (Fig. 4). Poor-quality data are partly a function of processing vintage — modern processing with new technology more successfully resolves reflections than older processing — and partly geological. For example, the quality of line 057-13 (Plate 10; Fig. 21), reprocessed in 2001, markedly decreases to the east towards the platform, partly due to the presence of near-surface coastal limestone and partly to the homogeneity of the strata, providing little variation in acoustic impedance. Consequently, there is a decreased signal-to-noise ratio in such sections.

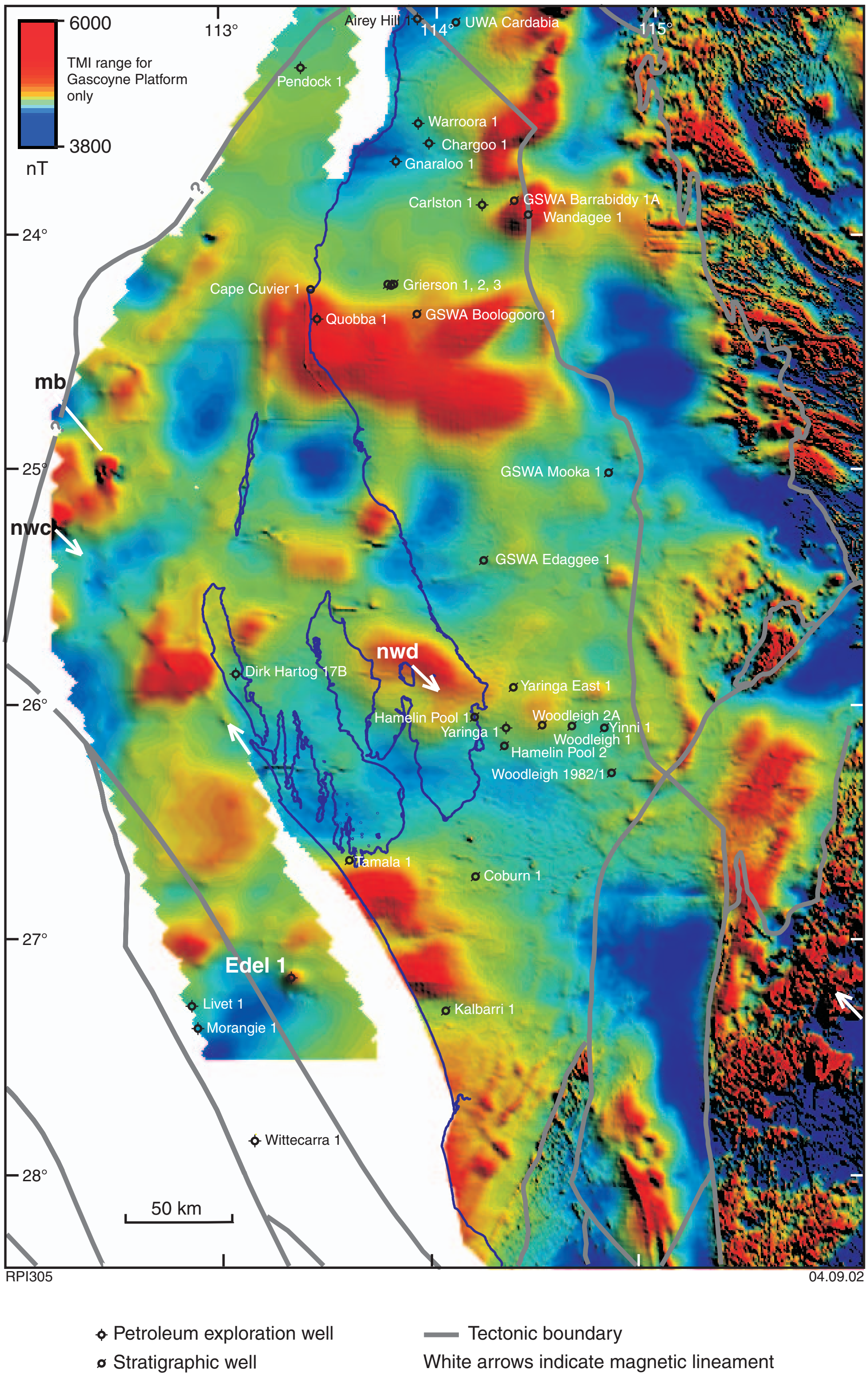


Figure 30. Total magnetic intensity image of the Gascoyne Platform. White arrows point to lineaments discussed in the text

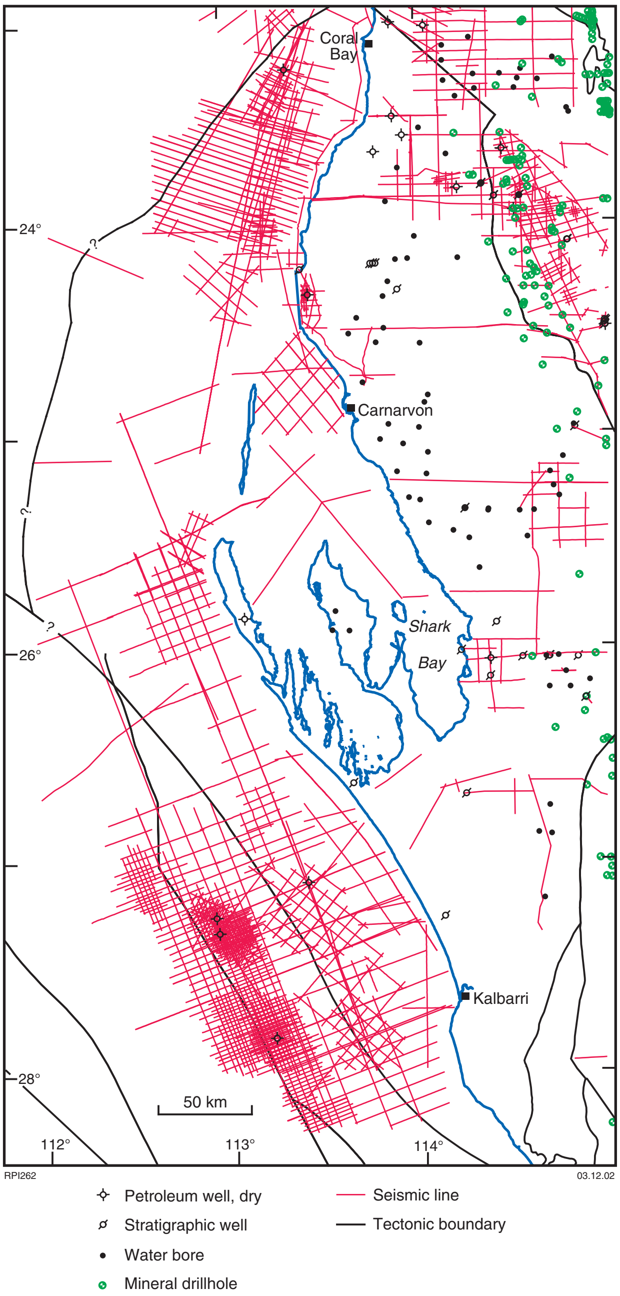


Figure 31. Distribution of seismic lines, wells, water bores and drillholes in the Gascoyne Platform and adjacent sub-basins

Interpretation

The Gascoyne Platform can be regarded as an area of elevated basement (Symonds and Cameron, 1977) compared to the surrounding structural units (Plate 10). Faulting during the main tectonic episodes in the Late Carboniferous – Early Permian, mid- to Late Permian, Late Jurassic – Early Cretaceous, and Miocene post-dates the main phase of deposition across the platform and increases towards its margins (Iasky and Mory, 1999). Most faults terminate at the Early Cretaceous breakup unconformity (Figs 16 and 32; and compare fault patterns on Figs 7 and 33 and Plates 2 and 7), indicating that the tectonic episode that separated Australia from Greater India had a significant effect on the platform. None of the mapped faults detach within the sedimentary section (Plates 3, 7, and 8). Breakup overprinted older structures by reactivating many pre-existing faults or zones of weakness, many of which were probably initiated during mid- to Late Carboniferous rifting (Iasky et al., 1998). The unconformity at the base of the Tumblagooda Sandstone (Fig. 34; Plate 8) indicates an earlier period of tectonism (?Cambrian – Early Ordovician). In the southern part of the Gascoyne Platform the seismic data show growth along major northeasterly striking faults (Fig. 3; Plate 10, sections FF' and HH') at the Upper Ordovician level, suggesting there was a period of extensional reactivation during the deposition of the Tumblagooda Sandstone. Several faults that terminate near the top of the Tumblagooda Sandstone (Plate 7; Plate 10, section CC') indicate that either minor tectonism, or faulting caused by compaction, pre-dated deposition of the Dirk Hartog Group. The latest major tectonism to affect the platform was mid-Miocene compression, which initiated reverse movements on pre-existing breakup or older normal faults (Figs 17 and 33; Plates 2 and 3) and formed anticlines (Fig. 32). Some of these anticlines outcrop along the Rough Range and Giralia Faults and the salt marshes near Lake MacLeod (Hocking et al., 1985; Crostella and Iasky, 1997). Offshore, Pendock 1 tested one of these anticlines for hydrocarbons without success (Plate 10, section AA'). Some Miocene reactivated faults have normal movement, but the tight folding on the footwall of these normal faults indicates transpression along a strike-slip fault (Fig. 10, shot point 700).

The dominant pre-Cretaceous structural trends are north-northeasterly in the northern part of the Gascoyne Platform, northwesterly in the central part, and northeasterly in the southern part (Fig. 29). The north-northeasterly trend in the northern area has been previously identified as the offshore extension of onshore anticlines along the Rough Range and Giralia Faults (Symonds and Cameron, 1977). The northwesterly structural trend in the centre of the Gascoyne Platform has also been previously recognized (Symonds and Cameron, 1977). Except for the southern part of the platform, northerly to north-northeasterly trending faults are commonly parallel to the coast, and appear to be a consistent control on this trend. This may be related to a pre-existing basement fabric. Faulting in the pre-Cretaceous section is typically extensional with generally small vertical displacements. The style of faulting below the mid- to Late Permian and base Tumblagooda unconformities (Figs 3, 7, 15, and 18; Plate 10) is also extensional with little evidence of reverse movement. However, Miocene reverse movement on major faults is common throughout the Gascoyne Platform (Figs 17 and 33). The Geelvink Fault System at the western margin of the southern Gascoyne Platform consists of a complex series of north- to northwest-trending, en echelon faults (Fig. 29). The southwestern margin of the Gascoyne Platform is interpreted as a hinge zone where the dip of the strata rapidly increases to the west into the Abrolhos and Houtman Sub-basins (Plate 10).

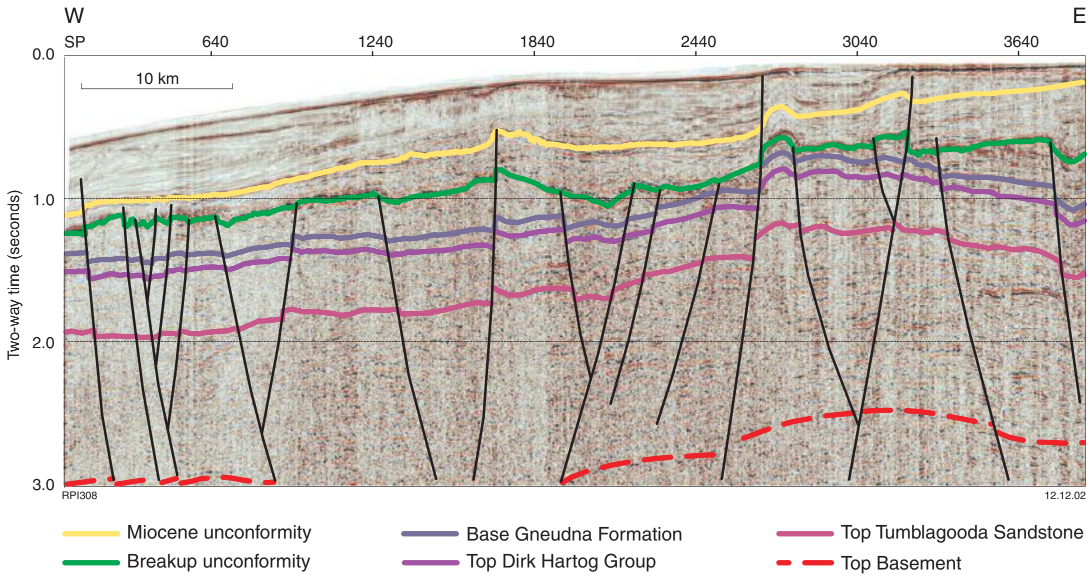


Figure 32. Seismic line 92M-100/100A showing structures formed by Miocene tectonism

A basement high below the breakup unconformity is recognized from both seismic and gravity data in the onshore northern part of the Gascoyne Platform, immediately east of Chargoo 1 (Figs 35a,b). On the seismic section this basement high may be interpreted as an igneous intrusion, a salt diapir, or an impact structure. It is unlikely to be a salt diapir because: the deformation of the strata is inconsistent with that caused by salt movement (Bally, 1983); the positive gravity anomaly implies a high density, which is inconsistent with salt; and no other such structures are known in the Gascoyne Platform. An igneous intrusion is a possibility as there is basement uplift associated with the intrusions at Edel 1 (Plate 10, section GG'), and magnetic data (Fig. 30) indicate that intrusives are widespread throughout the Gascoyne Platform and surrounding areas (Lockwood and D'Ercole, in prep.). However, the poor-resolution data near Chargoo 1 indicate a magnetic low, suggesting that the gravity high there is unlikely to have an igneous origin. The seismic data (Fig. 35a) show a zone of chaotic reflections at the centre of a fault-bound area of folded strata. There is good agreement between the inner, circular gravity high (Fig. 35b) and these faults, which could be possible ring faults. This geophysical evidence is comparable to that of the Woodleigh impact structure (Iasky et al., 2001). Further evidence for an impact structure is the arcuate geometry of the fault-controlled western margin of the Gnargoo Range, which is coincident with the western part of the inner, circular gravity high. In addition, the folded horizons at the shoulders of the basement high observed in seismic profiles and the morphometric similarity to the Woodleigh impact structure suggest that the basement high may be the central uplifted area of an impact structure. The fault pattern in this area on the two-way time structure maps (Figs 7, 12, and 29; Plates 6 and 7) are based on this interpretation. The age of this possible impact structure is constrained between deformed Upper Carboniferous strata and the overlying flat-lying Lower Cretaceous section.

The Bernier Ridge in the northern offshore part of the Gascoyne Platform is a large area where crystalline basement has been uplifted (Plate 10, section CC'). Seismic data show that this basement high is faulted along its western and eastern margins (Fig. 36). Devonian and older rocks are assumed to be upthrown and eroded over the basement high. There is no indication of thinning or thickening of strata towards the faulted contact, indicating a post-Devonian to Early Cretaceous age for this uplift. The most likely time for this basement uplift was during mid- to Late Permian tectonism, or during breakup in the Late Jurassic to Early Cretaceous. A thicker Cretaceous section to the east of the Bernier Ridge indicates that syndepositional normal movement continued after breakup on some of the faults related to basement uplift.

The interpreted base Gneudna Formation horizon (Fig. 12) is limited to the northern half of the Gascoyne Platform. It highlights a north-northeasterly trending ridge 30 km east of Pendock 1, and shallowing of the pre-Permian section towards the Wandagee Ridge. The Kockatea Shale has not been intersected by any wells in the Gascoyne Platform. However, the interpretation of seismic data tied with formation tops in Livet 1 and Wittecarra 1 in the Abrolhos Sub-basin indicates that the unit may extend into shallow-water offshore parts of the southern Gascoyne Platform. Although the top Kockatea Shale horizon (Fig. 37; Plate 4) appears to truncate at the eastern margin of the Abrolhos Sub-basin, the lower part of the unit and underlying Wittecarra Sandstone (the base of which is equivalent to the mid- to Late Permain unconformity) appears to extend almost as far as the coastline near Kalbarri (Fig. 18; Plate 5). To the west of the Geelvink Fault System the Kockatea Shale appears to deepen dramatically, and is probably greater than 6000 m below sea level in the western part of the Abrolhos Sub-basin (Plate 10, section FF').

Discussion

Seismic and gravity data indicate that the Gascoyne Platform consists of a main, northerly trending, elongate trough, which shallows abruptly to the east and south, and gradually to the west and north. The depth to basement for the Gascoyne Platform (Fig. 28), calculated from gravity data (Lockwood and D'Ercole, in prep.), broadly agrees with that determined by Iasky and Mory (1999) and indicates that the sedimentary succession reaches a maximum thickness of about 5000 m. Apatite fission-track analyses (Gibson et al., 1998) show that three main periods of tectonism affected the platform: Late Carboniferous – Early Permian, Late Jurassic – Early Cretacious, and Miocene (Crostella and Iasky, 1997; Iasky et al., 1998; Crostella et al., 2000). The Late Jurassic – Early Cretacious rifting, which culminated in the breakup of Australia from Greater India, and subsequent uplift and erosion in the Early Cretaceous, is easily recognizable on the seismic data as the base Cretaceous unconformity. The Miocene compressional event is also clearly evident from reactivated major faults throughout the Gascoyne Platform. Anticlines associated with Miocene movements have been the focus of hydrocarbon exploration in the Carnarvon Basin, although only a few have been tested on the Gascoyne Platform. In seismic data there is no clear

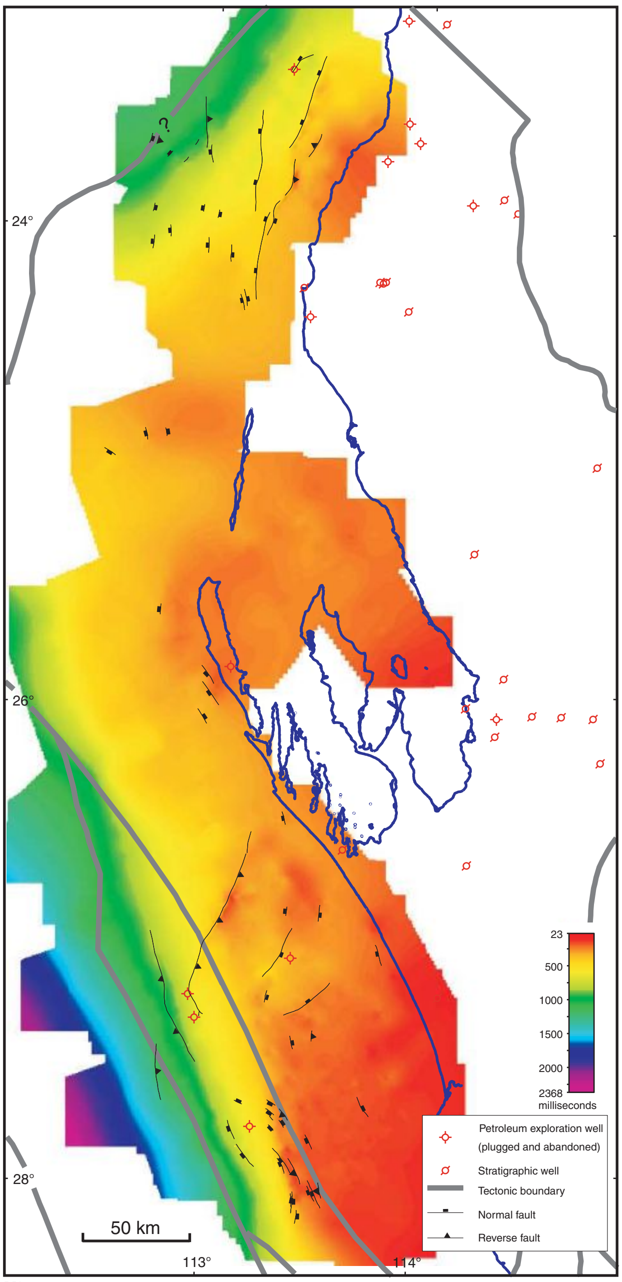


Figure 33. Two-way time structure map of the Miocene unconformity

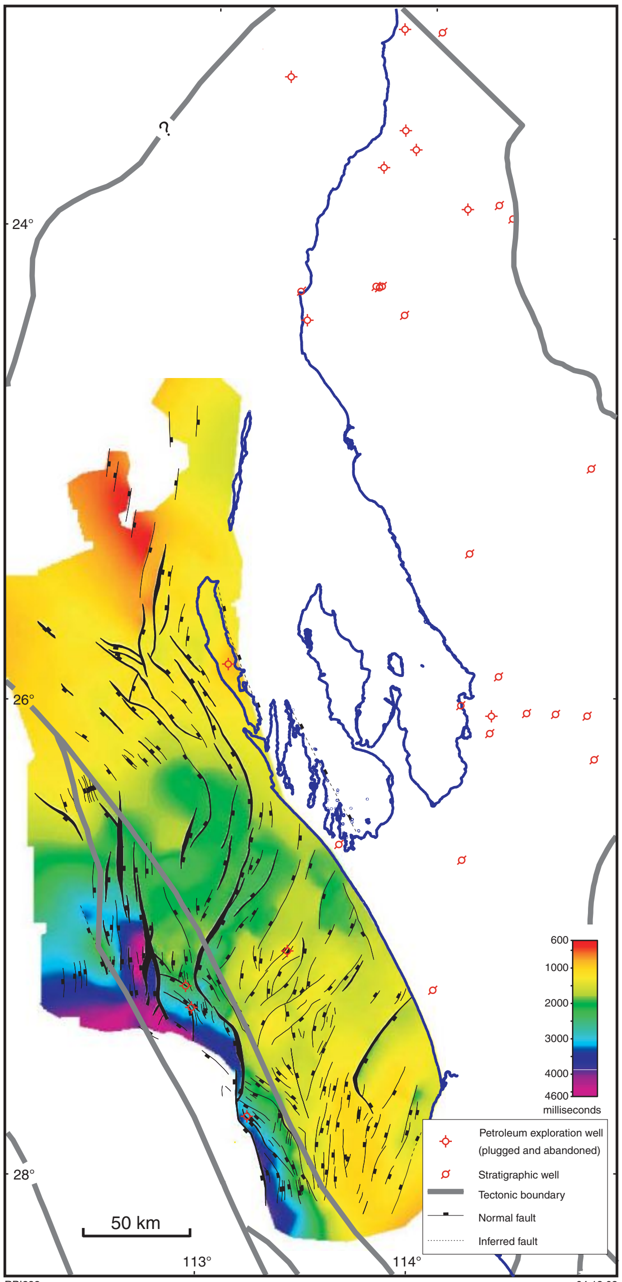


Figure 34. Two-way time-structure map of the near-basement unconformity

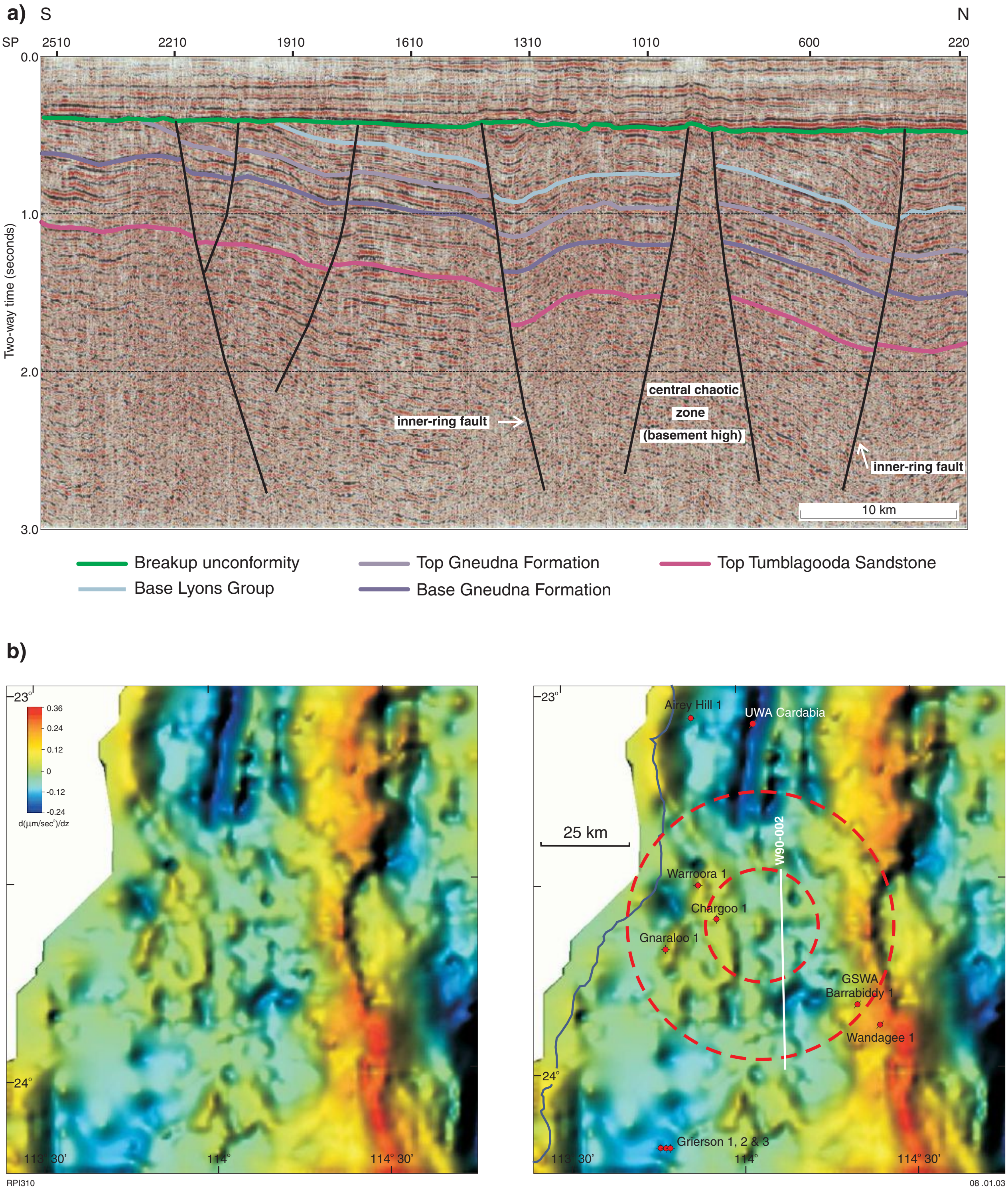


Figure 35. a) Seismic line CW90-02 showing a central zone of chaotic reflections with folded, fault-bounded strata similar to the deformation seen in the Woodleigh impact structure; b) image of the first vertical derivative of Bouguer gravity showing gravity anomalies typical of the central uplift and inner-ring faults in impact structures

evidence for Late Carboniferous – Early Permian tectonism, as the unconformity at the base of the Upper Carboniferous – Lower Permian Lyons Group cannot be distinguished. In contrast, the distinct mid- to Late Permian unconformity, related to a rifting event throughout the northern Perth Basin, can be seen in the offshore southern Gascoyne Platform. It is not clear what effect this had on the northern part of the platform because the pre-Cretaceous succession pre-dates this event, and the base Cretaceous (breakup) unconformity was probably superimposed on the older unconformity. Therefore, faulting in the pre-Cretaceous succession can be attributed to either mid- to Late Permian or Late Jurassic – Early Cretaceous rifting, or both.

Modelled thermal-maturity data indicate that Devonian and older rocks reached maximum burial in the Late Carboniferous – Early Permian, and that about 1300 m of strata were removed from the Gascoyne Platform during the main rifting episodes (Ghori, 1999). Thermal-maturity data from the upper Palaeozoic succession throughout the platform indicate low levels of maturity (Mory et al., 1998; Ghori, 1998), indicating that it was never deeply buried and was a positive structural feature throughout much of the Early Carboniferous – Early Cretaceous. The stratigraphy below the Cretaceous transgressive cycle becomes progressively younger to the north of the Gascoyne Platform, and the Ordovician–Devonian succession is thicker in the south. This indicates that the focus of early deposition shifted from the southern Gascoyne Platform in the early Palaeozoic, to the north from Late Devonian onwards. The lack of significant burial and the onlapping of Upper Devonian to Lower Permian units from the north indicate that the southern part of the platform, underpinned by the Northampton Complex, was a positive structural feature throughout most of the Triassic and Jurassic.

Basin evolution

Pre-Ordovician

Deposition in the Gascoyne Platform began with pre-Ordovician ?fluvial sediments, followed by a period of uplift and erosion, as implied by the unconformity at the base of the Tumblagooda Sandstone (Figs 3 and 15). The uplift was associated with localized faulting that continued throughout the early deposition of the overlying sediments (Tumblagooda Sandstone).

Ordovician to Early Devonian

Deposition in the Ordovician commenced with fluvial to coastal redbed sediments (Tumblagooda Sandstone), which were widespread over the entire Gascoyne Platform. Up to the end of the Devonian, the platform extended into the area now covered by the Merlinleigh, Byro, and Coolcalalaya Sub-basins — those sub-basins did not develop as separate entities until the mid-Carboniferous. The similarity of the Ordovician–Devonian succession on the Gascoyne Platform to that in the Merlinleigh Sub-basin indicates that deposition was continuous over these areas up to the Early Carboniferous (Quail Formation).

Faulting continued throughout the Ordovician in some parts of the Gascoyne Platform (Iasky and Mory, 1999). Towards the end of the Ordovician, or during the earliest Silurian, a relative rise in sea level led to the deposition of carbonates and evaporites in an open- to restricted-marine environment (Dirk Hartog Group). The Silurian depocentre is near the western side of the platform, in contrast to the Ordovician depocentre near the Ajana

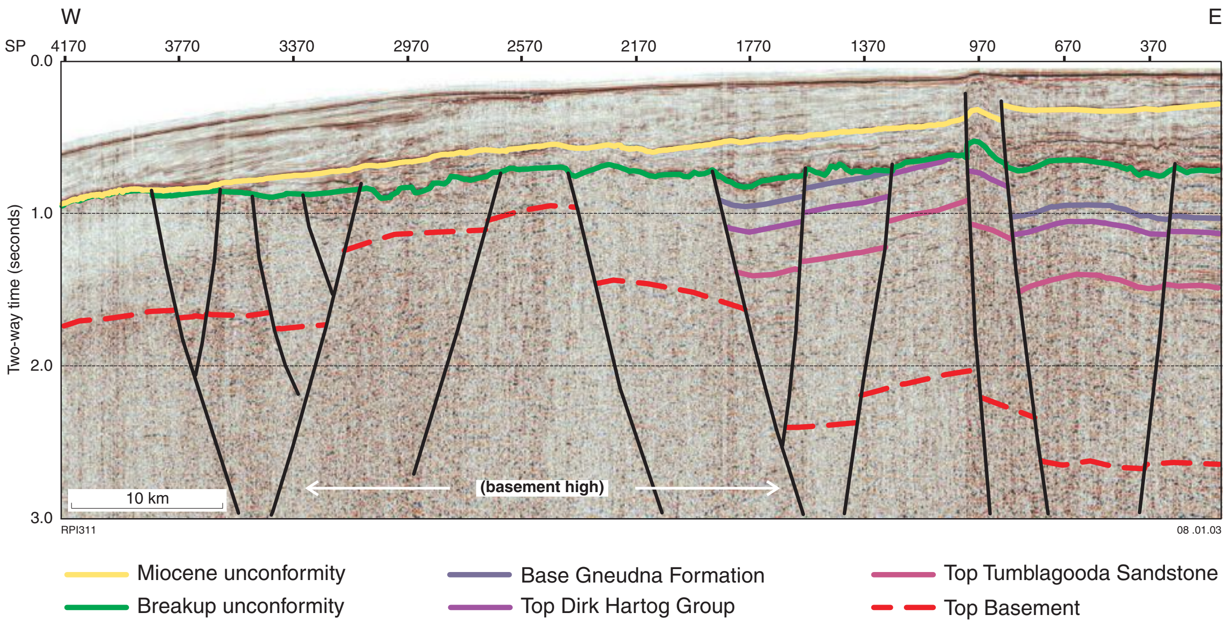


Figure 36. Seismic line 92M-128 showing offshore basement high and faulting continuing in the Cretaceous

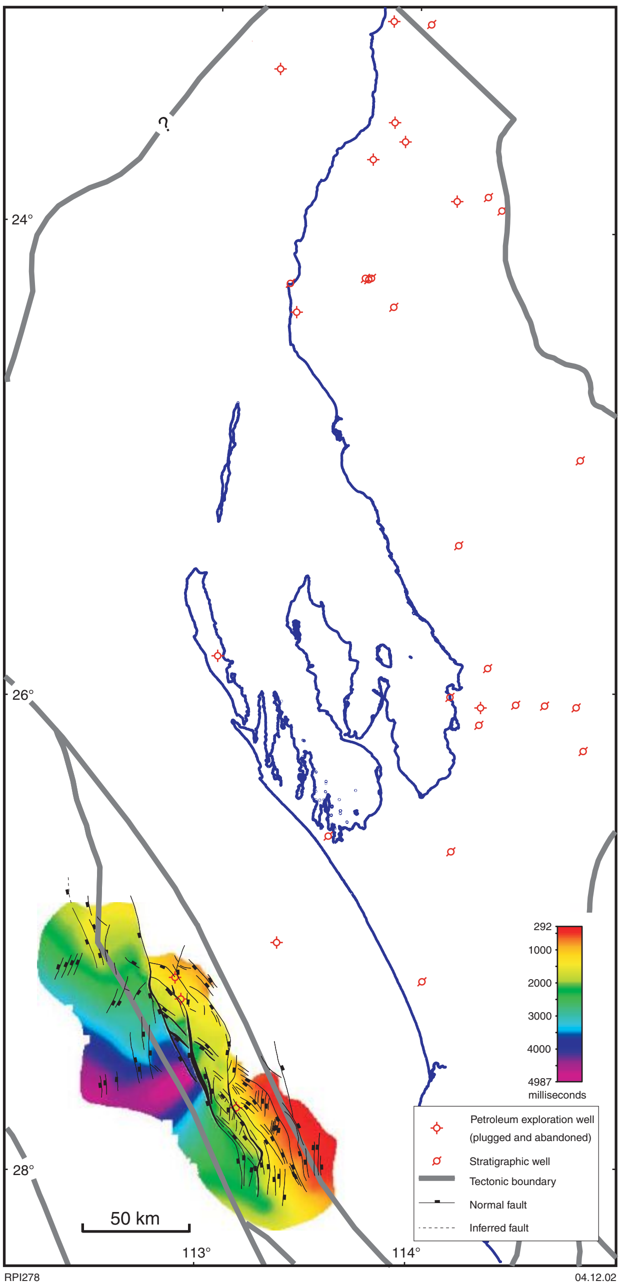


Figure 37. Two-way time structure map of the top Kockatea Shale

Ridge to the east. This implies relative uplift during the Silurian along the Wandagee and Ajana Ridges and in the southern Gascoyne Platform. Both ridges continued to be positive structural features throughout the depositional history of the platform (Iasky and Mory, 1999).

A short hiatus at the end of the Silurian preceded deposition of mixed siliciclastic sediments and dolomite in a shallow-marine environment (Faure Formation). This was followed by a minor relative fall in sea level and the deposition of sand in a similar environment to that of the Upper Ordovician Tumblagooda Sandstone, but with minor amounts of dolomite (Kopke Sandstone). Deposition of the succeeding mixed siliciclastic–carbonate succession (Sweeney Mia Formation) is preserved only over the central onshore part of the platform.

Mid-Devonian to mid-Carboniferous

After a period of non-deposition towards the end of the Early Devonian, deposition recommenced in the Emsian–Givetian, but was restricted mainly to the northern half of the Gascoyne Platform. Deposition of Early–Middle Devonian basal transgressive sands (Nannyarra Sandstone) was followed by Givetian-Frasnian shelf carbonates (Gneudna Formation) and Famennian fine-grained, shallow-marine to coastal siliciclastic sediments (Munabia Formation). In the Early Carboniferous, intermittent subsidence caused fluctuations in relative sea level, and braided-fluvial and alluvial-fan sediments (Moogooree Limestone and Quail Formation) were deposited over the northern Gascoyne Platform.

Mid-Carboniferous to Late Jurassic

The mid-Carboniferous was a period of uplift, erosion, and non-deposition over most of the Gascoyne Platform, driven by the collision of Gondwana and Laurasia. At this time, at least 1300 m of strata was stripped from the platform. Rifting in the mid-Carboniferous to Early Permian activated the Wandagee, Kennedy Range, and Darling Fault Systems. These fault systems controlled the development of major depocentres in the Merlinleigh, Byro, and Coolcalalaya Sub-basins, which were initially filled by thick, glacially influenced Carboniferous–Permian sediments (Lyons Group; Iasky and Mory, 1999; Eyles et al., 2002, 2003). In the Merlinleigh and Byro Sub-basins, post-rift deposition continued into the Late Permian. Carboniferous–Permian sediments were only deposited in the northernmost part of the platform and farther north towards the Cape Range peninsula.

The low thermal maturity of Silurian and Devonian sedimentary rocks on the Gascoyne Platform, and the lack of widespread Permian to Jurassic units over the central and northern parts, suggest that the platform was a relative positive structural feature, which diverted sediment around it until at least the end of the Jurassic. However, in the offshore southern part of the platform, Lower Permian strata of the northern Perth Basin (Carynginia Formation and ?Irwin River Coal Measures) onlap the platform. After a period of uplift and erosion in the mid- to Late Permian in the southern part of the area (Fig. 18), deposition of marine sediments recommenced (Lower Triassic Wittecarra Formation and Kockatea Shale). If Middle–Late Triassic deposition (Woodada Formation and Lesueur Sandstone) in the Abrolhos Sub-basin (Plate 10) encroached onto the southern part of the Gascoyne Platform, it has since been removed by erosion. The only Jurassic strata found to date are lacustrine facies, restricted to the Woodleigh impact structure east of Hamelin Pool (Woodleigh Formation). Middle–Late Jurassic strata are not preserved on the platform, due either to non-deposition, or removal by erosion at the onset of the major rifting phase associated with the breakup of Australia from Greater India.

Earliest Cretaceous

The breakup of Australia from Greater India began in the Middle Jurassic and culminated in complete separation by the Early Cretaceous. Although its effect on the Gascoyne Platform was smaller than in the regions to the north, the Late Jurassic cooling episode indicated by AFTA (Gibson et al., 1998) is probably related to these movements. Major northerly trending faults, such as the Wandagee and Kennedy Range Faults, were reactivated with significant dextral strike-slip, and northwesterly trending transfer faults, such as the Cardabia Transfer Fault, were formed (Crostella and Iasky, 1997; Iasky and Mory, 1999).

Cretaceous to Early Miocene

After breakup, basal transgressive sand (Birdrong Sandstone, Winning Group) was deposited over the entire Southern Carnarvon Basin in a coastal to nearshore environment. Overlying shallow-marine silts, radiolarite, clays, calcilutite, and calcarenite record progressively deeper waters across the platform. The Winning Group gradually thickens towards the northern part of the Gascoyne Platform, attaining its greatest thickness in the Exmouth Sub-basin (Figs 22, 23, and 24).

A change in ocean currents and rate of sediment supply initiated the transition to carbonate deposition in the Turonian (Haycock Marl) that was virtually complete by the Coniacian in the Southern Carnarvon Basin. Carbonate deposition continued from the Late Cretaceous (Toolonga Calcilutite, Korojon Calcarenite, and Miria Formation) into the Cainozoic (Cardabia and Giralia Calcarenites). Offshore, thick prograding carbonates were deposited throughout most of the Cainozoic, whereas onshore the Gascoyne Platform remained largely subaerial, with minor deposition in the Eocene and Miocene (Hocking et al., 1987). In the Miocene, a compressional tectonic episode reactivated pre-existing major faults with a significant strike-slip component (Figs 10 and 32), and created the anticlines near Lake MacLeod, which appear to increase in amplitude to the north. The Cainozoic cooling event indicated by AFTA (Gibson et al., 1998) correlates with this compression.

Late Miocene to Pliocene

After the Miocene phase of compression, deposition resumed with shallow-marine carbonates facies (Trealla Limestone) unconformably over the Cardabia or Giralia Calcarenites. The latest phase was the deposition of a thin veneer of Quaternary continental sediments in an arid climate. Onshore, this led to widespread formation of calcrete duricrust in the Pliocene, and thick Pleistocene coastal dunes.

Petroleum potential

Source rock

The main Palaeozoic intervals with demonstrated source-rock potential in the Gascoyne Platform are the Silurian Coburn Formation of the Dirk Hartog Group and Upper Devonian Gneudna Formation (Fig. 2; Ghori 1996, 1998, 1999, 2002). The Lower Triassic Kockatea Shale is regarded as the major oil-source rock (Summons et al., 1995) in the Perth Basin and may be a source of long-range migration of hydrocarbons from the Abrolhos Sub-basin into the southwestern part of the platform. Furthermore, at least in the Abrolhos Sub-basin, the overlying Woodada Formation has fair to very good petroleum-generating potential (Crostella, 2001) and may supplement the Kockatea Shale as a source. Although long-range migration from Jurassic source rocks of the Northern Carnarvon Basin — considered amongst the most effective of the North West Shelf (Scott, 1992; Longley et al., 2002) — is possible, it is unlikely as only small quantities of hydrocarbons have been found near Rough Range. The mudstone facies unit (Muderong Shale) in the Cretaceous Winning Group has generated hydrocarbons in the Northern Carnarvon Basin, and possibly biogenic gas on the Peedamullah Shelf (Crostella et al., 2000), but the unit is immature and cannot be considered a source interval on the Gascoyne Platform. Therefore, in this Report the discussion of maturity and timing for oil generation is limited to the Silurian, Devonian, and Triassic successions.

The best source beds analysed to date are from the Silurian Coburn Formation in Yaringa East 1 in the southern part of the platform, and the Devonian Gneudna Formation in Barrabiddy 1A in the northern part. In both wells these source-rock intervals are thin beds of laminated mudstone within carbonate facies, but are organic rich and oil prone. The Silurian source beds have an organic richness of up to 7.43% total organic carbon (TOC), potential yield ($S_1 + S_2$) of up to 38.1 mg/g rock, and a hydrogen index of up to 505. Devonian source beds have an organic richness of up to 13.56% TOC, potential yield of up to 40.09 mg/g rock, and a hydrogen index of up to 267.

Fifteen wells and 84 pseudo wells (based on seismic data; Appendix 8) were modelled to estimate the maturity at the top of the Silurian (Fig. 38) and Devonian (Fig. 39) successions. Barrabiddy 1A, Pendock 1, and Yaringa East 1 were used to reconstruct the timing of hydrocarbon generation for source rocks within the Coburn and Gneudna Formations. Wittecarra 1 was used to reconstruct the hydrocarbon-generation history of the Triassic Kockatea Shale at the western margin of the Gascoyne Platform. As the burial, thermal, and erosional histories are complex and poorly constrained on the Gascoyne Platform, two different scenarios were modelled for the two major erosional events. In the first, most of the erosion is accounted for during the Permian (Fig. 40, model A), and in the second, most of the erosion is accounted for at breakup in the Early Cretaceous (Fig. 40, model B).

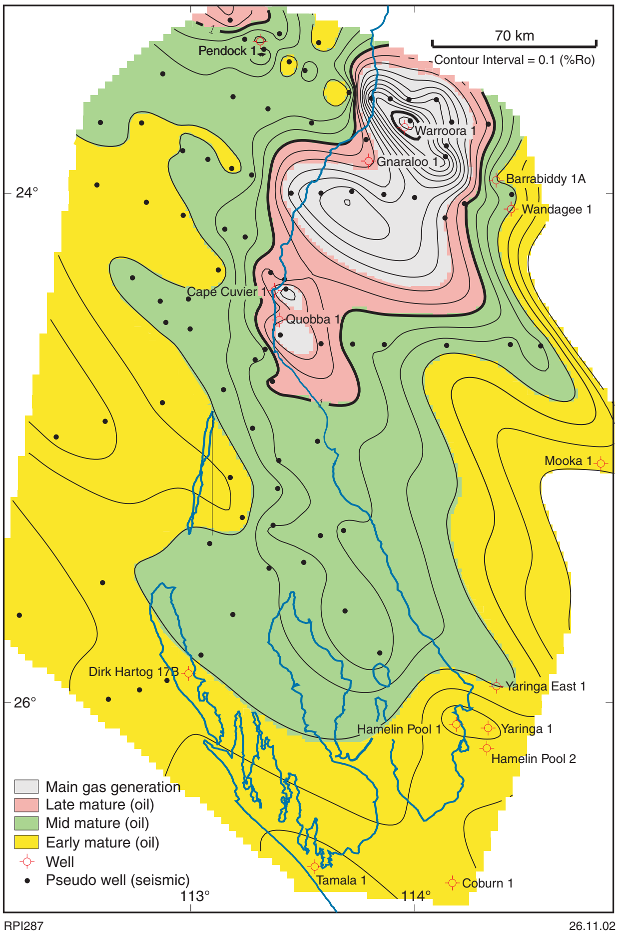


Figure 38. Maturity map for the Upper Silurian succession in the Gascoyne Platform

The maturity of the Silurian section increases northward within the Gascoyne Platform, probably due to deeper burial — it was intersected at 568 m in Coburn 1 in the south and at 1850 m in Pendock 1 in the north. In the south, in Coburn 1, GSWA Woodleigh 2A, and Yaringa East 1, Silurian source beds range from immature to early mature for oil. To the northwest, in Quobba 1 and Pendock 1, the Silurian section is buried more deeply, and is therefore fully mature and within the main phase of the oil-generative window (Fig. 38). Similarly, the Devonian section increases in maturity northward. The Devonian Gneudna Formation is mature in the northern Gascoyne Platform, where it was intersected at 276–778 m in Barrabiddy 1A and 1030–1692 m in Pendock 1, and becomes immature to the south (Fig. 39).

In the model with major erosion during the Permian (Fig. 40, model A), the maximum rate of hydrocarbon generation from Silurian and Devonian source rocks is at the end of the Permian. By comparison, the peak of hydrocarbon generation for these beds extends from the Permian to Middle Jurassic for the model with major erosion during the Early Cretaceous (Fig. 40, model B). However, in either case, pre-Permian to Late Permian traps are required to be charged during the period of maximum expulsion, and structures formed by later events have little chance of being charged from Silurian and Devonian sources.

The burial history and maturity modelling of Wittecarra 1 (Fig. 41) indicate that the rate of hydrocarbon generation of the Triassic Kockatea Shale peaked at the end of the Jurassic, just prior to breakup. On the Gascoyne Platform, these hydrocarbons could have charged existing structures (mid-Carboniferous to Late Permian) or may have filled contemporaneous structures. Secondary migration of hydrocarbons into Cretaceous–Miocene structures, from mid-Carboniferous – Late Permian structures breached by later tectonism, is also possible.

Reservoir

The Ordovician Tumblagooda Sandstone has variable porosity and permeability, although even at depths greater than 1000 m porosity is typically good, with an average of 13% (Fig. 42). An anomalous porosity value was measured at 341.68 m in Kalbarri 1 (porosity of 26.6% with a permeability of 1758 mD), implying that this section was never deeply buried. It has been suggested that porosity within the Tumblagooda Sandstone is facies dependent (Trewin and Fallick, 2000). Although this unit is known to have good reservoir characteristics, the samples taken from Wandagee 1, from a thin bed of laminated, silty facies previously assigned to the

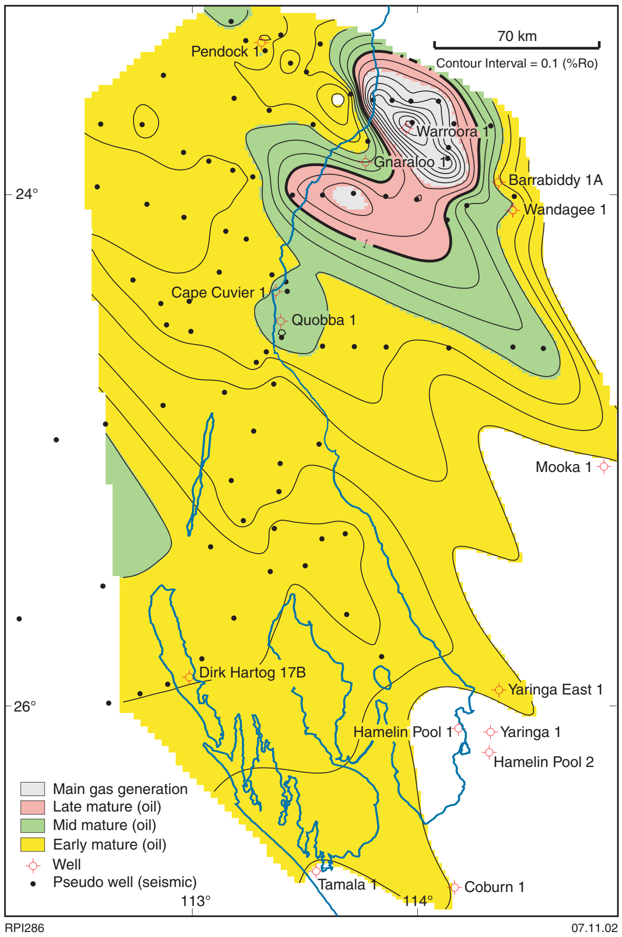


Figure 39. Maturity map for the Upper Devonian succession in the Gascoyne Platform

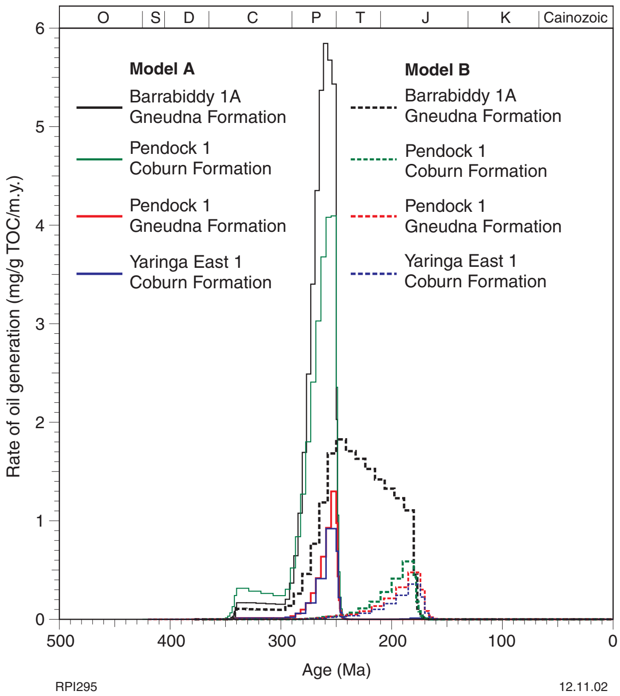


Figure 40. Timing of oil generation for Devonian and Silurian source rocks in Pendock 1, Barrabiddy 1A, and Yaringa East 1. Model A depicts the rate of hydrocarbon generation due to major erosion during the Permian. Model B shows the same due to major erosion during the Early Cretaceous

Tumblagooda Sandstone, but atypical of it, have porosities ranging from 1 to 3%.

The overall porosity and permeability of the carbonates within the Dirk Hartog Group are low, although some high values are noted in the Ajana Formation (Fig. 42). There are only a few permeability results available for the Dirk Hartog Group — not enough to be representative — but most were very low. The carbonates within the Dirk Hartog Group were extensively dolomitized and replaced, in part, by late-stage anhydrite cements, indicating that much of the original porosity has been destroyed (El-Tabakh et al., in prep.). In the northern Gascoyne Platform, where the Dirk Hartog Group has been buried relatively deep, this diagenesis is expected to be more pervasive (Iasky and Mory, 1999).

The Ajana Formation has the best reservoir characteristics within the Dirk Hartog Group (Fig. 42). For example, a sandstone unit within the Marron Member of the Ajana Formation in Coburn 1 (936–955 m) has a porosity of 22.9% and permeability of over 600 mD (Yasin and Mory, 1999a). Good porosity values have also been recorded from the Ajana Formation in Tamala 1 (14.1% at 957 m) and Yaringa 1 (16–22% from 1427–1523 m). The Coburn and Yaringa Formations have variable reservoir characteristics and may be regarded as potential reservoirs in parts of the Gascoyne Platform.

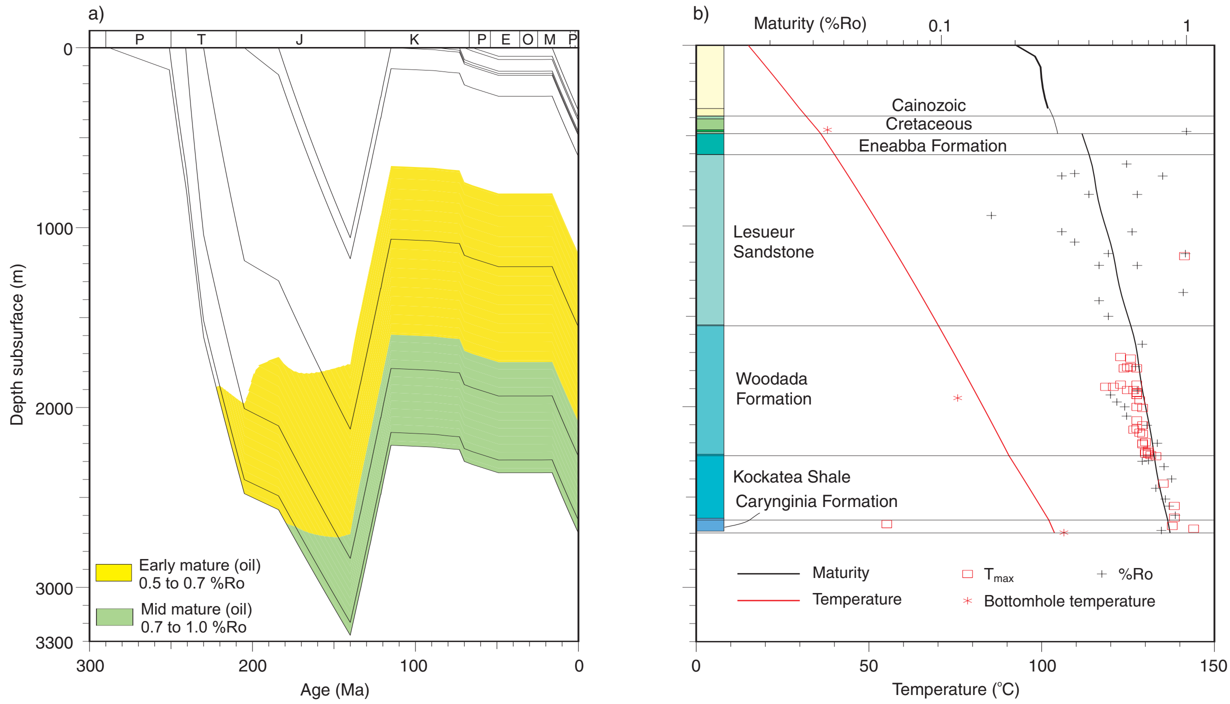
The Lower Devonian Faure Formation has poor to excellent porosity and permeability and could be a potential reservoir (Fig. 42). The highest recorded values of porosity and permeability, from a basal sandstone in GSWA Mooka 1, are 24.3% and of 3940 mD respectively (Mory and Yasin, 1998), although averages for the formation are typically lower (porosity of 11.3% and permeability of 52.98 mD). The porosity significantly decreases with depth (Fig. 42b).

The Lower Devonian Kopke Sandstone typically has good reservoir characteristics (Fig. 42). In Yaringa 1, porosities and permeabilities from the interval 354.5 – 741.6 m are up to 23% and 2380 mD respectively. In Yaringa East 1 porosities range from 15.6 to 27.1% (Yasin and Mory, 1999b), and in Coburn 1 from 23.8 to 28.5% (Yasin and Mory, 1999a). Permeabilities in these two wells have a range of 32.4 – 4560 mD.

Dolomite intervals within the Sweeney Mia and Gneudna Formations may also be potential reservoirs. Although well data show that these carbonate facies have little permeability (Gorter et al., 1994), similar dolomite in the Dirk Hartog Group must have had considerably better permeability in the past to facilitate dolomitization (El-Tabakh et al., in prep.). In contrast, dolomitization of the Point Maud Member within the Gneudna Formation appears to have enhanced the development of vuggy porosity and permeability (Mory and Yasin, 1999). Measured porosities in this unit in Barrabiddy 1A are up to 15.5%, and log-derived values are up to 28.1%, although the relatively high log porosities may be unreliable as they are measured from a caved interval (Havord, 1999). Log-derived porosities of up to 31% from Quobba 1 also demonstrate well-developed porosity within the Point Maud Member (Fig. 42b). The Sweeny Mia Formation has excellent porosity (17.5 – 29.5%), but moderate permeabilities (101–320 mD; Fig. 42). The Nannyarra Sandstone has good measured porosity (3.0 – 18.3%) in Pendock 1 and log-derived porosities (up to 23%) in Quobba 1 (Fig. 42b), but very low permeability (0.1 – 28 mD) in Pendock 1 (Fig. 42a). The Munabia Formation has good reservoir qualities with porosity and permeability up to 26.1% and 541 mD respectively in Barrabiddy 1A (Fig. 42; Mory and Yasin, 1999).

Although there are no porosity or permeability data for the Lower–Upper Triassic section in the Gascoyne Platform, evidence from the Perth Basin shows that the Wittecarra and Lesueur Sandstones are potential reservoirs (Crostella, 2001; Mory and Iasky, 1996).

Within the Cretaceous succession, the Birdrong Sandstone and the Windalia Sandstone Member (Muderong Shale) of the Winning Group have excellent reservoir characteristics (Fig. 42). The Birdrong Sandstone has porosities of 24.5 – 32.3% and permeabilities of 88.4 – 980 mD. This unit is a proven reservoir (Rough Range Oilfield and Tubridgi Gasfield; Crostella, 1996; Crostella et al., 2000) and an aquifer with artesian flows near the coast. Even where measurements where not taken, observations of available core indicate good porosity and permeability (Yasin and Mory, 1999a,b). In Barrabiddy 1A, the Windalia Sandstone Member has a high maximum core porosity of 36.9%, but a relatively low permeability of 106 mD (Mory and Yasin, 1999). In Coburn 1, this unit also has excellent porosities of 32.9 – 34.1%, but unlike



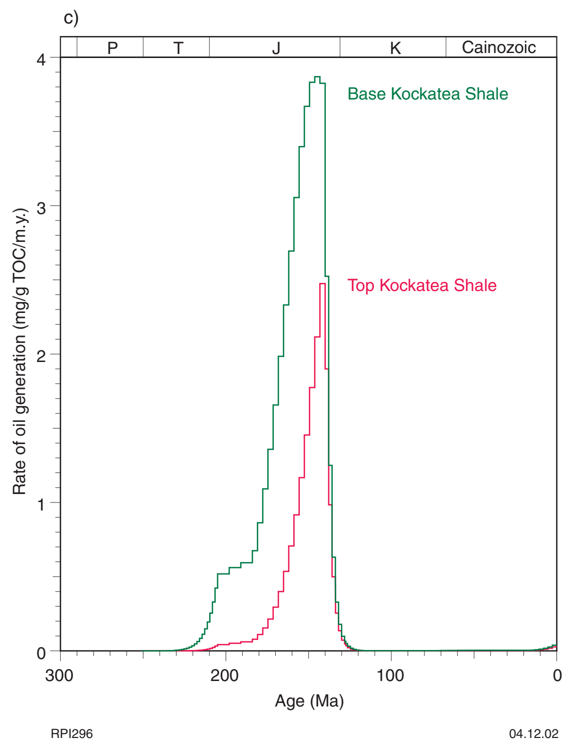


Figure 41. Burial history and timing of oil generation for the Kockatea Shale in Wittecarra 1: a) burial history and oil window plot; b) comparison of corrected present-day bottomhole temperature, vitrinite reflectance (%Ro), and T_{max} with modelled temperature and maturity; c) timing of oil generation

in Barrabiddy 1A, it also shows excellent permeability, ranging from 8170 to 9240 mD (Yasin and Mory, 1999a).

Seal

There are several potential Palaeozoic sealing sections within the Gascoyne Platform (Fig. 2). The basal shale of the Dirk Hartog Group (Marron Member) is up to 100 m thick and may seal the underlying Tumblagooda Sandstone, as well as sandstone within the member (Iasky and Mory, 1999). Intraformational shales higher within the group could also trap hydrocarbons, but are generally thin. Mudstone and shale of the Faure Formation are up to 150 m thick and may seal the Dirk Hartog Group. Shale and carbonate rocks of the Sweeney Mia Formation are almost 200 m thick and may seal the underlying Kopke Sandstone.

Shales up to 40 m thick within the Gneudna Formation could be an effective intraformational seal, as well as sealing the underlying Nannyarra Sandstone. The Carboniferous succession in the Gascoyne Platform is largely undefined, but elsewhere in the Carnarvon Basin it contains limestone and shale beds (Moogooree Limestone and Quail Formation) that could potentially seal the Munabia Formation. The Lyons Group is a thick, predominantly shaly unit that could seal underlying reservoirs, but is restricted to the northernmost part of the platform (Iasky and Mory, 1999).

In the southern part of the Gascoyne Platform the Kockatea Shale, which is a regional seal in the Perth Basin (Mory and Iasky, 1996), could seal underlying reservoirs.

The Muderong Shale, Windalia Radiolarite, and Gearle Siltstone are proven seals in the Northern Carnarvon Basin (Crostella et al., 2000) and should also be effective seals, where thick enough, for the Birdrong Sandstone in the Southern Carnarvon Basin. The presence of Miocene traps upgrades the economic potential of the Birdrong Sandstone within the area, provided the overlying seal is in place.

Traps

The main objective for petroleum exploration in the Gascoyne Platform has been the Birdrong Sandstone sealed by the Muderong Shale in Miocene anticlinal structures on the hangingwall of pre-breakup normal faults reactivated with reverse movement. In the footwall, pre-Cretaceous strata commonly dip away from the controlling fault, and the trap would be fault dependant (Fig. 32, shotpoint 3200). In some instances these faults were reactivated in the Miocene with normal movement and form rollover plays on the footwall (Fig. 10, shotpoint 700; Fig. 32, shotpoint 2800). Although such plays were targeted by early exploration, a few untested Miocene structures remain in the northern part of the area surrounding Pendock 1 (Plate 3). A likely problem with the Birdrong Sandstone is that strong artesian flow could displace or wash hydrocarbons from all but the most robust traps, unless such flow is diverted by pinchouts, low permeability, or faults.

Possible stratigraphic traps include incised channels filled by the Birdrong Sandstone at the breakup unconformity level (e.g. Fig. 36, between shotpoints 1300 and 1700) and sealed by the Muderong Shale. In the northern Gascoyne Platform, where the Birdrong Sandstone is missing, there may be additional traps in which dipping

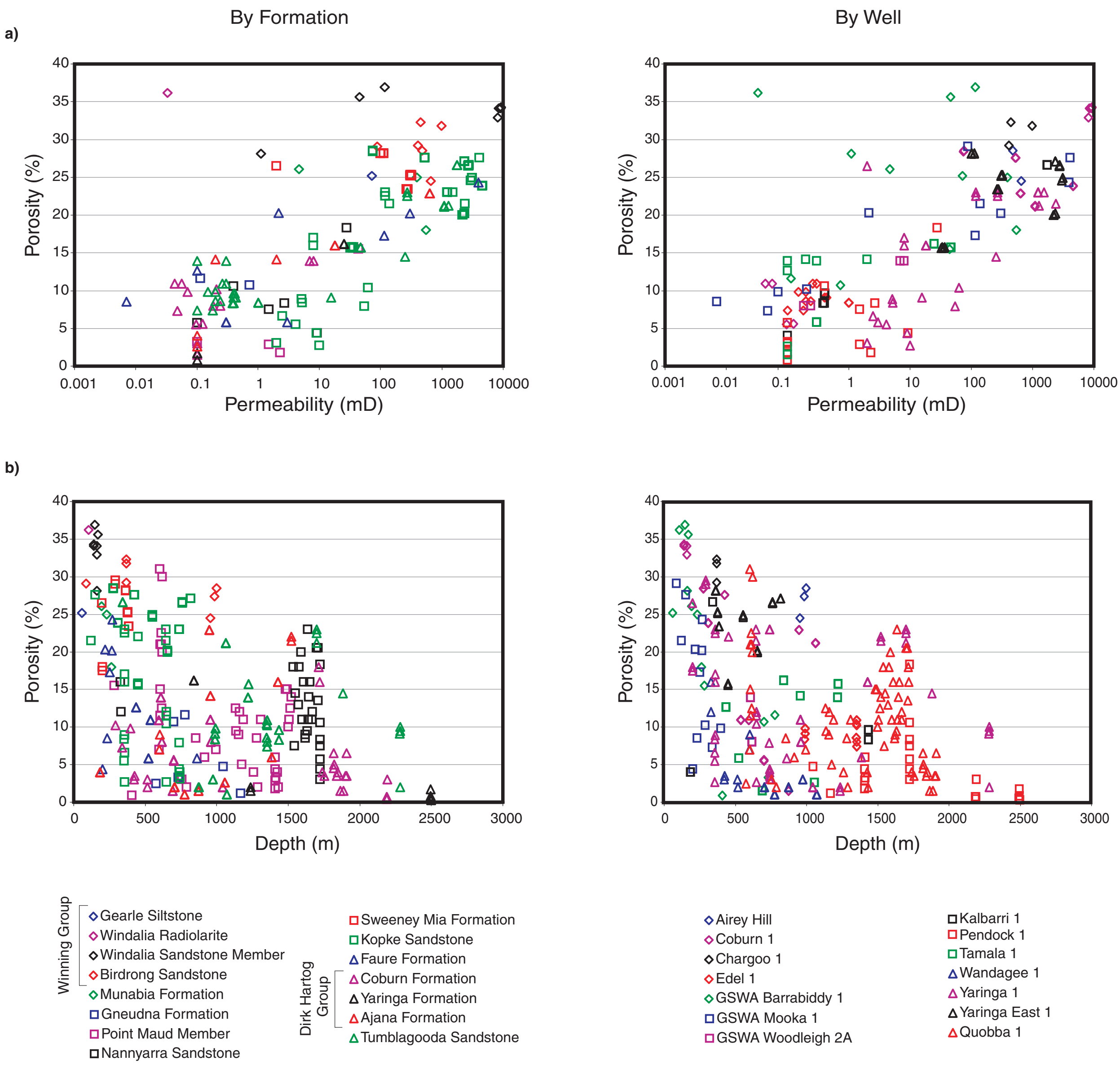


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Figure 42. a) Porosity versus permeability (by formation and well) for potential reservoirs; b) porosity versus depth for the same potential reservoirs

Palaeozoic reservoir rocks are truncated at the breakup unconformity and sealed by the Muderong Shale. Similarly in the southern area, dipping Lower Permian reservoir rocks truncated at the mid- to Late Permian unconformity may be sealed by the Kockatea Shale if the Wittecarra Sandstone is absent.

Palaeozoic traps in the Gascoyne Platform include Ordovician, Silurian, and Devonian reservoir rocks in rotated fault blocks, created by mid- to Late Permian and Late Jurassic – Early Cretaceous rifting. Such traps may be effective if sealed by intraformational shales. Other possible Palaeozoic plays in the southernwestern part of the platform include fault traps in which the Kockatea Shale seals the Tumblagooda Sandstone (Plate 7). These traps could have been charged by hydrocarbons that migrated up-dip from more deeply buried sections of the Kockatea Shale in the Abrolhos Sub-basin. The Wittecarra Sandstone Member at the base of the Kockatea Shale is present in Wittecarra 1 and Livet 1, and probably extends onto the southwestern part of the platform (Plate 5). The unit is a possible objective in fault traps where it is sealed by the overlying shales and juxtaposed against Lower Permian shale. In the northern part of the platform, east of Pendock 1, there are a few untested faulted anticlines within the Gneudna Formation along a north-northeasterly trending fault (Plate 6) in which reefal carbonate facies of the Point Maud Member of the Gneudna Formation may be sealed intraformationally.

Prospectivity

At the time of writing, a total of 32 petroleum exploration and stratigraphic wells had been drilled on the Gascoyne Platform. Of these, 10 were drilled as new-field wildcats, which equates to one new-field wildcat per 12 000 km^2. Seven wells were drilled to test the Birdrong Sandstone in Miocene anticlinal structures, and three (Yaringa 1, Carlston 1, and Edel 1) were drilled to test Palaeozoic structures, but were dry holes. It is unclear from the available seismic data, which are mostly of very poor quality, if any of these wells tested a valid structure below the breakup unconformity. The only hydrocarbon shows in the Silurian and Devonian sections in the Gascoyne Platform to date include: traces of gas and residual oil from the Coburn Formation in Dirk Hartog 17B (Pudovskis, 1957), minor gas and oil shows from the Silurian and Devonian sections in Pendock 1 (Genoa Oil N.L., 1970), minor gas from the Tumblagooda Sandstone in Wandagee 1 (Pudovskis, 1962), and residual oil from the Dirk Hartog Group in Tamala 1 (Oceania Petroleum Pty Ltd, 1973). Of over 40 wells, mostly drilled by WAPET, on the Cape Range peninsula, only four had significant hydrocarbons within the Birdrong Sandstone: Rough Range 1 and 1A, with a 7.5-m oil column; Parrot Hill 1, which intersected a 6.2-m oil column; and Roberts Hill 1, which penetrated a thin oil zone. Even though Ellis and Jonasson (2002) indicated that the geochemical data are equivocal, Partington et al. (2003) implied that these oils are sourced from Jurassic units. Although Jurassic source rocks are considered amongst the most effective of the Northern Carnarvon Basin (Scott, 1992; Longley et al., 2002), economic hydrocarbons from such a source are unlikely in the Gascoyne Platform, as long-range migration is required. Furthermore, it is unlikely that Jurassic-sourced hydrocarbons have migrated south into the platform because few of the structures along the Rough Range Fault have yielded hydrocarbons. The only area in which such migration is feasible is along the Bernier Ridge (Lockwood and D'Ercole, in prep.), but even there it is unlikely that hydrocarbons could have migrated south of the basement high.

The maturity of the Silurian Coburn Formation and Devonian Gneudna Formation increases to the north, with the former presently mature for hydrocarbon generation (Fig. 38) and the latter mostly in the early stage of maturation (Fig. 39). The modelled peak expulsion of hydrocarbons for Silurian and Devonian source rocks during the Late Permian to Middle Jurassic (Fig. 40) suggests that, to be effective, traps should have been emplaced before the Middle Jurassic. However, secondary migration into post-Late Jurassic structures may have taken place. For example, peak expulsion from the Triassic Kockatea Shale, which is within the oil-generative window along the southwestern margin of the Gascoyne Platform, was probably in the Late Jurassic. It is possible that hydrocarbons from the Kockatea Shale in the Abrolhos and Houtman Sub-basins, and the Locker Shale in the Exmouth Sub-basin, migrated into the adjacent Gascoyne Platform during Late Jurassic expulsion. Pre-Late Jurassic structures would be required to trap these hydrocarbons.

Miocene anticlinal structures are the most prospective traps in the Gascoyne Platform, but there is potential for Palaeozoic objectives. These have not been fully explored — only three wells had pre-breakup structural objectives: Edel 1 was drilled into a pre-breakup anticline formed by igneous intrusions; Yaringa 1 was drilled to test a pre-Cretaceous anticlinal structure, but closure of the structure is uncertain; and Carlston 1 was abandoned without finding the objective reefal limestones of the Gneudna Formation.

Conclusions

The Gascoyne Platform is a poorly explored, structurally elevated part of the Southern Carnarvon Basin that contains a ?Cambrian to Cainozoic sedimentary succession about 5000 m thick. The low level of thermal maturity in the Palaeozoic section over much of the platform indicates that it was never deeply buried and was a positive structural feature throughout much of its post-depositional history.

Seismic and gravity data indicate a north-trending, elongate trough in the onshore central part of the platform that shallows abruptly to the east and south, and gradually to the west and north towards the Cape Range peninsula. Isopachs of the Gneudna Formation indicate that the Devonian depocentre was near the present-day coastline. Drilling indicates that the Upper Carboniferous – Jurassic succession thickens to the north towards the peninsula, whereas shallowing basement in this area implies there is thinning of the lower Palaeozoic succession. The presence of progressively younger Palaeozoic units to the north and isopach maps based on seismic data indicate that the focus of early deposition was in the southern part of the platform and shifted to the north by the late Palaeozoic. Along the western margin of the platform, the Geelvink Fault System and its northern extension is a complex series of northerly to northwesterly trending, en echelon faults. This fault system can be regarded as a hinge zone along which a thin lower Palaeozoic sedimentary succession was downthrown to the west below the rapidly thickening Mesozoic succession of the Abrolhos, Houtman, and Exmouth Sub-basins.

A pre-Ordovician sedimentary succession in the Gascoyne Platform, imaged on seismic profiles below an unconformity, represents a tectonic episode pre-dating deposition of the Tumblagooda Sandstone. This unit may correlate with the Cambrian–Ordovician section in Wandagee 1, or perhaps even the uppermost part of the Badgeradda Group (Proterozoic–?Cambrian).

Early Ordovician, Late Carboniferous – Early Permian, mid- to Late Permian, Late Jurassic – Early Cretaceous, and Miocene tectonic episodes influenced the Phanerozoic depositional history of the Gascoyne Platform. However, the Early Cretaceous breakup event masks the effect of older events by reactivating many pre-existing faults. The last major structural event, mid-Miocene compression to transpression, reactivated normal faults with a reverse or strike-slip displacement. This event formed anticlines within the Cretaceous succession, which have been the main focus of petroleum exploration in the area, albeit unsuccessful.

Seismic data indicate that pre-Cretaceous structural trends are typically parallel to the coastline and consist of north-northeasterly trends in the northern part of the Gascoyne Platform, northwesterly trends in the central part, and northeasterly trends in the southern part. The gravity data show: northerly trending lineaments along the eastern margin; northwesterly and southwesterly trending lineaments within the platform that are probably related to transfer faults along zones of weakness within basement; and associated fault systems in the sedimentary section. Within the platform, faulting in the pre-Cretaceous section is typically extensional with generally minor vertical displacement.

On the platform, crystalline basement does not have a high magnetic intensity. The positive magnetic anomaly at Edel 1 is attributed to shallow Upper Permian volcanic rocks intersected within the sedimentary section, and other positive magnetic anomalies are possibly due to similar units within basement. Seismic and gravity data indicate a large basement high directly below the Early Cretaceous breakup unconformity in the northern offshore part of the platform (Bernier Ridge). The age and uniform thickness of the faulted succession indicate a post-Devonian to pre-Cretaceous age for the basement uplift. Another smaller basement high immediately below the breakup unconformity east of Chargoo 1, in the northern onshore Gascoyne Platform, may be the central uplifted area of an impact structure. The age of this structure is poorly constrained between the Late Carboniferous and Early Cretaceous.

In terms of petroleum potential, the Silurian Coburn and Devonian Gneudna Formations are the main source rock intervals on the Gascoyne Platform, and are mostly mature and early mature respectively. Furthermore, long-range hydrocarbon migration is possible from Triassic source rocks in the adjacent Abrolhos Sub-basin and Jurassic source rocks in the Exmouth Sub-basin.

The main objective for petroleum exploration in the Gascoyne Platform has been Miocene anticlinal structures, with the Birdrong Sandstone reservoir sealed by the Muderong Shale. A few of these structures in the northern part of the platform have yet to be tested. By comparison, Palaeozoic objectives in fault traps have not been adequately tested. Such objectives include the Tumblagooda Sandstone sealed by the Kockatea Shale in the southern part of the platform, and reefal carbonate facies within the Gneudna Formation to the north. In the southwestern part of the platform, fault traps involving the Wittecarra Sandstone Member sealed by the Kockatea Shale and juxtaposed by Lower Permian shales are possible.

To date, seven new-field wildcats have tested Cretaceous objectives, and three have tested Palaeozoic objectives in the Gascoyne Platform, but none were successful. The success of petroleum systems in the area requires that traps formed before peak hydrocarbon expulsion from Palaeozoic sources during the Late Permian to Middle Jurassic. Furthermore, pre-Late Jurassic traps are required for long-range hydrocarbon migration from the Kockatea Shale to be successfully accumulated. Secondary migration into younger traps is possible.

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Appendix 1

Wells drilled in the Gascoyne Platform and northern Abrolhos Sub-basin

Well name	*S. no.*	*Type*	*Latitude (S)*	*Longitude (E)*	*Ground elevation (m AHD)*	*Rig elevation (m AHD)*	*Total depth* (m)	*Bottomed in*	*Year*	*Operator*	*Status 1*	*Status 2*	*Gas show*	*Oil show*
Airey Hill 1	1629	NFW	23°03'56"	113°52'24"	68	72	1037	CPL	1980	Monarch	Water	Well	Nil	Nil
Cape Cuvier 1	51 V1	STR	24°13'31"	113°23'55"	72	72	457	Dg	1955	WAPET	Dry	P&A	Nil	Nil
Carlston 1	20760	NFW	23°49'51"	114°11'19"	35	38	1003	Dg	2002	Empire	Dry	P&A	Nil	Nil
Chargoo 1	389	NFW	23°35'52"	113°56'01"	27	28	428	CPL	1967	WAPET	Dry	P&A	Nil	Nil
Coburn 1	20408	STR	26°41'59"	114°13'36"	13	10	1093	Ot	1997	Knight Industries	Dry	P&A	Nil	Nil
Dirk Hartog 17B	557 V17	NFW	25°52'03"	113°04'47"	-87	90	1523	Ot	1957	WAPET	Dry	P&A	Nil	Nil
Edel 1	727	NFW	27°06'43"	113°23'29"	-95	30	2749	Ot	1972	Ocean Ventures	Dry	P&A	Nil	Nil
Gnaraloo 1	390	NFW	23°40'32"	113°47'10"	46	48	500	Cq	1967	WAPET	Dry	P&A	Poor	Nil
Grierson 1	51 V9	STR	24°12'05"	113°46'26"	12	12	438	?Dg	1955	WAPET	Water	P&A	Nil	Nil
Grierson 2	51 V10	STR	24°12'07"	113°47'12"	4	4	458	?Dg	1955	WAPET	Dry	P&A	Nil	Nil
Grierson 3	51 V11	STR	24°12'07"	113°45'37"	2	2	442	?Dg	1955	WAPET	Dry	P&A	Nil	Nil
GSWA Barrabiddy 1A	20371	STR	23°49'52"	114°20'05"	55	55	783	Dn	1996	GSWA	Dry	P&A	Nil	Nil
GSWA Boologooro 1	20734	STR	24°19'27"	113°53'53"	8	8	384	Dg	2001	GSWA	Dry	P&A	Nil	Nil
GSWA Edaggee 1	20734 V1	STR	25°21'27"	114°14'05"	35	35	351	Dk	2001	GSWA	Dry	P&A	Nil	Nil
GSWA Mooka 1	20372	STR	24°58'31"	114°48'25"	120	120	418	SDc	1996	GSWA	Dry	P&A	Nil	Nil
GSWA Woodleigh 1	20565	STR	26°03'19"	114°39'56"	108	108	333	p€	1999	GSWA	Dry	P&A	Nil	Nil
GSWA Woodleigh 2A	20566	STR	26°03'23"	114°31'39"	67	67	618	?SDy	1999	GSWA	Dry	P&A	Nil	Nil
GSWA Yinni 1	20734	STR	26°03'23"	114°48'59"	131	131	158	Jw	2001	GSWA	Dry	P&A	Nil	Nil
Hamelin Pool 1	440 V1	STR	26°01'31"	114°12'28"	5	10	1595	Ot	1968	Magellan	Water	P&A	Nil	Nil
Hamelin Pool 2	440 V2	STR	26°08'55"	114°21'24"	25	30	1219	Ot	1968	Magellan	Water	P&A	Nil	Nil
Kalbarri 1	832	STR	27°16'30"	114°06'32"	129	133	1540	Ot	1973	Oceania	Dry	P&A	Nil	Nil
Livet 1	20362	NFW	27°16'29"	112°54'15"	-212	22	1760	Pc	1996	Seafield	Dry	P&A	Nil	Poor
Morangie 1	20797	NFW	27°22'29"	112°55'30"	-213	27	2188	?Ʀw	2002	Origin	Dry	P&A	Nil	Poor
Pendock 1	493	NFW	23°16'58"	113°20'15"	-133	10	2501	SDc	1969	Genoa Oil	Dry	P&A	Nil	Poor
Quobba 1	2542	NFW	24°20'40"	113°26'14"	51	55	1931	SDy	1984	Canada NW	Dry	P&A	Poor	Nil
Tamala 1	833	STR	26°38'44"	113°38'09"	3	7	1225	?€	1973	Oceania	Dry	P&A	Poor	Nil
UWA Cardabia	–	STR	23°05'00"	114°03'00"	110	110	92	Kt	1986	UWA	Dry	P&A	Nil	Nil
Wandagee Corehole 1	19 V2	STR	23°53'20"	114°23'58"	69	69	220	Dg	1962	WAPET	Dry	P&A	Nil	Nil
Wandagee Corehole 3	19 V4	STR	23°49'48"	114°20'10"	56	56	223	?Dm	1962	WAPET	Dry	P&A	Nil	Nil
Wandagee 1	19 V1	STR	23°53'20"	114°23'58"	69	72	1073	Ot	1962	WAPET	Water	Well	Poor	Nil
Warroora 1	51 V30	NFW	23°30'35"	113°52'55"	26	29	1826	CPL	1955	WAPET	Dry	P&A	Nil	Poor
Wittecarra 1	2882	NFW	27°50'33"	113°12'38"	-190	8	2890	Ot	1985	BHP Petroleum	Dry	P&A	Nil	Poor
Woodleigh 1981/2	2075	STR	26°03'17"	114°40'07"	110	110	189	?p€	1981	Eagle	Dry	P&A	Nil	Nil
Yaringa 1	305	NFW	26°03'54"	114°21'40"	21	27	2288	Ot	1966	Conoco	Dry	P&A	Nil	Nil
Yaringa East 1	20339	STR	25°53'37"	114°23'32"	46	49	829	Dk	1997	Pace Petroleum	Dry	P&A	Poor	Nil

NOTES:

Stratigraphy

Kt: Toolonga Calcilutite
Jw: Woodleigh Formation
Ʀw: Wittecarra Sandstone
Pc: Carynginia Formation
CPL: Lyons Group
Cq: Quail Formation
Dm: Munabia Formation
Dg: Gneudna Formation
Dn: Nannyarra Sandstone
Dk: Kopke Sandstone
SDc: Coburn Formation
SDy: Yaringa Formation
Ot: Tumblagooda Sandstone
€: Cambrian
p€: Precambrian

Operators

BHP Petroleum: BHP Petroleum (Australia) Pty Ltd
Canada NW: Canada Northwest Australia Oil NL
Conoco: Continental Oil Company of Australia
Eagle: Ltd Eagle Corporation Ltd
Empire: Empire Oil and Gas
Genoa Oil: Genoa Oil NL
GSWA: Geological Survey of Western Australia
Knight Industries: Knight Industries Pty Ltd
Magellan: Magellan Petroleum Australia Ltd
Monarch: Monarch Petroleum NL
Ocean Ventures: Ocean Ventures Pty Ltd
Oceania: Oceania Petroleum Pty Ltd
Origin: Origin Energy Developments Pty Ltd
Pace Petroleum: Pace Petroleum Pty Ltd
Seafield: Seafield Resources PLC
WAPET: West Australian Petroleum Pty Ltd

AHD: Australian Height Datum
NFW: new- field wildcat
P&A: plugged and abandoned
STR: stratigraphic hole
S. no: GSWA statutory petroleum exploration report number

Appendix 2

Geophysical surveys conducted for petroleum exploration in the Gascoyne Platform and extending into the Abrolhos Sub-basin to 2002

Survey name	*Company*	*Year*	*Survey type*	*Line prefix*	*Total kilometres*	*No. of lines*	*S. number*
Gascoyne Platform							
AGSO S. 101; Southern Carnarvon M.S.S.	Australian Geological Survey Organisation	1991	2D reflection	101/	1739.98	19	na
AGSO S. 136; Carnarvon Tertiary Tie M.S.S.	Australian Geological Survey Organisation	1994	2D reflection	136/CTT95	4221.33	28	na
AGSO S. 57; North Perth Basin M.S.S.	Australian Geological Survey Organisation	1986	2D reflection	057/	2368.91	19	na
Bernier M.S.S.	Canadian Superior Oil (Aust) Pty Ltd and assoc. companies	1971	2D reflection	OE	1464.42	33	672
Bernier 1982 M.S.S.	Canada Northwest Australia Oil NL	1982	2D reflection	CG82	401.84	18	2163
Bernier (Offshore) Aeromagnetic S.	West Australian Petroleum Pty Ltd	1969	Aeromagnetic	na	4730.5	68	479
BMR Southern Carnarvon Basin S.S.	Bureau of Mineral Resources	1964	2D reflection	PELICANHILL	35.94	1	na
Capricorn 1982 M.S.S.	Canada Northwest Australia Oil NL	1982	2D reflection	CE82	348.19	12	2001
Carlston S.S. and Carlston Detail S.S.	Carnarvon Petroleum NL	1994	2D reflection	CP93	76.86	9	10192
Carnarvon Basin (Project 147) Aeromagnetic S.	Bureau of Mineral Resources	1956	Aeromagnetic	na	41728	–	na
Carnarvon Basin (Project 165) Aeromagnetic S.	Bureau of Mineral Resources	1956	Aeromagnetic	na	34140	158	na
Carnarvon Basin (Project 198) Aeromagnetic S.	Bureau of Mineral Resources	1959	Aeromagnetic	na	37360	70	na
Carnarvon Basin West M.S.S.	Canadian Superior Oil (Aust) Pty Ltd and assoc. companies	1966	2D reflection	CBW66	2459.3	28	298
Carnarvon West Aeromagnetic S.	Tasman Oil Pty Ltd	1965	Aeromagnetic	na	8206	–	210
Coverack 3D M.S.S.	Shell Development (Australia) Pty Ltd	2002	3D reflection	W01COV	–	131	10481
Coverack WG2D M.S.S.	Western Geco Australia Pty Ltd	2001	2D reflection	CV	1583	–	10480
Cuvier M.S.S.	West Australian Petroleum Pty Ltd	1961	2D reflection	C61	384.12	19	513 V1
Cuvier 1992 M.S.S.	Mobil Exploration and Producing Australia Pty Ltd	1992	2D reflection	92M	1678.99	38	10103
Dingo North S.S.	West Australian Petroleum Pty Ltd	1957	2D reflection	DN57	–	–	81 V5
Dingo S.S.	West Australian Petroleum Pty Ltd	1957	2D reflection	D57	–	–	81 V4
Dirk Hartog Reconnaissance Gravity S.	West Australian Petroleum Pty Ltd	1956	Gravity	na	–	na	399
Fitzroy Reef M.S.S.	Geometals NL	1979	2D reflection	GM79	152.96	6	1569
Geco Prakla Carnarvon Tie (GPCT-93) M.S.S.	Western Geco Australia Pty Ltd	1993	2D reflection	GPCT93	6000	45	10169
Gnaraloo West M.S.S.	Canadian Superior Oil (Aust) Pty Ltd and assoc. companies	1967	2D reflection	WG67	916.88	26	359
Hamelin S.S.	Oceania Petroleum Pty Ltd	1972	2D reflection	OH	158.03	2	730
Hartog M.S.S.	Continental Oil Company of Australia Ltd	1978	2D reflection	H78	1971.98	27	1364
Indian Ocean Offshore M.S.S.	Ocean Ventures Pty Ltd	1971	2D reflection	OV	243.31	6	660
Kalbarri M.S.S.	Ocean Ventures Pty Ltd	1972	2D reflection	K	236.84	6	706
Lake MacLeod West S.S.	Canada Northwest Australia Oil NL	1985	2D reflection	CG85	237.39	12	2751
Lyell Range 1983 Land S.S.	Canada Northwest Australia Oil NL	1983	2D reflection	CG83	126.54	6	2312
Lyndon–Quobba S.S.	West Australian Petroleum Pty Ltd	1972	2D reflection	B72	274.81	2	708
Minilya 1953 S.S.	West Australian Petroleum Pty Ltd	1953	2D reflection	M53	27	3	879 V1
Murchison 1970 M.S.S.	West Australian Petroleum Pty Ltd	1970	2D reflection	M70	63.53	3	786
Murchison 1972 M.S.S.	Ocean Ventures Pty Ltd	1972	2D reflection	M	462.28	17	769
Murchison Gascoyne D1 Detailed Gravity S.	Oceania Petroleum Pty Ltd	1972	Gravity	na	5300	na	662
Murchison Gascoyne Helicopter Gravity S.	Barewa Oil and Mining NL	1970	Gravity	na	–	na	578
Naturaliste 1972 M.S.S.	Ocean Ventures Pty Ltd	1972	2D reflection	N	98.57	5	770
Osprey 2001 Aeromagnetic S.	Woodside Energy Ltd	2001	Aeromagnetic	na	17159	–	10463

Appendix 2 (continued)

Survey name	*Company*	*Year*	*Survey type*	*Line prefix*	*Total kilometres*	*No. of lines*	*S. number*
Quobba 1983 Land S.S.	Canada Northwest Australia Oil NL	1983	2D reflection	CG83	253.68	9	2482
Quoin Head M.S.S.	Ocean Ventures Pty Ltd	1972	2D reflection	QH	1020.15	22	831
Pendock Structure S.S.	Genoa Oil NL	1969	2D reflection	PS69	31	–	477
Ranger S.S.	West Australian Petroleum Pty Ltd	1961	2D reflection	R61	2.31	2	69 V2
Ronsard M.S.S.	Endeavour Oil Company NL	1971	2D reflection	R71	342.40	14	636
Rundle M.S.S.	Mobil Exploration and Producing Australia Pty Ltd	1994	2D reflection	93MWR	1055.3	34	10182
Saltmarsh Reconnaissance S.S.	West Australian Petroleum Pty Ltd	1962	2D refraction	SR62	158.34	8	38
Sandy Point S.S.	West Australian Petroleum Pty Ltd	1968	2D reflection	SP68	27.77	4	536 V3
Shark Bay M.S.S.	Continental Oil Company	1965	2D reflection	SB65	249.03	4	175
Shark Bay Reconnaissance Gravity S.	West Australian Petroleum Pty Ltd	1956	Gravity	na	–	na	540
South Carnarvon Onshore Phase 1 Spec S.S.	Baker Atlas	1990	2D reflection	CW90	283.43	6	10040
South West Cape M.S.S.	West Australian Petroleum Pty Ltd	1971	2D reflection	SWC71	105.05	2	612 V9
Tamala M.S.S.	Ocean Ventures Pty Ltd	1972	2D reflection	T72	82.77	5	830
Tantabiddi Detail 1980 S.S.	Canada Northwest Australia Oil NL	1980	2D reflection	CE80	363.52	17	1651
Teledyne Exploration 1970 Line	Canadian Superior Oil (Aust) Pty Ltd and assoc. companies	1970	2D reflection	na	–	–	639
W90-17 M.S.S.	Mobil Exploration Australia Pty Ltd	1991	2D reflection	91MAH	346.29	4	10046
WA-196-P 1983 S.S.	Petrofina Exploration Australia	1983	2D reflection	WA83	133.52	14	2386
WA-7-P M.S.S.	Oceania Petroleum Pty Ltd	1972	2D reflection	OP	419.36	8	812
WA-81-P II M.S.S.	Continental Oil Company of Australia Ltd	1979	2D reflection	81P79	1374.61	26	1500
Warroowa S.S.	West Australian Petroleum Pty Ltd	1953	2D reflection	W53	19.7	2	879 V2
Woodleigh Detail S.S.	Mergui Holdings	1980	2D reflection	WD80	19.95	4	1669
Wooramel Reconnaissance S.S.	Continental Oil Company	1965	2D refraction	W65	773.66	24	168
Wotan S.S.	West Australian Petroleum Pty Ltd	1957	2D reflection	W57	–	–	81 V6
Yalbalgo–Yaringa Semi-Detail S.S.	Continental Oil Company	1965	2D reflection	YY65	361.41	13	227
		1965	2D refraction	YY65	84	–	227
Abrolhos and Houtman Sub-basins (surveys used in this Report)							
Livet M.S.S.	Seafield Resources PLC	1993	2D reflection	AS93	465.83	25	10191
Morangie M.S.S.	Seafield Resources PLC	1997	2D reflection	S97	499	26	10333
Murchison 81P M.S.S.	Conoco Australia NL	1980	2D reflection	M80	1281.7	50	1712
Perth Basin Aeromagnetic Survey	Enterprise Oil Exploration Ltd	1992	Aeromagnetic	na	28949	–	10141
Scarlet M.S.S.	Enterprise Oil Exploration Ltd	1992	2D reflection	E92AU08	2257.25	55	10114
Zuytdorp M.S.S.	Canadian Superior Oil (Aust) Pty Ltd and assoc. companies	1973	2D reflection	Z73	976.15	18	808

NOTES:
M.S.S.: marine seismic survey
S. number: Western Australia Geological Survey statutory petroleum exploration report number
S.S.: seismic survey
S.: survey
na: not applicable
–: data not available

Appendix 3

Seismic lines used in this Report

Survey name	*Line number*	*Shotpoint range*	*Year of processing*	*Quality of data*
Onshore				
Lyndon–Quobba S.S.	B72-001L	1–403	1992	Good
	B72-002L	1–390	1972	Poor
Lyell Range 1983 Land S.S.	CG83-09L	63–860	1983	Fair
Saltmarsh Reconnaissance S.S.	SR62-C-L	171–272	1962	Fair
South Carnarvon Onshore Phase 1 Spec S.S.	CW90-01	201–2101	1990	Fair
	CW90-02	201–2551	–	–
	CW90-03	201–3019	–	–
	CW90-04	209–2571	–	–
	CW90-05	201–1257	–	–
	CW90-06	201–2463	–	–
Offshore				
AGSO S. 57; North Perth Basin M.S.S.	057/13	2440–9600	2001	Good – very good
Bernier M.S.S.	OE-06A	-6–85	1971	Bad
	OE-06B	80–565	–	–
	OE-06C	553–923	–	–
	OE-10	1–285	–	–
	OE-11	80–1325	–	–
	OE-11A	1–99	–	–
	OE-12	-3–150	–	–
	OE-13	-5–147	–	–
	OE-14	259–459	–	–
	OE-14A	1–459	–	–
	OE-16	5–210	–	–
	OE-17	1–135	–	–
	OE-18	-3–131	–	–
	OE-19	1–133	–	–
	OE-20	-3–130	–	–
	OE-21	1–151	–	–
	OE-23	1–344	–	–
	OE-24	1–94	–	–
	OE-25	-3–190	–	–
	OE-25B	180–217	–	–
	OE-26	1–50	–	–
	OE-26B	32–219	–	–
	OE-29	1–122	–	–
	OE-31	1–257	–	–
Bernier 1982 M.S.S.	CG82-02M	721–2194	1982	Bad
	CG82-02MA	228–730	–	–
	CG82-04M	1–1640	–	–
	CG82-06M	1–1175	–	–
	CG82-10M	1–503	–	–
Capricorn 1982 M.S.S.	CE82-02M	1–580	1982	Bad
	CE82-03M	1–1780	–	Poor
	CE82-07MA	1–760	–	Bad
	CE82-12MA	1–1980	–	–
Cuvier 1992 M.S.S.	92M-100	101–1519	1992	Poor
	92M-100A	1433–3885	–	–
	92M-101	101–786	–	–
	92M-101A	713–1955	–	–
	92M-101B	1869–4660	–	–
	92M-101C	4574–6658	–	–
	92M-103	4092–6312	–	–

Appendix 3 (continued)

Survey name	Line number	Shotpoint range	Year of processing	Quality of data
	92M-103A	15–4178	–	–
	92M-104	101–3675	–	–
	92M-108B	11–950	–	–
	92M-108A	864–3630	–	–
	92M-110	101–3748	–	–
	92M-112	101–3728	–	–
	92M-114	101–4166	–	–
	92M-116	101–2421	–	–
	92M-116A	2335–4631	–	–
	92M-118	101–2919	–	–
	92M-118A	2833–4529	–	–
	92M-122	101–4324	–	–
	92M-124	101–830	–	–
	92M-124A	744–4339	–	–
	92M-128	101–4184	–	–
	92M-132	2737–3837	–	–
	92M-132A	15–2736	–	–
	92M-136	101–1517	–	–
	92M-136B	1518–2531	–	–
	92M-140	101–1319	–	–
Gnaraloo West M.S.S.	WG67-031	1–145	1967	Bad
Hartog M.S.S.	H78-101A	1–2296	1978	Good
	H78-101B	2221–3445	–	–
	H78-101C	3391–4495	–	–
	H78-102	1–2518	2001	–
	H78-103	1–4510	–	–
	H78-104	1–4432	–	–
	H78-105	1–4489	–	–
	H78-106	1–1128	–	–
	H78-107	1–4477	–	–
	H78-108	1–2029	–	–
	H78-109	1–736	1986	–
	H78-109A	652–4159	–	–
	H78-110/110A	1–1341	2001	–
	H78-110B	1291–3009	–	–
	H78-112	1–2059	2001	
	H78-116	1–850	–	–
	H78-116A	751–1360	–	–
	H78-116B	1250–3840	–	–
	H78-120	3721–4792	–	–
	H78-120A	1–3721	–	–
	H78-122	1–3721	–	–
	H78-124/124A	-53–601	1986	–
	H78-124B	600–3736	–	–
Indian Ocean Offshore M.S.S.	OV-4	18–213	1971	Bad
Kalbarri M.S.S.	K-4	2356–2996	1972	Bad
Livet M.S.S.	AS93-607	32–843	1993	Good
	AS93-624	110–774	–	–
	AS93-630/630A	32–1108	–	–
Morangie M.S.S.	S97-703	1001–2168	1997	Good
	S97-718	1001–1708	–	–
Murchison 1970 M.S.S.	M70-OS	10379–10490	1970	Bad
Murchison 81P M.S.S.	M80-307	117–1160	1980	Very good
Quoin Head M.S.S.	QH-01A	1–120	1972	Bad
	QH-01B	112–372	–	–
	QH-01C	373–730	–	–
	QH-01D	560–725	–	–

Appendix 3 (continued)

Survey name	*Line number*	*Shotpoint range*	*Year of processing*	*Quality of data*
	QH-03	37–440	–	–
	QH-04	194–476	–	–
	QH-05	12–426	–	–
	QH-06	49–461	–	–
	QH-07	1–303	–	–
	QH-10	1–302	–	–
	QH-13	1–191	–	–
	QH-14	1–380	–	–
	QH-15	49–420	–	–
	QH-19	-7–578	–	–
Ronsard M.S.S.	R71-010	1–188	1971	Bad
	R71-011	1–142	–	–
	R71-012	1–220	–	–
	R71-014	1–190	–	–
Scarlet M.S.S.	E92AU08-09	100–3035	1992	Good
	E92AU08-13	100–3274	–	–
	E92AU08-17	100–3388	–	–
	E92AU08-21	100–3631	–	–
	E92AU08-25	100–3366	–	–
	E92AU08-27	100–1158	–	–
	E92AU08-39	100–1400	–	–
	E92AU08-46	100–2715	–	–
	E92AU08-47	100–2824	–	–
	E92AU08-48	100–2754	–	–
	E92AU08-51	100–2823	–	–
	E92AU08-52	100–2865	–	–
	E92AU08-53	100–2754	–	–
	E92AU08-54	100–2300	–	–
Shark Bay M.S.S.	SB65-001	35–490	1999	Poor
	SB65-002	1–527	–	–
	SB65-004	45–250	1965	–
	SB65-014	434–500	–	–
Tantabiddi Detail 1980 S.S.	CE80-30M	1–651	1980	Poor
	CE80-34M	1–768	–	–
	CE80-39M	1–1918	–	Bad
WA-7-P M.S.S.	OP-1	220–968	1972	Poor
	OP-1A	-7–230	–	–
	OP-2	1–258	–	Bad
	OP-5	-4–628	–	–
WA-81-P II M.S.S.	81P79-203	180–1123	1979	Very good
Zuytdorp M.S.S.	Z73-05	1–201	1973	Poor
	Z73-06	-6–216	–	–
	Z73-08	-6–337	–	–
	Z73-09	1–350	–	–
	Z73-18	1–2055	1980	–

NOTE: –: as above

Appendix 4

Outcrop sections and selected water bores and mineral holes that penetrated the Cretaceous succession

Name	Latitude (S)	Longitude (E)	AHD (m)	Total depth (m)	Year	GSWA file or reference
Waterbores						
BF 3/6	22°27'35"	115°12'35"	52	85	1981	WRC
Boolathana 3	24°30'25"	113°49'35"	10	445	1906	S126 A1
Boolathana 5	24°34'45"	114°00'45"	30	459	1913	S126 A1
Boolathana 6	24°34'26"	113°47'05"	10	1 036	1919	S126 A1
Boolathana 7	24°27'25"	113°41'15"	9	503	?	S126 A1
Boolathana 11	24°31'50"	113°38'45"	3	508	?	S126 A1
Boologooro 1 (Griersons Tank)	24°17'12"	113°51'05"	4	460	?	S126 A1
Boologooro 2 (Shaw)	24°21'24"	113°49'35"	4	507	?	S126 A1
Brickhouse 1	24°51'26"	114°02'00"	34	803	1905	S126 A1
Brickhouse 2	24°57'26"	113°50'45"	9	618	1906	S126 A1
Brickhouse 4 (Boodalia)	25°10'56"	113°53'10"	9	476	?	S126 A1
Brickhouse 6 (Argyle)	25°01'45"	113°48'05"	9	585	1925	S126 A1
Brickhouse 7	25°18'25"	113°56'50"	6	490	?	S126 A1
Callagiddy 1 (South)	25°11'50"	114°02'15"	18	379	1920	S126 A1
Callagiddy 2 (West)	25°03'16"	113°55'06"	12	586	1920	S126 A1
Cardabia 2 (Century)	23°10'42"	114°08'39"	97	764	?	S126 A1
Denham 1/97	25°55'35"	113°32'20"	~20	535	1997	Water Corporation
Edaggee 2	25°18'58"	114°00'20"	21	413	?	S126 A1
Manberry 1	24°10'45"	114°12'40"	44	413	1918	S126 A1
Marron 2	25°22'02"	114°21'29"	52	201	1913	S126 A1
Marron 7	25°22'06"	114°35'32"	76	197	?	S126 A1
Meadow 9	26°52'52"	114°36'26"	131	98	1954	S126 A1
Mia Mia 4	23°25'00"	114°12'35"	37	365	1928	S126 A1
Mia Mia 11	23°20'35"	114°08'55"	37	416	1939	S126 A1
Minilya 1	24°04'26"	113°59'25"	15	368	1917	S126 A1
Minilya 2	23°41'20"	114°09'20"	15	462	1918	S126 A1
Minilya 3	23°54'35"	113°50'40"	5	687	1925	S126 A1
Minilya 4	23°45'10"	113°54'25"	7	689	1934	S126 A1
Minilya 5	24°10'40"	113°57'20"	11	518	1925	S126 A1
Minilya 6	24°11'00"	113°53'25"	0	401	1926	S126 A1
Minilya 8	23°50'53"	114°12'38"	8	429	1908	S126 A1
Minilya 9	23°33'50"	114°01'15"	11	516	1912	S126 A1
Nerren Nerren 2	27°11'25"	114°38'05"	GL	122	?	S126 A1
Pelican Hill 1	24°45'41"	113°42'55"	15	918	1902–03	S126 A1
Peron 1/98	25°50'20"	113°33'20"	~27	566	1998	Water Corporation
Winning 2	23°08'25"	114°16'50"	GL	612	?	S126 A1
Wooramel 5	25°38'20"	114°18'25"	18	374	1924	S126 A1
Yalbalgo 4	25°06'56"	114°44'40"	119	232	?	S126 A1
Mineral holes						
AFMECO JG 9	25°02'23"	114°58'23"	~135	302	1978	M item 806 A8461
BHP ND 1	26°18'56"	114°51'05"	170	375.5	1993	M item 7508 A40842
BHP ND 2	26°23'36"	114°41'50"	108	438.6	1993	M item 7508 A40842
Carpentaria CB 5	24°30'20"	114°35'50"	~100	263	1991	M item 11479 A58930
CRAE GBH 2	24°24'16"	114°32'55"	~100	331	1982	M item 11468 A36059
CRAE GRH 1	25°40'28"	114°49'34"	~115	224	1981	M item 11468 A36058
CRAE GRH 2	24°59'26"	114°42'55"	~100	298	1981	M item 11468 A36058
CRAE WC 1	23°47'25"	114°17'15"	GL	204	1982	M item 11468 A36059
CRAE WC 2	23°35'30"	114°12'10"	GL	200	1982	M item 11468 A36059
CRAE WC 3	23°47'25"	114°17'50"	GL	198	1982	M item 11468 A36059
CRAE WC 7	24°06'15"	114°22'25"	GL	138	1982	M item 11468 A36059
CRAE WC 8	24°16'55"	114°27'40"	GL	144	1982	M item 11468 A36059
CRAE WC 9	24°26'25"	114°27'55"	GL	150	1982	M item 11468 A36059
CRAE WC 10	24°33'45"	114°32'55"	GL	120	1982	M item 11468 A36059
CRAE WC 11	24°41'20"	114°38'40"	GL	162	1982	M item 11468 A36059
CRAE WC 13	24°54'35"	114°49'15"	GL	126	1982	M item 11468 A36059
Cyanamid 3A	24°16'15"	114°33'55"	GL	92.7	1965	M item 70 A927
Gunson OND 1	22°12'00"	115°00'05"	26	332	2001–2	M item 11354 A65329

Appendix 4 (continued)

Name	*Latitude (S)*	*Longitude (E)*	*AHD (m)*	*Total depth (m)*	*Year*	*GSWA file or reference*
Outcrop sections						
Birdrong TS	24°14'50"	114°49'50"	–	–	–	Hocking et al. (1987)
C–Y Creek	24°44'52"	113°56'31"	–	–	–	Hocking et al. (1987)
Muderong TS	24°08'10"	114°45'50"	–	–	–	Hocking et al. (1987)
Murchison House (Yalthoo A)	27°36'30"	114°12'35"	–	–	–	Haig (2002)
Murchison House (Yalthoo B)	27°36'00"	114°13'35"	–	–	–	Haig (2002)
Pillawarra Hill	27°28'32"	114°17'11"	–	–	–	Haig (2002)

NOTES:
AHD: Australian Height Datum
GL: ground level
GSWA reference: Geological Survey of Western Australia's S-series and M-series reference numbers
TS: Type section
WRC: Waters and Rivers Commission

References:

HAIG, D. W., 2002, Post-conference field excursion guidebook: Perth to Shark Bay: University of Western Australia, Forams 2002, International Symposium on Foraminifera, Perth, W.A., February, 2002 (unpublished).

HOCKING, R. M., MOORS, H. T., and van de GRAAFF, W. J. E., 1987, Geology of the Carnarvon Basin, Western Australia: Western Australia Geological Survey, Bulletin 133, 289p.

Appendix 5

Thickness of Cretaceous units penetrated in the Southern Carnarvon Basin

Well	*Total Cainozoic (m)*	*Total Cretaceous (m)*	*Toolonga Calcilutite (m)*	*Gearle Siltstone + Haycock Marl (m)*	*Muderong Shale + Windalia Radiolarite (m)*	*Birdrong Sandstone + Mardie Greensand (m)*
Petroleum wells						
Abduls Dam 1	–	–	NP	234	108	NP
Airey Hill 1	495	604	84	191	118	70
BMR 05 Yanrey	NP	477	45	234	146	19
Bundegi 1	NP	580	–	–	–	7
Cape Cuvier 1	122	241	135	13	23	12
Cape Range 1	392	708	7	515	154	32
Cassidy 1	1 108	774	–	703	41	–
Chargoo 1	NP	408	141	157	67	43
Chinty 1	114	425	–	269	128	11
Coburn 1	NP	164	57	51	38	18
Cody 1	952	900	–	404	102	24
Dailey 1	464	534	93	299	100	NP
Dirk Hartog 17B	355	318	273	28	16	1
East Marrilla 1	NP	345	–	94	187	64
Edel 1	324	NP	NP	NP	NP	NP
Enfield 1	666	269	–	43	33	3
Enfield 2	664	278	–	45	31	2
Garden Mill 1	NP	526	57	210	125	7
Giralia 1	NP	–	–	–	–	–
Gnaraloo 1	49	401	162	144	55	40
Grierson 1	–	455	221	–	–	–
Grierson 2	–	–	–	75	29	68
Grierson 3	41	–	–	–	–	–
GSWA Barrabiddy 1/1A	NP	190	–	97	93	NP
GSWA Boologooro 1	49	379	198	98	41	10
GSWA Edaggee 1	NP	273	199	28	44	2
GSWA Mooka 1	NP	71	–	24	34	13
GSWA Woodleigh 1	NP	154	18	25	32	79
GSWA Woodleigh 2A	NP	209	65	27	42	75
GSWA Yinni 1	NP	97	–	14	30	53
Hamelin Pool 1	NP	209	137	52	–	20
Hamelin Pool 2	NP	183	55	61	–	67
Hawksbill 1	550	457	–	245	169	NP
Hope Island 1	347	559	76	358	104	21
Jurabi 1	874	206	–	115	62	NP
Kalbarri 1	NP	162	104	–	NP	58
Kura Kura 1	494	381	5	188	160	NP
Laverda 1	757	108	–	17	38	18
Learmonth 1	598	848	22	669	137	NP
Learmonth 2	–	754	21	604	101	5
Leatherback 1	900	442	22	291	101	9
Lefroy Hill 1	576	740	10	610	68	5
Livet 1	388	150	45	NP	20	2
Locker 1	148	468	57	–	146	–
Loggerhead 1	1 105	555	–	388	107	10
Long Island 1	374	538	52	211	146	7
Longneck 1	218	1 048	–	870	150	27
Marrilla 1	NP	382	–	206	147	29
Melanie 1	912	398	28	246	115	9
Murat 1	1 076	522	–	386	113	23
Mydas 1	841	330	–	198	79	NP
Ningaloo 1	637	455	16	365	74	NP
North Giralia 1	146	487	52	314	69	52
Observation 1	508	418	64	221	116	17
Onslow 1	54	497	47	262	151	37
Peak 1	673	639	42	455	142	NP
Pendock 1D	617	271	34	140	54	8
Pyrenees 1	708	162	8	104	50	NP
Quobba 1	110	326	146	33	22	45
Remarkable Hill 1	NP	273	NP	79	177	17

Appendix 5 (continued)

Well *(m)*	*Total Cainozoic (m)*	*Total Cretaceous (m)*	*Toolonga Calcilutite (m)*	*Gearle Siltstone + Haycock Marl (m)*	*Muderong Shale + Windalia Radiolarite (m)*	*Birdrong Sandstone + Mardie Greensand*
Ridley 1	507	375	22	188	165	NP
Rivoli 1	1131	750	36	553	114	47
Rough Range 01	399	705	12	585	75	11
Rough Range 11	–	743	12	588	70	11
Rough Range South 5	446	684	31	557	35	16
Ruby 1	–	–	NP	236	102	2
Sandalwood 1	656	529	37	308	123	20
Sandy Point 1	752	220	42	–	29	NP
Sandy Point 2	666	519	58	411	50	NP
Santo 1	570	795	116	442	210	27
Sapphire 1	–	–	NP	172	164	3
Sawback 1	535	339	6	180	153	NP
Scafell 1	933	105	51	–	38	NP
Spider 1	354	526	–	349	120	57
Tamala 1	160	177	122	16	19	20
Tent Hill 1	109	460	86	276	58	40
Trealla 1	570	671		574	97	NP
Uralla 1	146	471	94	223	139	15
Wandagee 1	NP	169	15	56	96	2
Warroora 1	NP	343	47	144	70	12
West Giralia 1	137	572	85	285	102	48
Whaleback 1	590	579	43	376	90	12
White Opal 1	1333	654	67	441	131	15
Whitlock Dam 1	NP	387	6	259	90	32
Wingette 1	713	402	–	353	49	NP
Wittecarra 1	392	104	12	NP	3	–
Wonangarra 1	105	427	38	267	103	19
Woodleigh 1982/01	NP	52	–	NP	30	22
Yanrey 1	NP	277	30	230	17	NP
Yardie East 1	1192	1086	–	739	196	131
Yaringa 1	NP	140	65	51	–	24
Yaringa East 1	NP	204	110	31	29	34
Waterbores						
BF3/6	NP	–	–	–	–	60
Boolathanna 3	–	–	215	86	49	–
Boolathanna 5	–	–	211	–	–	24
Boolathanna 6	–	–	255	69	49	3
Boolathanna 7	–	–	291	30	78	12
Boolathanna 11	–	–	302	62	26	–
Boologooro 1 (Grierson's Tank)	–	–	240	89	49	–
Boologooro 2 (Shaw)	–	–	219	98	43	–
Brickhouse 1	–	–	261	41	47	20
Brickhouse 2	–	–	290	37	34	9
Brickhouse 4 (Boodalia)	–	–	–	44	49	2
Brickhouse 6 (Argyle)	–	–	295	52	60	13
Brickhouse 7	–	–	252	24	45	2
Callagiddy 1 (South)	–	–	–	46	44	–
Callagiddy 2 (West)	–	–	248	–	–	–
Cardabia 2 (Century)	–	–	41	175	333	5
Denham 1/97	–	314	260	11	23	20
Edaggee 2	178	199	–	29	41	3
Manberry 1	55	270	90	100	80	–
Marron 2	NP	211	140	24	43	4
Marron 7	NP	169	67	31	42	29
Mia Mia 4	–	–	64	163	103	–
Mia Mia 11	–	–	–	181	116	–
Minilya 1	–	–	–	–	48	8
Minilya 2	–	–	133	148	69	–
Minilya 3	–	–	279	90	52	8
Minilya 4	–	–	201	142	57	2
Minilya 5	–	–	177	110	42	41
Minilya 6	–	–	193	115	–	–
Minilya 8	–	–	91	128	49	9
Minilya 9	–	–	108	139	111	4
Nerren Nerren 2	–	30	3	3	NP	24

Appendix 5 (continued)

Well	*Total Cainozoic (m)*	*Total Cretaceous (m)*	*Toolonga Calcilutite (m)*	*Gearle Siltstone + Haycock Marl (m)*	*Muderong Shale + Windalia Radiolarite (m)*	*Birdrong Sandstone + Mardie Greensand (m)*
Pelican Hill 1	76	353	261	44	34	14
Peron 1/98	–	334	273	24	24	13
Winning 2	–	–	NP	125	184	NP
Wooramel 5	–	258	156	32	41	29
Yalbalgo 4	–	–	9	21	9	33
Outcrop sections						
Birdrong TS	–	26	–	–	–	26
C–Y Creek	–	222	24	151	–	–
Muderong TS	–	–	–	–	–	6
Murchison House (Yalthoo A)	–	–	19	–	–	33
Murchison House (Yalthoo B)	–	97	25	15	25	32
Pillawarra Hill	–	–	19	–	–	–
Mineral holes						
AFMECO JG 9	–	180	–	NP	180	–
Carpentaria CB 5	–	69	–	NP	52	–
CRAE GBH 2	–	208	36	88	48	36
CRAE GRH 1	–	89	–	20	51	18
CRAE GRH 2	–	43	–	–	35	8
CRAE WC 1	–	162	42	120	–	–
CRAE WC 2	–	–	65	–	–	–
CRAE WC 3	–	184	–	128	50	–
CRAE WC 7	–	69	69	–	–	–
CRAE WC 8	–	–	52	–	–	–
CRAE WC 9	–	–	62	–	–	–
CRAE WC 10	–	–	57	–	–	–
CRAE WC 11	–	118	31	42	45	–
CRAE WC 13	–	61	–	22	39	–
Gunson OND 1	NP	277	–	192	72	13

NOTES: Data from the waterbores do not allow the Gearle Siltstone to be differentiated from the Haycock Marl, nor the Muderong Shale from the Windalia Radiolarite. The Birdrong Sandstone and Mardie Greensand are in part laterally equivalent.

–: no data
NP: not present

Appendix 6

Interval velocities of wells with velocity surveys in the Gascoyne Platform and northern Abrolhos Sub-basin

Horizon	*Well*	*Depth range (m)*	*Interval velocity (m/s)*	*Average velocity (m/s)*
Cenozoic	Edel 1	324–354	2271	2571
	Livet 1	500–700	2386	(2500)[a]
	Pendock 1	326–759	3059	
	Tamala 1	0–274	2570	
Cretaceous	Kalbarri 1	123–182	1858	2291
	Livet 1	700–850	2220	(2300)[a]
	Pendock 1	759–1030	2284	
	Quobba 1	382–436	2223	
	Tamala 1	274–398	2873	
Kockatea Shale	Livet 1	1175–1678	3038	3038 (3050)[a]
Gneudna Formation	Pendock 1	1030–1664	4901	3993
	Quobba 1	436–1528	3913	(4000)[a]
	Wandagee 1	210–278	3167	
Dirk Hartog Group	Kalbarri 1	182–272	2738	4702[b]
	Pendock 1	1859–2468	5489	4309[c]
	Quobba 1	1718–1890	4862	(4500)[d]
	Tamala 1	574–1118	4355	
	Wandagee 1	399–944	4103	
Tumblagooda Sandstone	Edel 1	354–2714	4371	4319
	Kalbarri 1	272–1531	3956	(4200)[a]
	Livet 1	1744–1755	4201	
	Tamala 1	1118–1207	3840	
	Wandagee 1	944–1067	5225	

NOTES:
a: Actual average velocity used in the calculations
b: Average velocity excluding Kalbarri 1
c: Average velocity including Kalbarri 1
d: Average of b and c

Appendix 7

Velocity data from wells in the Gascoyne Platform and northern Abrolhos Sub-basin

Well	*Depth below datum (m)*	*One-way time (s)*	*Two-way time (s)*
Edel 1	324.30	0.1634	0.3268
	519.40	0.2162	0.4324
	891.20	0.3196	0.6392
	1159.50	0.3787	0.7574
	1449.00	0.4428	0.8856
	1827.00	0.5268	1.0536
	2302.50	0.6199	1.2398
	2713.90	0.7009	1.4018
Kalbarri 1	120.09	0.0893	0.1786
	178.61	0.1197	0.2394
	267.92	0.1486	0.2972
	570.59	0.2334	0.4668
	734.57	0.2755	0.5510
	950.37	0.3336	0.6672
	1314.30	0.4197	0.8394
	1527.96	0.4667	0.9334
Livet 1	478.00	0.2786	0.5572
	578.00	0.3190	0.6380
	658.00	0.3510	0.7020
	698.00	0.3685	0.7370
	827.00	0.4262	0.8524
	918.00	0.4662	0.9324
	978.00	0.4903	0.9806
	1078.00	0.5254	1.0508
	1152.00	0.5505	1.1010
	1178.00	0.5597	1.1194
	1278.00	0.5923	1.1846
	1378.00	0.6235	1.2470
	1478.00	0.6538	1.3076
	1578.00	0.6843	1.3686
	1658.00	0.7092	1.4184
	1718.00	0.7257	1.4514
	1733.00	0.7288	1.4576
Pendock 1	315.77	0.1490	0.2980
	410.26	0.1795	0.3590
	459.03	0.1910	0.3820
	519.99	0.2075	0.4150
	584.00	0.2240	0.4480
	675.44	0.2560	0.5120
	748.59	0.2865	0.5730
	818.69	0.3135	0.6270

Well	*Depth below datum (m)*	*One-way time (s)*	*Two-way time (s)*
Pendock 1	888.80	0.3495	0.6990
	952.80	0.3780	0.7560
	1019.86	0.4045	0.8090
	1096.06	0.4160	0.8320
	1278.94	0.4590	0.9180
	1422.20	0.4810	0.9620
	1598.98	0.5090	1.0180
	1653.84	0.5175	1.0350
	1848.92	0.5590	1.1180
	2172.00	0.6120	1.2240
	2275.64	0.6300	1.2600
	2458.52	0.6600	1.3200
Quobba 1	327.10	0.1414	0.2827
	427.80	0.1804	0.3607
	527.20	0.2094	0.4187
	625.80	0.2344	0.4687
	726.10	0.2594	0.5187
	825.60	0.2834	0.5667
	925.00	0.3094	0.6187
	1024.90	0.3344	0.6687
	1124.00	0.3584	0.7167
	1224.30	0.3804	0.7607
	1326.80	0.4014	0.8027
	1427.50	0.4244	0.8487
	1526.20	0.4464	0.8927
	1628.20	0.4694	0.9387
	1726.40	0.4874	0.9747
	1823.20	0.5034	1.0067
	1834.90	0.5054	1.0107
Tamala 1	267.31	0.1040	0.2080
	556.87	0.2044	0.4088
	819.00	0.2586	0.5172
	1114.65	0.3256	0.6512
	1200.00	0.3477	0.6954
Wandagee 1	138.68	0.0646	0.1292
	307.85	0.1154	0.2308
	461.77	0.1477	0.2954
	614.17	0.1877	0.3754
	720.85	0.2030	0.4060
	873.25	0.2485	0.4970
	995.17	0.2703	0.5406

Appendix 8

Seismically derived pseudo wells used for thermal-maturity modelling

Line no.	*SP*	*Easting*	*Northing*	*Latitude (S)*	*Longitude (E)*	*Elevation/ WD (m)*	*Top Cz (m)*	*Cz unconf. (m)*	*Top K (m)*	*K unconf. (m)*	*P unconf. (m)*	*Top C (m)*	*Top D (m)*	*Top S (m)*	*Top O (m)*
92M-100	3800	761063	7386258	-23.613224	113.558540	-47	47	195	195	1030	1030	1030	1030	1945	2945
	2740	742393	7392827	-23.556847	113.374624	-76	76	410	410	795	795	795	795	1235	2115
	1900	727456	7398077	-23.511626	113.227583	-131	131	775	775	1410	1410	1410	1410	2050	3100
	200	697338	7408650	-23.420115	112.931373	-455	455	1085	1085	1383	1383	1383	1383	2185	3185
92M-118	700	735733	7362533	-23.831241	113.314238	-53	53	300	300	830	830	830	1225	2020	2810
	1200	726906	7365821	-23.802841	113.227127	-93	93	450	450	825	825	825	825	1450	2200
	1800	716389	7369730	-23.769012	113.123383	-126	126	655	655	1020	1020	1020	1020	1885	2625
	2400	705818	7373666	-23.734873	113.019155	-153	153	645	645	900	900	900	900	1225	1825
	3400	688255	7386179	-23.624061	112.845340	-320	320	815	815	835	835	835	835	1460	2105
	4400	670751	7386678	-23.621501	112.673763	-617	617	905	905	1085	1085	1085	1085	1720	2315
92M-132	3700	732506	7334809	-24.081925	113.286988	-55	55	315	315	805	805	805	805	1755	2540
	3200	723721	7338089	-24.053589	113.200122	-67	67	275	275	610	610	610	610	1500	2230
	2200	706257	7344583	-23.997343	113.027545	-105	105	515	515	770	770	770	770	1430	2170
	1300	690456	7350477	-23.946110	112.871516	-155	155	570	570	860	860	860	860	1380	2155
	100	669387	7358325	-23.877637	112.663647	-352	352	750	750	860	860	860	860	1340	1990
B72-001L	50	858760	7285530	-24.502572	114.539646	90	-90	-30	-30	490	490	490	490	630	830
	100	845357	7286151	-24.500015	114.407444	67	-67	-15	-15	600	600	600	600	720	1150
	200	818408	7285619	-24.510579	114.141999	37	-37	5	5	795	795	795	795	1590	1990
	300	791673	7286235	-24.510283	113.878329	13	-13	30	30	950	950	950	1130	2545	3220
	350	778308	7286532	-24.510061	113.746502	9	-9	50	50	930	930	930	1235	2730	3615
	400	764876	7286671	-24.511161	113.614032	7	-7	90	90	1030	1030	1030	1030	2470	3440
B72-002L	280	826306	7350160	-23.926921	114.205228	31	-31	-23	-23	425	425	425	630	1130	1920
	200	804891	7352660	-23.908614	113.994585	7	-7	-7	-7	510	510	610	1300	1895	2945
	150	791605	7354032	-23.898723	113.863949	7	-7	-2	-2	630	630	680	1235	1870	3050
	100	778137	7355409	-23.888705	113.731534	6	-6	50	50	630	630	870	1500	2165	3300
	50	764893	7354660	-23.897717	113.601710	8	-8	90	90	610	610	735	1390	2040	3080
	1	751801	7354433	-23.901887	113.473258	15	-15	135	135	645	645	645	1185	1800	2810
CE80-30M	600	764116	7422873	-23.282325	113.582003	-70	70	525	525	1410	1410	1410	1410	1565	2365
CE82-03M	1700	776801	7400361	-23.483359	113.710038	-43	43	180	180	675	675	675	1010	1680	2435
	1000	758315	7410176	-23.397829	113.527505	-69	69	420	420	920	920	920	920	1915	2720
	732	751225	7413971	-23.364686	113.457550	-78	78	255	255	560	560	560	560	1260	2010
	320	740332	7419713	-23.314500	113.350150	-121	121	750	750	1250	1250	1250	1250	2510	3395
	10	732151	7424106	-23.276027	113.269527	-200	200	845	845	1230	1230	1230	1230	2265	3145

Appendix 8 (continued)

Line no.	*SP*	*Easting*	*Northing*	*Latitude (S)*	*Longitude (E)*	*Elevation/ WD (m)*	*Top Cz (m)*	*Cz unconf. (m)*	*Top K (m)*	*K unconf. (m)*	*P unconf. (m)*	*Top C (m)*	*Top D (m)*	*Top S (m)*	*Top O (m)*
CG82-02M	280	763245	7242459	-24.910323	113.606245	-4	4	305	305	495	495	495	495	2405	3690
	1600	744184	7269434	-24.670098	113.412954	-20	20	355	355	570	570	570	570	2625	3800
	2100	736643	7279318	-24.582083	113.336826	-46	46	375	375	690	690	690	690	1820	2880
CG82-04M	750	735563	7248404	-24.861214	113.331362	-27	27	360	360	665	665	665	665	2100	3200
	20	746649	7233865	-24.990647	113.443590	-20	20	330	330	585	585	585	585	2315	3445
CG82-06M	1070	740805	7284211	-24.537287	113.377065	-32	32	365	365	675	675	675	675	1875	2995
	50	723350	7265759	-24.706430	113.207789	-49	49	382	382	670	670	670	670	1720	2820
CG83-09L	80	749200	7315329	-24.255166	113.454441	55	-55	25	25	475	475	475	475	1475	2440
	200	750220	7311236	-24.291937	113.465193	35	-35	40	40	475	475	475	610	1870	2945
	500	749783	7300812	-24.386067	113.462710	13	-13	95	95	465	465	465	595	1680	2675
	800	747098	7290573	-24.478888	113.438033	19	-19	260	260	465	465	465	510	1680	2675
OE71-10	10	697339	7259781	-24.763951	112.951640	-73	73	165	165	570	570	570	570	1105	2120
	140	672953	7251487	-24.841771	112.711587	-90	90	200	200	515	515	515	515	515	1080
	250	651926	7244395	-24.908037	112.504334	-120	120	315	315	695	695	695	695	695	1420
OE71-16	20	698819	7134123	-25.897860	112.984686	-71	71	145	145	605	605	605	605	680	1630
	80	687478	7130177	-25.934978	112.872088	-103	103	145	145	685	685	685	685	885	1840
	150	674259	7125638	-25.977592	112.740741	-116	116	245	245	720	720	720	720	720	1605
QH72-01	540	699093	7191736	-25.377873	112.978827	-76	76	175	175	550	550	550	550	550	1460
	300	671594	7178275	-25.502800	112.707325	-117	117	265	265	685	685	685	685	685	1075
	20	636024	7163831	-25.636893	112.354966	-158	158	365	365	1310	1310	1310	1310	1310	1770
R71-010	10	721058	7319958	-24.217606	113.176718	-64	64	345	345	720	720	720	720	790	1530
	100	708400	7306693	-24.339068	113.054067	-69	69	355	355	730	730	730	730	1175	1910
	170	698650	7296379	-24.433439	112.959448	-70	70	340	340	660	660	660	660	1050	1770
R71-014	10	709166	7293189	-24.460852	113.063593	-65	65	345	345	595	595	595	595	980	1730
	100	696197	7305665	-24.349928	112.933986	-75	75	350	350	720	720	720	720	1155	1960
	180	684507	7316283	-24.255501	112.817434	-105	105	395	395	860	860	860	860	1320	2145
SB65-01	480	774522	7201848	-25.274673	113.725906	-8	8	215	215	635	635	635	635	1735	2655
	430	764559	7199861	-25.294392	113.627447	-5	5	180	180	605	605	605	605	1870	2850
	280	742721	7184684	-25.435031	113.413444	-10	10	240	240	685	685	685	685	1500	2730
	150	727400	7163771	-25.626161	113.264742	-9	9	270	270	635	635	635	635	1220	2345
	40	713725	7145787	-25.790495	113.131517	-7	7	215	215	635	635	635	635	1120	2150

Appendix 8 (continued)

Line no.	*SP*	*Easting*	*Northing*	*Latitude (S)*	*Longitude (E)*	*Elevation/ WD (m)*	*Top Cz (m)*	*Cz unconf. (m)*	*Top K (m)*	*K unconf. (m)*	*P unconf. (m)*	*Top C (m)*	*Top D (m)*	*Top S (m)*	*Top O (m)*
SB65-02	520	789838	7146475	-25.771193	113.889787	-9	9	120	120	465	465	465	465	1875	2895
	400	775185	7165467	-25.602715	113.739903	-11	11	190	190	630	630	630	630	1965	2970
	260	757981	7187681	-25.405424	113.564489	-5	5	230	230	650	650	650	650	1720	2745
	150	744298	7204562	-25.255423	113.425532	-18	18	245	245	675	675	675	675	1830	3085
	10	725982	7225983	-25.064996	113.240259	-13	13	250	250	675	675	675	675	1150	2235
SB65-04	240	746464	7220720	-25.109281	113.444110	-20	20	190	190	635	635	635	635	1900	3000
	140	731318	7207665	-25.229484	113.296216	-11	11	225	225	665	665	665	665	1325	2390
	50	717682	7195939	-25.337344	113.162812	-19	19	205	205	655	655	655	655	1075	1975
SR62-C-L	250	814258	7396695	-23.509621	114.077146	13	-13	7	7	645	645	1545	2 040	2675	3670
	220	802312	7397008	-23.509065	113.960233	15	-15	0	0	680	680	1615	2 090	2675	3615
	200	794301	7397189	-23.508903	113.881832	33	-33	-33	-33	395	395	1920	2 545	3190	4200
	180	786350	7397312	-23.509214	113.804025	21	-21	9	9	560	560	1410	1965	2495	3500
W90-02	1200	818182	7376102	-23.694592	114.119920	25	-25	-25	-25	525	525	1175	1590	2140	2970
	1400	818103	7370991	-23.740705	114.120244	26	-26	-26	-26	490	490	1430	1965	2600	3500
	2500	817572	7343542	-23.988373	114.120974	25	-25	-7	-7	475	475	475	870	1455	2340
W90-04	1600	835796	7385789	-23.603662	114.290230	45	-45	-45	-45	260	260	410	755	1320	2165
	1000	820839	7386332	-23.601801	114.143735	23	-23	-23	-23	560	560	1010	1455	2115	3025
	280	802851	7386924	-23.599929	113.967549	23	-23	-23	-23	510	510	1990	2705	3700	4715
WG67-31	10	726065	7432556	-23.200603	113.208808	-325	325	1410	1410	2150	2150	2150	2150	3800	4890
	120	747136	7426835	-23.249212	113.415480	-114	114	950	950	1580	1580	1580	1580	3120	4220

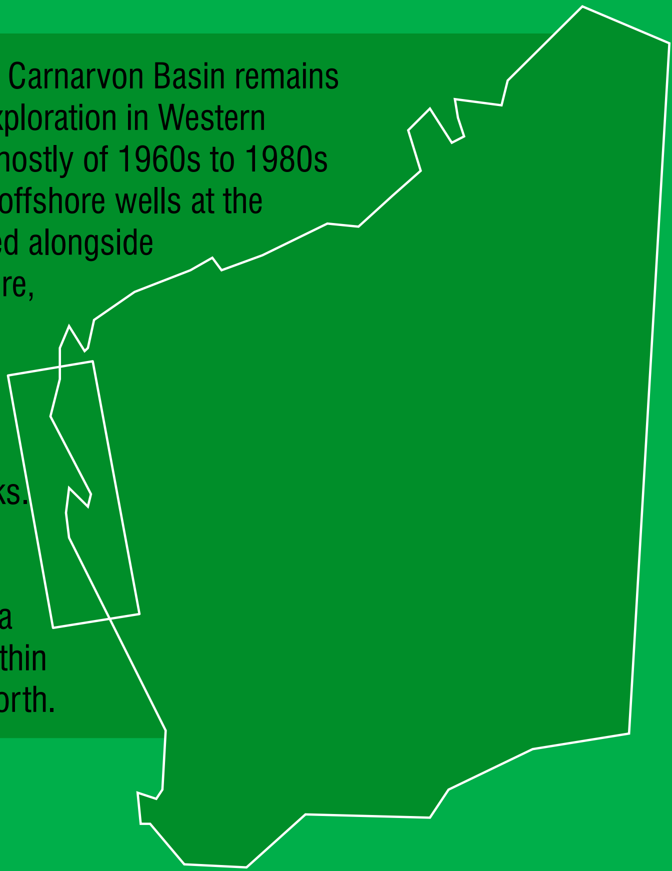
NOTES:

K unconf.: Cretaceous unconformity
P unconf.: Permian unconformity
Cz unconf.: Cainozoic unconformity

SP: shotpoint
WD: water depth

Top C: Top Carboniferous
Top D: Top Devonian
Top K: Top Cretaceous
Top O: Top Ordovician
Top S: Top Silurian
Top Cz: Top Cainozoic

The offshore Gascoyne Platform of the Southern Carnarvon Basin remains a poorly explored frontier region for petroleum exploration in Western Australia. In this Report, regional seismic data, mostly of 1960s to 1980s vintage, was tied to onshore wells and the three offshore wells at the extremities of the study area, and were interpreted alongside gravity and magnetic data to evaluate the structure, stratigraphy, and petroleum potential of the area. This evaluation focuses on the petroleum potential of the poorly tested Palaeozoic succession, which, by inference from onshore data, contains Silurian and Devonian source rocks. The most likely plays include faulted traps with objectives such as the Ordovician Tumblagooda Sandstone sealed by the Lower Triassic Kockatea Shale in the southwest, and reefal carbonates within the Upper Devonian Gneudna Formation to the north.



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SYMBOLS

Seismic line showing shotpoints

Coastline

Basin subdivision

Townsite

Petroleum exploration well (dry, plugged and abandoned)

Stratigraphic well

Water bore

Mineral hole

Outcrop site

Compiled by R. P. Iasky, C. D'Ercole, and K. A. Blundell

Edited by G. Loan
Cartography by L. Cosgrove and L. Fogarty

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The recommended reference for this map is:
IASKY, R. P., D'ERCOLE, C., and BLUNDELL, K. A., 2003, Location of petroleum exploration and stratigraphic wells, water bores, mineral holes, outcrop sites, and interpreted seismic lines, Gascoyne Platform, *in* Structure and petroleum prospectivity of the Gascoyne Platform, Western Australia *by* R. P. IASKY, C. D'ERCOLE, K. A. R. GHORI, A. J. MORY, and A. M. LOCKWOOD: Western Australia Geological Survey, Report 87, Plate 1.

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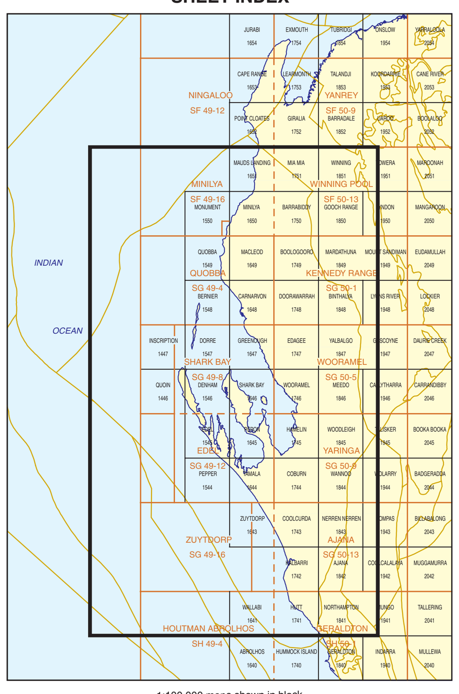

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1:250 000 maps shown in brown

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SCALE 1:750 000

0 10 20 30 40 50
Kilometres

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
Grid marks indicate 100 km intervals of the Map Grid of Australia Zone 49

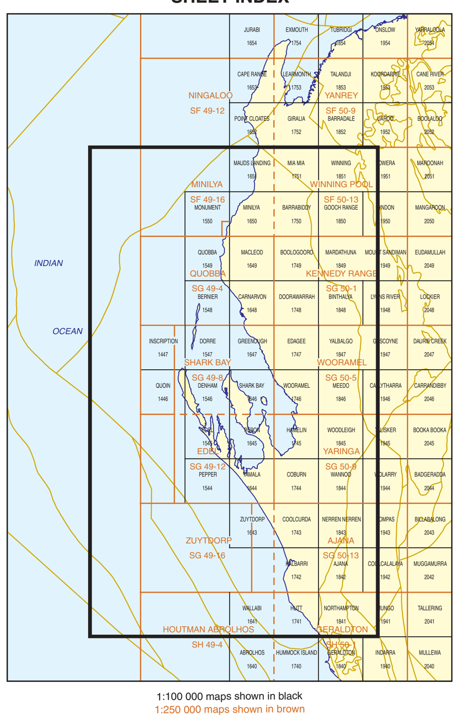
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA REPORT 87 PLATE 1

LOCATION OF PETROLEUM EXPLORATION AND STRATIGRAPHIC WELLS, WATER BORES, MINERAL HOLES, OUTCROP SITES, AND INTERPRETED SEISMIC LINES

GASCOYNE PLATFORM

RPI284 16.06.03

SHEET INDEX



SYMBOLS

- Seismic line (H78-120)
- Coastline
- Basin subdivision
- Normal fault, tick on downthrown side
- Reverse fault, tick on upthrown side
- Two-way time contours (100 milliseconds) (500)
- Two-way time contours (50 milliseconds) (550)
- Townsite
- Petroleum exploration well (dry, plugged and abandoned)
- Stratigraphic well
- Water bore
- Mineral hole
- Outcrop site

Compiled by R. P. Iasky, C. D'Ercole, and K. A. Blundell

Edited by G. Loan
Cartography by L. Cosgrove and L. Fogarty

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SCALE 1:750 000

0 10 20 30 40 50
Kilometres

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
Grid marks indicate 100 km intervals of the Map Grid of Australia Zone 49

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA REPORT 87 PLATE 2

TWO-WAY TIME STRUCTURE MAP OF THE MIOCENE UNCONFORMITY

GASCOYNE PLATFORM

RPI288

SYMBOLS

- H78-120 Seismic line
- Coastline
- Basin subdivision
- Normal fault, showing downthrown side and heave; tick on downthrown side
- Reverse fault, tick on upthrown side
- Inferred normal fault, tick on downthrown side
- 500 Two-way time contours (100 milliseconds)
- 550 Two-way time contours (50 milliseconds)
- Townsite
- Petroleum exploration well (dry, plugged and abandoned)
- Stratigraphic well
- Water bore
- Mineral hole
- Outcrop site

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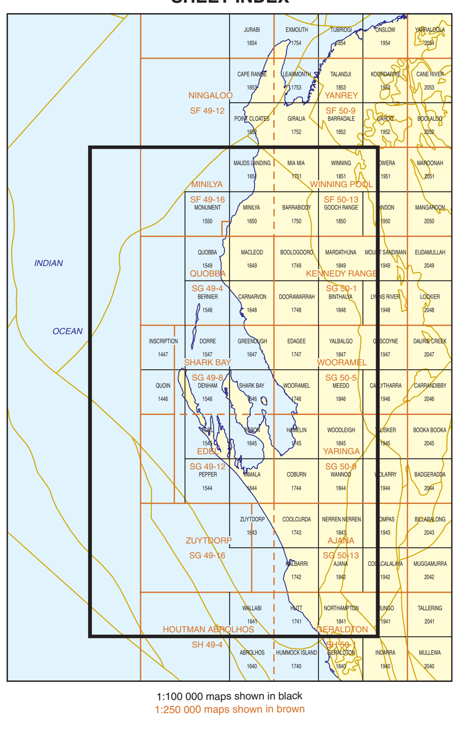

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SCALE 1:750 000

0 10 20 30 40 50

Kilometres

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
Grid marks indicate 100 km intervals of the Map Grid of Australia Zone 49

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA REPORT 87 PLATE 3

TWO-WAY TIME STRUCTURE MAP OF THE BASE CRETACEOUS (BREAKUP) UNCONFORMITY

GASCOYNE PLATFORM

SYMBOLS

- H78-120 Seismic line
- Coastline
- Basin subdivision
- Normal fault, showing downthrown side and heave; tick on downthrown side
- 500 Two-way time contours (100 milliseconds)
- 550 Two-way time contours (50 milliseconds)
- Townsite
- Petroleum exploration well (dry, plugged and abandoned)
- Stratigraphic well
- Water bore
- Mineral hole
- Outcrop site

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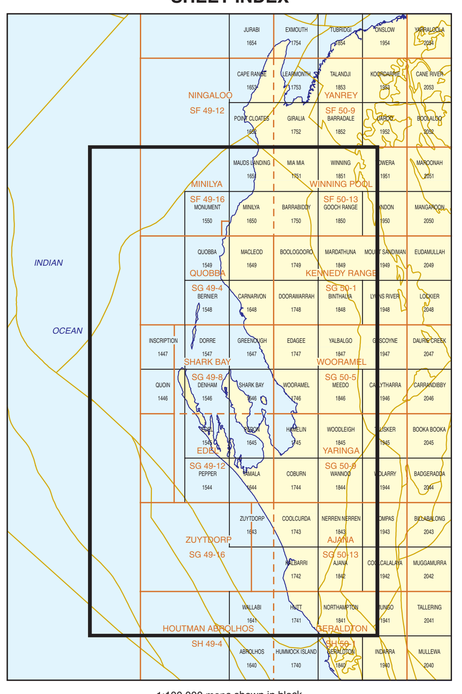

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1:250 000 maps shown in brown

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SCALE 1:750 000

0 10 20 30 40 50

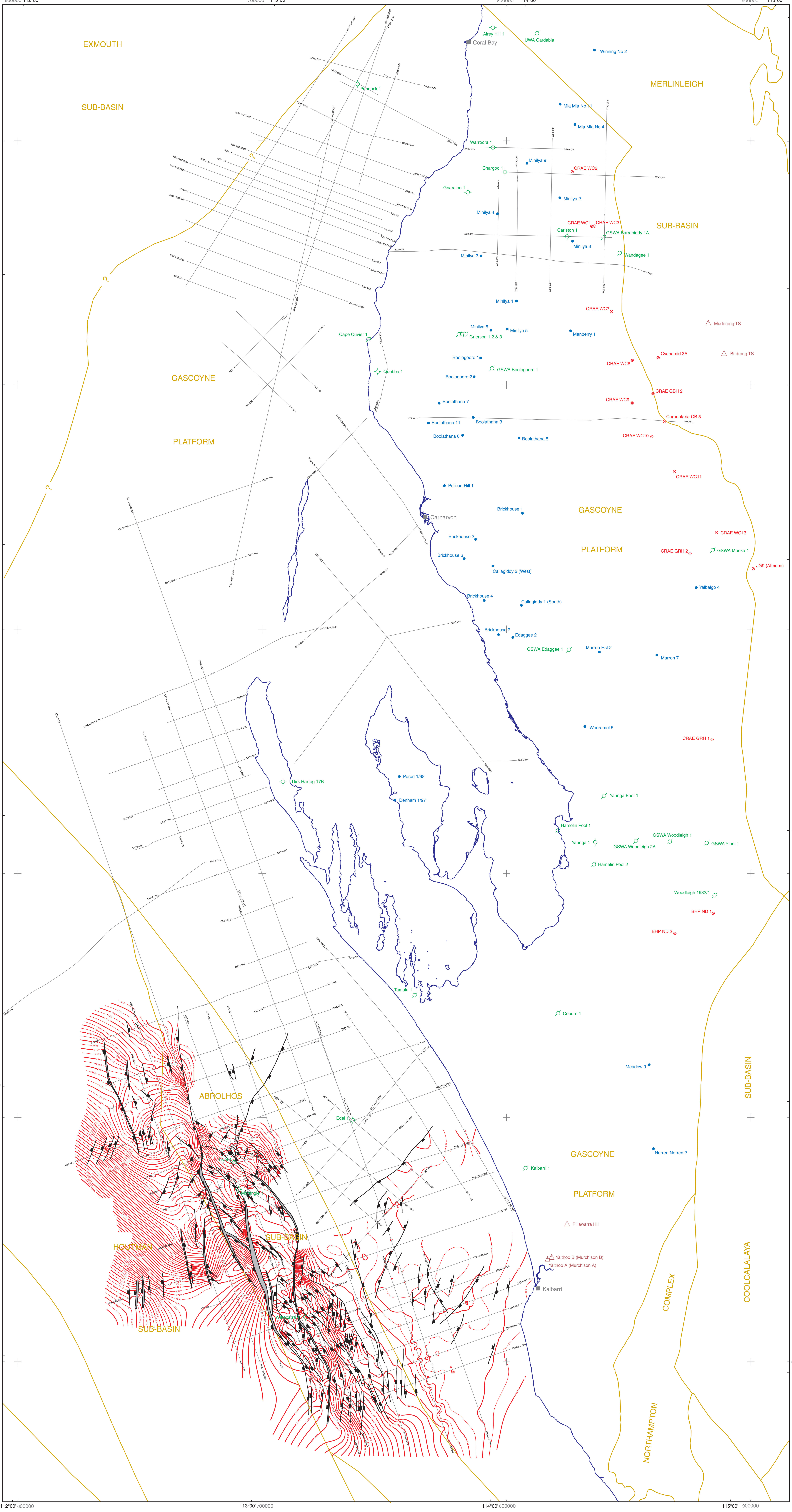
Kilometres

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
Grid marks indicate 100 km intervals of the Map Grid of Australia Zone 49

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA REPORT 87 PLATE 4

TWO-WAY TIME STRUCTURE MAP OF THE TOP KOCKATEA SHALE

GASCOYNE PLATFORM



SYMBOLS

- H78-120 Seismic line
- Coastline
- Basin subdivision
- Normal fault, showing downthrown side and heave; tick on downthrown side
- 500 Two-way time contours (100 milliseconds)
- 550 Two-way time contours (50 milliseconds)
- Townsite
- Petroleum exploration well (dry, plugged and abandoned)
- Stratigraphic well
- Water bore
- Mineral hole
- Outcrop site

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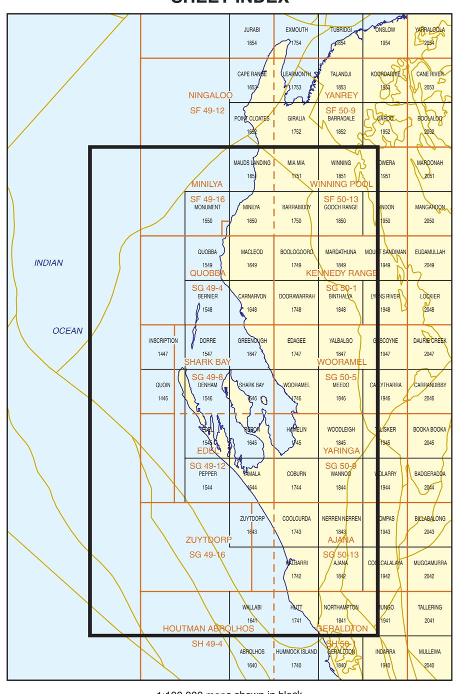

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0 10 20 30 40 50
Kilometres

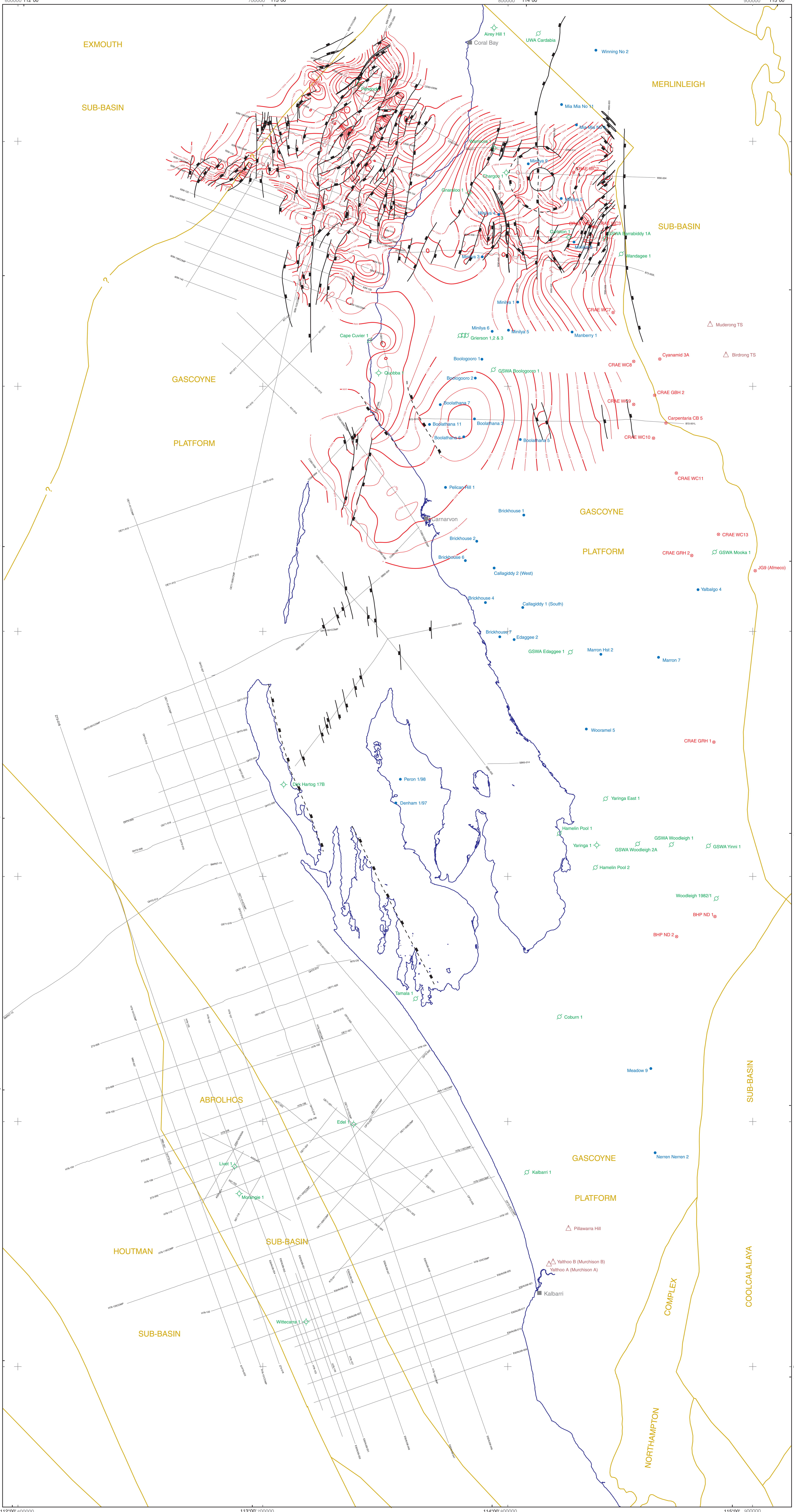
TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
Grid marks indicate 100 km intervals of the Map Grid of Australia Zone 49

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 87 PLATE 5

TWO-WAY TIME STRUCTURE MAP OF THE MID- TO LATE PERMIAN UNCONFORMITY

GASCOYNE PLATFORM

RPI291 16.06.03



SYMBOLS

- Seismic line
- Coastline
- Basin subdivision
- Normal fault, showing downthrown side and heave; tick on downthrown side
- Inferred normal fault, tick on downthrown side
- Two-way time contours (100 milliseconds)
- Two-way time contours (50 milliseconds)
- Townsite
- Petroleum exploration well (dry, plugged and abandoned)
- Stratigraphic well
- Water bore
- Mineral hole
- Outcrop site

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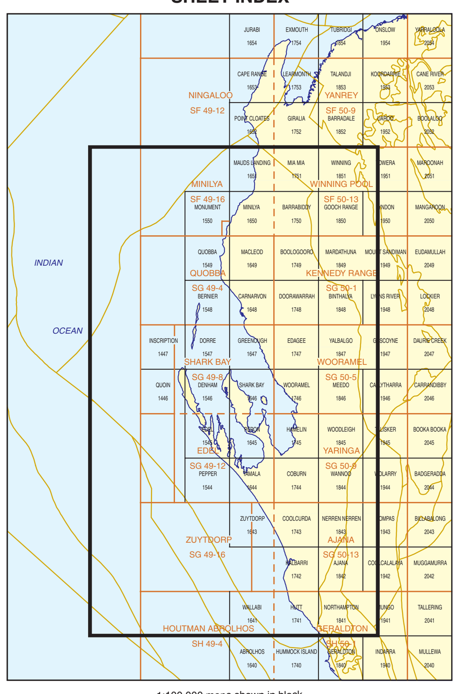

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Kilometres

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
Grid marks indicate 100 km intervals of the Map Grid of Australia Zone 49

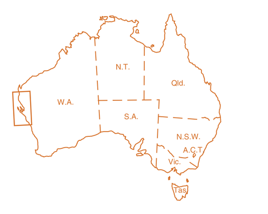
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 87 PLATE 6

TWO-WAY TIME STRUCTURE MAP OF THE BASE GNEUDNA FORMATION

GASCOYNE PLATFORM

RPI292

16.06.03



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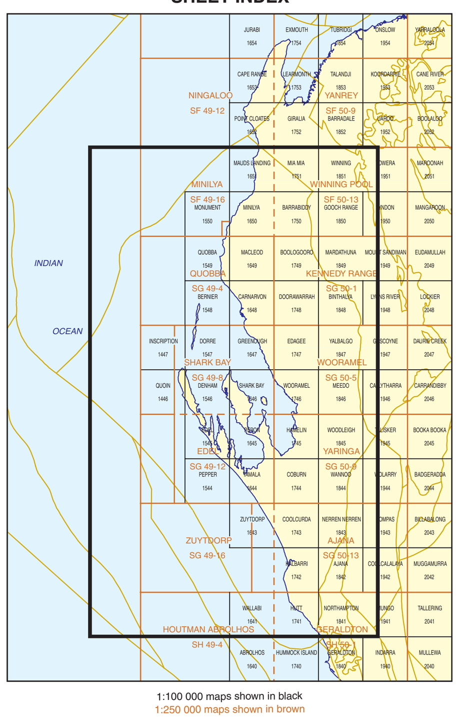

SYMBOLS

- H78-120 Seismic line
- Coastline
- Basin subdivision
- Normal fault, showing downthrown side and heave; tick on downthrown side
- Inferred normal fault, tick on downthrown side
- 500 Two-way time contours (100 milliseconds)
- Townsite
- Petroleum exploration well (dry, plugged and abandoned)
- Stratigraphic well
- Water bore
- Mineral hole
- Outcrop site

Compiled by R. P. Iasky, C. D'Ercole, and K. A. Blundell

Edited by G. Loan
Cartography by L. Cosgrove and L. Fogarty

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Kilometres

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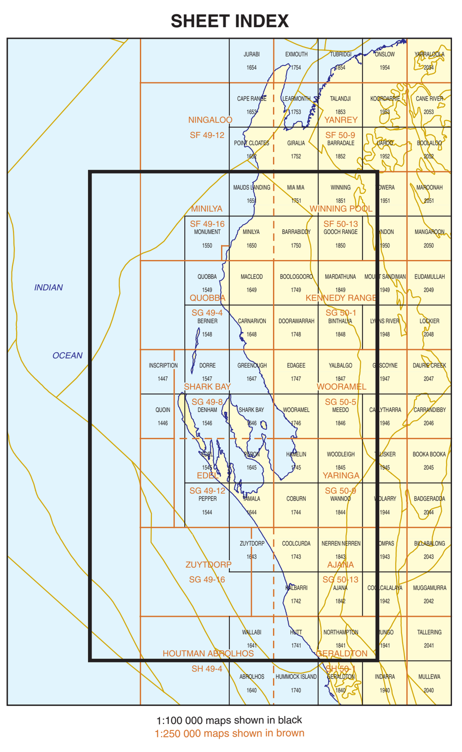
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
Grid marks indicate 100 km intervals of the Map Grid of Australia Zone 49

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA REPORT 87 PLATE 7

TWO-WAY TIME STRUCTURE MAP OF THE TOP TUMBLAGOODA SANDSTONE

GASCOYNE PLATFORM

RP293



SYMBOLS

- Seismic line
- Coastline
- Basin subdivision
- Normal fault, showing downthrown side and heave; tick on downthrown side
- Inferred normal fault, tick on downthrown side
- Two-way time contours (100 milliseconds)
- Townsite
- Petroleum exploration well (dry, plugged and abandoned)
- Stratigraphic well
- Water bore
- Mineral hole
- Outcrop site

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SCALE 1:750 000

0 10 20 30 40 50 Kilometres

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
Grid marks indicate 100 km intervals of the Map Grid of Australia Zone 49

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA REPORT 87 PLATE 8

TWO-WAY TIME STRUCTURE MAP OF THE NEAR-BASEMENT UNCONFORMITY

GASCOYNE PLATFORM

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Edited by K. Blundell
Cartography by L. Cosgrove and L. Fogarty

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The recommended reference for this plate is:
MORY, A. J., 2003, Well-log correlation, Gascoyne Platform, Southern Carnarvon Basin, Western Australia, *in* Structure and petroleum prospectivity of the Gascoyne Platform, Western Australia *by* R. P. IASKY, C. D'ERCOLE, K. A. R. GHORI, A. J. MORY, and A. M. LOCKWOOD: Western Australia Geological Survey, Report 87, Plate 9

Department of Industry and Resources

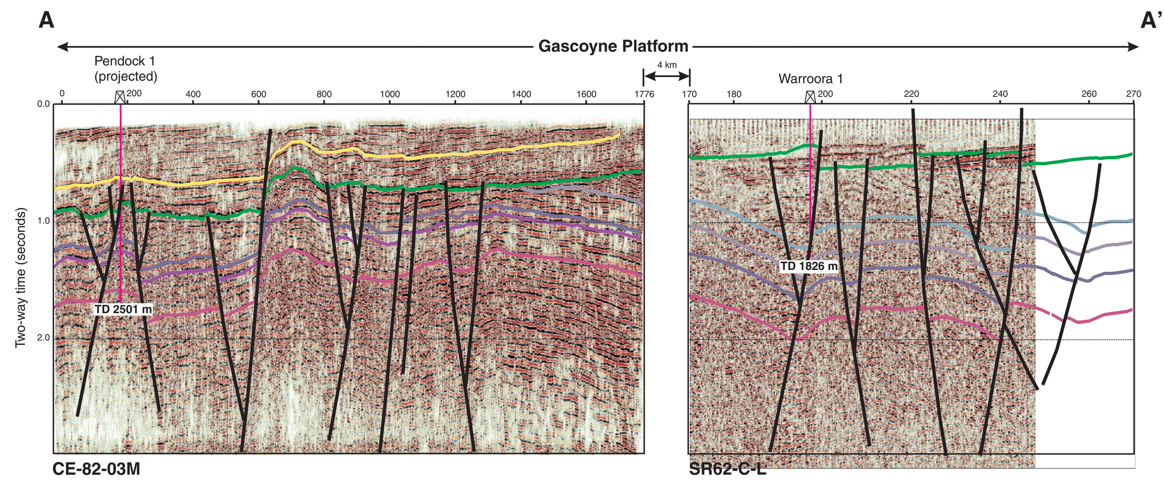
Geological Survey of Western Australia

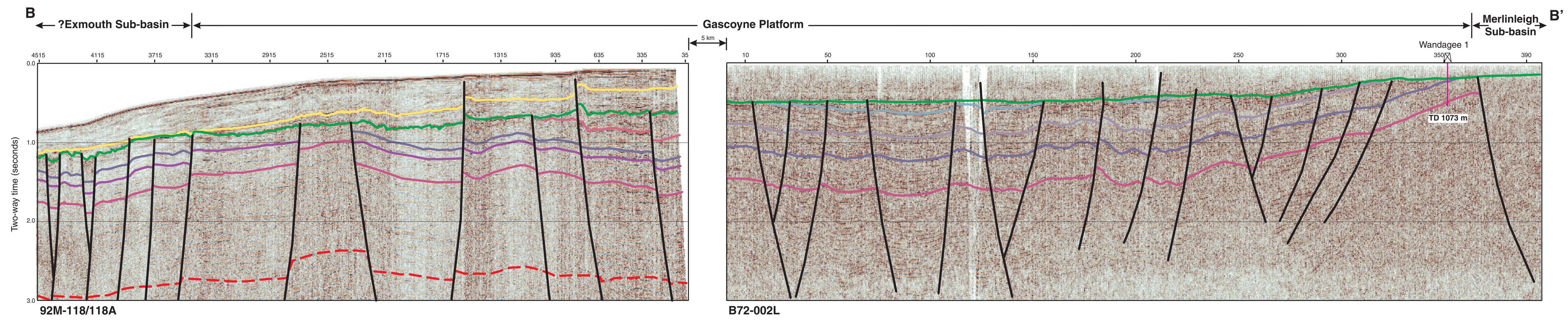
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 87 PLATE 9

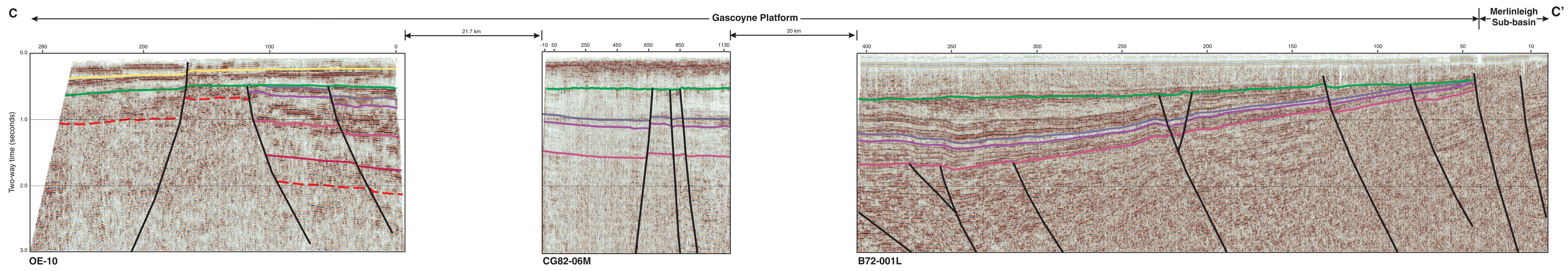
WELL-LOG CORRELATION
GASCOYNE PLATFORM

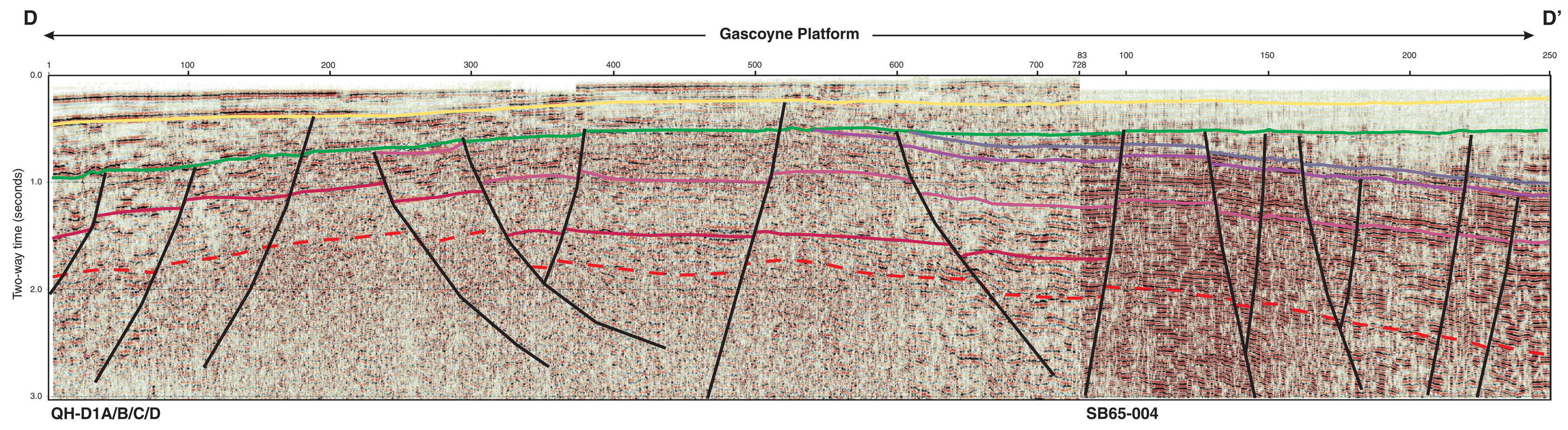
SOUTHERN CARNARVON BASIN
WESTERN AUSTRALIA

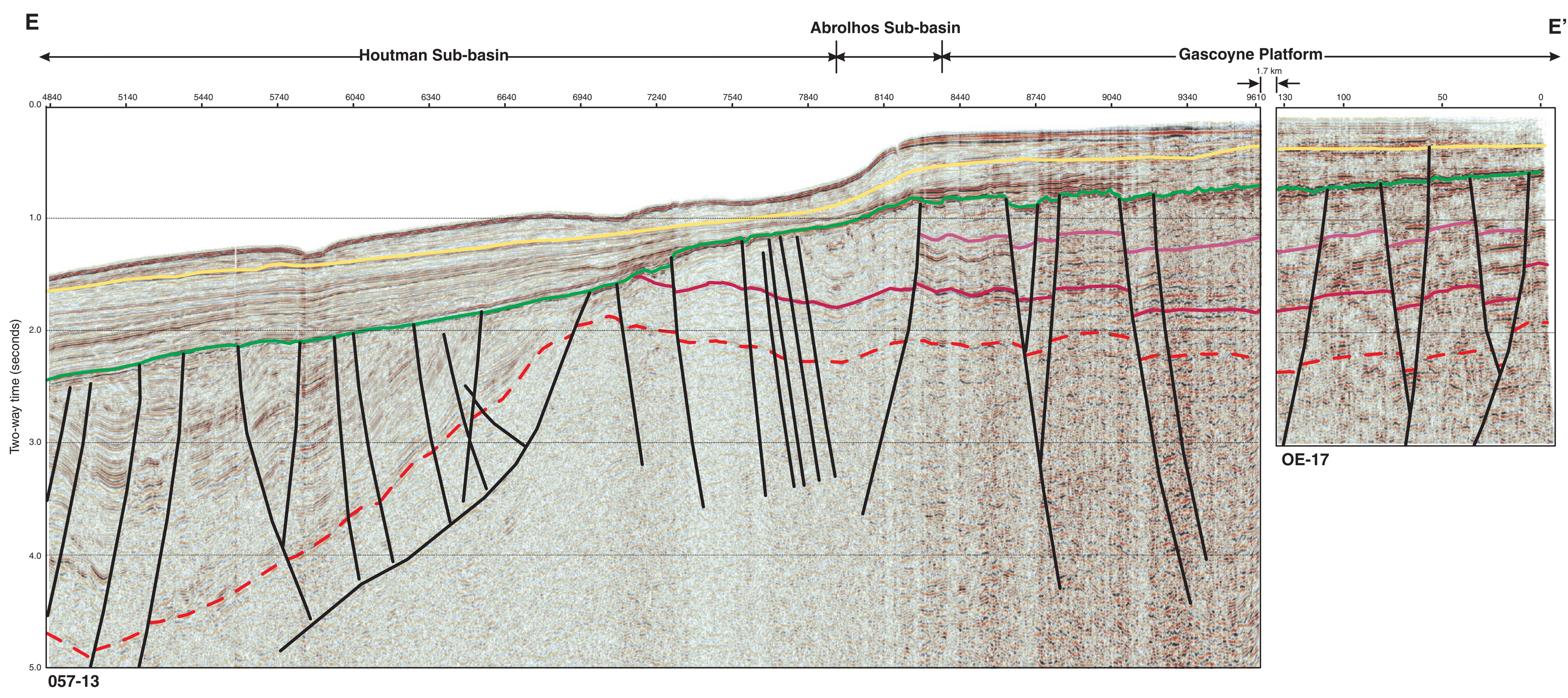
RPI283A 31.03.03

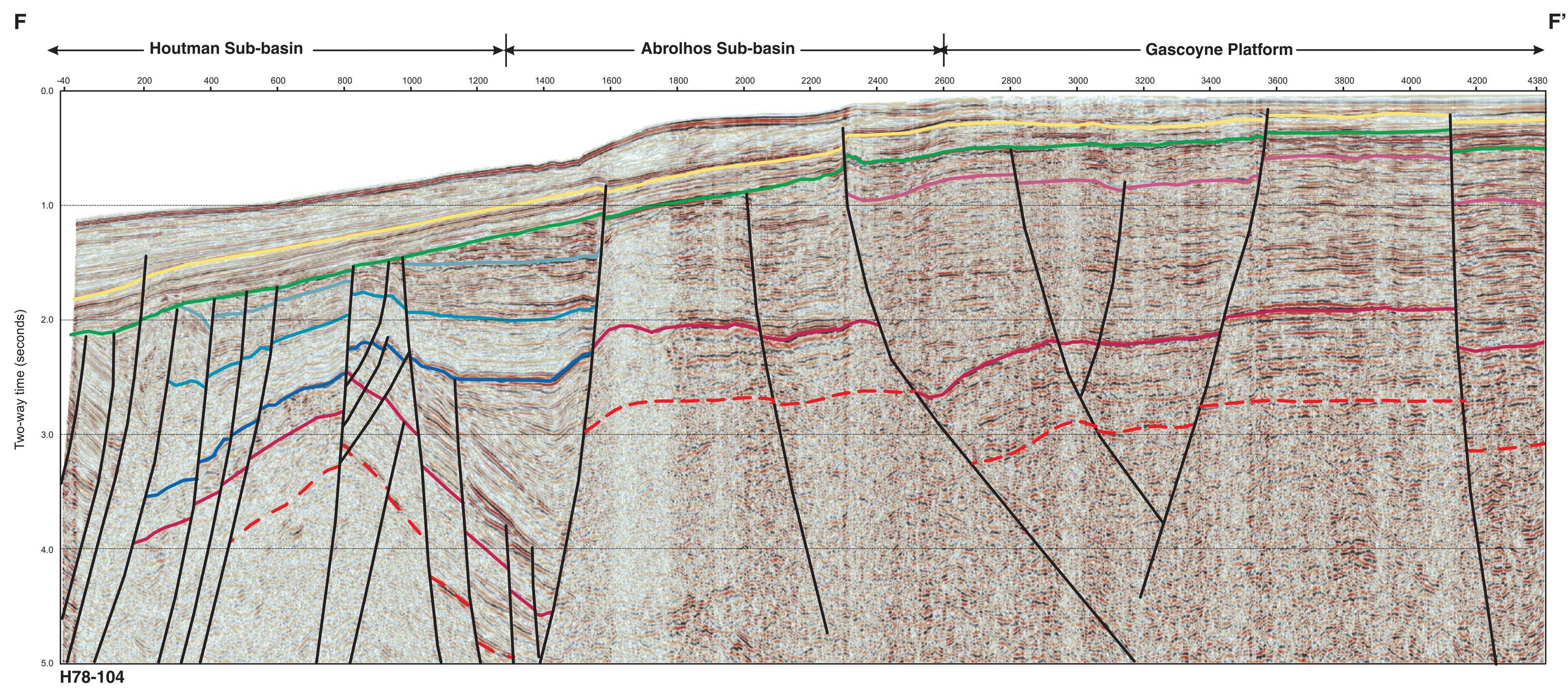


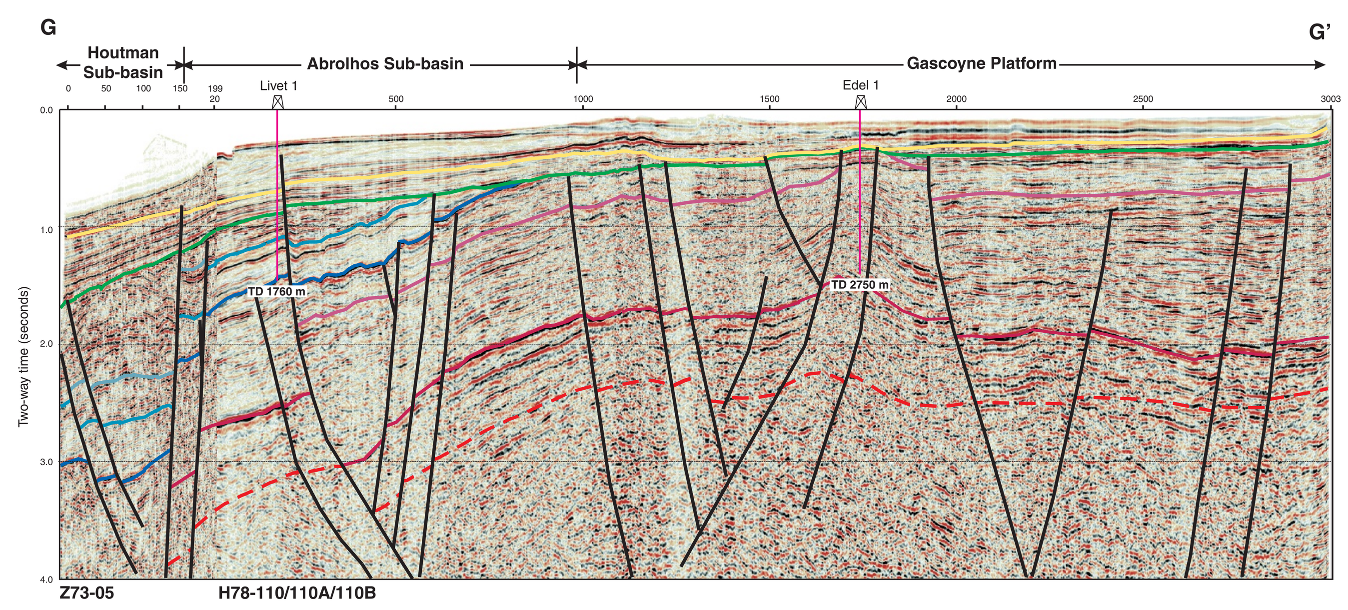


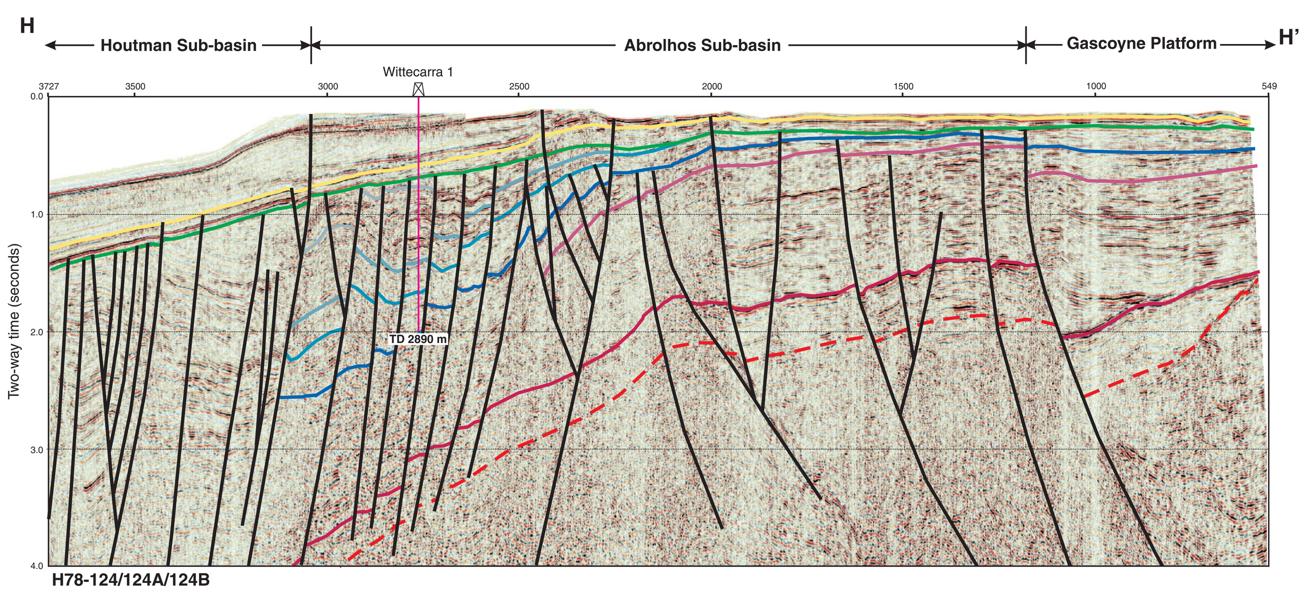


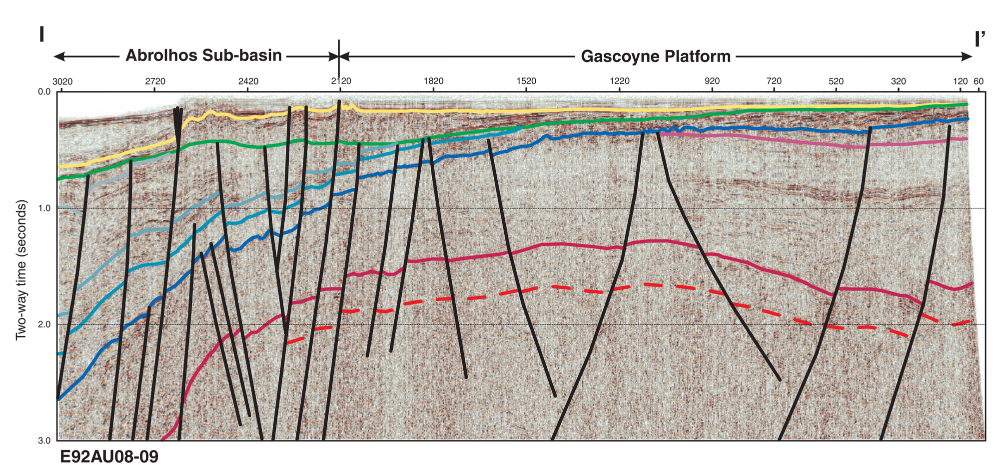




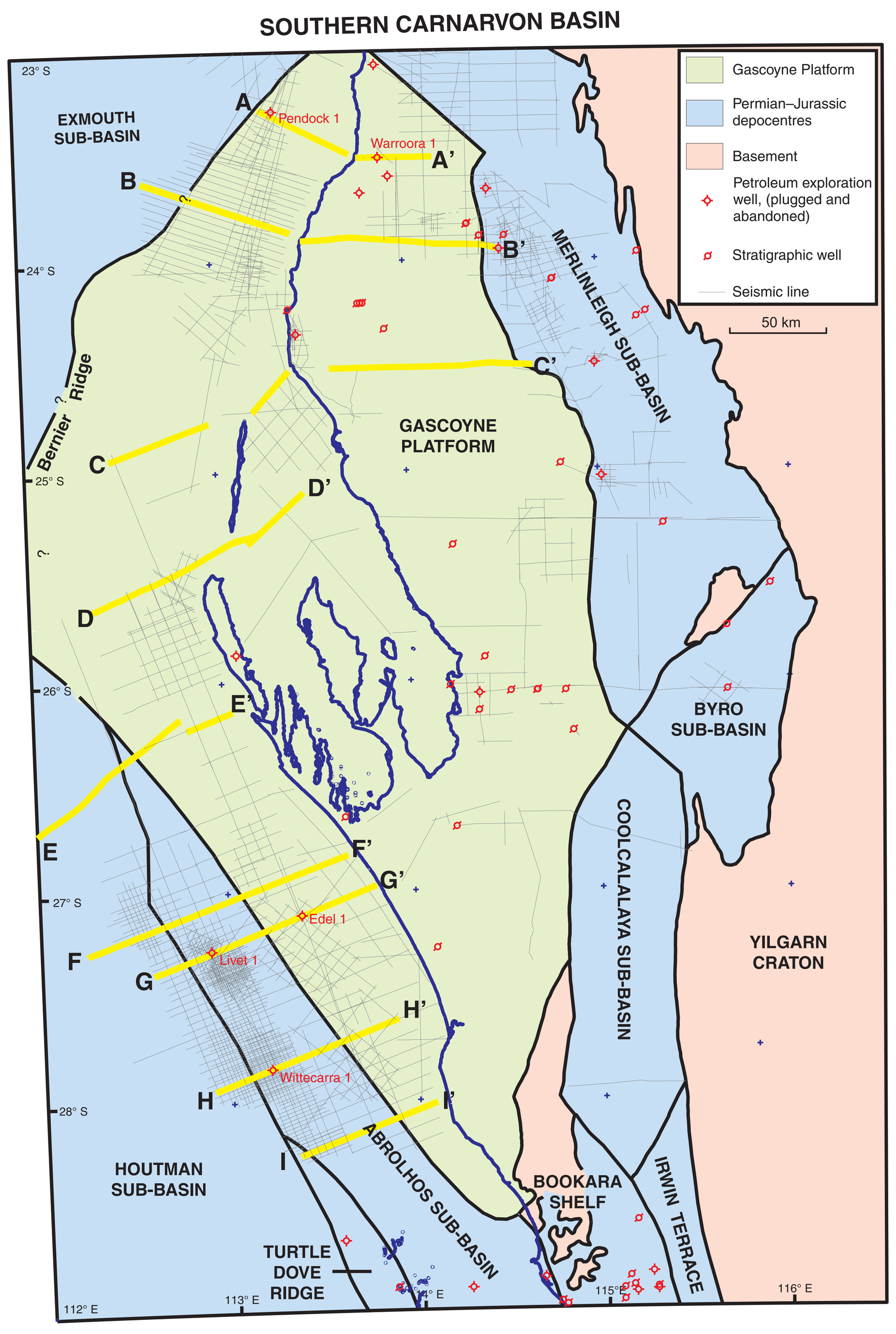


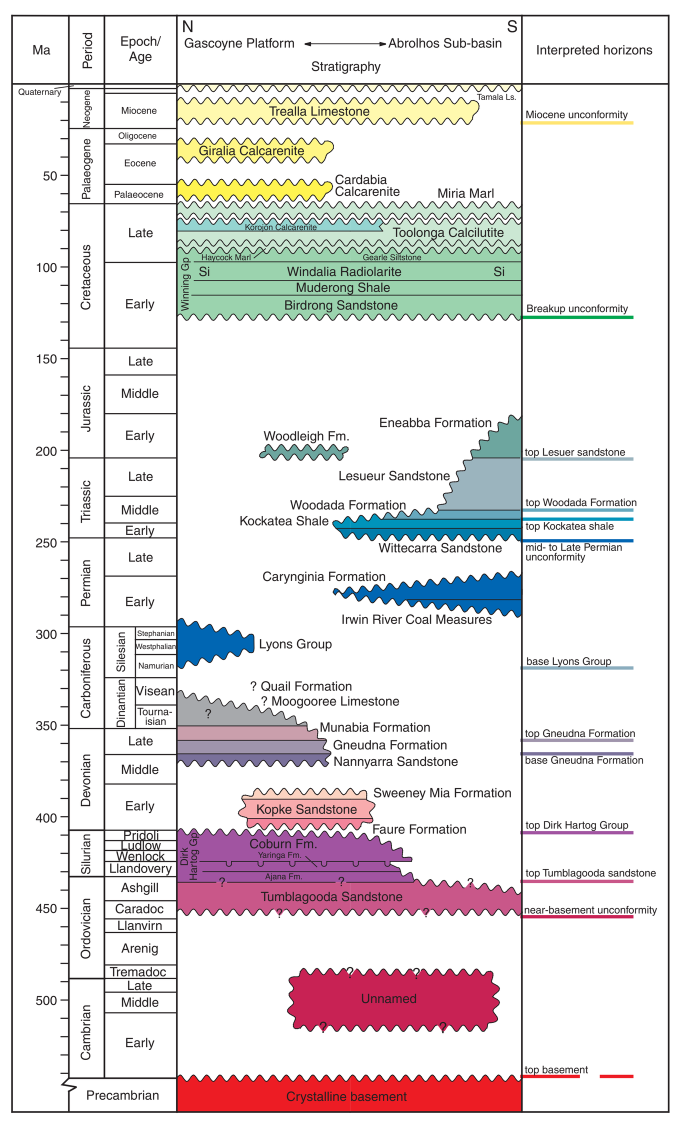






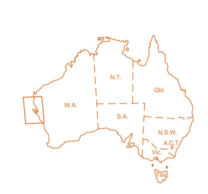
SOUTHERN CARNARVON BASIN





Si Siliceous
Fm. Formation
Gp Group
Unconformity

20 km
Horizontal scale for sections



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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA REPORT 87 PLATE 10

SEISMIC SECTIONS ACROSS THE GASCOYNE PLATFORM

SOUTHERN CARNARVON BASIN WESTERN AUSTRALIA

Compiled by R. P. Iasky and K. A. Blundell

Edited by G. Loan
Cartography by L. Cosgrove and L. Fogarty

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