Record 1990/73

GEOLOGICAL CROSS-SECTION ACROSS THE OFFSHORE CANNING BASIN

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SUMMARY

The Offshore Canning Basin comprises up to 14 km of Permo-Carboniferous to recent sediments and 7 km of lower and middle Palaeozoic sediments. In the section immediately onshore there are up to 6 km of Ordovician to Permian sediments and 3 km of Intra Proterozoic sediments. There has only been minor structuring within the Permo-Carboniferous to Holocene sequence, and the timing of the uplift of the Bedout High is suggested to be perhaps as old as mid-Carboniferous rather than Triassic. This significantly alters the expected maturation levels of the Palaeozoic sequences. Source rock quality is only moderate to poor being the major risk in this area, although contribution from the Palaeozoic sequence is a distinct possibility. Hydrocarbon shows are poor except for a thick interval of gas shows in Phoenix 1. A Cenozoic prograding stratal pattern occurs in the deeper water section, that compares favourably with that predicted for the global Neogene signature.

INTRODUCTION

DATA SET

SAMPHIRE MARSH 1 (WAPET, 1958)
BEDOUT 1 (BOCAL, 1971)
EAST MERMAID 1 (SHELL, 1973)
MINILYA 1 (BOCAL, 1974)
PHOENIX 1 (BP, 1980)
PHOENIX 2 (BP,1982)
LAGRANGE 1 (BP, 1982)

OFFSHORE CANNING SEISMIC SURVEY (JNOC, 1986 : JN)
SAMPHIRE EP 107 SEISMIC SURVEY (SOC, 1981 : 81B, onshore)

SCALE

The cross-section has been drawn at 1:100,000 scale with a vertical to horizontal exaggeration of 1. The total length of the line is 846 km, comprising 53 km onshore and 793 km offshore, and has a maximum depth of approximately 14 km.

HORIZONS DRAWN

A total of 14 horizons were carried on the offshore seismic and drawn on the cross-sections (Plate 1) ;

1) Tertiary - Base Pliocene - base Time Slice Cz6
2) Tertiary - Base Late Miocene - base Time Slice Cz5
3) Tertiary - Base Late Oligocene - base Cz4
4) Tertiary - Base Oligocene - base Cz3
5) Tertiary - Base middle Eocene - base Cz2
6) Cretaceous - Top Maastrichtian - top K11
7) Cretaceous - Top Cenomanian - top K8
8) Cretaceous - Base Aptian - base K4
9) Cretaceous - near Base Valanginian - base K2
10) Jurassic - Top Tithonian - top J10
11) Jurassic - Mid Callovian - base J7
12) Triassic - Top Rhaetian - top T6
13) Permian - Top Tatarian - top P7
14) Pre-Triassic - Pre-Kazanian - pre-P5(?)

Additional to these horizons, several Palaeozoic reflectors have been drawn. These horizons have not been correlated across each fault block, but simply represent the morphology and dip of the set of reflectors in each fault block marked.

For the onshore segment, 6 horizons were carried and drawn on the cross-section (Plate 1) ;

1) Top Cretaceous
2) Top Jurassic
3) Top Permian

4) Top Ordovician
5) Late Proterozoic Granite / Late to Middle Proterozoic sediments
6) Intra-Proterozoic sediments

TIME DEPTH PLOTS

Time/depth plots have been drawn for the six wells in the offshore section and for the one well in the onshore section; Phoenix 1, Phoenix 2, Minilya 1, Lagrange 1, Bedout 1, East Mermaid 1 and Samphire Marsh 1 (Plate 2). These plots are not burial history curves, but simply represent the palaeontological dating performed in each well, and show the precise nature of the biostratigraphic control which exists for the cross-section. The boxes drawn on the time/depth curves are the actual depth range of the palaeontological zones assigned in the well.

The Mesozoic age control in Samphire Marsh 1 in the onshore segment is poor, but reliable dating occurs in the Palaeozoic section. There are insufficient dates in Lagrange 1 to be confident of many of the time slices, thus where appropriate comparison was made with the biostratigraphy in Bedout 1. There appears to be spurious data in the Upper Tertiary in East Mermaid 1 (time slice Cz 5 & 6). This is indicated by Bedout 1 and Minilya 1 which can be reliably correlated on seismic whereas East Mermaid 1 mis-ties by 0.3 seconds. Older horizons in East Mermaid 1 tie accurately with the other wells. No dates are available for the top 1500 m of Phoenix 2 (Cretaceous and Tertiary). The basalt at the base of Lagrange 1 was dated as 253 $\pm$ 5 m.y.. It was presumed that the undated basalt in Bedout 1 is of similar age.

RESULTS

DATING OF HORIZONS

Proterozoic

Along section I-J-K adjacent to Samphire Marsh 1 (Plate 1), a thick (2-4 km) interval of Proterozoic sediments occurs, which are not intersected in wells nor crop out. They are unconformably overlain by Lower Palaeozoic rocks, and display irregular, discontinuous bedding on seismic. They are intruded by Late Proterozoic Granite which is dated as 700 to 500 my old, with the older date being preferred (BMR, 1961). The granite appears to be restricted to the area of the Samphire Marsh high block, with sediments flanking it to the north and south.

Ordovician

A conodont fauna in Samphire Marsh 1 in the Nambeet Formation indicates an early Arenig age (BMR, 1961; R.S. Nicoll pers. comm., BMR, 1990).

Pre-Triassic

The age and nature of the sequence beneath the Pre-Triassic horizon in the offshore is unknown, however, correlation with the onshore sediments around Samphire Marsh 1 indicates that a Middle to Early Palaeozoic age is most likely.

Permian

In the offshore the top of the Permian has been carried by correlating it approximately with the near base Triassic in Phoenix 1 and 2, and the Permian/Triassic unconformity above the basalt in Lagrange 1 and Bedout 1. The basalt in Bedout 1 was dated as Early Jurassic (176 m.y.) (Forman and Wales, 1981; Reeckmann and Mebberson, 1984) thus implying that it was an intrusion. However, Reeckmann and Mebberson (1984) note that there was no affect on the maturation of the overlying sediments, and that it was a Permian emplacement. This was supported by the dating of the basalt in Lagrange 1. It is the only actual Permian date (253 $\pm$ 5 m.y.) in the offshore section, although it was derived from a sample of altered and weathered basalt and could be slightly older.

Disconformably overlying the Ordovician onshore in Samphire Marsh 1, is the Permo-Carboniferous Grant Formation, which is described as Stage 1 and Stage 2 in age (McMinn, 1986) and equates with time slices C6 and P1.

Triassic

The only thick, well dated Triassic sediments are in Phoenix 1 and 2. Rapid thinning occurs onto the Bedout High as seen in Bedout 1 and Lagrange 1 and on section D-E-F (Plate 1).

Jurassic

Phoenix 1 and 2, Bedout 1 and East Mermaid 1 all have reasonably well dated Jurassic sequences. Minilya 1 probably penetrated to at least the Bajocian (time slice J5) but the interval was not dated. Lagrange 1 has dating in the Lower Jurassic (time slice J1 to 5), but no younger Jurassic dates are present for almost 600 m until the Cretaceous is reached. Disconformably overlying the Permo-Carboniferous in Samphire Marsh 1 are Upper Jurassic sediments which are poorly dated but probably represent time slices J4 to J9. Differences occur in the Early Jurassic time slice correlations between Phoenix 1 and 2, which could in part reflect the more precise dating in Phoenix 2.

Cretaceous

Minilya 1, Phoenix 1, Bedout 1 and East Mermaid 1 all have well dated Cretaceous sequences. Phoenix 2 has no dates above the Aptian (time slice K4), whilst Lagrange 1 has no dates above the Hauterivian (time slice K2). Overlying the Upper Jurassic in Samphire Marsh 1 is a poorly dated Cretaceous sequence, probably representing time slices K1 to K4.

Tertiary

Minilya 1, Bedout 1 and East Mermaid 1 all have well dated Tertiary sequences, although as noted above, time slices Cz 5 and 6 in East Mermaid 1 are believed to be spurious. Phoenix 1 has no dating younger than the Middle Miocene, whilst Phoenix 2 and Lagrange 1 have no Tertiary dating at all.

TIME AND FACIES DIAGRAM

Time Space

Numerous unconformities of regional extent are evident from the well and seismic data. They include ; Oligocene Cz3, Aptian to Albian K4 to K6, Valanginian K2, Oxfordian to Tithonian J8 to J10, Late Triassic to Early Jurassic T5 to J3, Early Permian, Early Ordovician to Late Carboniferous and Cambrian to Early Ordovician.

Time Slice Correlation

Ordovician and Permo-Carboniferous sediments have only been penetrated in the onshore wells, although on seismic data adjacent to Lagrange 1 and Bedout 1 (section B-E Plate 1) there is a Palaeozoic section beneath the Permo-Triassic unconformity that could represent a similar section to that which occurs near Samphire Marsh 1. In the Triassic (T.S. T2-6), major thickening occurs away from the Bedout High. Significant thinning in the Early Jurassic is evident over the Bedout High on seismic and from the Lagrange 1 biostratigraphy, but is not apparent from the Bedout 1 biostratigraphy. Thinning of the Early Jurassic sequence also occurs between Phoenix 1 and 2. The Cretaceous sequence thickens from the south to the north, and the Cenozoic thickens in an offshore direction.

Time Slice Facies

An initial transgressive Early Triassic fluvial, paralic and marine sequence (T2 - T5) is overlain by a major fluvial regression through until the Late Jurassic (T6 - J7). Onshore data suggests a period of continental inundation during the Kimmeridgian and Tithonian (J8 - J9), although not well dated or recorded in the offshore wells perhaps due to its manifestation as thin condensed intervals (Phoenix 2 ≈ 1850-1865m). This break in deposition toward the end of the Jurassic (J8 - J10) was followed by a short period of marine and paralic deposition, prior to another break in the Early Cretaceous (K2). Predominantly marine conditions with some paralic deposition continued until recent times, except for a regional break in deposition in the Oligocene (Cz3).

HYDROCARBON PROSPECTIVITY

RESERVOIR

The primary reservoir horizons are Jurassic and Triassic sandstones that were deposited in fluvial and paralic conditions. The Triassic sandstones have average porosities of 9 to 14% with permeabilities ranging from 0 to 300 md. The Jurassic sandstones have average porosities from 20 to 26%. (Bedout 1, Minilya 1)

SOURCE AND MATURATION

Source is considered to be the major risk within this area (Horstman & Purcell, 1986). The Lower Triassic sequence is generally mature, but overall has poor source rock quality. At best it has only a moderate to poor gas/condensate potential. The Jurassic and Cretaceous is considered to be immature. The potential of the underlying Palaeozoic sediments has not been assessed as it has not been intersected offshore despite attempts in Lagrange 1 to intersect this sequence, where they abandoned the well after drilling 391 m of basalt. In the onshore Canning Basin, excellent source potential occurs in the Early Ordovician, whilst in the Arafura Basin high TOCs occur in the Middle Cambrian (Bradshaw et al., 1990). A Palaeozoic sequence which is believed to be present along section B - E (Plate 1) could contain either of these potential source intervals.

The two different structural scenarios for the development of the Bedout High (See Structure - Pre-Triassic below) will markedly affect the maturation level of the Palaeozoic sequence. If the Bedout High developed prior to the Permo-Carboniferous, and thus was high during the Permian and Triassic as is suggested from the regional seismic data, then the middle and lower Palaeozoic sequences have not been subjected to excessive burial and could be still oil mature as occurs in the Arafura Basin (Bradshaw et al, 1990). Alternatively, if it was uplifted in the Triassic, then considerable thicknesses of Permo-Carboniferous and Early Triassic may have overlain the middle and lower Palaeozoic and have been subsequently removed.

SHOWS

Hydrocarbon indications are poor, except for Phoenix 1 which intersected a series of gas shows in the Triassic from 3890 m to 4880 m (TD). Gas shows were also recorded in East Mermaid 1 in the Early Jurassic.

SEAL

Regional seals occur in the Cretaceous, as well as numerous intraformational seals in the Triassic.

STRUCTURE

PRE-TRIASSIC

Major angular unconformities and associated breaks in deposition in the onshore section (Section I-J-K-L - Plate 1, Samphire Marsh 1 - Plate 2) can be recognised between the Proterozoic and Palaeozoic, the Ordovician and Permo-Carboniferous and the Permo-Carboniferous and Jurassic.

The offshore pre-Triassic structural history is uncertain because of the undated sequence which underlies the basin. Horstman and Purcell (1988, Fig. 2) presumed it was Precambrian. Interpretation of the age of this sequence depends on the significance given to the basalts intersected in Lagrange 1 and Bedout 1. They have been dated as Permian, have a weathered appearance and have both extrusive and intrusive characteristics. Depth to magnetic basement calculations were non-conclusive in that they did not predict the depth to the basalt in Lagrange 1 and Bedout 1 (Pers. comm. J. Leven, BMR, 1989). This suggests that the basalt probably has an extensive weathered profile altering the magnetite to hematite, and reinforces the concept of the basalt being an extrusive on a palaeohigh. On seismic data it is difficult to resolve the extent and attitude of the basalt (Plates 4 & 5), but it appears to occur along the unconformity over the Bedout High as a capping over the older

Palaeozoic/Proterozoic sediments. If this is the case, then it post-dates the development of the angular unconformity. This is the most likely scenario, as to the west, a thick section of presumed Permo-Carboniferous age thins onto the structural high (Section B - D Plate 1, Plates 4 & 5). Thus, structural development of the Bedout High must have occurred prior to the Permo-Carboniferous.

Forman and Wales (1981) refer to the event which created the Bedout High and intruded and extruded the basalt as the Bedout Movement, implying that these events were synchronous. They suggest that the Bedout Movement occurred in the late Permian or early Triassic. Horstman and Purcell (1988) also suggest that the structures in the area formed during the Triassic. To justify the Bedout Movement on the new seismic data, the Triassic and Permo-Triassic sediments marked on section D-E (Plates 1, 4 & 5) would have to be of Triassic age. As this represents 11 km of section, this is considered highly unlikely. Alternatively, the apparent thinning and suggestions of onlapping onto the Bedout High of the Permo-Triassic section would have to be regarded as spurious data (multiples ?).

The onshore section (Plate 1 I-J-K-L) suggests that the most likely age for a widespread angular unconformity to have developed is between the Ordovician and the Permo-Carboniferous. The uplift and faulting that produced the Bedout High may thus be related to the mid-Carboniferous phase of the Alice Springs Orogeny that produced uplift and erosion in the onshore Canning Basin and developed the "Base Grant Unconformity" (Goldstein, 1989). The angular unconformity surface dips to the northwest as do the underlying Palaeozoic/Proterozoic sediments. Immediately to the east of the Bedout High, a synclinal sequence of these sediments occurs that could represent Devonian and Ordovician sediments. Prior to the uplift and faulting of this sequence into the Bedout High, there was regional tilting to the northwest. This may have been a precursor to the mid-Carboniferous uplift, or could have originated during the Devonian.

TRIASSIC-JURASSIC

Minor fault reversal occurs within the Triassic sequence immediately east of the Bedout High and Bedout 1 (Section D-E Plate 1, Plates 5 & 6). An alternative interpretation is that this feature is an igneous intrusion. The folding associated with the fault reversal does not extend into the Jurassic sequence.

CRETACEOUS-HOLOCENE

In the Upper Jurassic sequence thinning onto the Bedout High occurs from the east to the west. The thinning appears to be due to truncation, thus suggesting a period of post Jurassic uplift associated with the Bedout High. Some reactivation is evident in the Cretaceous as many of the faults terminate in the Early Cretaceous, although no appreciable offset occurs along the faults. Stratigraphic thinning across the Bedout High occurs in both the Cretaceous and Tertiary, indicating differential subsidence over this area. The positive relief of the Bedout High during the Cretaceous is suggested by the paralic facies in Bedout 1 relative to the marine facies in other wells during the Upper Cretaceous (Plate 2 - Time Space).

SEDIMENTARY SIGNATURE OF THE NEOGENE

On seismic line JN-07 (Plates 3 & 4), there is a series of sedimentary packages that include thick prograding units in the Tertiary. They are repeated along the margins of the continental shelf of northwestern Australia. Comparison of the palaeogeographic maps for each of the respective time slices in the Tertiary reveals a close correlation between periods indicating low sea-level from inshore data, with thick prograding sedimentation on the continental margin. Conversely periods of high sea-level indicated from the inshore data correspond to coastal onlap of the continental margin sequences. Correlation of the inshore Tertiary sequences with the offshore Tertiary on seismic line JN-07 is hampered by the rapid change in thickness within prograding units and that within single time slice intervals two or more different events have occurred. A major time break in the Oligocene (TS Cz3) is evident from the well data in the inshore regions, which appears to correlate with the base of the thick prograding units.

Bartek et al., (in press) describe the "Neogene signature" from various locations and derive several stratal patterns that are characteristic. These include an upper Oligocene wedge that laps out at or near the shelf margin and thickens basinward (Cz4), and a lower Oligocene landward thickening. However on JN-07 (Plates 1 & 3) the characteristic stratal patterns described do not match the dating derived from Minilya 1 and Phoenix 1 in that the lower Oligocene (Cz3) is absent, as also noted by Apthorpe (1988) for most of the Northwest Shelf. However, the rest of the sequence described by Bartek et al., (in press) can be discerned on JN-07 (pers. comm. P. Vail, Rice University, February , 1990).

REFERENCES

APTHORPE, M., 1988, Cainozoic Depositional history of the North West Shelf. In, P.G. & P.R. PURCELL (Eds)., The North West Shelf Australia, 55 - 84.

BARTEK, L.R., VAIL, P.R., ANDERSON, J.B., EMMET, P.A., & WU, S., in press, The effect of Cenozoic ice sheet fluctuations in Antarctica on the stratigraphic signature of the Neogene.

BMR, 1961, Samphire Marsh No. 1 Well, Western Australia. BMR, Petroleum Search Subsidy Acts Publication No. 5.

BRADSHAW, J., NICOLL, R.S., & BRADSHAW, M.T., 1990, The Permo-Carboniferous to Cambrian Arafura Basin, Northern Australia. The APEA Journal, 30, 1, (in press).

FORMAN, D.J., & WALES, D.W., 1981, Geological evolution of the Canning Basin, Western Australia. Bureau Mineral Resources, Australia. Bulletin 210.

GOLDSTEIN, B.A., 1989, Waxings and wanings in stratigraphy play concepts and prospectivity in the Canning Basin. The APEA Journal, 29, 1, 466 - 508.

HORSTMAN, E.L., & PURCELL., P.G., 1988, The Offshore Canning Basin - A Review. In, P.G. & P.R. PURCELL (Eds)., The North West Shelf Australia, 253 - 257.

MCMINN, A., 1986, Permo-Carboniferous Palynology of the Grant Formation in Samphire Marsh 1 Canning Basin, BMR Core and Cuttings Laboratory (unpublished).

REECKMANN, S.A., & MEBBERSON, A.J.,1984, Igneous intrusions in the North-West Canning Basin and their impact on oil exploration. In, P.G. PURCELL (Ed)., The Canning Basin W.A., 389 - 399.

OFF-SHORE CANNING BASIN PLATE 6

LINE - IN14

OFF-SHORE CANNING BASIN

LINE - JN14

PLATE 5

OFF-SHORE CANNING BASIN PLATE 4

LINE JN - 07

OFF-SHORE CANNING BASIN

LINE JN - 07

PLATE 3

OFFSHORE CANNING BASIN BIOSTRATIGRAPHY

PLATE 2

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