PALAEOGEOGRAPHY 5

GEOLOGICAL CROSS-SECTION OF THE ARAFURA BASIN

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thicknesses from well data only ignoring the evidence on seismic. Values of total sediment thickness are crucial in maturation modelling . Hence there are significant discrepancies between the maturation models presented by Petroconsultants (1989), and the trends indicated in this analysis.

NORTHERN TERRITORY GEOLOGICAL SURVEY PETROLEUM BASIN STUDY, ARAFURA BASIN

A major synthesis of the recent exploration results is available from the Northern Territory Geological Survey (NTGS) as part of their Petroleum Basin Study publications (Petroconsultants, 1989). Detailed information on the stratigraphy and petroleum potential can be found there. It is not intended to reproduce the details of their results in this study, however there are several aspects of this study which differ from the findings of the NTGS publication (Petroconsultants, 1989). They include:

1) The dolomite sequence dated as Caradoc (Late Ordovician) is re-dated as Arenig (Early Ordovician) on the basis of analysing the conodont fauna present in Arafura 1 and Goulburn 1 (pers. comm. R.S. Nicoll). Further dating is being done on this sequence at the BMR and will be reported to the Sponsors at a later stage.

2) The Proterozoic sequence in Arafura 1 is described as 610 my old (Petroconsultants, 1989), without quoting error bars or the source of the date. In Arafura 1 well completion report the sequence has dates of 1750 my $\pm$ 20 for detrital mica and 760 - 480 my $\pm$ 20 for post depositional mica. No source for the 610 my date or the method of analysis is reported. The 610 my figure is thus treated with suspicion. Thus a Middle to Late Proterozoic age is assigned. (Note: 610 approximately equals the mid-point of 760 and 480, but it would be entirely incorrect to quote that as the age of the sequence!).

3) The structuring around Tasman 1 is very complex. In Figure 10 (Petroconsultants, 1989) the structural interpretation immediately adjacent to the well correlates correctly with the well data. However, off the structural high on the flanks of the structure, the interpretation is completely inconsistent with other seismic lines in the report (Petroconsultants, 1989 - Enclosure 8). The two-way time structure maps in the report (Petroconsultants, 1989 - Enclosure 10 and 11) also disagree with the level of the horizons that are shown in Figure 10 (Petroconsultants, 1989). Figure 10 is believed to be incorrect, and Enclosures 8, 9 and 10 are correct (Petroconsultants, 1989).

4) Petroconsultants (1989) state that up to 5 km of Palaeozoic sediment is preserved in the basin. However, the cross-section along the southern bounding fault (A-B) shows that although over 4 km of Cambrian to Carboniferous section is preserved, there is also at least 5 km of section between the post-Carboniferous and base Jurassic unconformity. Thus potentially more than 9 km of Palaeozoic rocks may be preserved in the graben. This thickness is consistent with the seismic interpretation provided in Enclosure 8 (Petroconsultants, 1989). They presumably derived their

wells along the section; Tasman 1, Torres 1 and Arafura 1 (Plate 1). These plots are not conventional 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. In many instances the biostratigraphic control could be refined with more sampling that would assist stratigraphic correlation and designation of the Time Slices present. In part this is presently being performed at the BMR.

INTRODUCTION

DATA SET

TASMAN 1 (Esso)
TORRES 1 (Esso)
ARAFURA 1 (Petrofina)

ESSO - M81A Seismic Survey : 1981
SION RESOURCES - Arafura Sea S81 Seismic Survey : 1981

ARAFURA BASIN : Northern Territory Geological Survey Petroleum Basin Study (Petroconsultants) : 1989

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 section is 240 km and has a maximum depth of approximately 10 km.

HORIZONS DRAWN

A total of nine horizons were carried on the seismic sections (Plates 2 & 3), which are represented as epoch intervals on the cross-section (Plate 1):

1) Cretaceous - Base Turonian - Top Time Slice 8
2) Top Jurassic
3) Top Permo - Triassic (?)
4) Top Permian (?)
5) Top Carboniferous
6) Top Devonian
7) Top Dolomite Unit (Early Ordovician)
8) Top Proterozoic
9) Top Intra Proterozoic

A major unconformable horizon at the base of the Jurassic and Cretaceous sequence has been mapped coincident with and cross-cutting the pre-Jurassic (Bathonian) horizons. At the north-eastern limit of the section, Palaeozoic (?) and Proterozoic (?) horizons have been drawn to indicate the morphology of the section.

TIME DEPTH PLOTS

Time/depth plots have been drawn for each of the three

SUMMARY

The Arafura Basin contains a sequence of Palaeozoic rocks lying north-east of Darwin, and which extends from onshore Australia, to perhaps as far as the Irian Jaya mainland. There are over 9 km of Palaeozoic rocks preserved along the southern bounding fault of a major graben (the Arafura Graben) located in the southern part of the basin. In the uplifted centre of the graben, there is less than 3 km of the Palaeozoic section preserved. The basin is underlain by a Middle to Late Proterozoic sequence which thickens to the east, and is probably equivalent to the onshore McArthur Basin. Overlying the Arafura Basin is the Mesozoic Money Shoal Basin, which is approximately 1 km thick over the central parts of the graben, thickening rapidly to the west and thinning to the east and north.

The structural cross-section that has been drawn is located entirely offshore. It has been compiled using modern seismic and well control. It runs from south-east of Tasman 1 in a general north and north-east direction tying with Torres 1 and Arafura 1. It passes through the central and north-eastern parts of the graben, and the north-eastern part of the basin. Two-way time to depth conversions were based on the velocity surveys from the wells within the graben, but were modified locally outside the graben. The structural analysis presented is largely based on the evidence found along the line of the section. A more complete structural analysis would require a regional examination of the entire seismic network. Information from the recently published Petroleum Basin Study on the Arafura Basin (Northern Territory Geological Survey) has been incorporated into this report, although there are major differences between some of their findings and the interpretations presented here.

To date the major risk in hydrocarbon exploration has been finding adequate reservoir conditions and seal. Contradictory interpretations are present between the maturation and structural modelling of the graben. Untested plays include possible Permian and Triassic sediments (up to 5 km thick) which exist along the flanks of the graben and which will probably contain good source potential and improved reservoir conditions. To the north outside the graben, there are poorly explored areas where it is speculated that there are thick Palaeozoic and Proterozoic sequences.

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GEOLOGICAL CROSS-SECTION OF THE

ARAFURA BASIN

PHANEROZOIC HISTORY OF AUSTRALIA

PROJECT 175A

JOHN BRADSHAW

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VERSION 1

RESULTS

DATING OF HORIZONS

The palaeontological dating depicted on the time/depth curves differs markedly from some of the original well completion reports. These differences are due in part to the "wildcat" nature of this area in its first round of exploration, and will become more refined with further exploration. The principal differences occur in the Dolomite Unit (Ordovician) and the post-Carboniferous sections adjacent to the north and south bounding faults of the graben.

Proterozoic

As described above (Point 2), what appears to be a spurious date of 610 my for the Proterozoic sequence at the base of Arafura 1 has been used by Petroconsultants (1989). A more realistic date for the sequence is between the detrital mica age of 1750 $\pm$ 20 my and the post diagenetic mica age of 760 - 480 $\pm$ 20 my. Similar depositional ages (1690-1670 my) have been determined for both the Mt Isa Group and McArthur Group, which contain Late to Middle Proterozoic sequences (Page, 1981). It is speculated that the Proterozoic sequence shown in the deeper parts of the cross-section equates with the sediments in the McArthur Basin which underlie the Arafura Basin in its onshore extension. A 610 my date suggests that an Amadeus Basin sequence would be present. However, introducing an Amadeus sequence in that setting would require significant revision of the structural pattern of this area of Australia.

Cambrian

Arafura 1 contains a series of clastic and carbonate sediments which have been dated broadly as Early Ordovician to Middle Cambrian. Refinements of the dating in the Ordovician section immediately above these horizons (see below) suggests the dating of the Cambrian sequence may need revision. The ages depicted on the Time/Depth curves are not altered from the original analysis, and should be considered as indicative only.

Ordovician

A thick dolomite was intersected in Tasman 1, Torres 1, Arafura 1 (Plate 1) and Goulburn 1. In the first two wells it was assigned a Devonian age (in the absence of any palaeontological data) but was suggested to be perhaps of Ordovician age. In the latter two wells a conodont fauna was described and it was assigned a Late Ordovician (Caradoc) age. The top of this unit is a strong seismic reflector that can be tied into all wells (although it is very complex around Tasman 1). Subsequent re-analysis of the considered to be immature in the eastern parts of the basin. However, McKirdy & Horvath (1976) describe strandings of oil along the coastline adjacent to the Arafura Basin. Currents suggest the oil has been derived from seepages in the eastern part of the Arafura Sea and they believe the oil to have a Cretaceous source. As shown on the cross-section (Plate 1) the Cretaceous is thin and has not been buried beyond a kilometre, thus making a Cretaceous source unlikely, without invoking a long distance migration of oil from the Malita Graben to the west where thicker and more deeply buried Cretaceous is present.

RESERVOIR AND SEAL

The reservoir characteristics within the Arafura Graben are poor to fair, with a large proportion of the Palaeozoic sequence having low porosities and permeabilities. This is due to both the original rock type and diagenetic effects. The best reservoir sequence occurs within the Carboniferous section (13 - 17 % porosity - Tasman 1). Secondary porosity enhancement is possible within the Ordovician carbonates, especially where karstic erosive surfaces are encountered.

Thick shale formations that could represent a potential basin wide seal, do not occur in the Arafura Graben. The regional distribution of low permeabilities suggests that both localised and more regional seals are possible, although they will be dependent on fault seals.

The untested Permo-Triassic (?) and Permian (?) sequences may include good reservoir and seal characteristics as recorded in the Bonaparte Basin (Mory, 1988).

PLAYS

The Palaeozoic plays tested to date have been structural targets with reservoirs in the Devonian and Carboniferous clastics and the Ordovician dolomites. The structures tested have been a very large anticline in the centre of the graben (Torres 1), a perched fault block against the southern bounding fault (Tasman 1) and localised fault block highs (Kulka 1, Arafura 1 & Goulburn 1). Petrofina identified possible structural and stratigraphic plays in sub-grabens where thickening of the Devonian is predicted to produce better reservoir potential (Petroconsultants, 1989). Numerous roll-overs into normal faults also exist within the graben.

There have been no tests of any stratigraphic plays, the Permo-Triassic (?) and Permian (?) section, or the Palaeozoic section outside the Arafura Graben. The Permo-Triassic (?) and Permian (?) have good potential as they are likely to have better source rocks encountered in the wells in the Arafura Graben are provided by Petroconsultants (1989).

Hydrocarbon shows have been encountered in the Carboniferous, Devonian and Ordovician. Oil staining occurred in cuttings from the Carboniferous limestones and clastics in Tasman 1, and the oil was determined to not be biodegraded. An interval of almost 300 m of hydrocarbon shows occurred in the Devonian of Arafura 1, including impregnated oil in core. Oil shows in the cuttings and mud of the Ordovician occurred in Arafura 1. No significant hydrocarbon shows were encountered in Torres 1.

The best source rock potential, with TOC's of up to 8.65 %, occurs in the Cambrian (Middle ?). In the Ordovician the samples measured showed low to fair source potential, although comparisons can be made with similar aged rocks in the Amadeus Basin where good source potential exists. The Devonian contains low to fair source potential with TOC values ranging up to 3.86 %. The Carboniferous has only low source potential with most TOC values being below 1 %. The Permo-Triassic (?) and Permian (?) have not been intersected by drilling, although fair to good potential exists in the Bonaparte Basin in this age sequence (Mory, 1988).

The maturation modelling presented by Petroconsultants (1989) is complicated by estimates of the depth of burial and erosion, but suggest that the Palaeozoic section passed into the oil generative window between the Devonian and the Cretaceous, and that in places the Cambrian is still within the oil generative window. However, despite suggesting that up to 4 km of sediment has been removed from structural features such as Torres Anticline, no event of that magnitude is shown on the burial history curves (Enclosure 12 - Petroconsultants, 1989). A major problem with the modelling of the Arafura Graben is that the maturation levels derived from conodonts in the Ordovician from Arafura 1 and Goulburn 1 are low, giving no indication of the sorts of burial and truncation that is suggested from the seismic. As the Permo-Triassic (?), Permian (?) and Carboniferous sequence on the flanks of Torres Anticline show no thinning or onlap onto the structure it is difficult to envisage a reconstruction that does not involve a thick cover of Late Palaeozoic and Early Mesozoic over the region.

If it is assumed from the maturation levels that no more than 1 to 1.5 km of section was eroded from Torres Anticline, then it must have been a high block flanked by a pair of half grabens. However, the geometry of the reflectors do not match this scenario. Another possibility is that the heat flow rates were much lower than in comparative structural settings. Obviously there is marked disagreement between these separate concepts and without either new models or new data they will not be easily resolved.

The overlying Mesozoic sequence of the Money Shoals Basin is

Bathonian. Differential subsidence may have contributed to this region being a hingeline onto which the Jurassic thins and pinches out. Some apparent change in the thickness of the Palaeozoic section occurs within this structure, although this may simply be due to rotation of the beds and faulting in the plane of the section.

The reflectors of the Cambrian to Permian (?) sequence show no divergence into the fault plane on either the northern or southern bounding faults (section A-C and X-X' - Plates 1, 2 & 3), thus suggesting that the graben development post-dates at least the Permian (?). There is a slight flattening of the dip of the Permo-Triassic (?) sequence along the southern bounding fault, although this could be related to the perched structural high associated with Tasman 1. However, there is an angular unconformity at this level, approximately equal to the area of dip flattening, such that movement on the fault could have commenced during the Permo-Triassic (?). There does not seem to be any growth over the fault at this interval. The combined truncation and down lap relationship on this horizon, which is adjacent to a major fault zone, suggests that tectonics have played a part in the formation of the unconformity rather than it being solely due to eustatic effects.

Minor reactivation has occurred on some of the major faults during the Cretaceous and/or Tertiary, offsetting the Jurassic to Tertiary sections. This occurs along the southern bounding fault where there is an abrupt change in seismic character across the fault. It could be due to lateral movement, with locally as much as 20 km apparent dextral offset.

Enclosure 9 of Petroconsultants (1989) shows a two-way time structure map to the Base of the Mesozoic. There is a marked re-alignment of the strike of the contours from east-nor-east in the west and south-west, to north-nor-west in the north and north-east. The focus of this major change in direction is centred entirely within the Arafura Graben. The deviation may relate to late stage structural rejuvenation of the region due to tectonic activity on the northern margins of the Australian plate during the Tertiary. The tectonically less stable graben could have absorbed some of the effects of the structuring, whilst the southern parts of the basin acted as a buttress to the compressional effects. The stress would have resulted in regional uplift of the northern parts of the basin. A large degree of rotation is suggested from the structure map, although the dip of the unconformity (1 degree) is shallow, suggesting that the pattern is due to regional uplift and flexing, rather than simple rotation.

MATURATION, SHOWS AND SOURCE POTENTIAL

Detailed analyses of the maturation levels, shows and show that the faulting pattern and axial trends do not fit any simplistic basic wrench or rifting structural model. Further analyses of these maps show that major changes in structural style occur across the pre-existing permit boundaries, which suggests that for a thorough structural examination of the area, a fully integrated and consistent re-mapping of the graben should be made, paying attention to the way the faults are linked together.

Torres Anticline is the largest structural trap in the graben, although its origin is not clear. If the graben was bounded by normal listric faults then it could be explained by rollover into the fault plane. As the bounding faults are believed to have a strike slip component, the most likely origin of the anticline is wrenching. However on the basis of the structural maps so far produced, it is very difficult to align the axial crest and fault patterns correctly onto a strain ellipse. One or more periods of uplift may have contributed to its origin.

Most other Palaeozoic basins of Australia have undergone many periods of deformation with changes in the direction of rotation and compression (Smith, 1984; Bradshaw & Evans, 1988), and as a result do not fit into any single structural regime. The Arafura Basin needs to be examined in relation to these other basins, especially as it also records the regional 280 - 300 my heating event that has been detected by fission track analysis in the Amadeus and McArthur Basins and for which there is structural evidence in the Ngalia Basin (Bradshaw and Evans, 1988).

Timing Of Deformation

Major breaks in the Palaeozoic record of the Arafura Graben occurred during the Ordovician and Silurian, Early Carboniferous, and Permo-Triassic (?) to Bathonian. Except for the latter, there is no evidence of significant angularity between the reflectors. Any Palaeozoic deformation prior to the Permo-Triassic (?) to Bathonian must have been very gentle, perhaps as regional flexing and tilting. The facies diagrams suggest that the event resulting in the Carboniferous unconformity was sufficient to alter the location of the depocentre and to affect the distribution and relationship of the marine and non-marine sediments. Regional uplift to the east of the Arafura Basin could have occurred on the Oriomo High in Papua New Guinea or along the Wessel Rise between Arnhem land and Irian Jaya. This may have blocked a previous marine connection and created the regional tilting which altered the depocentre within the basin.

Eastward thickening of the Proterozoic sequence occurs over what appears to be a negative flower structure near the centre of section B-D. The eastern most extent of the Jurassic occurs very close to this feature. This structure was probably a hingeline controlling deposition during the Proterozoic, and was reactivated during the major deformation from the Permo-Triassic (?) to

STRUCTURAL FEATURES

The Arafura Graben is the main structural feature so far observed within the Arafura Basin. Outside the graben there is a major synclinal structure north of Arafura 1 which probably extends further to the west. The potential exists for more structures in the poorly explored northern regions of the basin.

The bounding faults of the graben trend in a north-west to south-east direction, and are poorly defined at their eastern and western extremities. The southern bounding fault is a near vertical fault that has apparent normal displacement of the Palaeozoic section of about 8 km (section A-B Plate 1, Plates 2 & 3). The northern bounding fault is also close to vertical and has apparent normal displacement of about 5 km (section B-C). The steep nature of these faults suggests they have strike slip components, especially as no evidence of them soling out can be detected on the seismic sections (to 5.0 secs or approximatley 12.5 km).

Along the line of section (A-C - Plates 1, 2 & 3), it is apparent that the areas within the graben and adjacent to the northern bounding fault are more strongly faulted and fractured than the equivalent section along the southern bounding fault. The Early Ordovician reflector is essentially straight and unbroken as it dips into the southern bounding fault (seismic section X-X'- Plate 1, & Plates 2 & 3). If the southern bounding fault was a listric normal fault then the morphology of this horizon would be substantially different, with roll-over into the fault and faulted components.

Two interrelated explanations are possible for this structural pattern. 1) Examination of the plan shape of the graben shows that the southern bounding fault is sinuous but has an overall straight path, whereas there are marked offsets along the northern bounding fault. If these faults do have a strike slip character (and the direction of movement parallels the general strike of the faults), then the southern bounding fault would be in a zone of lateral movement, and thus subject to minimal transpressional or transtensional effects. The northern bounding fault however would be under maximum transtensional or transpressional effects. The northern area would thus be subject to more fracturing and faulting than the southern area. 2) Complementing the possible strike slip nature of the bounding faults is that if the southern margin is a releasing bend where extension was developed, and the northern margin was simultaneously under compression on a restraining bend, then there would be greater relative displacement in a vertical sense along the southern margin.

This cursory examination needs to be assessed relative to the regional tectonic fabric. Quick analyses of the composite time structure maps of Petroconsultants (1989), Enclosures 10 & 11, Sion Resources (1981) shot several regional lines from the eastern end of the graben to the Australian and Indonesian border. Although the quality of the seismic is much poorer than the seismic within the graben, there is a distinct synclinal feature north of Arafura 1 (section F-G - Plate 1), that contains perhaps up to 5 km of Palaeozoic and/or Proterozoic and is a minimum of 50 km wide and 100 km long. It extends beyond the limit of the modern seismic coverage, and the flanks of the feature are poorly defined on seismic.

Modern seismic extends beyond the graben to the north by only 10 -15 km. However, there appears to be a positive correlation of the seismic character to the north of the graben with that within the graben adjacent to the southern bounding fault. This relationship can best be seen by comparison of the Esso seismic lines M81A-132 (s.p. 2800) and M81A-118 (s.p. 4600). The character tie and velocities suggest that it is possible that the entire sequence from the Permo-Triassic (?) to Cambrian is preserved on the northern side of the northern bounding fault on line M81A-118. The Devonian to Cambrian sequence is believed to be preserved on the northern side of the northern bounding fault on line M81A-132, as shown on the cross-section (A-C). This relationship suggests that the Palaeozoic section north of the graben is dipping in a north-westerly direction, just as it is inside the graben.

This Palaeozoic character tie is at odds with Petroconsultants (1989) where it is stated that "Correlation of horizons identified either north or south of the graben are not compelling.", and "the extent of the preserved Palaeozoic section and nature of the extensive Arafura Basin sediments beyond the graben confines can only be speculated upon." The thickness of non-magnetic sediments has been estimated to be greater than 10,000 m to the north and northeast of the central part of the graben (Balke & Burt, 1976 - Fig. 4). Thus the potential to the north should not be quickly dismissed and is worth further exploration attention.

South of the central part of the graben, the tie from within the graben to outside it is uncertain. Outside the graben there is a high velocity strong reflector below the Mesozoic unconformity that may represent the Ordovician Dolomite Unit, or may be the top of the Proterozoic. The dip on this sequence is similar to the regional dip of the Cambrian section onshore overlying the Proterozoic, and can be extrapolated to approximately the same structural level. The Cambrian onshore contains a thick shale sequence (Raiwalla Shale - Plumb et al, 1976), which is compatible with the transparent seismic character of the sequence. Thus this sequence has been tentatively assigned a Cambro-Ordovician age.

Paralic conditions were dominant in Goulburn 1 during the Devonian, grading to fluvio-lacustrine in Tasman 1. Marine carbonates were deposited during the Namurian in Tasman 1, and have not been identified elsewhere in the graben. A widespread fluvial facies is envisaged during the Carboniferous although at Torres 1 that sequence was removed during uplift and erosion, or was not dated in the well (see time/depth plot for Torres 1). Fluvio-lacustrine and paralic conditions existed during the Jurassic altering to widespread marine conditions by the Cretaceous.

Time Slice Correlation

The three major unconformities are shown, with the estimated thickness changes in each time slice. The major thickness changes occur in : Devonian 8 and 9 (however Torres 1 is poorly dated), Carboniferous 5 and 6, and the pinch out of the Jurassic and Early Cretaceous between Torres 1 and Arafura 1. The Carboniferous 1 and 2 postulated in Torres 1 (no dating) may actually be Carboniferous 5 and 6, and would be compatible with the eastward thinning of this sequence. There is a complimentary relationship between the Devonian thickening from Tasman 1 to Arafura 1 and the Carboniferous thinning from Tasman 1 to Arafura 1.

Time Slice Facies

The thick marine lower Palaeozoic is overlain by the dominantly clastic fluvial to paralic sequences of the Devonian and Carboniferous. For both the Devonian and Carboniferous the marine/paralic facies occur where the sequence is thickest. (eg. paralic conditions dominate in Arafura 1 in the Devonian, and marine facies occur in Tasman 1 during the Carboniferous.). On the low relief pre-Bathonian unconformity, fluvio-lacustrine and paralic sequences developed prior to the Cretaceous 8 and 9 marine incursion. During both the Jurassic and Cretaceous the depocentre was in the west.

BASINAL LIMITS

The Palaeozoic sequence comprising the Arafura Basin has many times been suggested to extend from onshore Australia to near Irian Jaya (Nicol, 1970: Smith and Ross, 1986: Petroconsultants, 1989). The basis of this belief has largely been speculative, based on aeromagnetic data, old vintage seismic and regional correlations from outside the immediate area. However, the modern seismic allows a better approximation of the nature of the rocks that may exist north and south of the graben. The lateral continuity of the Palaeozoic reflectors and the apparent absence of any angular unconformities between horizons where there are major time breaks suggest that the Palaeozoic within the graben was part of a broad platform sequence similar to the other platform deposits of the same age in onshore Australia.

offshore east of Aru Island in Irian Jaya (600 km north of the Arafura Graben), a 1200 m thick section of Permian carbonates and Triassic sandstones and shales was pentrated (Katili, 1986). Thus a Permian and Triassic age is probable. It is also possible that the undated section in the Arafura Graben is entirely Carboniferous, but this is believed to be unlikely because of the precise constraints and trends of the dating in the preceeding sequence (Time/depth curves - Plate 1).

The boundary on the cross-section (section A-B) between the postulated Permian (?) and Permo-Triassic (?) is a major sequence boundary that is an unconformity that truncates the underlying sequence and upon which there is downlap of the overlying sequence (see Esso - Line M81A-109 - parallel to southern bounding fault). In the Petrel Sub-basin of the Bonaparte Basin, 600 km to the southwest (Cross-section 3 - Bradshaw, 1989), there is a distinct sequence boundary with both downlap and truncation. It is present on the northern flank of the basin between Petrel 1 and Flat Top 1. It equates with the red bed sequence of the Malita Formation, and can be dated as Middle Triassic to Early Jurassic. It can not be resolved further as no fauna was recovered from the red bed sequence, although the formation is speculated to be of Late Triassic to Early Jurassic age. Thus the Permo-Triassic (?) interval in the Arafura Graben could be as young as Late Triassic to Early Jurassic (see Bradshaw (1989) for a more complete discussion).

TIME AND FACIES DIAGRAMS

Time and facies correlation diagrams were drawn by extrapolating the time/depth plots for each well : time space, time slice correlation and time slice - facies (Plate 1). All three diagrams essentially portray similar data, except that the time space diagram is plotted against time and the time slice correlation and time slice - facies diagrams are plotted against depths using the base of the Jurassic as a datum. The reliability of the extrapolations can be directly assessed by examining the data points on the time depth plots of each well.

Time Space

This diagram shows the three major unconformities within the Arafura Graben sequence that are identified from well data : Ordovician - Silurian, Early Carboniferous, and Post-Carboniferous to Bathonian. This diagram is biased by well data, such that the Permian (?) and Permo-Triassic (?) sequences identified on seismic are not portrayed.

Marine conditions dominated the lower Palaeozoic, although the absence of conodonts in the dolomite sequences in Torres 1 and Tasman 1 may suggest slightly different facies to Goulburn 1.

conodont fauna has shown that the upper part of the sequence in Goulburn 1 is considerably older and is of Early Ordovician (Arenig) age (pers. comm. R.S.Nicoll). Consequently the upper parts of the sequence in the other wells have been tentatively placed at the same age. Continuing work at the BMR is examining whether there is a diachronous relationship to the top of the unit in the other three wells. Arafura 1 was found to contain a similar conodont fauna to Goulburn 1, and is thus of similar age. However, no fauna was recovered in both Torres 1 and Tasman 1. This suggests that they may be either a different facies, or they could be older than the top of the dolomite in Arafura 1 and Goulburn 1.

Devonian and Carboniferous

The age of these sequences has not been substantially altered from that recorded in the well completion reports. Conodonts sampled by the BMR confirmed the Devonian age of the sequence in Arafura 1 (pers. comm. R.S. Nicoll). However, in Tasman 1 a tentative Late Carboniferous Stage 2 (?) age was assigned by Esso to the sequence immediately below the Jurassic unconformity. The extremely speculative nature of this date is not recorded by Petroconsultants (1989), thus removing the possibility of alternative conclusions (Plate 1).

Permian to Permo-Triassic

Few reports on the Arafura Basin allude to the possibility of Palaeozoic rocks younger than the Carboniferous. However, on the flanks of the drilled structures, there are quite thick post-Carboniferous sections underneath the Jurassic unconformity (see the flanks of Torres 1 on section A-C - Plate 1 & Plates 2 & 3). These post-Carboniferous sections are eroded at the well location and thus cannot be accurately dated. Adjacent to both Arafura 1 and Kulka 1 there is at least 2 to 4 km of post-Carboniferous sediments. South of Torres 1 (section A-B - Plate 1) there is at least 5 km of post-Carboniferous section adjacent to the south bounding fault. As the total Carboniferous to Cambrian is only 4 km thick, the post-Carboniferous section represents the major proportion of the Arafura Basin stratigraphy, and to date has been largely ignored in any analysis of either petroleum prospectivity or general stratigraphy.

The actual limits on the age of the post-Carboniferous section is between Late Carboniferous (or perhaps Early Permian - Stage 2 ?), to the Jurassic unconformity which is dated as Bathonian in Tasman 1. Comparison of the approximate depositional rates of the pre-Permian sequence (see time/depth curves - Plate 1) with the thickness of the undated sequence (up to 5 km) suggests that a considerable period of time was involved in the deposition of the post-Carboniferous sediments. If allowance is made for the possible additional sequence that has not been preserved, then the time period involved is even greater. In the well ASM-1X, located reservoir potential and good source potential. There is a faint suggestion of lobate reflectors in some of the Permian (?) sequence which could provide stratigraphic traps along the southern margin of the graben.

The Palaeozoic potential outside the graben is yet to be adequately proven. Future seismic to the north of the graben will provide keys to exploration in these regions. A different maturation profile may exist outside the graben and different facies could also be present. Although the basin is envisaged as a broad platform sequence during the Palaeozoic, structural precursors to the graben may have controlled sedimentation, especially during the latter parts of the Palaeozoic and into the Mesozoic. In the Canning Basin, Devonian reefs developed on the platform and margins of the basin. An analogy can be made with the Arafura Basin, especially as Devonian dolomites are reported from Irian Jaya (Smith and Ross, 1986). In the Amadeus and Canning Basins good source and reservoir potential exists in Ordovician rocks of the same age as those in the graben. Rocks of similar age in the Amadeus Basin contain the largest mainland oilfield in Australia. Middle Cambrian rocks in the Georgina Basin are good source rocks as also shown in the Arafura Graben. Thus on a regional scale the potential outside the graben in Ordovician sequences is still high.

If a thick Palaeozoic section exists to the north of the graben then structuring could be developed by evaporites. Sabkha type environments have been postulated for sections of the Ordovician dolomites where gypsum is present. However, no thick evaporites are recorded in the wells in the graben or on the seismic, but they exist both in the Middle Palaeozoic in the Canning and Bonaparte Basins and the Early Palaeozoic of the Amadeus Basin.

The Proterozoic sequence has not been dealt with in the previous discussions, but should be included in any discussion of regional source potential. In the onshore McArthur basin, live oil has been recovered from the Proterozoic Velkerri Formation that is about 1.43 billion years old (Jackson, Sweet and Powell, 1988), and additional source potential exists both higher and lower down in the Proterozoic sequence. The Proterozoic should be rated with reasonable potential especially where there are early formed traps or where the sequence is thinner such as in the eastern extremities of the basin, and outside the graben.

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