27 March, 1996

RECORD 1995/64

ARAFURA SEA
SEISMIC STRUCTURE MAPS

by

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1995

Bibliographic reference
Moore, A., 1995 - Arafura Sea Seismic Structure Maps. Australian Geological Survey Organisation Record 1995/64.

ISSN
ISBN

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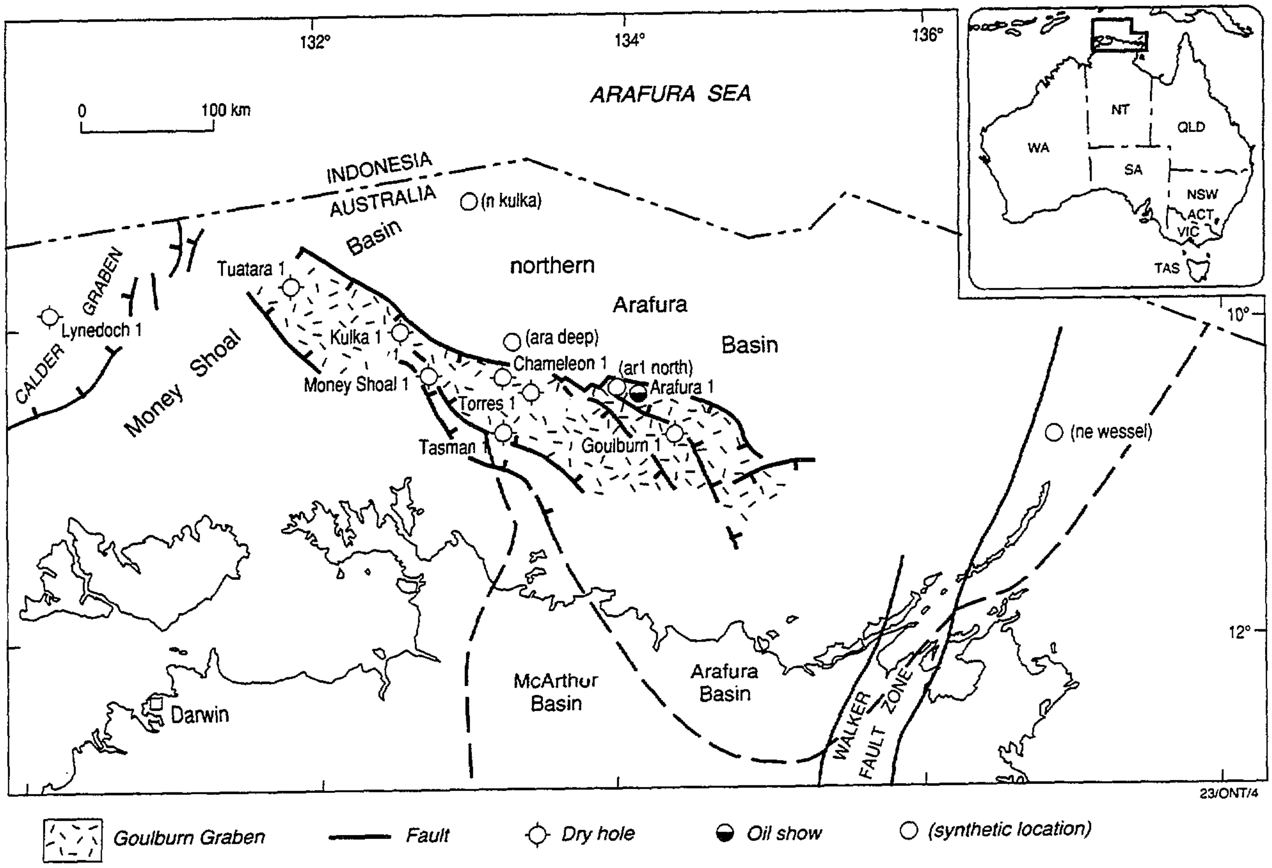
SUMMARY

The stratigraphic interpretation and initial structural mapping of reconnaissance seismic data collected by AGSO in the Arafura Sea, were presented in AGSO Record 1992/84, the Arafura Prospectivity Evaluation Report by Labutis et al (1992). This Record is a follow-up to that report, and contains additional maps and a key more clearly relating the seismic horizons to the stratigraphy explained in that record.

The regional seismic time structure maps included in AGSO Record 1992/84 have been converted to depth. Two additional seismic horizons of Early Palaeozoic age, and an isotime map of the seismic time interval between them, representing the Cambro-Ordovician interval, have been contoured in two way time. An additional isotime map, of the interval from top of Devonian calcareous sandstone (*A. parva* zone, Frasnian) to top of the Ordovician dolomite oil reservoir (within *P. elegans* zone, Arenigian) is also presented. The limits of this interval are also the tops of the principal oil shows in the Arafura 1 well. These isotime maps show the early development of anticlines that would have been in a position to intercept early-migrated oil.

This further interpretation of the AGSO seismic was accompanied by geohistory analysis of the wells drilled in the Goulburn Graben, and analysis of the oil shows in Arafura 1 (Record 1995/65). The oils were dated as originating from Cambrian source rocks. One of the significant findings of the geohistory study is that in the Goulburn Graben, hydrocarbon generation from common types of kerogen occurred during the early to mid Palaeozoic. The major structuring (late Triassic) post-dates the time of hydrocarbon generation and migration, hence the structural traps mapped within the graben did not exist at the time of oil migration. This helps to explain the lack of oil shows in most of the Goulburn Graben wells. Older structuring should be sought, mainly outside the graben to the north, where prospective Lower Palaeozoic and Upper Proterozoic successions, and later migration of hydrocarbons, are predicted. There is no borehole north of the bounding faults of the Goulburn Graben, and seismic correlation across the faults is speculative. Drilling is required to confirm the presence of prospective sediments, and to provide basic stratigraphic information in the huge basinal areas outside the graben on its northern and eastern sides.



1. Locality map of the Arafura Sea showing the Goulburn Graben, the oil exploration wells drilled in it, and the synthetic well sites outside it in the northern Arafura Basin

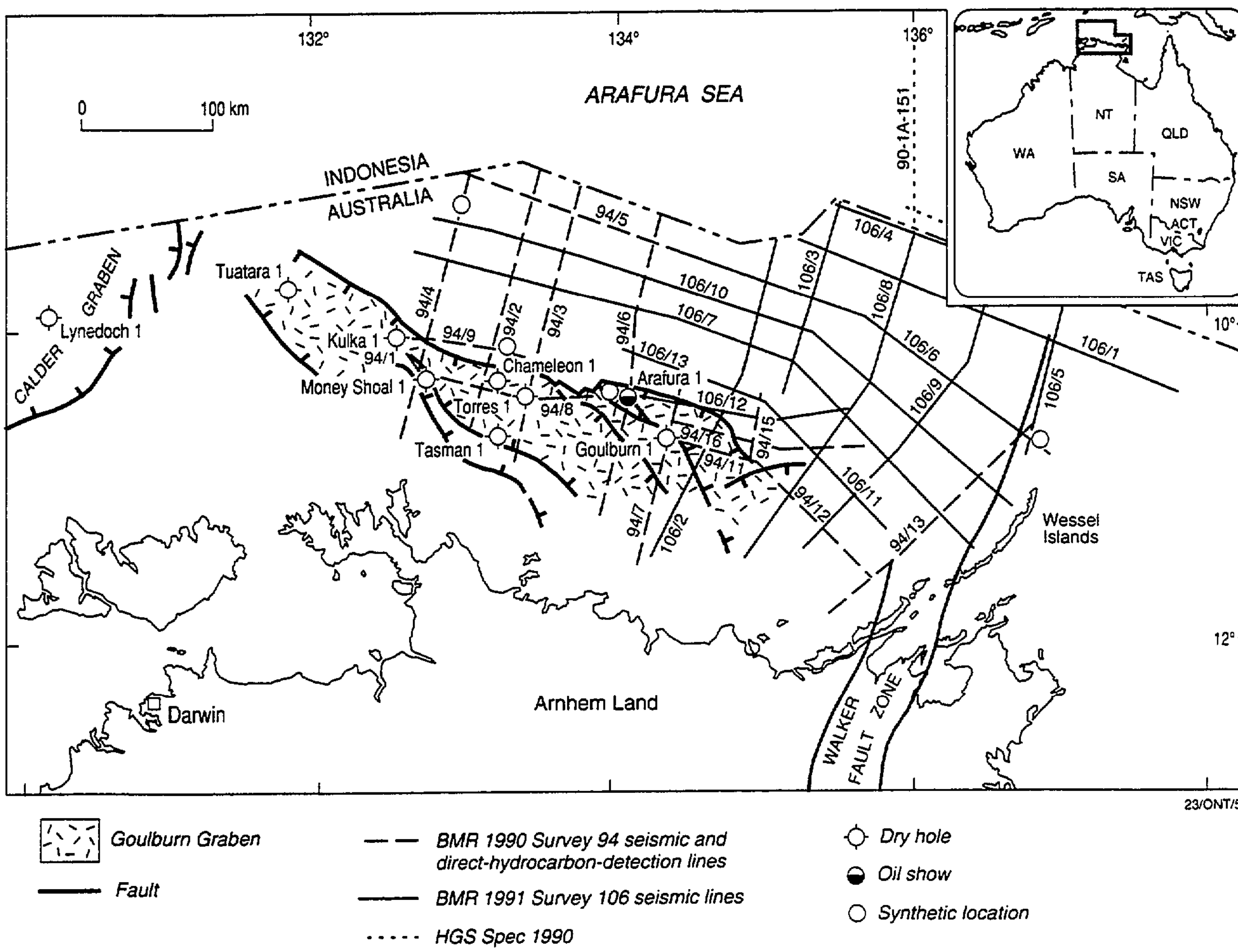


Figure 2. Locality map showing AGSO seismic surveys and wellsites in the Arafura Sea.

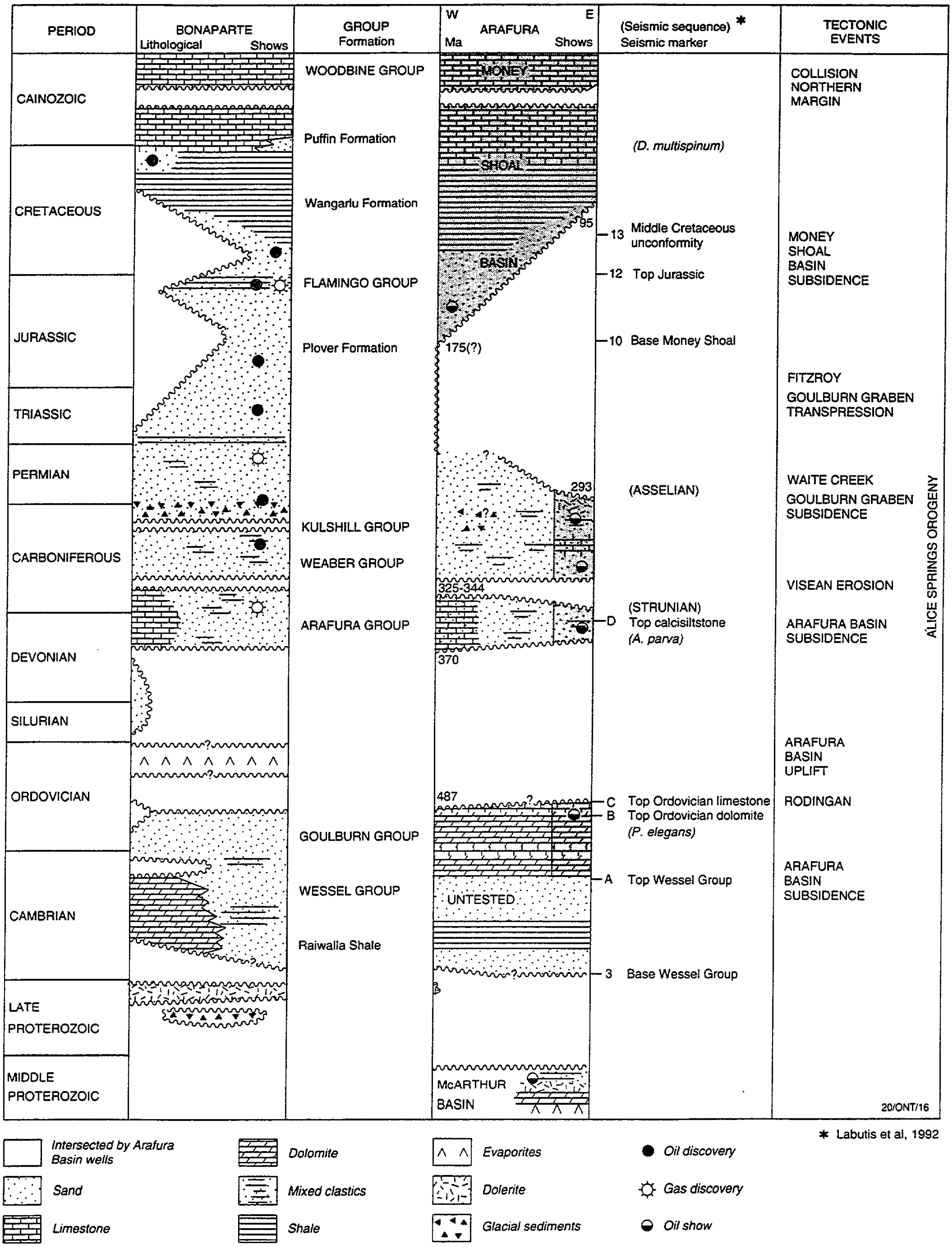


Figure 3. Lithostratigraphy, seismic horizons and sequences, and major tectonic events in the Arafura Sea. Some seismic or well sequences are named after the biostratigraphic zones occurring within them.

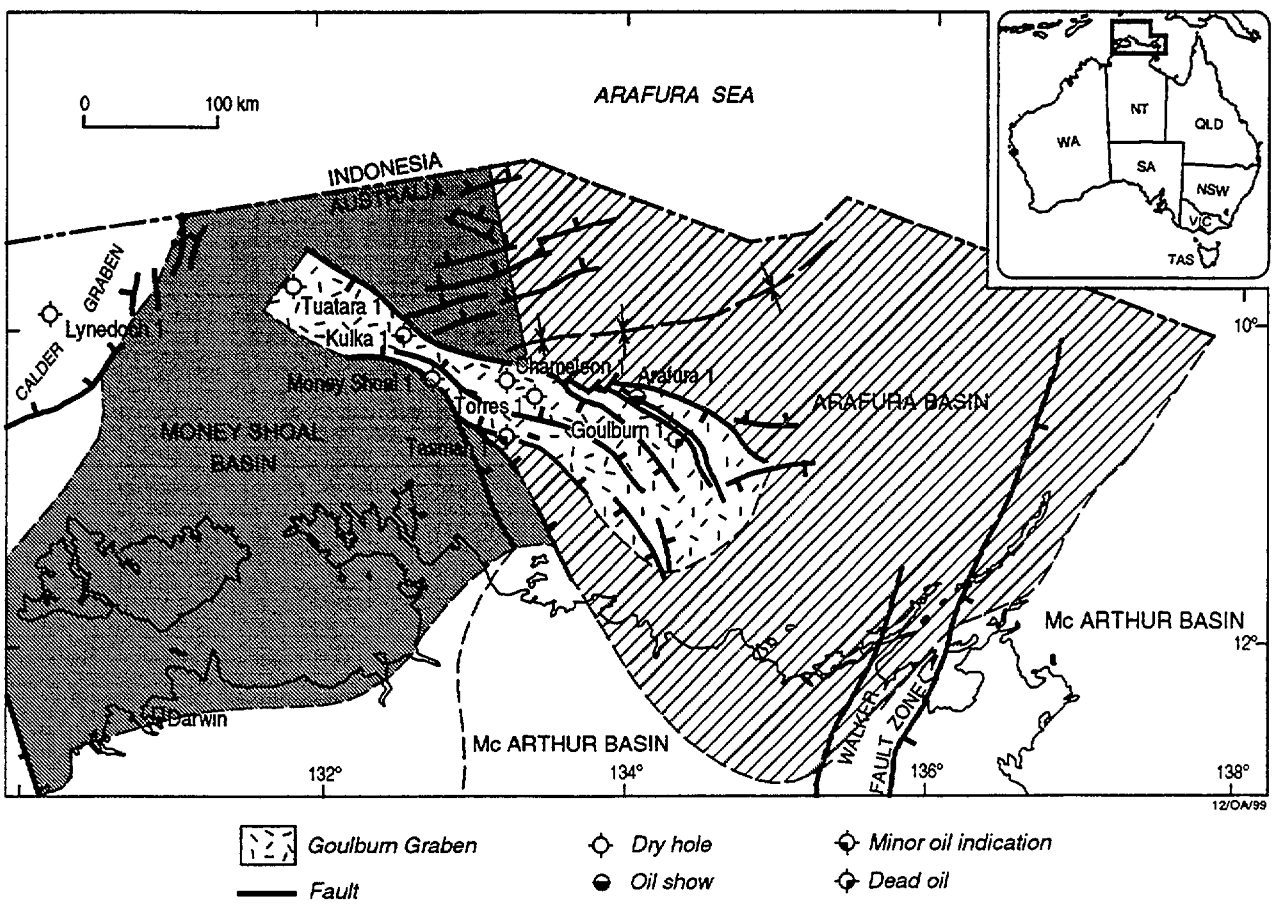


Figure 4. Major structural elements of the Arafura Sea. In the central area the mainly Mesozoic Money Shoal Basin overlies the Palaeozoic Arafura Basin and the Goulburn Graben within it. On this diagram its extension over the graben, and the shallow eastern parts, have been omitted in order better to demonstrate the underlying structure at the base of the Cambrian.

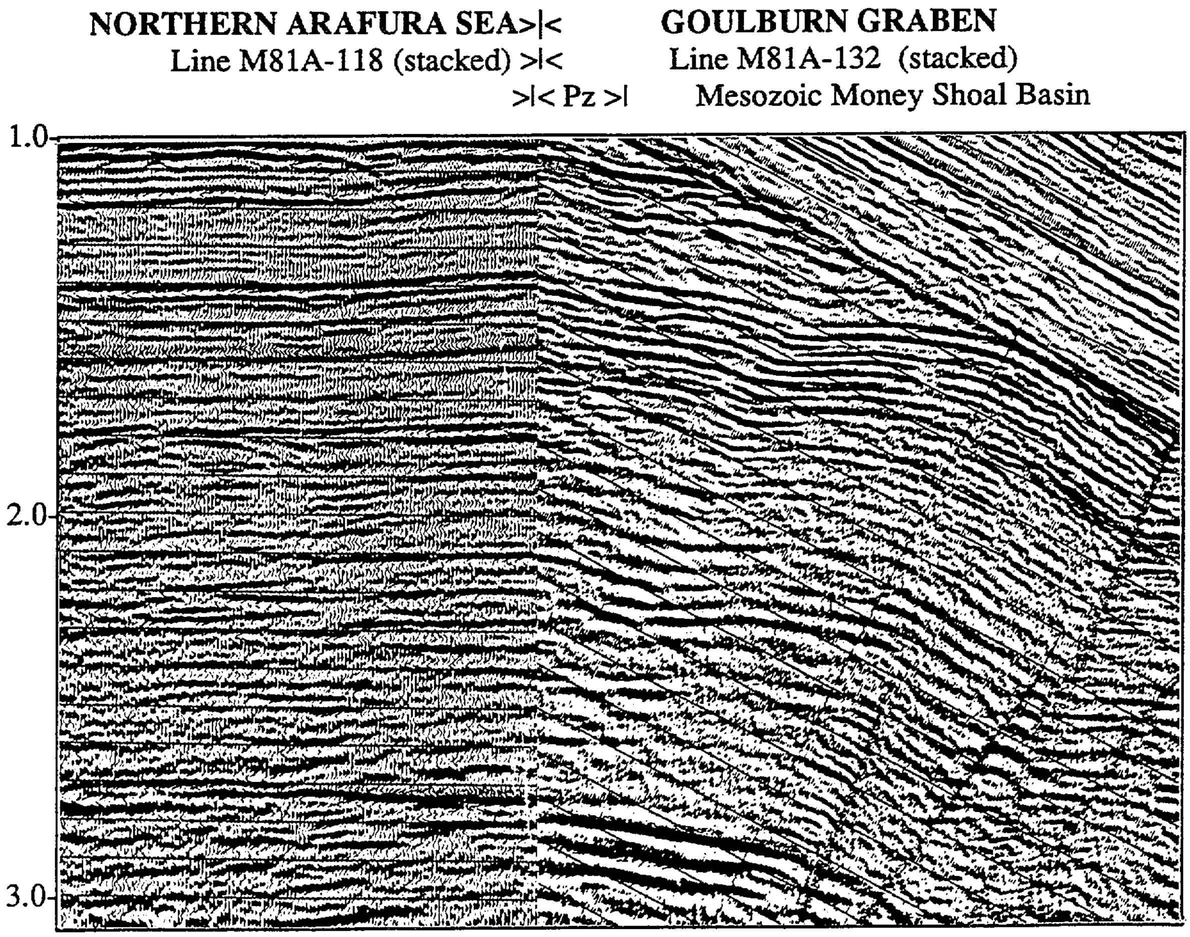


Figure 5. Correlation of seismic sections in the northern Arafura Sea and the Goulburn Graben. The dipping Palaeozoic succession in the graben has been rotated to lie horizontally, matching the northern succession.

INTRODUCTION

Location

The area covered by this study (Figure 1) is located in the Arafura Sea north of Arnhem Land in the Northern Territory of Australia, in water depths ranging from 30 to 200m, but mostly less than 100m. It extends from longitude 131°30' East to 138° East, and from the border of the territorial waters of Australia and Indonesia at around latitude 9° South to 12° South. The basin-wide grid of regional seismic reflection profiles established by AGSO (the Arafura Basin Reconnaissance) in 1990 and 1991 and used as the primary seismic grid in this study is shown on Figure 2. The wells drilled in the Goulburn Graben, and the synthetic well sites to the north, analysed in Record 1995/65, the companion record to this one, are also shown.

Geological Setting

The geology of the northern margin of Australia beneath the Arafura Sea is not well known. It contains the Money Shoal, Arafura and McArthur Basins of Cainozoic-Mesozoic, Palaeozoic and Proterozoic age respectively. These partially overlap to form a sedimentary pile well over 10 kilometres thick in places (Bradshaw et al, 1990). Over most of the area the older basinal successions have not been severely tectonised, and geothermal gradients are low. Oil exploration wells are restricted to the Goulburn Graben, near the southern rim of the Arafura Basin (Figure 1 and Enclosure 1). The stratigraphy derived from the wells is described in Labutis et al (1992) and Bradshaw et al, (op.cit.), and summarised in Figure 3 of this record.

Money Shoal Basin

The Money Shoal Basin occupies the western parts of the Arafura Sea (Mory, 1988, McLennan et al, 1990, Labutis et al, op.cit.). Well data shows that the base is time transgressive, and ranges in age from Late Jurassic in the west, to Late Cretaceous in the east. The Tertiary succession is thin or absent in the eastern parts of the basin, and has not been sampled in the wells. There are up to 400m of Jurassic marine clastics at the base in the western part. These unconformably overlie the eroded Palaeozoic sediments of the Arafura Basin. In the east, the shales above the 'base Cenomanian' maximum flooding surface (*D. multispinum* dinoflagellate zone (Helby, Morgan and Partridge, 1987)) overly the basal unconformity, and form a potential regional seal for hydrocarbons (shown by dark shading in Enclosure 1).

Arafura Basin

The Arafura Basin extends from onshore outcrops of Cambrian rocks in Arnhem Land and the Wessel Islands (Bradshaw et al, op.cit.) to the Australian-Indonesian border and beyond, possibly as far as the mainland of Irian Jaya. In Australian waters it covers an area of more than 130,000 km^2. The main structural provinces of the basin are shown in Enclosure 1. Its simple synclinal shape is interrupted on its southern margin by the west-northwestward trending Goulburn Graben (Figure 4). The Goulburn Graben contains up to 10 km of marine and marginal marine clastics and carbonates ranging in age from Lower Cambrian to Permian, with possibly some Triassic in a few restricted locations. The greater part of the basin, the Northern Arafura Sub-basin, east and north of the graben, is undrilled. It is probably composed of Lower Palaeozoic marine clastics and carbonates. It overlies and overlaps the McArthur Basin offshore.

McArthur Basin
The McArthur Basin is widely exposed and studied onshore (Jackson et al, 1988). It has not been intersected offshore. It is a thick and complex basin of (?Upper and) Mid Proterozoic marine and marginal-marine sediments, and it contains at least one major internal angular unconformity, together with five oil source rocks (Crick, 1992; Crick et al, 1988) and a thick dolerite sill. The McArthur Basin thickens rapidly from the west, east and south to form a sequence several kilometres thick under the center of the Arafura Basin and disconformable with it. In that area, the succession is likely to be uppermost Proterozoic (Roper Group), but toward the Wessel Islands in the east an angular unconformity at an almost peneplaned surface separates older, probably Middle Proterozoic, McArthur Basin sediments from the onlapping Cambrian Wessel Group of the Arafura Basin.

GEOPHYSICAL EXPLORATION HISTORY
Although Shell and others conducted aeromagnetic and seismic exploration during the 1960s and 1970s, the modern work dates from 1981, when Esso, Diamond Shamrock, Sion Resources and Petrofina began acquiring seismic data, followed by BHPP with seismic in the late 1980s and early 1990s. The work was confined mainly within the Goulburn Graben, but a few reconnaissance lines extended further northward. Some of these happened to cross from the Goulburn Graben into the northern basin in areas of poor seismic data. They created the impression that the northern area was one of shallow basement, despite the contrary evidence from the interpretation of the aeromagnetics. Seismic evidence of a northerly basin extension is, however, visible on some of the earlier lines, e.g. the WM series (see below) and also the northern ends of the series M81A-120 to -140. Because these showed a thick sedimentary succession on their northern ends, they were then reinterpreted to be still within the graben, even though they had been designed to extend across the northern bounding fault into the northern province (and did so). Seismic surveys of regional significance and with good subsurface penetration include:

SURVEY	OPERATOR	CONTRACTOR	YEAR	LINE ID
Wessel Marine	Beaver	Western Geophys.	1972	WM & W
M81A	Esso	GSI	1981	M81
Arafura Sea	Sion	GSI	1981	S81
AM81	Mincorp	GSI	1981	AM81
DS81	Diamond Shamrock	Western Geophys.	1981	DS-81
DS84	Diamond Shamrock	Western Geophys.	1984	DS-84
HA88A & B	BHPP	Halliburton	1988	HA88A & HA88B
HA89A & B	BHPP	Halliburton	1989	HA89A & HA89B
HA90A	BHPP	GECO	1990	HA90A
ABR	AGSO		1990	94/
	AGSO		1991	106/

A complete listing of geophysical work undertaken in the basin and surrounding areas up until 1989 is contained in Petroconsultants (1989).
The AGSO data set of approximately 5320 km of stacked seismic profile, shown in Figure 2, forms a basin-wide grid of seismic lines that is largely complementary to the industry surveys and is the only modern multichannel seismic grid covering most of the basin including the northern sub-basin.

BHPP conducted an aeromagnetic survey in 1989 over the whole of its permit areas (NT/41P and /42P) between 130^{o} and 132^{o} 30' East, and BP flew airborne laser fluorosensing 'ALF' surveys over parts of the Arafura Sea in 1989 (Martin & Cawley, 1991).

SEISMIC DEPTH STRUCTURE AND ISOPACH MAPS

Seven seismic structure maps, four of single horizons, and three of intervals, are presented as enclosures in this record. Two horizons, namely the Base of the Money Shoal Basin and the Base of the Arafura Basin, are presented as depth maps, and the interval between them as an isopach map. Two additional Lower Palaeozoic seismic horizons have been mapped in two-way time and are presented, along with two isotime (time thickness) maps of intervals associated with them. The relationship of the seismic horizons to the stratigraphy is shown on Figure 3.

Base of Money Shoal Basin (Horizon 10)

The Base of the Money Shoal Basin (seismic horizon 10 in Labutis et al, 1992 and in Figure 3) defines the boundary between the Mesozoic Money Shoal Basin, and the Palaeozoic Arafura Basin. The structure is shown in depth (metres) on Enclosure 2. The contour interval is 100 m.

The horizon shallows rapidly eastward from a depth of about 2500m west of longitude 133 degrees East, to only a few hundred metres east of longitude 134 degrees East, and south of latitude 11 degrees South. The edge of the Money Shoal Basin is probably a depositional limit. The base of the succession (horizon 10) is strongly time-transgressive, ranging from Mid Jurassic at Kulka 1 in the west, to Cenomanian or younger in the east. The Money Shoal Basin sediments onlap the Palaeozoic sediments of the Arafura Basin. They are thin, with little dip, in the central and eastern areas of the Arafura Sea, yet are still significant for hydrocarbon exploration in those areas because the basal succession is shaly (Wangarlu Formation eq.) to the east of Torres 1, forming a potential seal over the Arafura Basin succession, e.g. at Arafura 1 (Labutis et al, op.cit.).

Base of Arafura Basin (Horizon 3)

The Base of the Arafura Basin (horizon 3 in Labutis et al, 1992 and in Figure 3, the base of the Wessel Group, nominal base of Cambrian), represents the top of the Proterozoic McArthur Basin succession where that basin is present, or the top of basement elsewhere. The structure is shown in depth (metres) on Enclosure 3. The contour interval is 500 m.

The depth of the horizon varies from more than 10 kilometres in the west, to zero at the outcropping edge of the Arafura Basin in the east. The overlying sediments are thought to be of mid to lower Cambrian age, although they have been seen only in outcrop on the islands of northeastern Arnhem Land (the Wessel and English Company Islands) and drilled only on the mainland - not in any well offshore. Within the Goulburn Graben horizon 3 is highly structured, with large anticlines and numerous fault terraces, but in the northern sub-basin its structure is a simple syncline, apart from the western rim, where there are fault blocks. North-south trending rift structures of the Walker Trough are evident on seismic underneath the peneplaned base of Cambrian near the Wessel Islands, but they have little effect on horizon 3.

Isopach of Arafura Basin (Horizons 3-10)
The thickness of the Arafura Basin (isopach of horizons 3-10) is shown in metres on Enclosure 4. The contour interval is 500 m. The basin exceeds 7500 m in thickness in the central northern area, and it thins markedly by erosion on the southern, eastern and western margins of the basin. It continues to the north outside Australian waters. Because the relief on the basal horizon is so much greater than that on the upper horizon (the base of Money Shoal Basin), the isopach map looks similar to the structure map of horizon 3.

SEISMIC TIME STRUCTURE AND TIME THICKNESS (ISOTIME) MAPS

Horizons that have been correlated within the graben, but which have not been carried into the northern basin, are designated by letters, e.g. A, B, rather than numbers. These have been tied confidently to wells.

Horizon A (Top of Lower Cambrian Wessel Group) Time Structure
The time structure map of theTop of the Wessel Group (horizon A of Labutis et al, 1992 and of Figure 3) is presented as Enclosure 5. The mapped seismic horizon is correlated with an acoustic boundary at 3596m (1.740 sec) in Arafura 1 well. In earlier interpretations, the interval below was dated Proterozoic (1750-2100 Ma) by dating of detrital mica, and reported as basement. Similarly, isotopic dating of the outcrop on Elcho Island originally gave a Proterozoic age. However, identical trilobite faunas were subsequently recovered from the outcrop on Elcho Island and from the interval 3150 m to TD at 3635 m in Arafura 1 well (Bradshaw et al 1990). The interval below 3596m in Arafura 1 well is now interpreted as part of the Wessel Group of Middle Cambrian age, and horizon A is interpreted to be the top of that group.

The map shows structure very similar to that on the base of the Arafura Basin (Enclosure 3). The seismic horizon can not readily be correlated out of the Goulburn Graben, because of large bounding faults, areas of poor seismic data on the upthrown side, and the lack of a distinctive seismic character. However, a character correlation between portions of two industry profiles on opposite sides of the bounding faults was described by Bradshaw (1989, p 10). This correlation is shown above on Figure 6. Because of the well-known pitfalls of character correlation, it is not treated here as definitive, with confident correlation of individual horizons, but as an indication only, that the Palaeozoic Arafura Basin may extend northward out of the graben. There is some suggestion that the A horizon exists in the northern sub-basin at a shallower level than that inside the graben. If so, the mid Cambrian succession may never have been as deeply buried, hence potential reservoirs might not have had porosity and permeability degraded to the same extent as happened inside the graben.

Horizon B (Top of Ordovician Dolomite Oil Reservoir) Time Structure
The time structure map of the top of the Ordovician dolomite (horizon B of Labutis et al, 1992 and of Figure 3) is presented as Enclosure 6. This seismic horizon is correlated with an acoustic boundary at 1835 m KB (1.180 sec) in Arafura 1 well. It has a distinctive high amplitude seismic character. The underlying carbonate succession occurs also in Goulburn 1 at 978m KB, and at 2174 m in Torres 1. Despite its very high interval velocity, (> 6000 m/sec), it is an oil reservoir at Arafura 1. This is significant in assessing the succession in the northern Arafura Sea, which has a similarly high seismic stacking velocity.
This horizon could not be correlated confidently from the wells to the northern sub-basin, so mapping is confined to the graben.

The map shows a few small areas of closure in the vicinity of Arafura 1, but the major feature of the map, the Torres anticline, was found dry by the well, Torres 1, drilled to test it. The reason is that oil generation in the probable Cambrian source rocks occurred, and the oil migrated, before formation of the Goulburn Graben and the Torres anticline. In addition, the Palaeozoic succession at Torres 1 was buried at least 2, possibly 4 km below its present depth during the formation of the graben, and potential reservoirs within it were degraded.

Isotime (Time thickness) of 'Lower Palaeozoic' interval
The 'Lower Palaeozoic' isotime map, (Enclosure 7) shows the seismic time interval between the base of the Cambrian Wessel Group (horizon 3) and the top of the Ordovician dolomite (horizon B). Both the Goulburn Graben and the area to its north are contoured on the map. The age of the interval, and the identity of the seismic horizons, in the northern area is uncertain because of the difficulty of correlation across the northern bounding fault of the graben. The seismic signature in the northern basin generally does not resemble that of the Cambro-Ordovician or the Permo-Carboniferous sequence in the graben. However, Bradshaw (1989, p10) described a location where the seismic signatures do look similar, permitting the interval to be tentatively identified as of Early Palaeozoic age outside the graben. Bradshaw's correlation is shown here on Figure 4.

Isotime (Time thickness) of Devono-Ordovician interval
The isotime map of the Devonian-Ordovician (Enclosure 8) shows the seismic time interval between horizon B, the top of the Ordovician dolomite oil reservoir (within *P. elegans* zone, Arenigian in Labutis et al, op.cit.) and horizon D, the top of the Devonian calcareous sandstone (*A. parva* zone, Frasnian). The limits of this interval are also the tops of the principal oil shows in the Arafura 1 well. Both this map and the lower Palaeozoic isotime map (Enclosure 7) show a thin east of Money Shoal, and another southwest of Arafura 1. This indicates the early development of anticlines in those areas, that would have been in a position to intercept early-migrated oil. Triassic diastrophism reshaped these features, possibly causing re-migration or escape of any contained hydrocarbons.

DISCUSSION

The depth and isopach maps (Enclosures 2, 3 and 4) show that the formation of the Goulburn Graben and most of its internal structural features such as the Torres anticline pre-date the deposition of the Money Shoal Basin, which began in the mid-Jurassic. Unfortunately, potential structural traps formed in Palaeozoic sediments during graben development are not old enough to be hydrocarbon prospective. The geohistory analyses of the Torres 1 and other wells (AGSO Record 1995/65) make it clear that Lower Palaeozoic source rocks were buried to maturity and then uplifted prior to the Triassic age formation of the graben. This means that hydrocarbons were expelled and migrated before the newer traps associated with the graben were formed The mature early Palaeozoic source rocks in the area of the Goulburn Graben were buried again during the slight extension episode that began graben formation, perhaps as early as lowermost Permian time. Left lateral transpression during the Triassic then created uplift within the graben, tilted and exposed the thick early Permian succession, and put in place features now dominant, such as the Torres anticline. Older traps, that might have contained hydrocarbons generated earlier, were disrupted by the transformation of structure that occurred in the Triassic. In addition, processes associated with the earlier (?Permian) deep burial caused degradation of the older Palaeozoic-age reservoir rocks, which were then uplifted to within the range of the drill.

Tectonic movements were not as violent in the eastern part of the graben. The best oil shows were found in the Arafura 1 well in the east, suggesting that hydrocarbons may survive better in a gentler tectonic environment.

The area north of the graben has had a much more subdued tectonic history. Early-formed traps there have survived, and source rocks did not become generative until more recent times. The synthetic well site Arafura Deep Basin (ara deep on Figure 1) is located in one of the thickest (7.5 km) areas of the Arafura Basin, where the 'oil window' is 4 kilometres thick (from 2 to 6 km deep). Source rocks in the upper half of the succession in this area would not become mature for hydrocarbons until the accumulation of sediments of the overlying Money Shoal Basin buried them to a sufficient depth during the Cainozoic, hence traps in the northern basin and on the northern upthrown margin of the graben are older than the era of migration predicted by this model of the basin.

The undrilled northern sub-basin of the Arafura Basin extends from the northern bounding fault of the Goulburn Graben to the limit of Australian territorial waters, and beyond into Indonesian waters and the Merauke Basin south of the Aru Islands and Irian Jaya. The age of the succession is presumed to be Palaeozoic. This opinion is based on its seismic signature, which is stratified, though with a high stacking velocity, and unlike the signature of the indurated sediments drilled on the southern platform at Money Shoal 1. These latter also appear on aeromagnetics maps as shallow basement, whereas in the Northern Arafura Sub-basin the basement interpreted from aeromagnetics is as deep as ten kilometres. Seismic character correlation, referred to earlier, and illustrated in Figure 4, reinforces the opinion that the succession may be Palaeozoic rather than Proterozoic. The thickness of the Northern Arafura Sub-basin succession varies from a minimum of between one and two kilometres in the west, where it is truncated by an angular unconformity at the base of the Money Shoal Basin, to greater than seven kilometres in the central area, where it disconformably overlies the McArthur Basin. Toward the Wessel Islands in the east, the basin shows signs of thinning, and mild onlap at an almost peneplaned surface, beneath which lie the Proterozoic sediments of the McArthur Basin. The eastern rim is uplifted and bevelled off by erosion at the sea bed. The basal Cambrian succession is partially exposed in the Wessel Islands, and the thickness of the Wessel Group there, added to the intersection of its top in Arafura 1, was used to help identify seismic horizon 3 at the wellsite as the base of the Arafura Basin succession. The east-west fault trends in the western part of the sub-basin may represent structuring of early Palaeozoic age, but are also typical of areas bordering highs of later age where northwest-southeast and northeast-southwest trending troughs intersect. The same fault trends are present to the north of the Londonderry High near the intersection of the Sahul Syncline and the Cartier Trough as well as in the northern Browse Basin.

CONCLUSIONS

The seismic mapping, combined with the geohistory studies based on well information (Moore, 1995), has led to the following conclusions -

- There is a stratified seismic succession beneath the thin mainly Mesozoic Money Shoal Basin in the large undrilled synclinal area north of the Goulburn Graben. It is probably of Palaeozoic and Proterozoic age.
- The Northern Arafura Sub-basin had a gentler tectonic history than the graben; the succession in parts of it may not have been buried so deeply as to destroy the source and reservoir potential, and oil may have been generated later.

- The oil seen in the Lower Ordovician succession in Arafura 1 well originated in the underlying Cambrian and migrated only a short distance updip (southward, see Enclosure 6). It has been in its present site, a small fault-controlled closure, since about the late Permian period. It survived the Triassic diastrophism that accompanied the formation of the Goulburn Graben, possibly because the movement was gentler in the east of the graben than further west.
- The oil seen in the calcareous Devonian in Arafura 1 did not originate in that sequence, but in marine Cambrian source rocks underlying and down dip from its present location. There is very little volume of Devonian rock mature for oil in the vicinity.
- Within the Goulburn Graben the most prospective successions, the lower to mid Cambrian and the lower Ordovician (Tremadocian), were heated to maturity during the early Palaeozoic, as a result of both burial and elevated heatflow. Likewise, sources in the Devonian and Permo-Carboniferous successions reached maturity in the pronounced subsidence that preceded the uplift of the Torres Anticline and the formation of the graben in Triassic time. The various phases of tectonism and prolonged exposure and erosion that followed the early maturity for hydrocarbons within the Goulburn Graben afforded ample opportunity for remigration or escape of those that were generated.
- Structural traps within the graben largely post-date the main phases of hydrocarbon generation.
- The final phase of uplift that followed the formation of the Goulburn Graben brought previously very deeply buried reservoirs within range of the drill. These reservoirs have been degraded by the consequences of deep burial, such as compaction, and recrystallisation after pressure solution of quartz.

Paradoxically, because parts of the Palaeozoic successions outside the graben were not subjected to the same depth of burial, and probably did not undergo the transpressional movements that resulted in exhumation in the graben, they remained immature until burial by the Money Shoal Basin succession in the late Mesozoic and early Cainozoic. This makes the areas north of the Goulburn Graben more prospective on the grounds of timing.
The Upper Jurassic, Cretaceous and Tertiary succession of the Money Shoal Basin is almost everywhere too thin to be mature for hydrocarbons. However, the shaly Late Cretaceous may be a seal for late products of generation in the underlying Palaeozoic succession.

Hydrocarbon exploration strategy should be to look a) for early-formed traps that might have intercepted the possibly prolific HCs expelled during the Palaeozoic, or b) for areas where source rocks were not very deeply buried at an early epoch, or c) where the Permo-Triassic diastrophism was less intense. Within the graben, the Cambro Ordovician and the Devono-Ordovician time-thickness (isotime) maps show thins east of Money Shoal 1 well and southwest of Arafura 1 that suggest early structuring there. The likelihood of a history of deep burial and exhumation similar to that of the Torres anticline, combined with extensive reshaping of the structure during the Permian and the Triassic, would seem to discourage this type of play within the graben.

There is some sign of earlier trap formation in the far eastern end of the Goulburn Graben, around and east of the Arafura 1 well. If, as appears likely, this area was subjected to a lower degree of subsidence, tectonism, and subsequent uplift, then the reservoirs may not be as greatly damaged by diagenesis as those westward and deeper in the graben have proven to be. This consideration applies with greater effect to the Northern Arafura Sub-basin, where strong deformation is not evident on seismic. If this area has not undergone deep burial followed by uplift and erosion, but is now near maximum depth of burial, then migration of

hydrocarbons will have occurred later than trap formation, and reservoirs will not have been damaged by deep burial. There is an analogy here with the Canning Basin, where reservoirs commonly are poor in the younger succession of the Fitzroy Graben, but often very good in older sequences on the flanking terrace or platform areas, where Lower Palaeozoic reservoirs have not been degraded by deep burial. In certain areas these reservoirs on the flanks of the Fitzroy Graben have been enhanced by the exposure of the carbonates, or by the circulation of phreatic waters through them. The same might well have happened to Lower Palaeozoic reservoirs north of the Goulburn Graben, prior to the onset of migration from source rocks. The possibility remains, that the poor seismic reflectivity and high seismic interval velocity that discouraged early explorers of the northern Arafura Basin might be signs of reservoir enhancement by karstification of Lower Palaeozoic carbonates.
Only drilling will test these hypotheses.

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APPENDIX 1

Conversion of Seismic Time Maps to Depth

Conversion to depth was done on the Petroseis seismic mapping system, version 6.95 (Petrosys, 1992) from a digitised seismic time database. Faults were interpreted and correlated manually, and digitised to form a fault location database. The depth to the horizon was calculated at specified shotpoints and posted to seismic base maps by the computer. The fault database was overlaid on to the posted depth maps. The posted depths were then contoured manually around the faults, and the contours were digitised. The resulting depth contour database was overlaid on to the fault map and the seismic base map to produce enclosures 2, 3 and 4. Seismic time values for horizon 10 (base of Money Shoal Basin) were converted to depth using a time-depth function (Monyshol.tzc) calculated by the Petroseis software from a table of entered values. The values were derived from well information. Times and depths at the Base Money Shoal Basin horizon were taken from well completion reports and plotted on graph paper. The line of best fit was drawn manually through the plotted values. The depth values at specific times were read from the graph and keyed into the software in the form of a table. The table is presented below.

MONYSHOL.TZC

2T (sec)	Z (m)
0.1	85
0.2	176
0.4	360
0.6	560
0.8	800
1.0	1100
1.3	1573
1.6	2080
2.0	2600

The resulting depth map is presented as Enclosure 2.

The thickness of the Arafura Basin (Enclosure 4) was calculated by the software from an interval velocity supplied by the user. The velocity used was a constant, 4500 m/second, derived from information in well completion reports. The computer calculated values were posted on a fault and base map and contoured by hand. The hand-drawn contours were digitised, then plotted with the base map and fault map to produce the isopach map.

The depth to the base of the Arafura Basin (Enclosure 3) was calculated by the computer at each shotpoint by addition of the depth to base of Money Shoal Basin and the thickness of Arafura Basin. The values were posted by the Petroseis system on to a seismic and fault base map and contoured by hand. The hand-drawn contours were digitised, and the resulting digitised contour map was added to (overlaid on) the fault map and the seismic and well base map to produce the depth map. The result is a human- rather than computer-contoured plot.

1:1000000

0 10 20 30 40 50

KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 135 00 00E

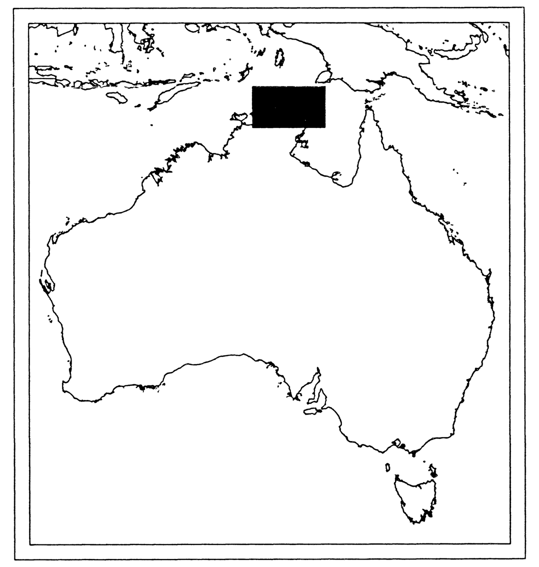
STRUCTURAL ELEMENTS
OF THE
ARAFURA SEA
ENCLOSURE 1

ARAFURA SEA HORIZON 10

File araf_hor10 pic
Prepared by Lachlan Hatch
Date 25th May 1995

For Aidan Moore, telphone 06-2499583

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION



1 500000
0 10 20 30 40 50
KILOMETRES
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 135 00 00E

DEPTH TO BASE OF MONEY SHOAL BASIN
HORIZON 10

C I = 100M		A.MOORE
DATUM = S L.		MAY 1995

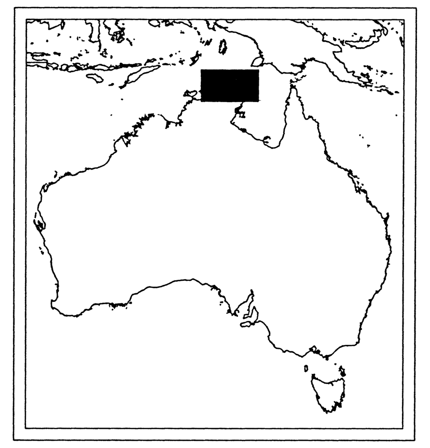
Enclosure 2

User . lhatch File . px20371.djt Date November 22, 1995

ARAFURA SEA HORIZON 3

File araf_hor3.pic
Prepared by Lachlan Hatch
Date 26th May 1995
For Aidan Moore telephone 06-2499583

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION



1:500000

0 10 20 30 40 50

KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 135 00 00E

ARAFURA BASIN
DEPTH TO BASE OF ARAFURA BASIN
HORIZON 3

C I. = 500M		A.MOORE
DATUM = S L		MAY 1995

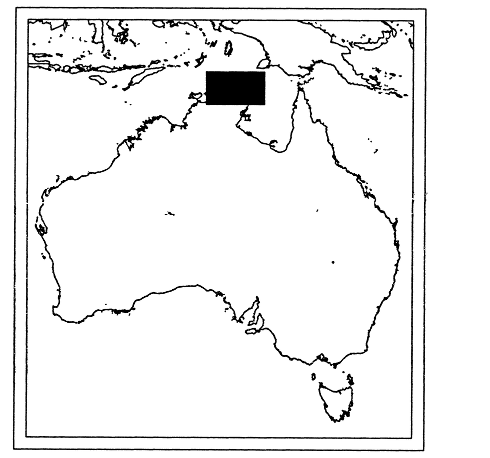
Enclosure 3

User : lhatch File : px21850.djt Date . November 22, 1995

ARAFURA SEA HORIZON 10-3

File araf_hor10_3 pic
Prepared: by Lachlan Hatch
Date 26th May 1995
For Aidan Moore telephone 06-2499583

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION



1: 500000
0 10 20 30 40 50
KILOMETRES
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 135 00 00E

ARAFURA BASIN
THICKNESS OF THE ARAFURA BASIN
ISOPACH HORIZONS 10 - 3

C.I. = 500M		A.MOORE
DATUM=HORIZON 10		MAY 1995

Enclosure 4

User : lhatch File : px20062.djt Date . November 22, 1995

ARAFURA SEA HORIZON A

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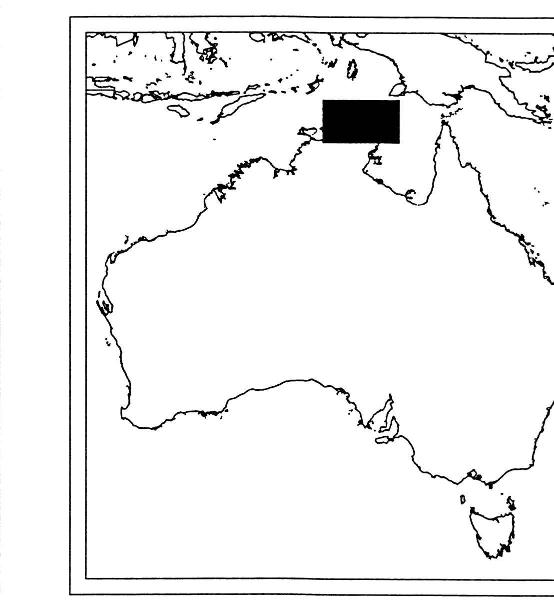


1 500000

0 10 20 30 40 50

KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 135 00 00E

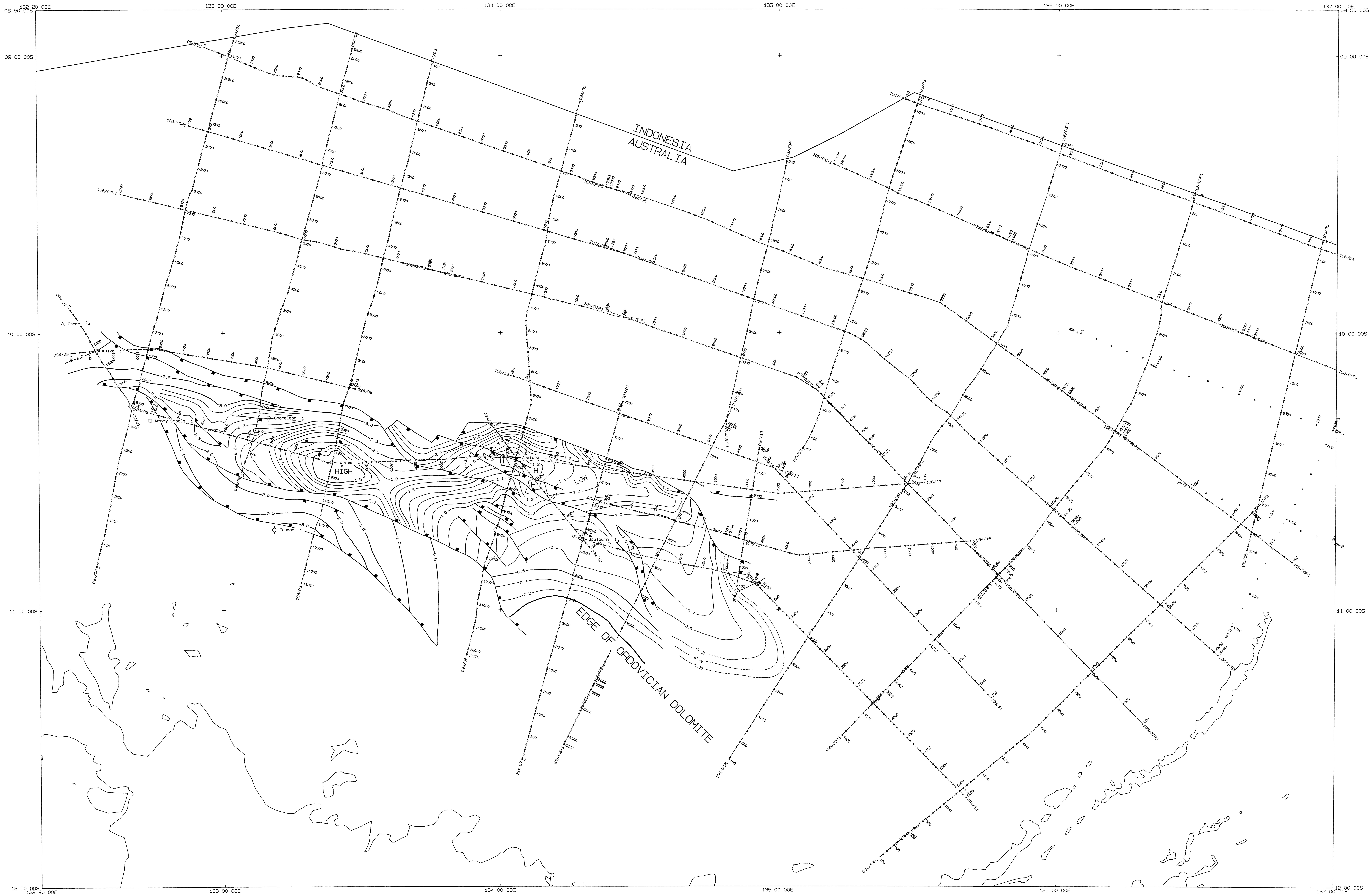
2 WAY TIME STRUCTURE ON TOP OF WESSEL GROUP (3596m KB, 1.740sec in Arafura 1) C.I. = 0.1sec (0-3sec) C I = 0.5sec (>3sec)		
		Datum = S.L
		A.Moore 1995

File araf-hora pic
Prepared by Lachlan Hatch
Date May 1995
For Aiden Moore telephone 06-2499583

Enclosure 5

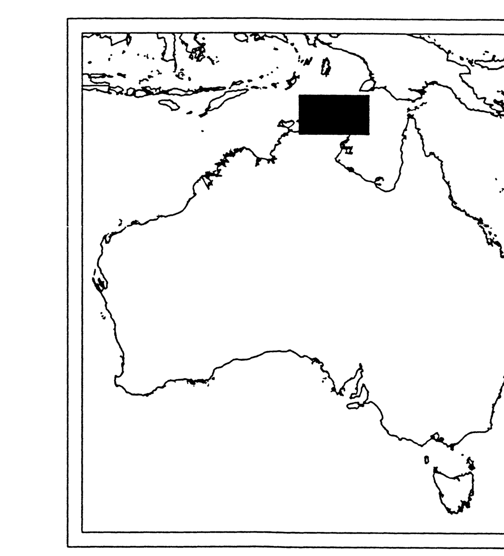
User . lhatch File . px24174.djt Date . November 23, 1995

ARAFURA SEA HORIZON B



AGSO

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION



1. 500000

0 10 20 30 40 50

KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 135 00 00E

2 WAY TIME STRUCTURE TOP OF ORDOVICIAN DOLOMITE OIL RESERVOIR
(1835m KB, 1.180 sec in Arafura 1 well)
C I = 0.1sec (0-2sec)
C.I = 0.5sec (>2sec)

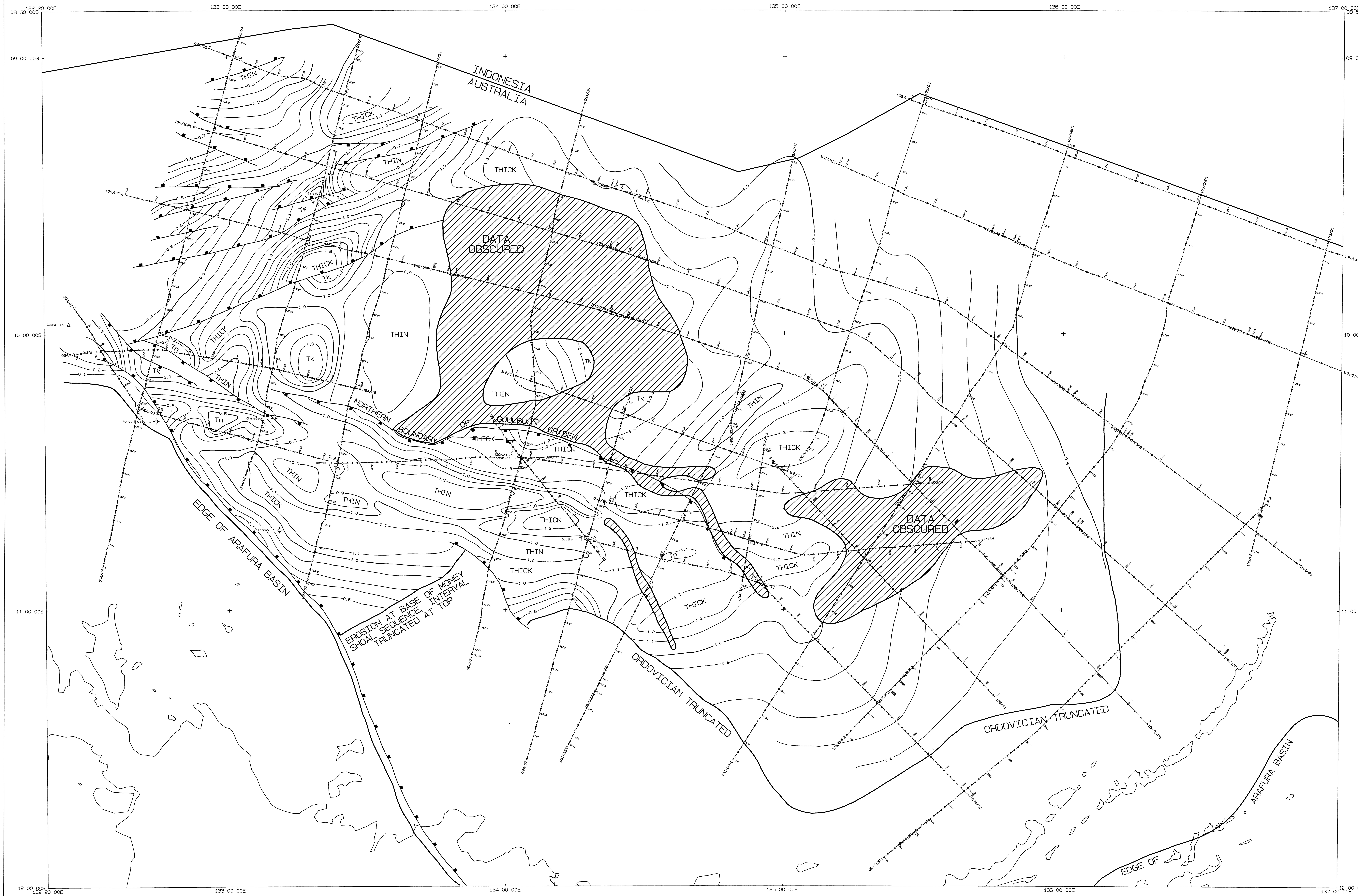
		Datum = S.L.
		A Moore 1995

File araf-horb pic
Prepared by: Lachlan Hatch
Date May 1995
For Aiden Moore telephone 06-2499583

Enclosure 6

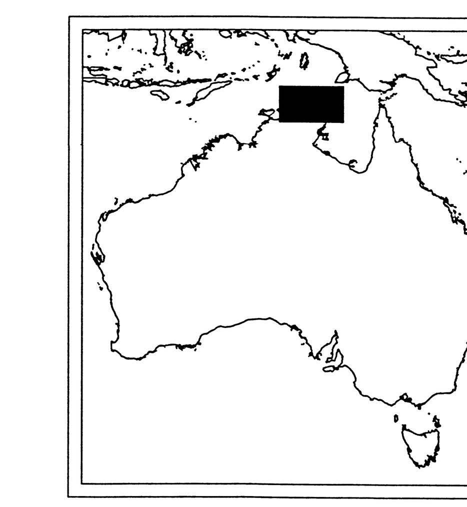
User lhatch File . px24198.djt Date November 23, 1995

ARAFURA SEA HORIZON 3-B 3-5



File: araf-hor3b35 pic
Prepared by: Lachlan Hatch
Date: may 1995
For: Aiden Moore telephone 06-2499583

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION



Warning: Horizons cannot be correlated across the northern bounding faults of the Goulburn Graben. The interval contoured north and east of the Graben (horizons 3-5) might not be related to the interval contoured within the Graben, south and west of the northern bounding faults (horizons 3-B).

1: 500000
0 10 20 30 40 50
KILOMETRES
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 135 00 00E

Isotime of Cambro-Ordovician (Base Cambrian to top of Ordovician Dolomite) in Goulburn Graben.

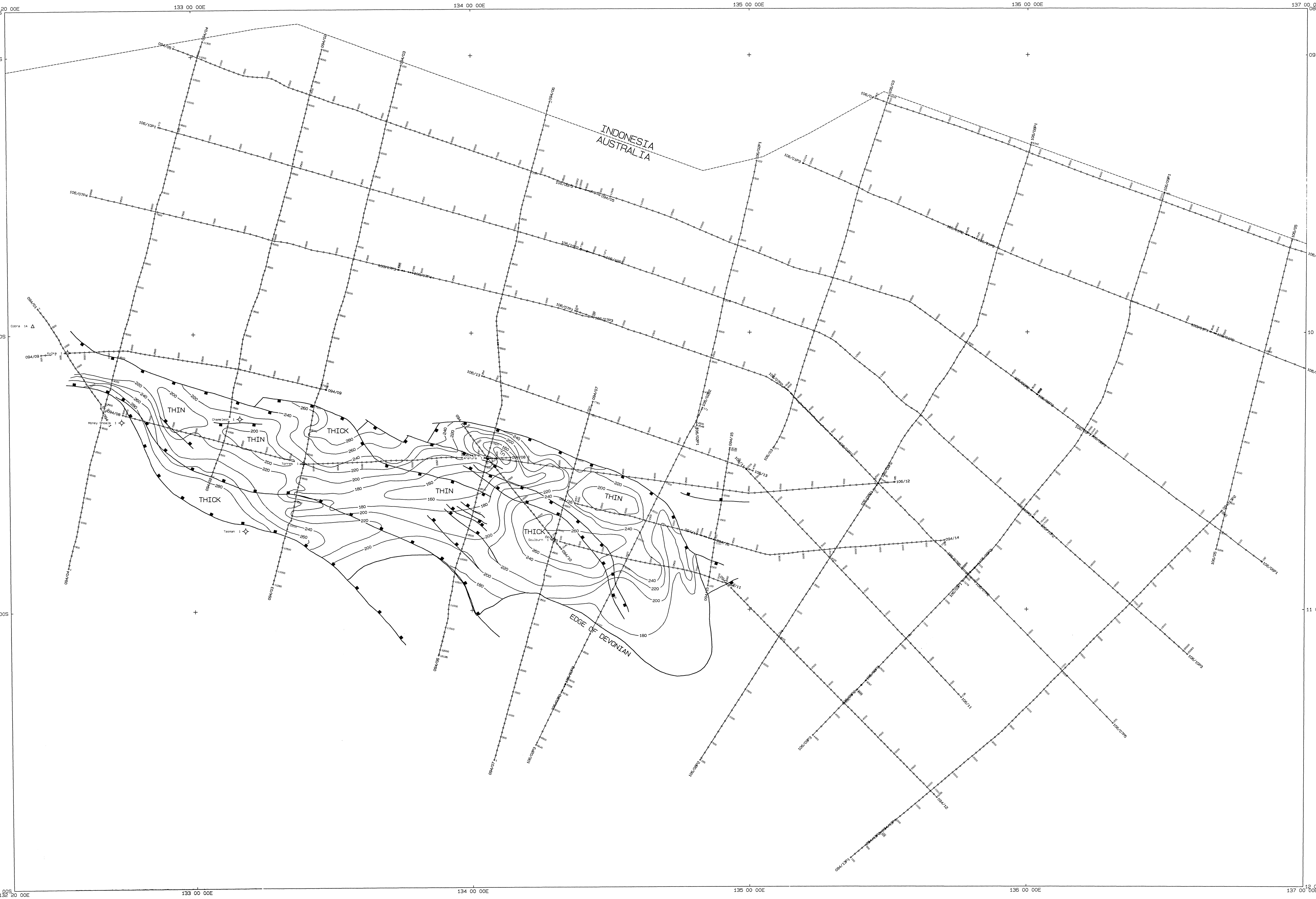
"Lower Palaeozoic" interval (horizons 3-5) north and east of Goulburn Graben.

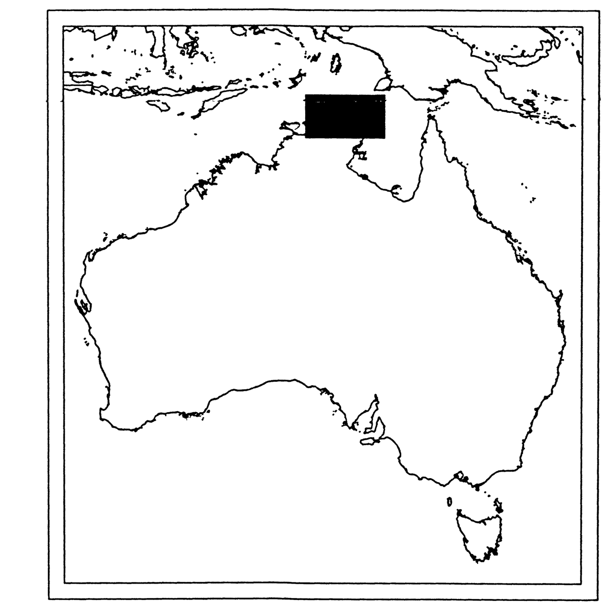
C.I. = 0.1sec		A.Moore
		May 1995

Enclosure 7

User . lhatch File . px25632.djt Date . November 23, 1995

ARAFURA SEA HORIZON B–D





1. 500000
0 10 20 30 40 50
KILOMETRES
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 135 00 00E

ISOTIME TOP OF DEVONIAN CALCAREOUS SANDSTONE TO TOP OF ORDOVICIAN DOLOMITE

(1409M KB TO 1835M KB IN ARAFURA 1)
(HORIZONS D TO B)

C.I = .020 SEC		A.MOORE
DATUM = D		JULY 1995

File: araf.horb-d.pic
Prepared by: L.Hatch
Date: July 1995
For Aidan Moore 062499538

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Enclosure 8

User . lhatch File : px24536.djt Date . November 23, 1995