PALAEOGEOGRAPHY 22

GEOLOGICAL CROSS-SECTION OF THE NORTH PERTH BASIN

R. SEGGIE

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

ONSHORE SEDIMENTARY &
PETROLEUM GEOLOGY

RECORD 1990/65

RECORD 1990/65

GEOLOGICAL CROSS-SECTION OF THE

NORTH PERTH BASIN

BY

ROBERT SEGGIE

Bureau of Mineral Resources, Geology and Geophysics &

Australian Petroleum Industry Research Association

CONTENTS

SUMMARY

The far northern Perth Basin is confined to the offshore and is divided into three narrow structural belts parallelling the north-north-west strike direction of the basin. These are from east to west: the Edel Platform, the Wittecarra Terrace and the Houtman Trough. The Edel Platform consists of up to 3500 metres of Silurian clastics overlain by a platform cover of up to 1200 metres of late Phanerozoic sedimentary rock (based on the interpretation of the Edel-1 well). The Wittecarra Terrace consists of over 2000 metres of Triassic overlying 1200 metres of Early Permian with potential for a thick Silurian section. This basinal sequence is overlain by less than 500 metres of Jurassic to Holocene clastics and carbonates. The Houtman Trough is comprised of up to 6000 metres of Jurassic strata overlying up to 6000 metres of unknown section interpreted to consist of Silurian, Permian and Triassic units. Due to a paucity of data other interpretations of the stratigraphy are possible.

Within the structural belts most features are tensional in nature but the zones of complex faulting between the structural belts are suggestive of transtensional movement. Movement appears to be of earliest Triassic age in the east and latest Triassic, mid Jurassic and latest Jurassic to Neocomian age in the west. Crustal extension of up to 30% occurred between the Late Permian and latest Jurassic over the Jurassic and Triassic depo-centres. Both a deep crustal detachment and the transtensional model of Marshall et al., (1989) are generally supported by the data. However, the most convincing flower structures occur at the boundaries between the major tectonic elements. The faults within these structures cut up to the Neocomian unconformity and suggest that strike slip movement occurred for a short time prior to the Early Cretaceous (Time slice K3) deposition.

The structural cross-section is 400 kilometres long and is compiled from modern seismic and drilling results. It connects the Edel-1 well to the Wittecarra-1 well and, by jump tie, to DSDP 259 in the abyssal plain.

Detailed biostratigraphic, facies and palaeo-environmental analysis of the Wittecarra-1, Batavia-1, Houtman-1 and Edel-1 wells is tied to the time slices of the BMR Palaeogeography Mapping Project and reveals a connection between all depositional hiatuses in the area (based on palaeontology) and the times of fault movement (based on seismic interpretation). The times of hiatus are: Late Permian (time slice P4-P6); Middle Triassic (time slice T3); Triassic/Jurassic boundary (time slice T6-J1); Neocomian (time slice K1-K3); Albian to Santonian (time slice K5-K9) and Eocene to Miocene (time slice Cz2-Cz5).

A good hydrocarbon show in the Jurassic in the Houtman-1 well (drilled on a large structure) appears to have been poorly evaluated. Wittecarra-1 and Batavia-1 did not test valid structural closures and did not encounter significant hydrocarbon shows.

The Triassic Woodada Formation has been identified as the main oil source in the vicinity of the cross-section. The rich oil source in the basal Kockatea Shale, present further south, has not been intersected here but may still exist. Excellent reservoir, source, seal and traps exist in the Wittecarra Terrace and Houtman Trough.

INTRODUCTION

Aims

The Northern Perth Basin Cross-Section has been designed to highlight the structure and stratigraphy of this part of the basin, presenting basic data as well as giving an interpretation. This has been achieved by choosing a selection of the highest quality seismic data that, where possible;

* crosses major tectonic elements,
* cuts the structural grain perpendicularly,
* intersects significant wells, and
* highlight structure and seismic stratigraphy.

Also, by using the palaeontology and lithology from the most useful petroleum exploration and other wells, the seismic sequences and hence the structure, stratigraphy and palaeogeography were identified, assessed and linked to the time slices (TS) of the Palaeogeography Mapping Project.

Basin Nomenclature

The various structural elements in the northern Perth Basin have been given conflicting names by different authors in the past. The following definitions are broadly based on Playford et al. (1976), Smith & Cowley (1987) and Marshall et al. (1989) (see Plate-1):

Abrolhos Sub-Basin

"That part of the off-shore Perth Basin situated west of the Northampton Block, the Dandaragan Trough and the Beagle Ridge. To the north it is separated from the Carnarvon Basin by the weakly developed Batavia Arch"(Playford et al., 1976). However, this definition places the northern boundary of the Perth Basin in the middle of the area being studied so, for the purpose of this work, the Perth Basin is extended further to the north. Also, the Batavia Arch is poorly defined in the literature.

This region is subdivided into three major fault bounded tectonic elements by both Smith & Cowley, 1987 and Marshall et al., 1989. Here they are defined as structural elements (similar to Smith & Cowley, 1987) rather than Sub-Basins (Marshall et al., 1989)

Edel Platform

This is adjacent to the coast and consists mainly of a Silurian sequence.

Wittecarra Terrace

A thick Triassic section with little Jurassic cover characterises this feature.

Houtman Trough
This contains a thick Jurassic sequence and extends westwards towards the Perth Abyssal Plain where thin Tertiary deep water sediments predominate.

Data Base

Seismic Lines

The seismic surveys used to construct this cross-section are listed below .

OPERATOR	SEISMIC SURVEY NAME	DATE	LICENCE
CONOCO	Murchison Marine SS Reprocessed by BHP in 1986	1980	WA-196P
Esso	A76A Marine Seismic Survey	1976	WA-59P
Esso	A77A Marine Seismic Survey	1977	WA-59P
Esso	A78A Marine Seismic Survey	1978	WA-59P
BMR	Perth Basin (Survey 57)	1986	WA-59P

Seismic data in the Perth Basin is generally of poor quality with few continuous reflectors. The best, available seismic data cover the northernmost Perth Basin area, being from the Murchison Marine Seismic Survey, originally recorded by Conoco during the 1970's and reprocessed by BHP in 1986. Data to the south, recorded by Esso during the late 1970's, and the regional BMR Perth Basin Survey (1986) were also used.

The cross sections are constructed from the interpretation of lines 124 and 109 from the Murchison Survey (reprocessed and migrated by BHP) and BMR Line 57/09.

Wells

The wells used in this cross-section (see Plate 1 for location map) are listed below, from north to south:

WELL NAME (SEISMIC LINE. LOCN)	YEAR	LATITUDE	LONGITUDE	W.D	T.D.	OPERATOR
Edel-1 (Murch.SS Lines 110B SP1740 & 109A SP3120)	1972	27 06 48S	113 23 24E	95	2750	Ocean Venture
Wittecarra-1 (Murch.SS Line 124B SP2770)	1985	27 50 37S	113 12 33E	190	2890	BHP

Houtman-1	1978	28 39 55S	113 34 35E	152	3860	ESSO
(ESSO Line A76A-29 SP3489)						
Batavia-1	1978	28 53 59S	114 15 36E	53	2941	ESSO
(ESSO Line A77A-68 SP2737)						
DSDP 259	1972	29 37 03S	112 41 47E	4696	346	JOIDES
(BMR Seismic Cruise 57, Line BMR 57/4 SP8170)						

Edel-1 and Wittecarra-1 are incorporated into the cross-section whereas Batavia-1 and Houtman-1 are incorporated into the time facies analysis because of their good palaeotological control. DSDP 259 was used as a basis for interpreting the deep water section. Other wells in the north of the basin (see Plate 1) include Geelvink-1A, Gun Island-1 and South Turtle Dove-1B. Geelvink-1A is located in a highly faulted area that mitigated against a meaningful seismic interpretation being made; Gun Island-1 is not located on a seismic line; and a re-interpretation of the palynological slides is required and South Turtle Dove-1B does not have good palynological definition and is located too far south to be used in this study.

Scale

The Cross-Section (Plate 1) has been produced at 1: 100,000 scale with no vertical exaggeration and is a total of 400 kilometres in length with a maximum interpreted sedimentary thickness of 7 kilometres, based on the interpretation of seismic and magnetic data.

Depth Conversion

Velocity/ depth curves were plotted for relevant off-shore wells in the north Perth Basin and revealed considerable variation (Edel-1, Wittecarra-1, Houtman-1, Geelvink-1, Batavia-1, Gun Island-1 and Sth Turtle Dove Ridge-1 were used). This variation can be correlated to differences in water depth as well as differences in the age of the section.

The water depth factor was removed, revealing two distinct velocity/depth relationships which roughly correspond with the Edel Platform area and the rest of the Abrolhos Sub-Basin. The velocity/depth curve for Batavia-1 was close to the average for the Edel Platform and was used for depth conversion here. The velocity/depth curve for Wittecarra-1 was the best fit for the remainder and was used for depth conversion in that area.

Horizons Drawn

A total of 15 seismic horizons are shown on the cross-section on Plate 1 but due to the different ages of the strata in the different structural regions no more than 11 were carried for any one region. These horizons are listed below and are linked to the time slices of the palaeogeography mapping project.

Eastern Area (Edel Platform)

Horizons in this area were picked at the
* Water bottom
* Top Eocene (TS Cz2)
* Top Cretaceous (subdivision uncertain)
* Top Triassic (TS T5-T6)
* Top Permian (TS P3-P4)
* Top Silurian (TS S1-S2)
* Intra Silurian (TS S1-S2)
* Base Silurian (metamorphic basement?)

Central Area (Wittecarra Terrace)

Horizons in this area were picked at:
* Water bottom
* Top Eocene (TS Cz2)
* Top Cretaceous (TS K11)
* Top Aptian/Albian (TS K5)
* Top Jurassic (TS J1)
* Top Triassic (TS T6)
* Intra Lesueur Formation seismic marker (TS T4)
* Top Woodada Formation (TS T2)
* Top Kockatea Formation (TS T1)
* Top Permian (TS P3-P4)
* Top Silurian (TS S1-S2)

Western Area (Houtman Trough)

Horizons were picked for unconformity, disconformity or simply as strong marker horizons due to a lack of a direct well tie and are interpreted as:

* Water bottom
* Top Eocene (TS Cz2)
* Top Cretaceous (TS K10-K11)
* Top Aptian/Albian (TS K4)
* Top Jurassic (TS J9-J10)
* Intra Yarragadee Marker(TS J6-J8)
* Top Cadda Fm (TS J6)
* Top Cockleshell Gully Fm (TS J4-J5)
* Top Triassic (TS T2-T6)

Time/Depth Plots

Time verses depth plots were constructed for the Edel-1, Wittecarra-1, Houtman-1 and Batavia-1 wells. Batavia-1 and Houtman-1 were not tied to the cross-section due to an overly long and tortuous series of line ties but they have been included to enable an analysis of the Jurassic and a more thorough assessment of the Triassic and other sequences to be made.

The time verses depth plots were constructed by tying the available palaeontology from each well to the radiometric time scale of Harland et al.(1982). The palynological scheme of Helby et al., 1987 was used for the Mesozoic and Kemp et al., 1977 was used for the Permian. Internationally recognised zonations for foraminifera ,nannoplankton and other microfossils were used for the Cretaceous and the Cainozoic. The results for each well are discussed below.

Edel-1 had no indisputable palaeontological data but had numerous radiometric ages determined for a volcanic or hypabyssal igneous suite (Ocean Ventures, 1972). The most reliable analyses gave an age of 261-267 My ± 5 My, corresponding to Time Slice P3 to P4 in the Permian (see Plate 1). The igneous rocks are interpreted to have intruded, as a ring dyke complex, into a Silurian, sandstone dominated, red bed sequence. Cretaceous contamination of the cuttings indicates the presence of a thin sequence of this age near the top of the hole and the seismic interpretation indicates the presence of a Tertiary sequence overlying this. No Silurian, Permian or Triassic strata have been unambiguously dated in the well.

The numerous problems associated with the dating of this well and the possible interpretations of the sequence encountered are discussed in Appendix-1.

Wittecarra-1 contained good palynological and micropalaeontological definition throughout the section (BHP, 1986). A thin Permian sequence belonging to time slice P3 to P4 (Sakmarian to Kungurian) was the deepest sequence encountered in the well (see Plate 1). This was unconformably overlain by the thickest and most complete Triassic section encountered in this part of the Perth Basin, spanning all the Triassic time slices (T1-T6) with the exception of T3 and characterised by rapid deposition (at an approximate rate of up to 100 metres per million years). No Jurassic was identified, however, a thin basal Jurassic sequence has been interpreted. A thin Aptian to Albian (TS K4 to K5) sequence unconformably overlies this which is in turn disconformably overlain by a Maastrichtian to Paleocene sequence (TS K10 to Cz1). A Pliocene to Holocene section is the youngest encountered, resting with apparent conformity on the underlying units and cropping out on the sea floor.

Batavia-1 has also been palaeontologically well sampled, providing a geologic column from the Early Permian through to the Late Jurassic (Galloway, 1978a). Permian strata (time slice P3 or Sakmarian - Artinskian) comprise the oldest rocks encountered in the well (see Plate 1). Unconformably overlying this is a nearly complete sequence of Triassic covering time slices T1, T2, T4 and T5 with T3 interpreted as being absent due to erosion and non deposition and T6 being faulted out. Triassic deposition was slower than at Wittecarra-1 resulting in a thinner section. The overlying Jurassic is well represented also, with all the time slices except J9 and J10 (covering the Tithonian) being present. No younger material was collected or analysed. Despite this, a Cretaceous to Holocene sequence similar to that encountered in Wittecarra-1 is interpreted.

Houtman-1 is one of the most densely palaeontologically, sampled wells in the northern Perth Basin and contains the thickest Jurassic section in this part of the basin (Galloway, 1978b). The well bottomed in the Early Jurassic (time slice J2, or possibly J1) and intersected all the younger Jurassic time slices (see Plate 1). The Jurassic spans approximately 3000 metres with at least another 500 metres of Early Jurassic beneath total depth (based on extrapolation using Batavia-1. The time/depth plot shows the Jurassic section to have been rapidly deposited (at an approximate rate of up to 150 metres per million years).

A thin Early Cretaceous sequence of Barremian to Aptian age (time slices K3 and K4) unconformably overlies the Jurassic. This is in turn overlain by a thin Campanian to Maastrichtian sequence (K10). A sequence of Early Tertiary disconformably overlies this and crops out on the sea floor.

Deep Sea Drilling Project, Leg 27 site 259 was drilled in the Perth Abyssal Plain. Although the well results are used in this report, the thin and time restricted age limited section did not warrant display on a Time/Depth plot (Robinson et al., 1974 ; Bolli, 1974). Aptian to Albian claystones, 235 metres thick, overlie basaltic basement. The overlying Cainozoic clay and ooze is 67 metres thick.

RESULTS

SEISMIC INTERPRETATION

The seismic lines in the North Perth Basin exhibit complex structure and stratigraphy (Plate 1), highlighting the importance of good biostratigraphic control from well ties. The time/depth plots for Batavia-1, Wittecarra-1 and Houtman-1 (Plate 1) highlight the various time breaks in the sequence. Also, facies data from the well logs, the sample descriptions and the palaeontology enable the main prograding sequences to be identified along with the major marine transgressions and regressions. It is on this basis that correlation away from the fault block intersected by the key Wittecarra-1 well was possible.

A preferred interpretation is presented for the three seismic lines and two alternative interpretations are presented for the Houtman Trough.

The area traversed by the cross-section is broken into three separate regions on the basis of structure and stratigraphy: the Edel Platform, Wittecarra Terrace and the Houtman Trough. The continental slope is part of the Houtman Trough but is treated separately, together with the abyssal plain, due to the lack of well data and good seismic data.

Edel Platform

The interpretation of the Edel Platform area is based on the Edel-1 well having intersected a thin section of Tertiary and Cretaceous underlain by a thick section of Silurian red beds (Tumblagooda Sandstone) intruded by Permian phonolites, trachytes and lamprophyres. Other possible interpretations suggest the presence of thick Triassic and Permian strata here (Smith & Cowley, 1987 and Marshall et al., 1989) and are discussed in Appendix-1.

The Edel Structure is a roughly symmetrical dome coincident with a strong circular magnetic anomaly. This is consistent with an intrusive ring dyke complex.

Except for the basal section, the Silurian is characterised by non continuous reflectors typical of a channelled sequence and is over 3000 metres thick on seismic (Plate 1 & 2) which is consistent with outcrop mapping (Hocking et al., 1987). There is a thin section (less than 700 metres) of Permian, Triassic, Cretaceous and Tertiary unconformably overlying the Silurian. The Silurian shows little thickness variation whereas the Permian and Triassic thicken to the west, and the Triassic pinches out in the east. The Cretaceous is present over all the Edel Platform whereas the Tertiary forms a westwardly thickening wedge restricted to the north and west. The Jurassic is absent from the Edel Platform.

On seismic (Plates 1 & 2) it is only the Edel Platform which displays significant (Proterozoic?) basement character with many variously dipping reflectors which can be interpreted as ancient half grabens or more likely as a combination of relict strata, metamorphic foliation, fractures, faults and other structures. These generally correspond with the faulted areas.

The lower Tumblagooda sequence is cut by faults that show thickness variation in this section giving a Silurian age to the faulting (see Plates 1 & 2). These are associated with deep seated basement structure (areas with the most prominent intra-basement seismic character). The occasional influence of faults on the base of the Permian is indicative of: a final late movement at the end of the Late Carboniferous; minor faulting at earliest Permian time or; topography at the time of onset of Permian deposition. Some faults have been reactivated, cutting as high as the top of the Triassic. The Cretaceous and Tertiary are not cut by any faults in this region and the Jurassic is not present. The section above basement displays only minor structuring in the eastern part of the Edel Platform, compared to the central and western portions.

The prospectivity of the Edel Platform is low for all interpretations as the sequence comprises coarse grained, oxidised red beds, as encountered in the Edel-1 well. No source or regional seal is interpreted despite the presence of Dirk Hartog Formation dolomites and evaporites (potential seal to the Tumblagooda Sandstone) to the north east in the Shark Bay area. The overlying Triassic and Permian are too thin and shallow to be prospective without the presence of a deeper source.

Wittecarra Terrace

This area is highly faulted, the interpretation being mainly based on the Wittecarra-1 well, located in the centre of the terrace, as well as the tie from the Edel-1 well and coastal outcrop.

The Silurian is interpreted as being present (over 1000m thick) in the east on the basis of a different seismic character from the underlying section (basement) (Plates 1 & 2). Further west on the section its presence is inferred, with basement not being evident. The Permian is 1000 metres thick over this part of the cross-section, with the exception of local thinning due to Permian faulting and erosion. The Early Triassic aged Kockatea Shale unconformably overlies the Permian and exhibits little thickness variation whereas the overlying Woodada Formation forms a regressive sequence which is strongly eroded in the east, resulting in its thickness varying from 100 to 700 metres. The Woodada Formation is conformably overlain by the Lesueur Formation which shows evidence of syndepositional structuring. A lacustrine shale of regional extent forms the base of this unit. A thin Jurassic sequence is interpreted to unconformably overlie the Triassic but no specific age determination was possible. This sequence exhibits growth faulting and prograding and is unconformably overlain by a very thin Aptian/Albian sequence, devoid of faulting. This is disconformably overlain by a Santonian to Eocene carbonate sequence which can be subdivided into Santonian to Maastrichtian and Paleocene to Eocene. Miocene to Pliocene shelfal carbonates disconformably overlie this. Further south, the Wittecarra Terrace contains a significant section of Jurassic (dated in Batavia-1).

The Wittecarra Terrace is characterised by closely spaced normal faulting. In the east the faulting appears to sole out at the base of the Silurian or within basement whereas in the west the faulting is interpreted to sole out in the Permian. Alternatively, the listric faulting can be interpreted as being deeply rooted to form very large negative flower structures. In the western area there is a faulted arch which appears to form a large fault controlled structural anticline with exploration potential.

In the eastern part of the Wittecarra Terrace (see Plate 1 & 2) the faulting cuts only as high as the base of the Triassic except for one fault which cuts as high as the top Woodada Formation. In the west the faults either cut up almost to the top of the Triassic or up to the base of the Cretaceous.

Houtman Trough

Three possible interpretations can be made due to a lack of a direct well tie (Plate 1).

Preferred Interpretation (Plate 1)
A seismic character tie can be made to the Houtman-1 well locality (see location map on Plate 1), where over two kilometres of Yarragadee Formation was intersected. A large thickness of Yarragadee Formation is likely therefore, in the area of the cross-section. It is interpreted to be underlain by the Cadda Formation and the

Cattamarra Coal Measures (based on Houtman-1 and outcrop onshore). The lowest seismic horizon is then most likely the top of the Triassic. The plays are therefore Jurassic, similar to those for the Houtman-1 well, with sedimentologically immature Jurassic sandstones forming the reservoir targets. The Triassic and Permian plays are too deep (over 5000 metres), if present. Marshall et al., 1989 and Smith and Cowley, 1987 both interpret the base of the Jurassic to be even deeper.

<u>Alternative Interpretation 1</u> (Plate 1)
The area can also be interpreted with both the Jurassic and Triassic being thinner, due, at least in part, to erosion of the youngest part of each unit. The top of the Triassic probably coincides with near the top of the Woodada Formation (TS T2). The intervening section would be Jurassic, most likely consisting of Yarragadee overlying the Cadda Formation and Cockleshell Gully Formation. The lowest reliable horizon would then be the top Permian with the horizon overlying this being the top of the Kockatea Shale. Using this model, the Jurassic, and the Woodada Formation would be shallow enough (less than 4000 metres) to be viable exploration plays in this area.

<u>Alternative Interpretation 2</u> (Plate 1)
The third interpretation assumes a thin Jurassic (specific age uncertain but probably TS J1-J4) overlying a thinner Triassic section (TS T1-T4?) and underlain by the Permian, resulting in the Triassic plays being at a similar depth to those encountered in the Wittecarra Terrace. This interpretation has many problems due to the inability to reconcile this area along strike lines to the north (where the section thins) and then tie back to the Wittecarra-1 area. If correct the main plays are the Woodada Formation and the Permian.

<u>Discussion</u>
The Houtman Trough is bounded in the east by a major down to basin growth fault. Adjacent and to the west of this there is a set of prograding sequences interpreted to be fans which were deposited in the Jurassic. The uppermost set of progrades would be an alluvial fan complex of the Yarragadee Formation (TS J8-J10) for the preferred interpretation. The deeper progrades are consistent with both the rapid deposition of the Cattamarra Coal Measures and, for Alternative Interpretation 1, the major regression of the Triassic Woodada Formation.

The Houtman Trough exhibits two styles of faulting: steep normal faults, with associated antithetic faulting, and listric faults which either sole out at 2-3 kilometres

(Yarragadee Formation for the preferred interpretation) or at 4-5 kilometres (Early Triassic for the preferred interpretation). The steep normal faults cut as high as the base of the Cretaceous and in some cases as high as the Palaeogene and show syndepositional growth for the whole interpretable pre- Cretaceous section. This is particularly evident on the major bounding fault at the eastern edge of the Houtman Trough. The shallow listric faults cut up to the base of the Cretaceous but the deeper listric faults only cut as high as the intra-Yarragadee Formation (preferred interpretation). The deeper listric faults can also be interpreted as antithetic to the main deep basement involved faults.

The section in this area contains structure, mature source, reservoir and regional sealing units.

Continental Slope and Abyssal Plain (Western Houtman Trough)

The interpretation of the continental slope and abyssal plain area utilised seismic from the BMR North Perth Basin Project, Marine Survey 57. This area is very complex due to the erosive nature of the slope and the intense structuring of the pre-Cretaceous section. The interpretation from the Houtman Trough, further east, was carried into this area and to the abyssal plain where a rough jump tie to DSDP 259 was performed (Robinson et al., 1974; Bolli, 1974).

Generally, pre-Cretaceous section is increasingly eroded and faulted to the west, beneath the base Cretaceous unconformity, making age estimations of the section beneath the unconformity very difficult at any one locality. This faulting cuts as high as the base of the unconformity. Arching similar to that interpreted in the Houtman Trough area occurs in this region in technologically drillable water depths.

The sedimentary section in water depths shallower than 1000 metres is approximately the same thickness as that interpreted in the Houtman Trough, further east. The presence of reservoir, seal, structure and mature source are therefore highly likely with the Jurassic providing the most likely exploration targets.

In the abyssal plain oceanic basement is interpreted on the sea floor or beneath a veneer of Cretaceous sediment. Rotated fault blocks of strata are evident in the area and are interpreted as North Perth Basin section (Jurassic to Silurian in age) overlying continental basement.

STRUCTURAL ANALYSIS

The various hiatuses identified by the time/depth plots correlate with time of faulting and other structural events identified on seismic. The details of this are shown on Plate 1 and their relationship with sedimentation are summarised below in "Geological History".

The type of structures identified on seismic (see Plates 1 & 2) include shallow listric faulting, deep listric faulting and growth faulting in the Wittecarra Terrace, Houtman Trough and continental slope. Rotated fault blocks occur in all areas and no fold structures occur except where listric faulting converges.

To more accurately ascertain the timing and nature of the structural development of the basin, balanced cross-sectioning techniques were employed. The "line lengths" of the seismic horizons shown on the cross-section (Plate 1) were measured and show that over the Wittecarra Terrace there was 20% crustal extension from the near top Permian to the top of the Triassic, with most extension occurring immediately prior to Kockatea Shale deposition (TS T1 time) and a further 5% extension during the Jurassic to Neocomian. The Houtman Trough underwent extension of 17% during the Jurassic. The total amount of crustal extension, along the 100 kilometre long portion of cross-section west of the Edel Platform, was measured to be 9 kilometres or 9% during the Jurassic to Neocomian. The faulting of the Late Permian - Triassic section in the Wittecarra Terrace appears to underlie the Jurassic in the Houtman Tough and continue westwards to the basin edge. As this type of faulting involved a 20% crustal extension it is extrapolated that crustal extension of approximately 30% occurred along this 100 kilometre long portion of the cross-section between the Late Permian and the Neocomian.

There is an increase in the measured line length of successive seismic horizons (time lines) up the section. Despite significant variations in the amount of extension there is no period when line lengths shorten, thereby precluding any compression in the area. Any interpreted strike slip motion in this area would therefore be transtensional. The positive flower structure interpreted by Marshall et al.(1989) to the right of centre on BMR line 9 shows no shortening according to my interpretation and must therefore be resolved within a tensional framework.

No consistent level of detachment could be calculated using the Chamberlin method (Gibbs, 1983) with calculated levels of detachment ranging from 5 - 30 kilometres. This is most likely due to a lack of control on the base level of erosion at any one time or on the exact timing of syndepositional structuring (the continuation of sedimentation during structuring and the complexity of structuring would have contributed to this). There is therefore no good control on the amount of downwarp resulting from any single extensional movement. However, by using the cross-sectional area of the much thicker section between the major unconformities and the amount of extension during these times, a consistent depth of detachment of 20-30 kilometres is calculated. Detachments as shallow as 5 kilometres were calculated for more restricted intervals. These are probably due to a combination of the shallow detachment (2.5-6 kilometres as observed on the seismic) and the deep crustal detachment. A detachment at 20-30 kilometres below the surface is of the right order of magnitude for deep crustal detachment as described by Jackson and McKenzie (1983) and Wernicke and Burchfiel (1982). Pure extension could therefore have caused the stratigraphy and structure observed on the cross-section.

However, the ocean floor magnetic anomalies west of the Perth Basin reveal an oblique separation between greater India and Australia. A strike slip component must therefore be expected in the structuring, as seen at the boundaries between the three structural provinces where complex structuring has strike slip characteristics. The oldest oceanic crust has been dated at 125 my BP (Neocomian) (Johnson et al., 1979) which coincides with the time when structuring ceased on this cross-section.

Lowell (1985) refers to structures which are initiated as pure extension but are reactivated as strike slip, as a "superposed structural style". These structures display the geometry of the initial extension but no strike slip structural geometry. On the cross-section, strike slip structuring is restricted to the boundaries between the structural belts and no other unambiguous strike slip structures occur. Strike slip movement would therefore have occurred after the formation of the youngest purely extensional normal faults had formed. Listric faults in the Houtman Trough show no growth and are truncated by the Neocomian unconformity with the youngest affected strata being of J9-10 age. They therefore formed between time slices J10 and K3. This suggests a short lived period of strike slip occurring immediately prior to continental drifting (formation of oceanic crust. This needs to be confirmed by three dimensional modelling using a strain ellipse.

Marshall et al.(1989) interpret transtension as the basin forming mechanism. Geologic mismatching between the terraces and troughs; and the widespresd presence of flower structures are cited as the major evidence. There is no unambiguous evidence for flower structures in the limited area of this study and the geologic mismatch interpreted at the boundaries of the major tectonic elements by Marshall et al. (1989) does not necessitate strike slip. Both regional, high resolution seismic and deep crustal seismic are required before any firm conclusions can be drawn about the basin forming tectonics.

GEOLOGICAL HISTORY

Proterozoic

The basement beneath the Perth and Carnarvon basins is believed to have been cratonised during the Proterozoic (Jaques et al., 1986) and is most likely to be granulites similar to those occurring in the Northampton Block which have been radiometrically dated at 1,054±50Ma. The Gascoyne province to the east of the Carnarvon Basin is comprised of granulites dated at between 2.0 and 2.4 Ga (Jaques, et al. 1986).

The intra-basement seismic reflectors observed on the Edel Platform were most likely formed at this time.

Proterozoic - Silurian: Not Recorded

No dated section of this age is preserved in or around the Perth or Carnarvon Basins. The cross-section shows 3000 metres of Silurian, the basal sequence of which may be pre-Silurian.

Silurian S1-S2: Sedimentation

The earliest sediments deposited in this region are the redbeds of the Tumblagooda Sandstone (Hocking et al., 1987) which are over 3000 metres thick on the Edel Platform. The dominance of discontinuous reflectors in this unit and the oxidised nature of the sediments suggest a braided stream deposit. This unit extends at least as far west as the Wittecarra Terrace on seismic evidence.

Silurian S3-Permian P2: Not Recorded

Sedimentation continued intermittently until the Early Permian in the nearby Merlinleigh Sub-Basin. It is believed, by analogy, that deposition continued through to the Early Carboniferous; but that Late Carboniferous uplift and Permo-Carboniferous glaciation has resulted in extensive erosion with no new deposition until the Early Permian. No wells in the far northern Perth Basin have intersected TS P1 or P2 strata, however, preservation of some deposits of this age is likely as TS P1 and P2 glacial and peri-glacial sedimentation was widespread in both the Perth and Carnarvon Basins.

Permian P3-P4: Sedimentation

Batavia-1 and Wittecarra-1 bottomed in strata of this age and facies correlations indicate a shoreline facies between the wells with a marine unit in the north and a fluvial section to the south.

Permian P5-P6: Not Recorded

No strata of this age are recorded in the wells in the study area (see Time/Depth Curves - Plate 1). The deep cutting listric faulting observed on the eastern Wittecarra Terrace occurred during this time (see cross-section - Plate 1).

Permian P7: Localised Sedimentation

The Wagina Sandstone was deposited as a system of coalescing alluvial fans at the end of this time, indicating uplift of a nearby sediment source area (Bergmark & Evans, 1987). This sand is interpreted to be present in Batavia-1 but was not intersected in Wittecarra-1 due to either fault movement and resultant localised erosion or a possible faulting out of the section at the well intersection.

Triassic T1-T2: Sedimentation

A major marine transgression occurred at the beginning of the Triassic giving rise to the deposition of the Kockatea Shale (Playford et al., 1976). Basal transgressive sandstones were deposited as off-shore bars and strandlines (noted onshore by Bergmark & Evans, 1987) to form, in conjunction with the underlying Wagina Sandstone, the principle exploration target in the north of the basin.

During TS T2 time a regression occurred, resulting in the deposition of a major prograding delta to form the Woodada Formation. Environments of deposition therefore grade from shelfal marine to paralic and fluvial. This section contains the richest oil prone source rocks analysed in the most northern part of the basin (BHP, 1986).

T3: Not Recorded

A minor tectonic event, evidenced by faulting and minor flexure on the Wittecarra Terrace (see cross-section - Plate 1), occurred at this time without deposition in the area. Varying amounts of erosion resulted but this appears to have also been coupled with the maximum retreat of the sea.

T4-T6: Sedimentation

An excellent reservoir quality sandstone (top of the Woodada Formation) overlain by a dense seal of highly oxidised lacustrine shale in excess of 100 metres thick was then deposited over a large area (present in Wittecarra-1 and Batavia-1) suggesting an eustatically controlled event. This is an untested and highly promising exploration play in the region.

In the middle of TS T4 regression occurs, associated with fluvial braided stream deposition. The highly oxidised nature of the sediments (red and green colouration) is characteristic of a fluctuating water table and a warm climate (monsoonal). By T5 time the climate had changed as the red staining is no longer prevalent except in a lacustrine deposit early in TS T5. During TS T5 time scattered coals occur and rocks of TS T6 age display a possible marine influence, evidenced by occasional dinoflagellates.

T6/J1 Boundary: Not Recorded

The Jurassic-Triassic boundary has not been recorded in this area due to a lack of dateable fossils at this level in Wittecarra-1 and the apparent faulting out of this sequence in Batavia-1.

Jurassic J1-J4: Sedimentation

In Wittecarra-1 fluvial, prograding sands (probably TS J1) overlie the paralic Triassic T6 strata (see interpreted seismic section - Plate 2 and time slice facies diagram Plate 1), whereas Batavia-1 lacks any TS T6 inferring the presence of a hiatus, however, a faulted out section is possible.

A fluvial sandstone dominated sequence of TS J1 age is recorded in Batavia-1 and may exist in Houtman-1. In Batavia-1 the TS J2-J4 aged section is fluvio- deltaic to paralic (based on the presence of dinoflagellates) whereas in Houtman-1 the section is fluvio-deltaic (based on the lack of dinoflagellates). Scattered coals are present in the TS J2/J3 section.

J5-J10: Sedimentation

Marine deposition (Cadda Formation) in Houtman-1 and paralic deposition in Batavia-1 during TS J5 indicate that a marine transgression entered from the north at that time (Time Slice Facies Diagram Plate 1). Open marine deposition became widespread during early TS J6 but regression to paralic sand deposition and to fluvio-lacustrine shales, coals and sands (starting in Batavia-1) followed before the close of TS J6. TS J6 closed with the localised, rapid deposition of fluvial sands at Houtman-1 (associated with a local unconformity).

The strata of TS J7 to early TS J8 comprise fluvial sandstones and siltstones, minor coals and marine shale incursions, typifying a fluvio-deltaic facies. After the last marine incursion rapid fluvial sandstone deposition ensued, continuing to the close of the Jurassic. This also contains siltstones, mudstones and coals typical of a rapidly deposited braided stream system. Dolomite horizons are also present.

Cretaceous K1-K3: Not Recorded

This period includes the time of separation of India from Australia - 125my ago (Johnson et al., 1979; Veevers et al., 1974; Marshall et al., 1989). Extensive faulting cuts pre-Cretaceous strata in the Wittecarra Terrace, Houtman Trough and the continental slope without affecting the overlying Cretaceous strata (see interpreted seismic section - Plate 2), verifying the age of breakup. This is also the time of maximum regression.

K3-K5: Sedimentation

Marine shales of this age appear to have been deposited over all of the northern Perth Basin in a continental shelf setting, representing the maximum transgression of the Early Cretaceous sea.

K5-K9: Not Recorded

A lack of deposition at this time is due to an interpreted highstand.

K10-Cainozoic Cz2: Sedimentation

Shallow marine carbonate deposition was widespread during this time but with a regression during the Paleocene (TS Cz1) in Houtman-1.

Cz2-Cz5: Not Recorded

Erosion and general marine regression occurred here at this time.

Cz5-Cz6: Sedimentation

Pliocene to Holocene sediments form a thin patchy veneer of marine carbonates, muds and sands over the basin. In many areas submarine erosion is evident.

IMPLICATIONS FOR PETROLEUM HABITAT

Reservoir and Seal

Reworked sands overlain by thick dense shales form the most promising reservoir and seal combinations in the basin (transgressive sequences). Thick sand pulses occur within shale units to form another promising reservoir and seal combination (prograding sequences). The identified reservoir and seal combinations are listed below:

Early Permian (P3-P4): SECONDARY TARGET

Marine shale facies and fluvial facies of TS P3-P4 age are known in the basin so sand and shale combinations are highly likely. A lack of significant data from the north

Perth Basin precludes any significant analysis of the Permian here, apart from TS P3-P4.

The marine shales, sandstones and limestones of the Caryngina Formation transgress over the fluvial to paralic shales, sands and coals of the Irwin River Coal Measures. Within both of these units reservoir and seal combinations occur in the basin, including fractured limestone in the Caryngina Formation at the Woodada Gas Field to the south (Hall, 1989).

Late Permo-Triassic Boundary (P7-T1): PRIMARY TARGET

The most notable reservoir/seal combination is the basal Triassic sand and underlying Permian Wagina Sandstone overlain by the base of thick Early Triassic Kockatea Shale (Hall, 1989). There is concern that the sand may be absent or of poor reservoir quality in this area (Smith & Cowley, 1987 & Hall, 1989) but it appears that this unit is at least partially faulted out in the wells in the area.

This forms the most prolific reservoir and the main exploration target in the basin (Hall, 1989).

Middle Triassic Prograding Complex (T2): SECONDARY TARGET

The Upper Kockatea/Woodada Formation forms a prograding complex (see central and eastern Wittecarra Terrace on Plate 2) which contains thick sand pulses located within a marine shale. The sands do not appear to be correlatable (Facies Analysis Diagram on Plate 1).

Middle Triassic (basal T4): PRIMARY TARGET

A "transgressive" sand of reworked fluvio-deltaic sands is sealed by a dense lacustrine shale. The sands appear to be of excellent reservoir quality. This target is not mentioned in any literature.

Oil shows in Wittecarra-1 (BHP, 1986).

Late Triassic (basal T5): SECONDARY TARGET

Another lacustrine transgressive play occurs later in the Triassic but is not as thick as the basal T4 event. It is therefore regarded as less prospective.

Early Jurassic (J1): SECONDARY TARGET

The sand dominated fluvial Eneabba Member is overlain by a fluvio-deltaic section containing locally thick shales to form seals to the ubiquitous sands (Time Slice/Facies Diagram - Plate 1). The sandstones commonly exhibit clay choked pores (Galloway, 1978b and pers. comm. with well site geologist on Houtman-1).

Middle Jurassic (J2-J5): SECONDARY TARGET

The Cattamarra Coal Measures consist of interbedded sandstones and shales of a paralic to lower fluvial origin (Time Slice/Facies Diagram - Plate 1). This provides a succession of interbedded reservoirs and seals.

This section produces oil at Mt Horner and holds significant reserves (Warris, 1988).

Bajocian (J5-basal J6): PRIMARY TARGET

Where intersected, the sandstones underlying the Cadda Formation sealing shales do not appear to be reworked so the reservoir consists of immature paralic to fluvio-lacustrine sands of the underlying Cattamarra Member (Galloway, 1978b). However, adequate porosity and permeability are present. The complex clay mineralogy demands careful drilling techniques. Reworked sands are likely as the Cadda Formation represents a major marine transgression.

Oil and gas shows in Houtman-1 (Galloway, 1978b).

Oxfordian (basal J8): SECONDARY TARGET

Another marine transgression occurs here but has produced a thinner seal than the Cadda Formation shales and is therefore less likely to form a reliable reservoir/seal combination.

Traps

The intensive faulting of the section in the northern Perth Basin (especially the Permo-Triassic) necessitates the presence of thick seal units to provide fault seal. The main traps are therefore rotated fault blocks with minor fault throws. These traps are proven for the Permian/Triassic boundary target (Dongara Gas and Oil Field) and are likely to be successful for the Middle Triassic (T4) target (hydrocarbon indications in Wittecarra-1) and the basal Cadda Formation target (oil and gas shows in Houtman-1).

The other target horizons lack a thick seal and therefore require unfaulted structural rollovers or alternatively, in the case of the Middle Triassic (T4) prograding complex, up-dip pinch out of reservoir sands on a structural nose.

Prospective structural features identified on the cross-section (Plate 1) include:

* a large faulted structural rollover adjacent and to the west of Wittecarra-1 suitable for the three Primary targets (west of centre of line C-D);

* a large faulted rollover further west in 1 kilometre water depth, interpreted as being suitable for the primary Jurassic target (east of centre of line A-B);
* another large faulted rollover further west in 1.5 kilometre water depth with potential for at least one of the primary targets (west of centre of line A-B);
* numerous large rotated fault blocks on the eastern Wittecarra Terrace, ideal for the basal Triassic target (centre of line C-D);
* numerous large rotated fault blocks with minor throw in the Houtman Trough and beneath the continental slope (western end of line C-D and eastern half of line A-B)

Hydrocarbon Shows

Houtman-1: Basal Cadda Formation Play

Fluorescence, cut and brown oil staining in core, a gas anomaly on the density/neutron log, high Carbon number hydrocarbons (liquid)on the gas detector and gas and oil scum from Formation Interval Tests indicate a gas saturated sandstone with considerable liquids, some in the liquid state in the reservoir. Production testing yielded no hydrocarbons, only mud filtrate, indicating deep invasion by the mud and the potential for significant formation damage. This is supported by the fact that the formation was open to high weight drilling mud (11.5 lb/gal. equating to a 34% or 1600 psi pressure differential at this depth) for one month prior to casing and testing and the fact that the sandstones contain substantial kaolinite. The clogging of pore throats is believed to be the result. The core analysis and production testing indicate that the sand lacked any permeability but this is contradicted by the SP log and caliper log responses.

Wittecarra-1: Top Woodada Formation Play

Minor fluorescence with moderate cut was encountered with increased gas readings between 1850 and 1950 metres. A small, faulted, four way dip closure is apparent in seismic two way time (BHP, 1986) but closure is less obvious once the effect of the sloping water bottom is removed.

Source Potential and Maturation

Permian (P1-P4): rich? gas prone?

Despite being a proven source to the south-east (Hall, 1989), only a small amount of Permian has been intersected so little can be said here except that similar mainly humic source rocks are likely, providing a dominantly gas prone source (Thomas & Brown, 1983).

This unit is most likely mature to overmature for oil generation in the study area due to its generally deep burial.

Kockatea Shale (Tl): rich? oil prone

The thin basal Kockatea Shale is a rich oil prone source rock with abundant exinite and phytoplankton (Thomas & Brown, 1983) but as this unit is thin, basal onlap onto high areas will result in patchy occurrence. This basal section is missing in Wittecarra-1 and Batavia-1 but faulting at this level is interpreted for both wells.

This section is mature for oil generation in the Wittecarra Terrace and is probably overmature in the Houtman Trough (Smith & Crowley, 1987).

Woodada Formation: rich oil prone

The Woodada contains abundant exinite in the substantial shale units in Wittecarra-1 and forms a rich oil prone source rock (Smith & Crowley, 1987).

This section is marginally mature for oil generation in the Wittecarra Terrace and is probably overmature in the Houtman Trough (Smith & Crowley, 1987).

Lesueur Formation: poor gas? prone

Despite being a sandstone dominated red bed sequence the Lesueur Formation contains scattered coals towards its top which may contribute to hydrocarbon generation (Smith & Crowley, 1987).

This unit is probably immature except for the Houtman Trough.

Cattamarra Coal Measures: moderate gas (& oil?) prone

Despite its name this unit does not contain abundant coal in the two wells in which it is encountered in this part of the basin. It is, however, thick and extensive. At Mt Horner Oil Field Warris (1988) describes this unit as a fair to good oil prone source rock.

This unit is also probably immature (Smith & Crowley, 1987) except in the Houtman Trough where it is buried to five kilometres.

Cadda Formation: lean gas prone

Despite being a dark marine shale, this unit lacks significant organic matter and is gas prone (Thomas & Brown, 1983). Warris (1988) on the other hand describes the Cadda Formation as an excellent rich oil source in the Mt Horner area.

Yarragadee Formation: moderate gas (& oil?)prone

Despite being sand dominated, this unit, like the Lesueur Formation, contains scattered coals which, because of the great overall thickness of the unit, represents a potential source.

This unit is probably immature.

Migration

The extensive faulting of the pre-Cretaceous section provides ample path ways for vertical migration. The presence of a number of source units throughout the section favours the migration of hydrocarbons into any valid trap in the Houtman Trough or Wittecarra Terrace.

The Edel Platform lacks both source and seal so any hydrocarbons migrating the long distance to this area would not have been trapped.

REFERENCES

Bergmark, S. L., & Evans, P. R., 1987 - Geological controls on reservoir quality of the northern Perth Basin. APEA Journal, 27(1), 318-330.

BHP Petroleum Pty Ltd, 1986 - Wittecarra-1 well completion report (unpublished).

Bolli, H. M., 1974 - Synthesis of the Leg 27 biostratigraphy and paleontology; in Robinson, P. T., et al., 1974, Initial Reports of the Deep Sea Drilling Project, Vol 27, Washington (U.S. Government Printing Office)

Galloway, M. C., 1978a - Batavia-1 well completion report, ESSO Australia Ltd. (unpublished).

Galloway, M. C., 1978b - Houtman-1 well completion report, ESSO Australia Ltd. (unpublished).

Gibbs, A.D., 1983 - Balanced cross-section construction from seismic sections in areas of extensional tectonics. Journal of Structural Geology, Vol.5, 153-160.

Hall, P. B., 1989 - The future prospectivity of the Perth Basin. APEA Journal, 29(1), 440-449.

Harland, W. B., Llewellyn P. G., Pickton, C. A. G., Smith, A.G. & Walters, R., 1982 - A Geologic Time Scale, Cambridge University Press., Cambridge.

Helby, R., Morgan, R. & Partridge, A. D., 1987 - A palynological zonation of the Australian Mesozoic. Mem. Ass. Australas. Palaeontols 4, 1-94.

Hocking, R. M., Moors, H. T. & Van De Graff, W. J. E., 1987 - Geology of the Carnarvon Basin Western Australia. GSWA Bull. 133.

Jackson, J. & Mc Kenzie, D., 1983 - The geometrical evolution of normal fault systems. Journal of Structural Geology, Vol.5, No.5, 471-482.

Jaques, A.L., Lewis, J.D., & Smith, C.B., 1986 - The Kimberlites and Lamproites of Western Australia. GSWA Bull. 132

Johnson,B.D., Powell, C.McA.,and Veevers J.J., 1979 - Early spreading history of the Indian Ocean between India and Australia. Earth and planetary Science Letters, 47 (1980) 131-143

Kemp, E. M., Balm, B. E., Helby, R. J., Kyle, A., Playford, G., & Price, P. L., 1977 - Carboniferous and Permian Palynostratigraphy in Australia and Antarctica, a review. BMR Journal of Australian Geology and Geophysics, 2, 177-208.

Lowell, J.D., 1985 - Structural Styles in Petroleum Exploration. OGCI Publications, Oil and Gas Consultants International Inc. Tulsa, Oklahoma, USA, 437-460.

Marshall, J. F., Lee, C. S., Ramsay, D. C., & Moore, A. M. G., 1989 - Tectonic Controls on sedimentation and maturation in the off-shore north Perth Basin. APEA Journal, 29(1), 450-465.

Ocean Ventures Pty Ltd, 1972 - Edel-1 well completion report (unpublished).

Percival, I.G., & Cooney, P.M., 1985 - Petroleum Geology of the Merlinleigh Sub-Basin, Western Australia. APEA Journal, 25(1), .

Playford, P. E., Cockbain, A.E. & Low, G. H., 1976 - Geology of the Perth Basin, Western Australia. Geological Survey of Western Australia Bulletin, 124.

Reeckman, S.A. and Mebberson, A.J.,1984 - Igneous intrusions in the north-west Canning Basin and their impact on oil exploration, in Purcell, P.G. (Ed.), The Canning Basin, W.A.:Proceedings of Geol. Soc. Aust./Pet. Expl. Soc. Aust. Symposium, Perth, 1984.

Robinson, P. T., et al., 1974 - Lithology of Mesozoic and Cenozoic sediments of the eastern Indian Ocean, Leg 27, Deep Sea Drilling Project; in Robinson, P. T., et al., 1974, Initial Reports of the Deep Sea Drilling Project, Vol 27, Washington (U.S. Government Printing Office)

Smith, G.C., & Cowley, R.G., 1987 - The tectono- stratigraphy and petroleum potential of the north Abrolhos Sub-basin, Western Australia. Apea Journal, 27(1), 112-136.

Thomas, B.M.,& Brown, S.A., 1983 - Hydrocarbon generation in the northern Perth Basin. APEA Journal, 23(1), 64-74.

Veevers, J. J. & Heirtzer, J. R., 1974 - Tectonic and palaeogeographic significance of Leg 27; in Robinson, P. T., et al., 1974, Initial Reports of the Deep Sea Drilling Project, Vol 27, Washington (U.S. Government Printing Office)

Warris,J.,1988 - The geology of the Mount Horner Oil Field, Perth Basin, Western Australia. APEA Journal, 28(1), 88-99.

Wernicke, B. & Burchfiel, B.C.,1982 - Modes of extensional tectonics. Journal of Structural Geology, Vol.4, No.2, 105-115.

APPENDIX-1

EDEL-1 INTERPRETATION

APPENDIX-1

EDEL-1 INTERPRETATION

A number of interpretations for the section intersected in the Edel-1 well have been made by various authors in the past. A total of 2395 metres of redbeds were encountered by the well without reaching the base of the unit. They consist of predominantly iron stained red sandstones with interbedded conglomerates, siltstones and volcanics. Controversy surrounds the palaeontological age determinations obtained for samples from the well as the dates obtained are rumoured to be contamination from a previous well. These samples were collected in the junk basket and provided a sparse flora from dark grey shales whereas the sidewall core samples yielded no palynomorphs as one would expect for a highly oxidised red bed sequence. However, some Triassic ages were determined from cuttings from the interval corresponding with the junk basket sampling (but these have been questioned). A Cretaceous age determination from the red bed sequence is assumed to be up-hole contamination.

A recent and lengthy conversation with Murray Johnstone (ESSO Australia) is set out here (Murray was with WAPET at the time when Edel-1 was drilled by Ocean Ventures):

* The Well Completion Report honoured the palaeontology and named the sequence as the Edel Formation of Permo-Triassic age. Ocean Ventures, were very concerned about the apparent contradiction between the lithostratigraphy and palaeontology results for the thick red bed sequence intersected in the well. Ocean Ventures therefore contacted WAPET who had the most experience in the sedimentary geology of this part of the continent. They tracked the recent drilling history of the drillship that drilled Edel-1 and noted from the tour reports that the junk basket used on the Edel-1, well for collecting the rocks that yielded palaeontological specimens, had been last used on the North-West Shelf while drilling a deep Triassic aged section for Woodside Petroleum. The samples chosen from the junk basket for analysis were dark grey shales; a lithology not otherwise intersected in the Edel-1 well. Murray Johnson concludes that a dirty junk basket was run into the hole.

* The logged wells (onshore) in the region including Yaringa-1, Kalbarri-1, Shark Bay-1, Dirk Hartog-17B and the Denham town bore bottomed in the same sandstone dominated red bed sequence which has been dated as Silurian in Shark Bay-1 and Kalbarri-1 using conodonts.

This lithology is the same as that intersected in the Edel-1 well.

* All the Permian in the Perth and Carnarvon Basins is typically very carbonaceous with disseminated woody maceral throughout.

  Hocking et al (1987) also conclude that the sequence is Silurian Tumblagooda Sandstone intruded by igneous hypabyssal rocks. This is based primarily on the lithostratigraphic correlation with nearby wells and the outcrop onshore. For this section to be other than Tumblagooda Sandstone requires the presence of a major down to the west, basin margin fault with a throw in excess of 2000 metres, located between the well and the present coastline. No such fault is evident on the gravity or magnetics in the region or on the seismic lines which approach the shore-line.

Lynton Jaques, an igneous petrologist with the BMR, made the following remarks regarding the volcanics encountered in Edel-1:

* The petrology report and the Potassium/Argon dating report indicate that the original radiometric dating is essentially correct (definitely not Silurian), but required recalculation with a revised decay constant. The ages for the six deepest samples were recalculated as 261-267 Ma $\pm$ 5 Ma. This is consistent with a Kungurian to Kazanian age (TS P3- P4) in the Late Permian (Harland et al., 1982). The age determinations from the shallower samples are unreliable because of weathering or the use of pyroxene rather than biotite. The date from the shallowest sample was made from a pyroxene concentrate (less reliable for dating due to low K and Ar concentration) and the sample beneath that was based on biotite from altered ?trachyte. The most reliable ages were obtained from biotite from little altered lamprophyres which were also the deeper samples.

* The igneous material is classified as trachyte, phonolite and lamprophyre. The lamprophyres were either shallow intrusions (shallower than 1000 m) or volcanic, whereas the trachytes and phonolites are interpreted as volcanic as they contain flow banding (trachytic texture). On this basis the section intersected in the Edel-1 well must be Permian with interlayered volcanics.

Thin sills and dykes can exhibit flow banding as well as chilled margins containing glass (Reeckman & Mebberson, 1984). The rock resulting from magma injecting into water filled porous sandstone is also likely to exhibit a near surface texture (less than 1000 metres) at depths consistent with the deeper igneous rocks encountered in the well.

The igneous rocks are essentially the same age so if they are volcanic then the deposition of the 3000+ metres of sandstone dominated redbeds in the Edel-1 locality must have occurred very rapidly at a time when much slower sedimentary deposition was occurring in the Perth and Carnarvon basins.

Hypabyssal rocks of this approximate age have been intruded at many localities along the western margin of Western Australia. Reeckman & Mebberson (1984) summarises many of these, concentrating on the Canning Basin region:

Perindi-1: "Basalt to dolerite dyke ,156 metres thick with several thin stringers of basalt above and below the main body. The dolerite is a quenched intrusion white to green at its margins grading to black at its less altered centre. It is coarse to fine grained and grades from dolerite to basalt with patches of devitrified glass. Minerals present include plagioclase laths and augite with minor magnetite ilmenite pyrrhotite and quartz in a groundmass of devitrified glass and fine grained plagioclase."

This is part of a dyke swarm in the offshore Canning Basin and is dated by the fission track method at 255±Ga which coincides with the Tatarian stage of the Late Permian. This age is supported by stratigraphic relationships.

Fraser River-1 and Barlee-1: Microgabbro laccoliths intruded during the Late Permian based on fission track dating and stratigraphic relationships. Located in the north-west, onshore Canning Basin.

Pearl-1, Wamac-1 and Bedout-1: Dolerite dykes intruded during the Late Permian to earliest Triassic based on radiometric dating, fission track dating and stratigraphic relationships.

Enderby-1: rhyolites of probable Permian age (based on stratigraphic relationships) intersected in the offshore Carnarvon Basin.

The detailed textural description given for the dyke intersected in Perindi-1 is very similar to the description of the igneous suite encountered in Edel-1, as described by Le Maitre in the Well Completion Report (Ocean Ventures, 1972).

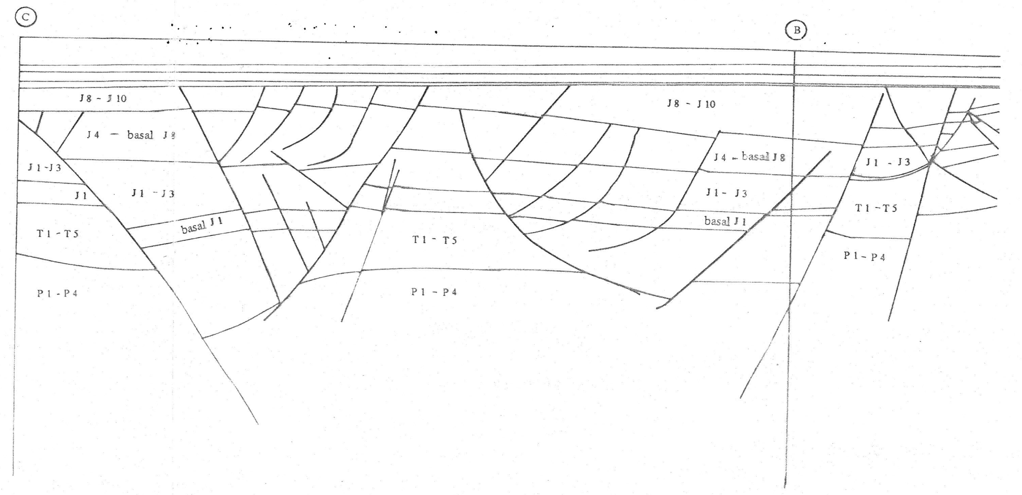
This study therefore prefers the interpretation that the Edel Volcanics are an intrusive dyke swarm intruded into water saturated porous and permeable Silurian Tumblagooda Sandstone, resulting in the substantial domal structuring of the upper part of this unit.

The other possible interpretation is explained in detail by Smith & Crowley (1987) who conclude that a thick Late Permian to Triassic sandstone red bed sequence was sourced from the nearby Tumblagooda Sandstone and was deposited very rapidly at the same time as vulcanism and shallow igneous intrusion. Their interpretation hinges on the Triassic palynological age determinations and implies that volcanism occurred from the Permian to the Late Triassic (a period of 50 million years).

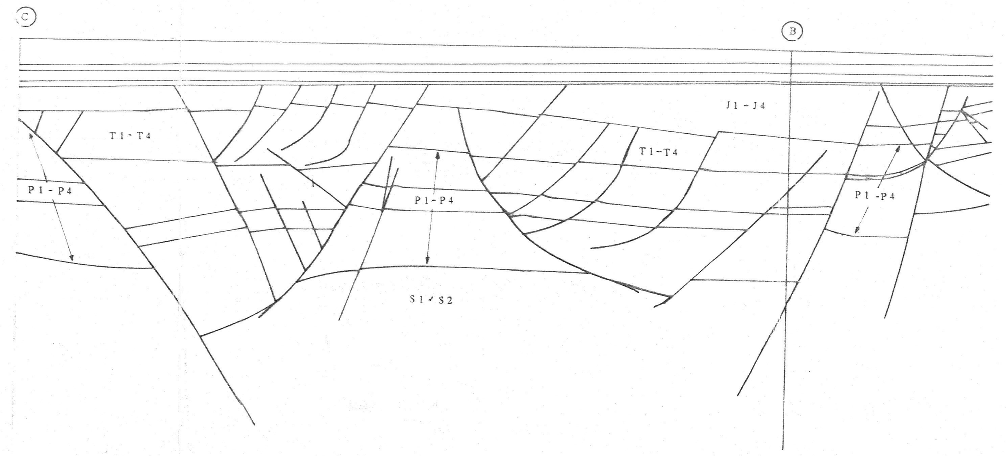
NORTH PERTH BASIN STRUCTURAL CROSS - SECTION & BIOSTRATIGRAPHY

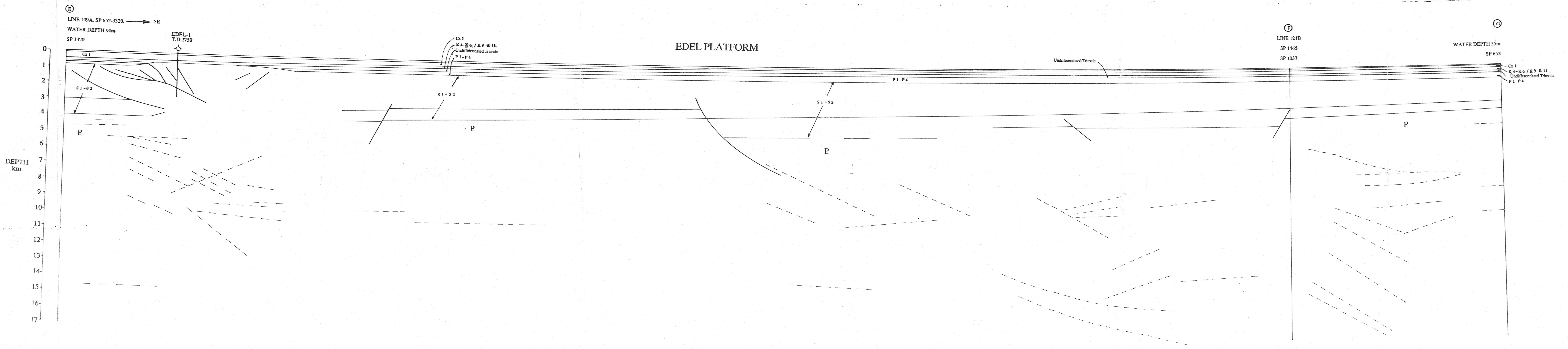
ROBERT SEGGIE

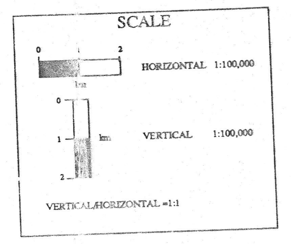
ALTERNATIVE INTERPRETATION 1

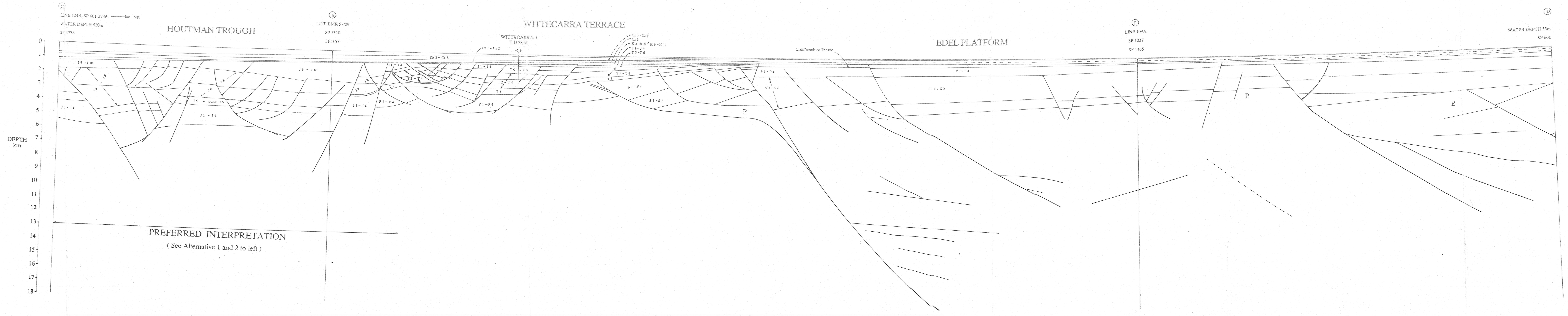


ALTERNATIVE INTERPRETATION 2

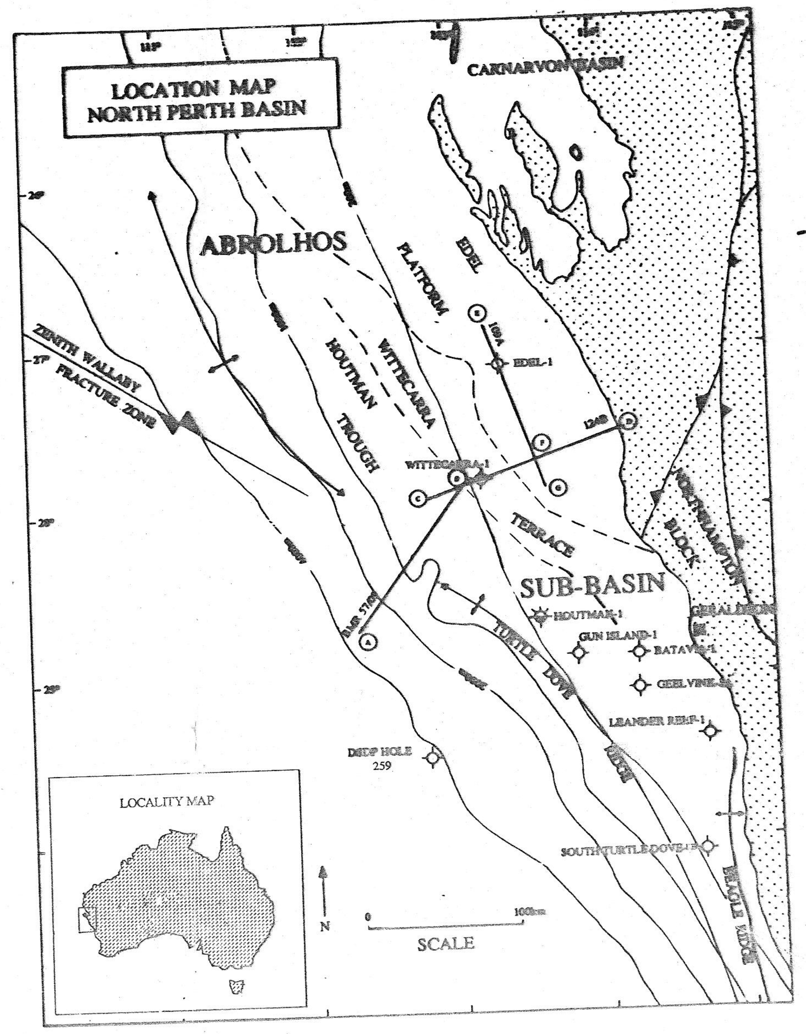


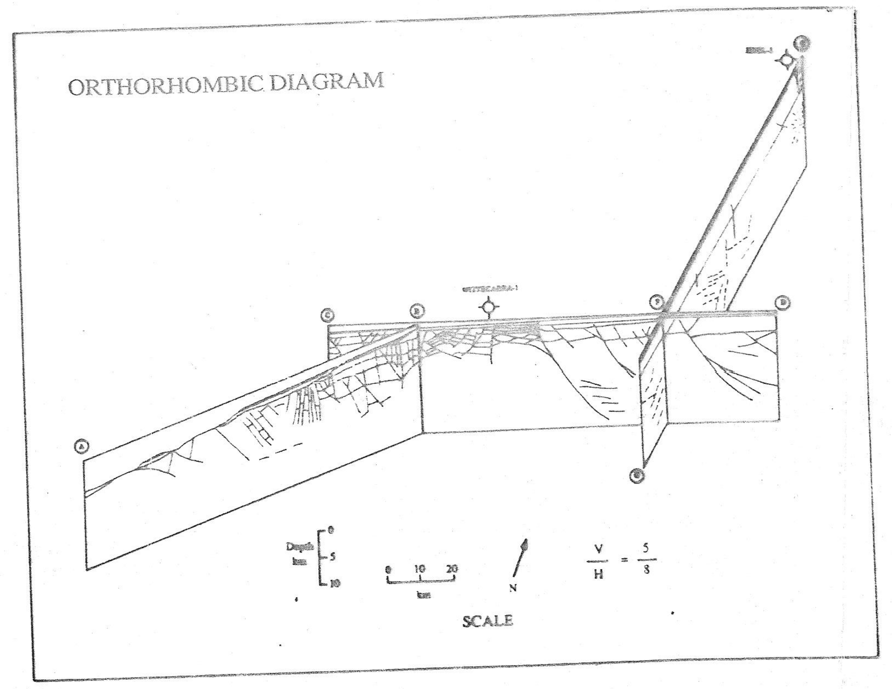


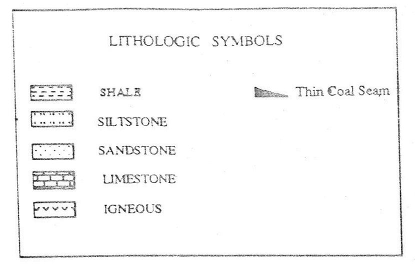


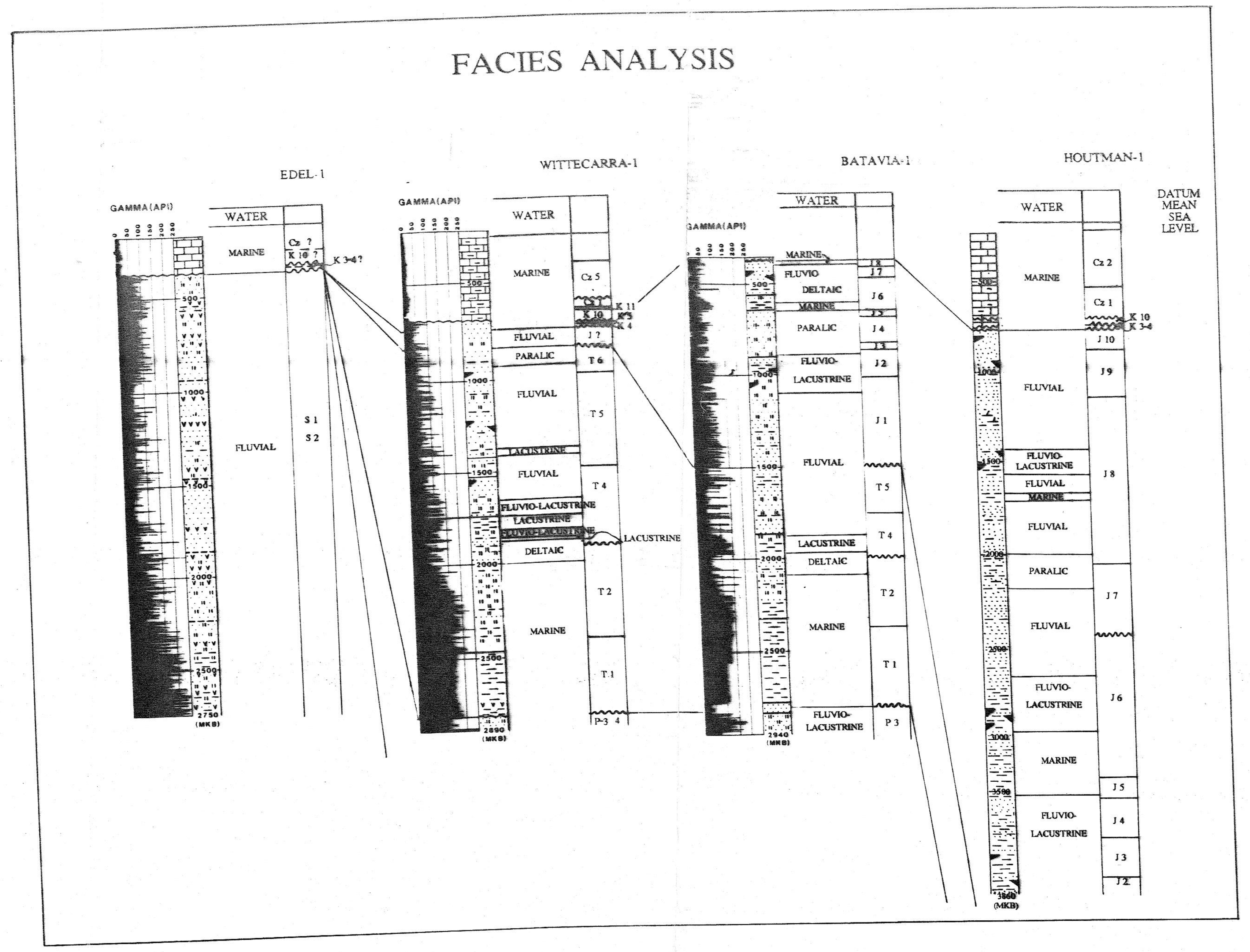


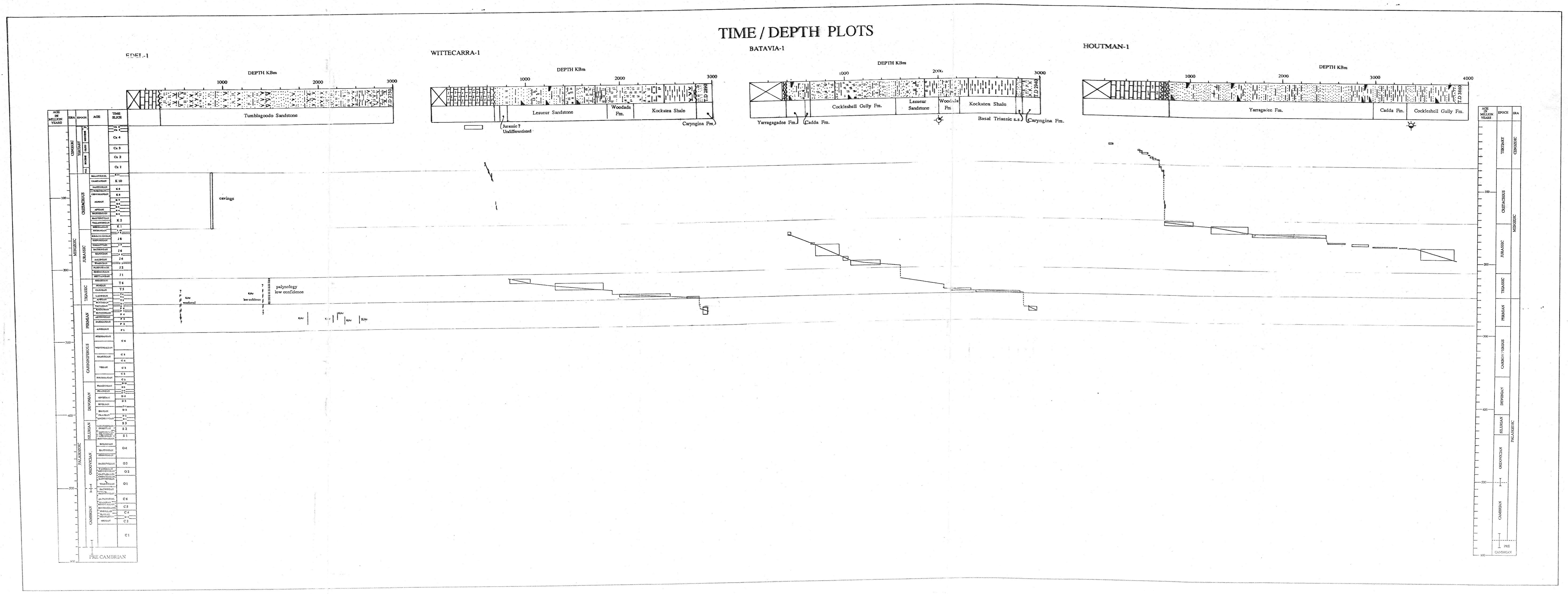
1990/65

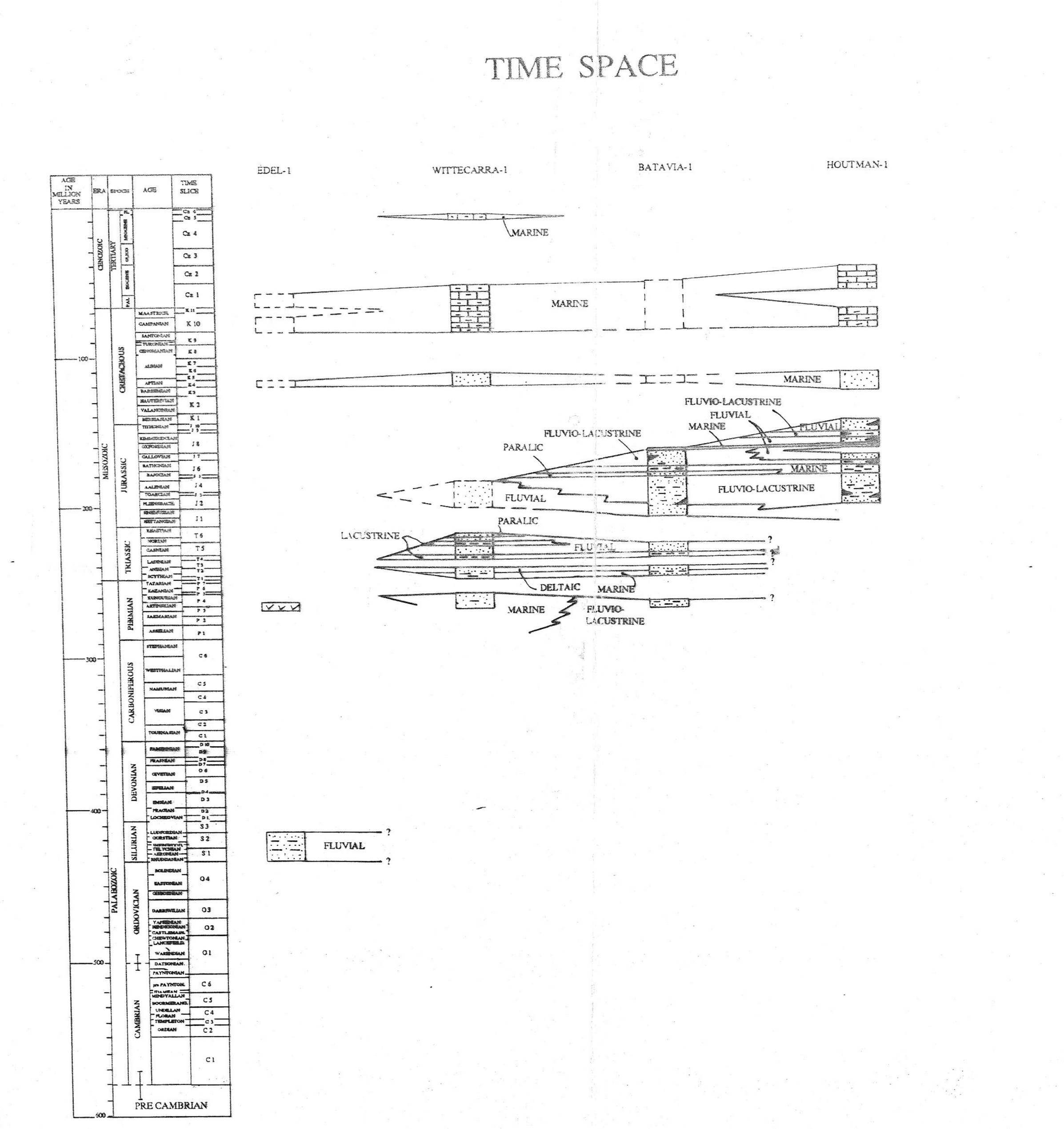












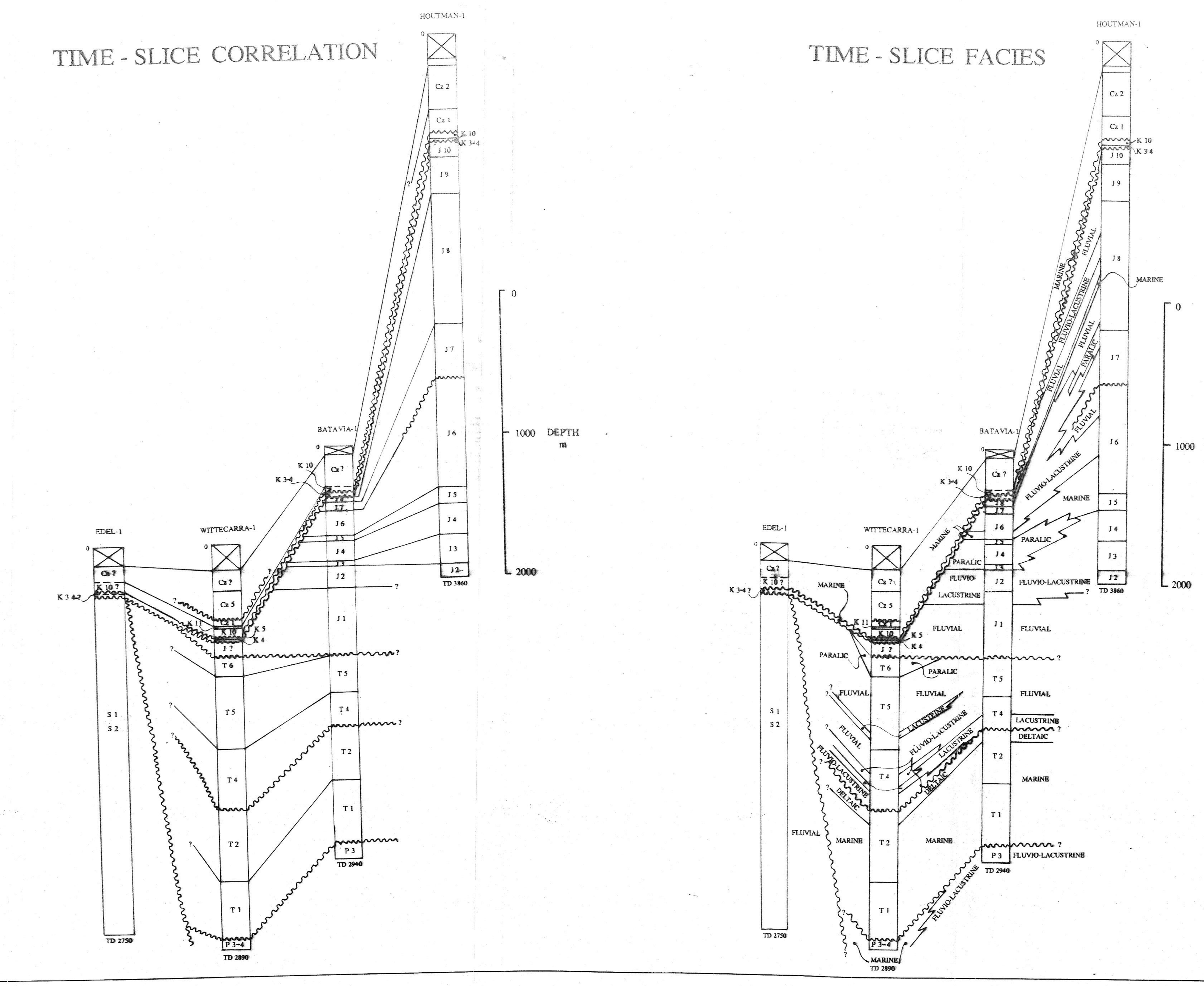


PLATE 1

Drafted by	John Vizy
Version 1	January, 1990

(Palaeogeographic Maps Project -Phase 2)

Phanerozoic History of Australia
Project 175A

NORTH PERTH BASIN

PLATE 2

BHP Petroleum

SURVEY : HARTOG PERMIT : WA-196-P

LINE : 124B

SHOT POINTS: 601-2639/2640-3039/3040-3736

MIGRATED STACK
[MERGED]

NORTH-EAST

RECORDING PARAMETERS

NORTH PERTH BASIN

PLATE 3

BHP Petroleum

SURVEY : HARTOG PERMIT : WA-196-P

LINE : 1243

SHOT POINTS: 601-2639/2640-3039/3040-3736

MIGRATED STACK
[MERGED]

NORTH-EAST

RECORDING PARAMETERS

PROCESSING SEQUENCE