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AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

AUSTRALIAN PETROLEUM SYSTEMS

DAMPIER SUB-BASIN MODULE

Volume 1

by
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INTRODUCTION

PURPOSE

The project aim is to apply the time slice palaeogeography concept to the Dampier Sub-basin area. The time slice concept was developed in, and is based on the work of the BMR-APIRA Palaeogeographic Maps and Phanerozoic History Projects.

From the time slice defined palaeogeography the project has examined the controls on source, seal, reservoir distribution, and the structural and potential maturation history of the Dampier Sub-basin.

The analysis is based on information from 30 wells and examination of in excess of 3000 km of seismic line data. Results are presented as time slice data and palaeogeographic interpretation maps, regional cross sections and summary tabulations.

PALAEOGEOGRAPHY AND PETROLEUM SYSTEMS SUMMARY

The Dampier Sub-basin is an amalgam of the Gondwanan and the Westralian Petroleum Super Systems.

Gondwanan Petroleum System

Earliest Gondwanan sedimentation (Time Slice TR1) is a major marine transgression over older sediments of the Enderby Terrace. The transgression peaked at the end of Time Slice TR3 and was followed by erosion in Time Slice TR4. This event ended the Gondwanan Petroleum System. Deltaic and fluvial meander belt systems prograded from the north and north east onto a restricted shallow marine shelf. On the Enderby Terrace a basal reworked transgressive sandstone reservoir is overlain by a shelf claystones. These claystones are the first regional source and seal rock in the area. Oolitic shelf carbonates, interbedded with the shelf claystones, are an additional reservoir. On the Enderby Terrace the source interval matured in the late Cainozoic. Elsewhere the Gondwanan Petroleum System is deeply buried and would have matured during Time Slices J7 to J10. There have been no discoveries in the Gondwanan Petroleum System. Potential exists for hydrocarbons sourced from within the system to be reservoired within the Westralian Petroleum System.

Westralian Petroleum System:

All discoveries have been within this petroleum system. The giant gas condensate fields of the Rankin Trend (Time Slices TR5 to J1) are reservoired in fluvio-deltaic and marginal marine sands that are likely sourced from prodelta and lower delta plain fine grained facies. The oil reserves of the Lewis Trough area occur at the top of mass flow sequences (Time Slices J9 to K1), the oil being sourced from associated organic rich basin shales(Time Slice J6 to J10). The adjacent Enderby Terrace is on a migration pathway for oil sourced from the Lewis Trough.

The Westralian Petroleum System commenced in Time Slice TR5. Deltaic lobes built out from the southeast, with marginal marine conditions in the central area and shallow marine shelf sediments in the northwest. During Time Slice TR6 the delta systems prograded into the Rankin area the best source rock being associated with the lower delta plain facies. Tidal channel and beach deposits fringe the deltaic system and are the best reservoirs. Point bars, fluvial and estuarine channel and offshore bars are present.

Tectonism in Time Slice J1 resulted in an area northwest of the Enderby Terrace becoming a major depocentre. A marine regression exposed the Enderby Terrace resulting in incision. Following this a late Time Slice J1 transgression resulted in reworked transgressive sands on the Terrace. Deltaic lobes now prograded from the southeast onto a low energy shallow marine shelf. The transgression peaked in Time Slice J2 and J3 when an oolitic bank was deposited in the Gandara area and limestones on the Enderby Terrace. This broad palaeogeography was maintained until Time Slice J5 although carbonate deposition was reduced.

The depocentre northwest of the Enderby Terrace became the Lewis Trough at the end of Time Slice J5, the result of major tectonism. Volcanism occurred in the hinterland. From Time Slice J6 to J7 deltas prograded across the Enderby Terrace and input sediment directly into the Lewis Trough. The Enderby Terrace was episodically exposed and Time Slice J6 and J7 sediments eroded. The best source rock correlates with the prodelta facies of these shelf edge deltas. The Rankin Platform margin acted as a dam to sediment from the east. The Rankin Trend was either sub-aerially exposed or very shallow marine. The arkosic sandstones related to the volcanism are not the best quality reservoirs due in part to diagenetic porosity reduction.

From Time Slice J8 to J10 the Lewis Trough was a restricted marine embayment even though the sea level was very high. Sedimentation in the Lewis Trough was characterised by mass flow depositional lobes and organic rich basin claystones. The Lewis Trough was filled by the end of Time Slice J10. A coastal zone in the hinterland is thought to have fed the sand into the proximal end of submarine channels that terminated at the Lewis Trough. Major depositional lobes occur near Montague, Angel, Legendre, Rosemary and probably Malus. The background sedimentation is marine claystones with episodic indications of anoxia. These claystones are the most oil prone source rocks encountered with the best quality occurring towards the northeastern end of the trough. Major oil accumulations are reservoired within the uppermost sands of the depositional lobes being sourced from the adjacent claystones. Hydrocarbons from this mature source have migrated into reservoirs on the adjacent Rank Trend and Enderby Terrace.

A key to the prospectivity the Westralian Petroleum System is the extremely effective regional seal facies formed by claystones of Time Slices K2 to K7.

A continuing sea level rise in the earliest Cretaceous established open oceanic circulation but major sediment supply to the trough was abruptly terminated. Distal prodelta deposits sourced from the southwest are good source rocks in earliest Time Slice K1. Minor mass flow deposits occur in the Talisman area. In Time Slice K2 an early margin sag phase hinged on the Rosemary Fault System and characterised by extreme clastic starvation is established. Henceforth deposition is in open marine shelf, shelf slope and base of slope environments.

Glauconitic sandstone deposition is characteristic of the outer and middle shelf environments on the Enderby Terrace from Time Slice K1 onwards. The shelf slope and basin deposits are mainly siltstones and claystones. Carbonate content increases offshore. The best source rocks occur in middle to outer shelf and shelf break environments in the vicinity of Rosemary, an area that is also a locus for minor clastic sediment input. The early margin sag transgression peaks in Time Slice K4 when the coast is probably far to the east. By this time the Rankin Trend, a positive submarine topographic feature has been onlapped and buried by a thin claystone sequence.

Major margin sag commenced in Time Slice K5-K7. Fine grained carbonate deposition on an extremely clastic-starved marine shelf and shelf slope environment dominates the remainder of the Cretaceous Time Slices and forms a regional basin seal. Oceanic oxygen minima events occur in Time Slices K8 and K9. The best source rocks occur in upper slope deposits but lack maturity. A minor clastic source is still centred on the Rosemary area.

In Time Slice Cz1 a major sea level fall occurred. A zone of glauconitic sandstone is predicted to have formed on the shelf margin at this time. These glauconitic sandstones are of reservoir quality but require fault migration from underlying source.

Post Time Slice Cz1 deposition is poorly constrained by palynological data and is not discussed here.

PLAY ANALYSIS SUMMARY

I. The Dampier Sub-basin is a low risk exploration area with a current success rate for exploration wells greater than 50% and may be as high as 80%.

II. Hampton 1, Montague 1, Withnell 1 and Saturn 1 have been identified as wells with potential for additional assessment.

III. There is geological evidence to indicate a Triassic, or older, source for the gas condensate discoveries. It is not established from purely geological criteria wether the Jurassic is a source of gas condensate but it is certain that the Jurassic is a source of oil. The Triassic section could also be a source of oil although there is no conclusive empirical geological evidence available to us to make this assessment.

IV. Evidence suggests an abundance of hydrocarbons for the available traps particularly in the Lewis Trough and Rankin Trend areas. Many of the discoveries in reservoirs beneath the base Cretaceous seal facies are apparently filled to spill point.

V. Reservoir quality varies, but in general, there does not appear to be a significant cut off depth yet established for the basin and factors such as overpressure and drilling expense rather than reservoir quality, appear to be controlling drilling depths.

VI. There are a number of untested, potentially oil prone, play types on the Enderby Terrace and Lewis Trough area.

VII. Gandara 1 and Saturn 1 drilled in the Kangaroo Syncline area both drilled into structures that are immature at total depth and that had extremely poor access to more mature areas. Very large untested structures that drain large areas of deeper mature source exist in the area and are considered to be good prospects.

VIII. Seismic stratigraphic interpretation shows there are potential reservoir facies encased in mature oil prone source rock within the Lewis Trough, but these are stratigraphic rather than structural plays.

ACKNOWLEGMENTS

In the preparation of this report, significant time and effort was contributed by members of the Australian Petroleum Systems Group and others within AGSO. Without the dedication of those involved, the project study would have been less extensive and correspondingly certain products would not have been produced.

Lynton Spencer and John Needham, senior authors of this report, were mainly responsible for the geological and geophysical interpretation, respectively. In conjunction with other members of the Group, the senior authors were involved in all of the other aspects of the study.

John Bradshaw is the manager and co-ordinator of the Australian Petroleum Systems Group and was responsible for the organisation of geological and geophysical information for the project study as well as producing various data outputs from STRATDAT and ORGCHEM database for analysis. Based on his experience in the previous Projects, John has provided valuable technical information and assistance to the Stage III Project.

Marita Bradshaw, based on her experience in the previous Palaeogeographic Map Projects, synthesized the results of the Dampier Sub-basin analysis into a petroleum system framework and provided valuable technical information and assistance.

Clinton Foster was involved with the organisation of the STRATDAT database and contributed towards the analysis of the biostratigraphic data which was synthesised by Alan Partridge.

Technical support was provided by Scott Edgecombe, John Vizy and Giuliana Zuccaro, this ranged from data collation and writing software programs to generating the various products.

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John Wilmot and Steve Winn are colleagues who worked on the Browse Sub-basin Module. They provided the introductory sections on methodology and time slice data used in this report.

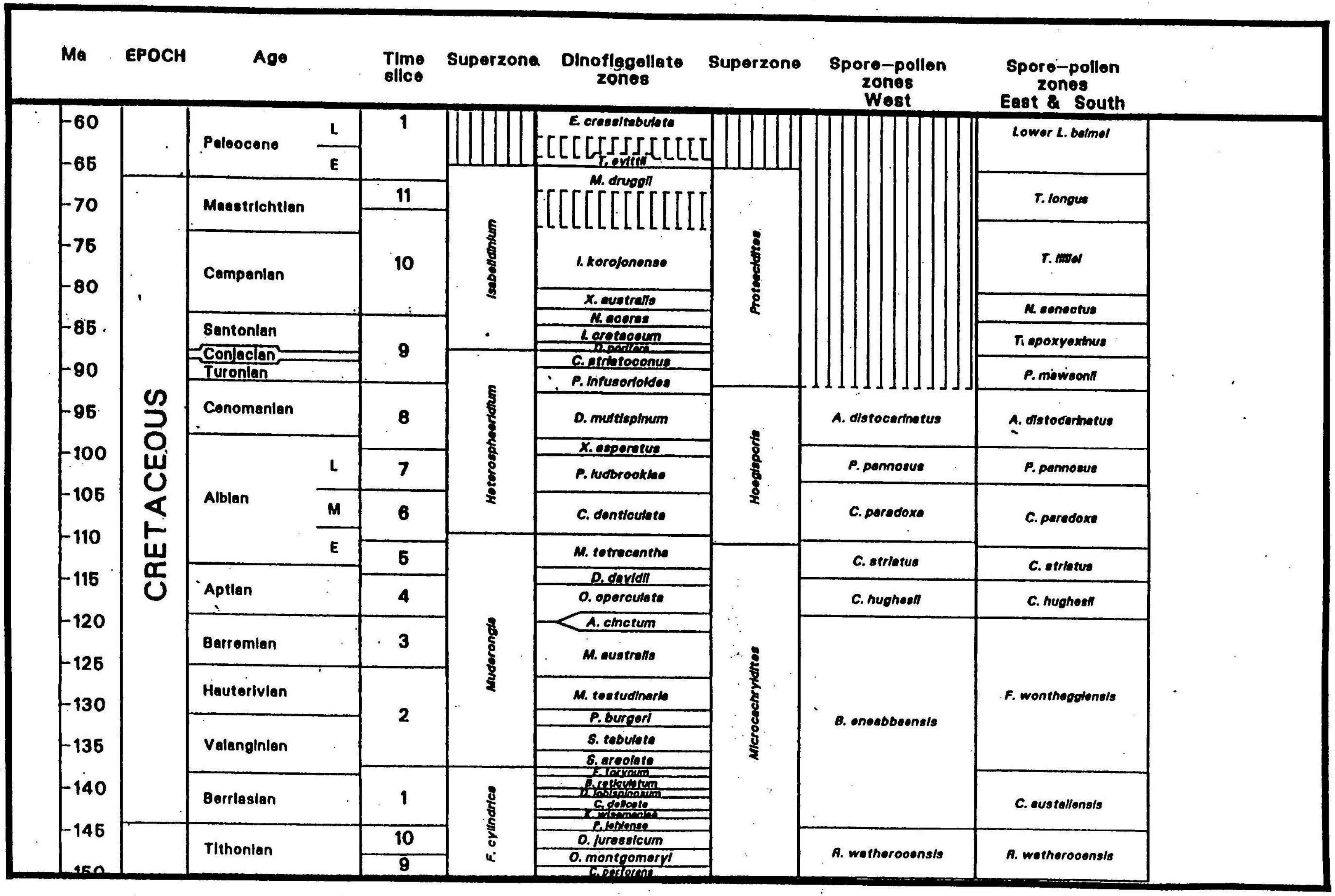


Figure 1 Cretaceous time slices versus fossil zonations

TIME SLICE DEFINITION AND BOUNDARIES

Biostratigraphic schemes used in the study are:

(1) Integrated dinoflagellate and spore-pollen zonation of the Australian Mesozoic developed by Helby et al (1987)

(2) Foraminiferal zonation for the North West Shelf (Wright, 1977; Heath & Apthorpe,1981,1984; Apthorpe, 1988)

(3) Foraminiferal zonation for the Cainozoic (Blow, 1969, 1979; Berggren, 1969; Kennett & Srinivasan, 1983)

(4) Australian Phanerozoic Timescales Volume 1 - 10 (Shergold, 1989; Webby & Nicoll, 1989; Strusz, 1989; Young, 1989; Jones, 1989; Archbold & Dickens, 1989; Balme, 1989; Burger, 1989a; Burger, 1989b; Truswell et al, 1989).

These schemes are referenced to the Harland 1982 Time Scale (Harland et al, 1982).

The time slice boundaries occur at natural breaks in sedimentation or changes in facies that are common to several basins. Some time slices are representative of geological events that have continent wide effects.

There are difficulties in selecting time slices that are applicable across Australia due to contrasting depositional and tectonic regimes as well as from differences in biostratigraphy such as the spore-pollen zonations in Eastern Australia and dinoflagellate zones in western Australia.

The precise correlation, duration and absolute ages of the time slices were derived from lengthy consultation with many biostratigraphers, industry sponsors and the State Geological Surveys. The time slices are the basis of the products in both the Palaeogeographic Maps Project and the Phanerozoic History of Australia project. Thus the details presented in this study can immediately be related to more regional concepts and maps already produced.

Key time slices interpreted in the Dampier Sub-basin study are within the Triassic, Jurassic, Cretaceous and Tertiary periods. A total of six time slices for the Triassic, ten time slices for the Jurassic, eleven for the Cretaceous and seven for the Tertiary have been utilised from the previous projects.

The selection criteria for these time slices are discussed in the following sections and illustrated in Figures 1 & 2 and shown in Enclosure 3. They are derived from Bradshaw & Yeung 1992 and Bradshaw et al (in prep).

Detailed definitions of the Triassic and Cainozoic Time Slices are not yet available. Enclosure 3 summarises the spore-pollen, dinoflagellate and foraminiferal zones and related Time Slice boundaries.

JURASSIC TIME SLICE J1: HETTANGIAN TO SINEMURIAN (213 - 200 Ma)
Jurassic/Triassic boundary is not marked biostratigraphically. It occurs within the *A. reducta* and *P. crenulatus* spore-pollen zones, and the *D. priscum* dinoflagellate zone.

Ma	EPOCH	Age	Time slice	Superzone	Dinoflagellate zones	Superzone	Spore-pollen zones West	Spore-pollen zones East & South
140		Berriasian	1	*F. cylindrica*	*E. torynum* *B. reticulatum* *D. lobispinosum* *C. delicata* *K. wisemaniae*			*C. australiensis*
145, 150	JURASSIC	Tithonian	10 9	*F. cylindrica*	*P. iehiense* *D. jurassicum* *O. montgomeryi* *C. perforans*		*R. watherooensis*	*R. watherooensis*
155	JURASSIC	Kimmeridgian	8	*Pyxidiella*	*D. swanense* *W. clathrata*	*C. dampieri*	*M. florida*	*M. florida*
160	JURASSIC	Oxfordian	8	*Pyxidiella*	*W. spectabilis*	*C. dampieri*	*M. florida*	*M. florida*
165	JURASSIC	Callovian	7	*P. ceratophora*	*R. aemula* *W. digitata*	*C. dampieri*	*M. florida*	*M. florida*
170, 175	JURASSIC	Bathonian	6	*P. ceratophora*	*W. indotata* *C. halosa*	*C. dampieri*	*C. cooksoniae*	*C. cooksoniae*
180	JURASSIC	Bajocian	5	*P. ceratophora*	*D. caddaense*	*C. dampieri*	Upper / Lower *D. complex*	*D. complex*
185	JURASSIC	Aalenian	4			*C. dampieri*	*C. turbatus*	*C. turbatus*
190	JURASSIC	Toarcian	3 2			*C. dampieri*	*C. turbatus*	*C. turbatus*
195	JURASSIC	Pliensbachian	2	*Shublikodinium*	*D. priscum*	*C. dampieri*	*C. torosa*	*C. torosa*
200, 205	JURASSIC	Sinemurian	1	*Shublikodinium*	*D. priscum*	*C. dampieri*	*C. torosa*	*C. torosa*
210	JURASSIC	Hettangian	1	*Shublikodinium*	*D. priscum*	*C. dampieri*	*C. torosa*	*C. torosa*
215		Rhaetian	6	*Shublikodinium*	*R. rhaetica*		*A. reducta*	*P. crenulatus*
220, 225	C	Norian		*Shublikodinium*	*H. balmei* *S. listeri*		*M. crenulatus*	*P. crenulatus*

Figure 2 Jurassic time slices versus fossil zonations

JURASSIC TIME SLICE J2: PLIENSBACHIAN TO EARLY TOARCIAN (200 - 191 Ma)
Time Slice J2 corresponds to the *N. vallatus* datum. Marked by facies change in many basins and commencement of deposition in others, eg on the northwest margin there was a facies change from marginal marine clastic sediments to shallow water limestone.

JURASSIC TIME SLICE J3: EARLY TO MIDDLE TOARCIAN (191 - 189 Ma)
Time Slice J3 is marked by a distinct change in lithology and depositional environment in the Surat and other eastern Basins. It corresponds to *Applanopsis spp*, and is marked by the development of ironstone oolite beds within the Evergreen Formation and its equivalents.

JURASSIC TIME SLICE J4: LATE TOARCIAN TO EARLY BAJOCIAN (189 - 180 Ma)
Time Slice J4 corresponds to the commencement of deposition of the Hutton Sandstone in the Eromanga and Surat Basins, the Algebuckina Sandstone in the Poolowanna Trough, the Cattamarra Coal Measures in the Perth Basin, and the expansion of deposition in the Papuan Basin. Biostratigraphically it is loosely defined as occurring within the lower part of the *C. turbatus* zone.

JURASSIC TIME SLICE J5: EARLY TO MIDDLE BAJOCIAN (180 - 177 Ma)
Time Slice J5 is marked by a marine transgression in the Perth Basin. It is biostratigraphically defined by the *D. caddaense* dinoflagellate zone. Ammonites contained within sediments of Time Slice J5 in the Perth Basin allow direct correlation with the European stages.

JURASSIC TIME SLICE J6: LATE BAJOCIAN TO EARLY CALLOVIAN (177 - 167 Ma)
The base of Time Slice J6 equates with the top of *D. caddaense* dinoflagellate zone. Stratigraphically, the base of the time slice coincides with the end of the Cadda transgression in the Perth Basin and the top of the time slice equates to the regional "Callovian Unconformity" seen in several basins on the North West Shelf.

JURASSIC TIME SLICE J7: MID CALLOVIAN TO EARLY OXFORDIAN (167 - 162 Ma)
The base of Time Slice J7 equates with the bases of the *M. florida* and *W. digitata* zones and the top is defined by the base of the dinoflagellate zone *W. spectabilis*. It also represents an episode of uplift and erosion, prior to the commencement of sea floor spreading, on the North West Shelf and coincides with the transition of the Hutton Sandstone deposition to a lower energy shale prone Birkhead Formation fluvio-lacustrine regime.

JURASSIC TIME SLICE J8: EARLY OXFORDIAN TO KIMMERIDGIAN (162 - 150 Ma)
Time Slice J8 encompasses the time of maximum transgression in the Jurassic. The top boundary coincides with an unconformity on the North West Shelf, the Papuan and Laura Basins. It also coincides with a facies change in many other basins. Biostratigraphically, the base of the time slice equates to the base of the *W. spectabilis* dinoflagellate zone and the top corresponds to major zonation boundaries in both dinoflagellate and spore-pollen schemes.

JURASSIC TIME SLICE J9: EARLY TITHONIAN (150 - 147. 5 Ma)
The base of Time Slice J9 is marked by a regional unconformity observed in the Papuan and Bonaparte Basins. It is defined biostratigraphically by the *C. perforans* and *O. montgomeryi* dinoflagellate zones and is within the lower part of the *R. watherooensis* spore pollen zone. Time Slice J9 represents a phase of relative regression on the North West Shelf that corresponded to a shift in the Eromanga Basin from low energy Birkhead deposition to the higher energy sandsheet regime of the Adori Sandstone.

JURASSIC TIME SLICE J10: LATE TITHONIAN (147. 5 - 144 Ma)
The base of Time Slice J10 corresponds to the base of the *D. jurassicum* dinoflagellate zone. The top of the time slice represents the Jurassic/Cretaceous boundary that lies within the *P. iehiense* dinoflagellate zone. The first appearance of *C. australiensis* pollen is used as the biostratigraphic definition of the base Cretaceous in Australia. Time Slice J10 also represents a transgressive phase following the regression of Time Slice J9.

CRETACEOUS TIME SLICE K1: BERRIASIAN TO EARLY VALANGINIAN (144 - 137 Ma) The base of Time Slice K1 is defined by the Jurassic/Cretaceous boundary, that is within the *P. iehiense* dinoflagellate zone and equates with the base of the *C. australianensis* spore-pollen zone.

CRETACEOUS TIME SLICE K2: VALANGINIAN TO HAUTERIVIAN (137 - 125 Ma)
The base of Time Slice K2 represents a major unconformity in many basins, particularly on the western margin of the Australian continent. It also corresponds to a major sea level fall on the Haq et al (1987) chart. Biostratigraphically the base is defined by the *E. torynum / S. areolata* dinoflagellate zone and the *C. australianensis / F. wonthaggiensis* spore-pollen boundary. It equates to the M10 magnetic anomaly and to the start of a major phase of sea floor spreading along the western margin in the Perth, Cuvier and Gascoyne Abyssal Plains.

CRETACEOUS TIME SLICE K3: BARREMIAN (125 - 119 Ma)
This time slice is characterised by transgression of the sea into central and western Australia. There is no direct biostratigraphic correlation to the Barremian stage, but it is based on a working definition equivalent to the *M. australis* dinoflagellate zone.

CRETACEOUS TIME SLICE K4: APTIAN (119 - 114 Ma)
Time Slice K4 records the peak marine transgression across the Australian continent. It is biostratigraphically defined by the dinoflagellate zones *A. cinctum, O. operculata* and *D. davidii*; and the *C. hughesii* spore-pollen zone. Time Slice K4 corresponds to changes in stratigraphy in many basins with the deposition of marine shales over sandstones in offshore basins.

CRETACEOUS TIME SLICE K5: EARLY ALBIAN (114 - 110 Ma)
Time Slice K5 encompass a period of sea level retreat. It equates to the *C. striatus* spore-pollen zone and approximates the *M. tetracantha* dinoflagellate zone.

CRETACEOUS TIME SLICE K6: MIDDLE ALBIAN (110 -104 Ma)
Continued regression occurred during Time Slice K6. The base of the time slice equates to the base of *C. paradoxa* spore-pollen zone and the top equates to the top of *C. denticulata* dinoflagellate zone.

CRETACEOUS TIME SLICE K7: LATE ALBIAN (104 - 99 Ma)
Time Slice K7 represents a transgressive episode and corresponds to a global oceanic anoxic event. Biostratigraphically it approximates the *P. ludbrookiae* dinoflagellate zone.

CRETACEOUS TIME SLICE K8: LATE ALBIAN TO CENOMANIAN (99 - 91 Ma)
During this time slice the sea retreated from the centre of the continent, but there is a rise in relative sea level on the western margin. It is biostratigraphically defined by the C2, C3a and C3b foram zones, approximates the *X. asperatus* and *D. multispinum* dinoflagellate zones and *A. distocarinatus* spore-pollen zone.

CRETACEOUS TIME SLICE K9: TURONIAN TO SANTONIAN (91 - 83 Ma)
Carbonate sedimentation became dominate on the western margin during this time slice. It is biostratigraphically defined by the C4 to C8 foram zones, the *C. triplex* and *T. pachyexinus* spore-pollen zones, and approximates the *P. infusorioides* to *I. cretaceum* dinoflagellate zones.

CRETACEOUS TIME SLICE K10: CAMPANIAN TO EARLY MAASTRICHTIAN (83 - 70 Ma)
Time Slice K10 corresponds to the commencement of sea floor spreading in the Tasman Sea. It is biostratigraphically defined by the C4 to C8 foram zones, the *N. senectus* and *T. lilliei* spore-pollen zones, and approximates the *N. aceras* to *I. korojonense* dinoflagellate zones.

CRETACEOUS TIME SLICE K11: MIDDLE TO LATE MAASTRICHTIAN (70 - 65 Ma)
Time Slice K11 is biostratigraphically defined by the C12 and C13 foram zones, the *M. druggii* dinoflagellate zone and the *T. longus* spore-pollen zone. Its top boundary represents the Mesozoic / Cainozoic boundary.

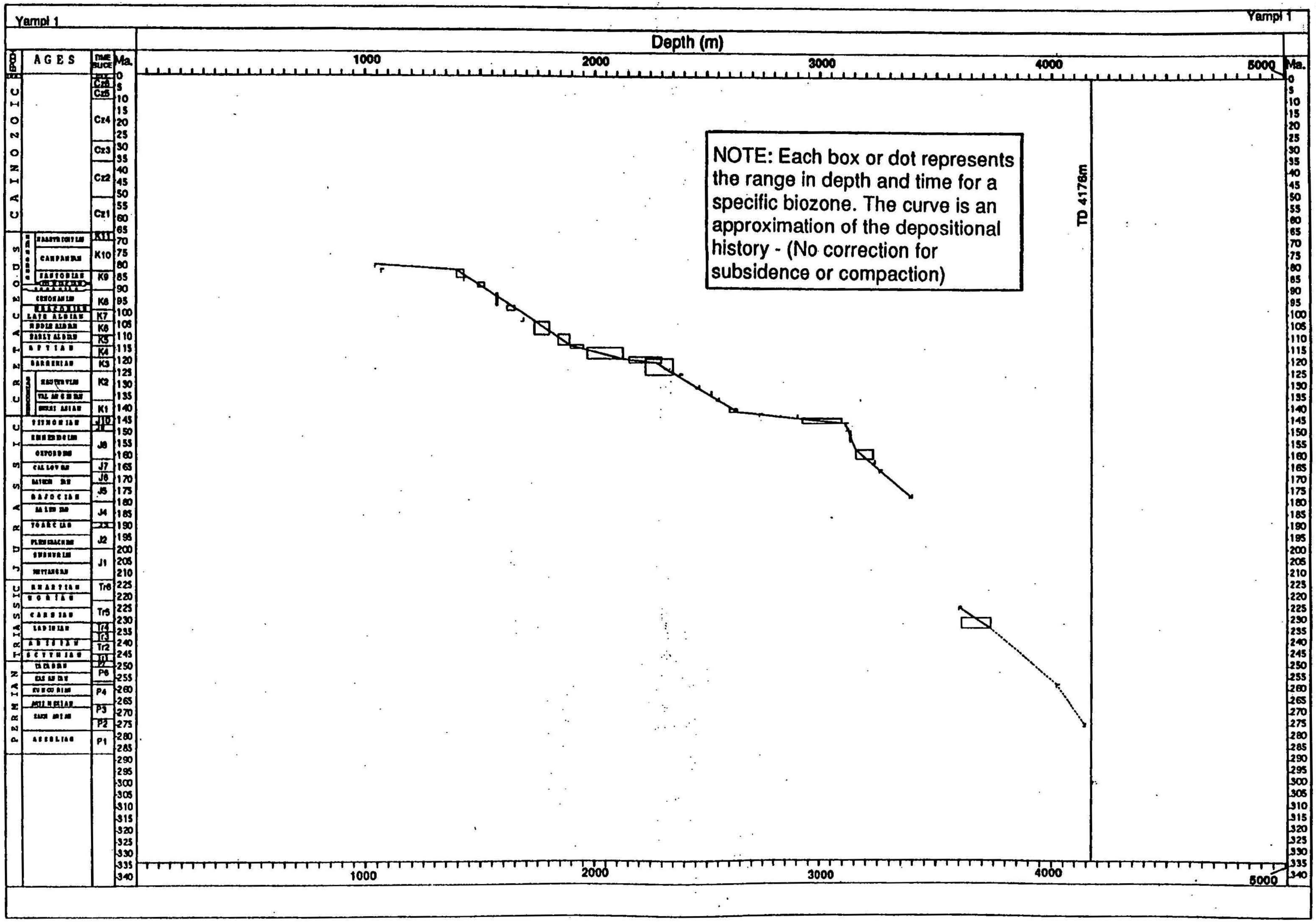


Figure 3 Example of an interpreted age/depth plot

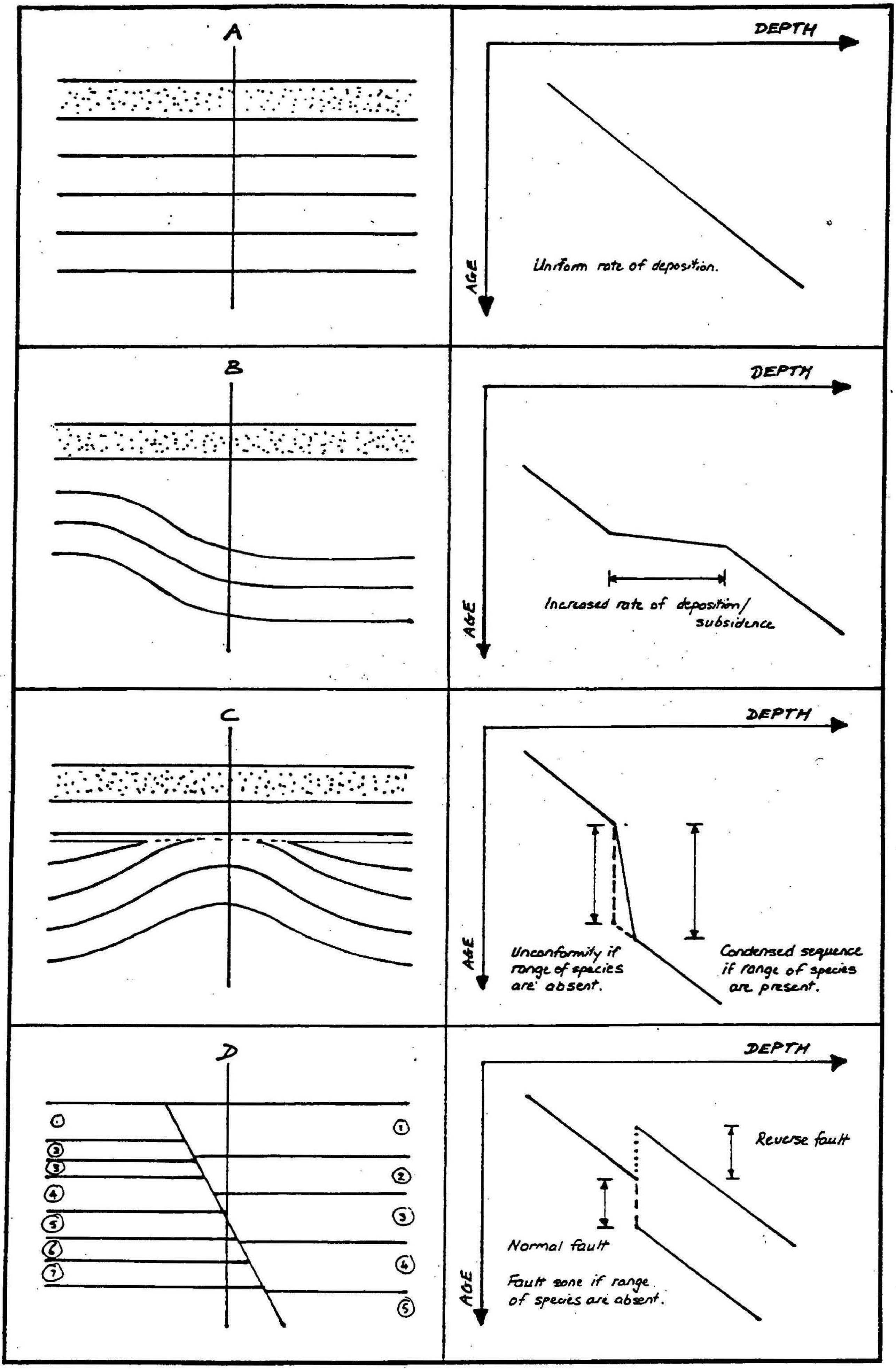
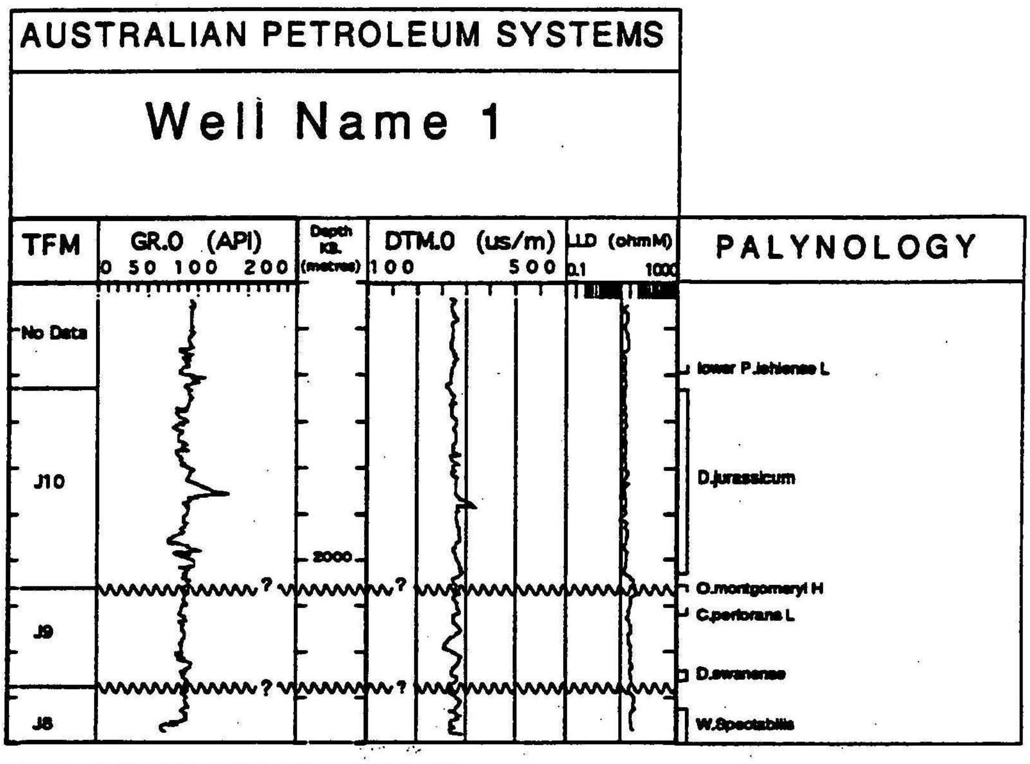


Figure 4 Schematic diagram of age/depth plot interpretations

LEGEND



TFM CODES FOR TIMESLICES

PALYNOLOGY SEE APPENDIX 1 & ENCLOSURE 3

Unconformity

Possible Unconformity or Condensed Sequence

VERTICAL SCALE 1:7 500

Figure 5 Legend for enclosures 4 - 9 displaying time slice boundaries (TFM).

METHODOLOGY

Biostratigraphic data from Well Completion Reports and published information were reviewed by consultant biostratigrapher Alan Partridge. Reinterpretation of the ages of palynological and palaeontological assemblages were conducted for the Dampier Sub-basin wells and documented into the STRATDAT database. Depths of occurrences of species zones were plotted against time slice ages, with associated codes representing highest or lowest known occurrences and youngest or maximum age determinations.

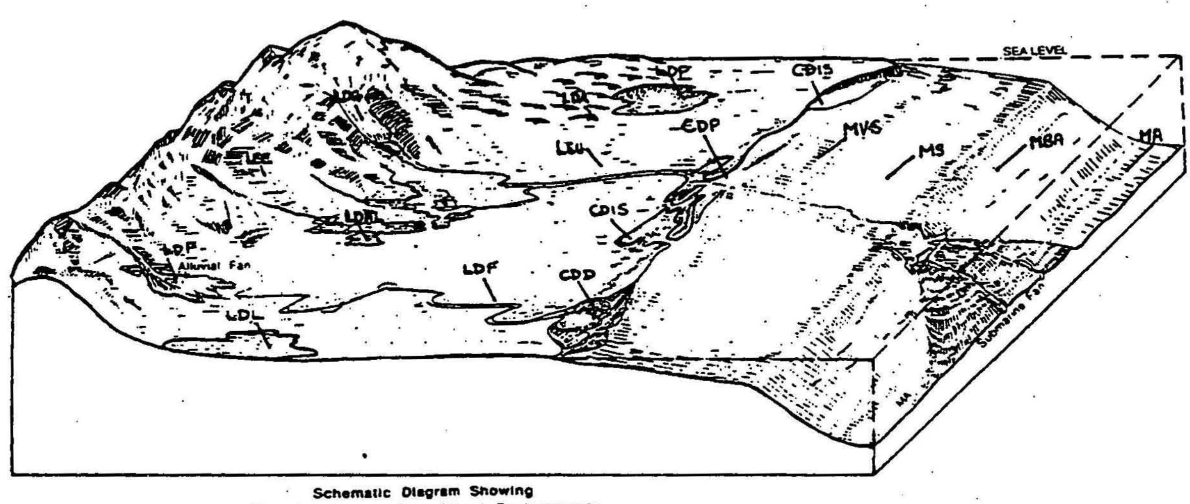
Age/depth plots were constructed to provide quick-look interpretations of apparent changes in the rate of sedimentation, presence of condensed sections, unconformities, and fault intersections at well locations. An example of an interpreted age/depth plot is shown in Figure 3, and an example illustrating age/depth plot interpretations is shown in Figure 4. Depths of time slice boundaries are derived from age/depth plots and correlated with wireline logs as shown in Figure 5.

The interpreted picks of the time slice boundaries from the age/depth plots have coincided with key sequence boundaries and marine flooding surfaces with reasonable consistency, thus providing confirmation of the picks of the chronostratigraphic surfaces from the log correlations and palaeogeographic maps.

Palaeoenvironmental interpretations were made mainly from gamma ray and sonic log signatures. Lithological descriptions from ditch cuttings, sidewall cores and conventional cores were used with log correlations to determine the facies type and depositional environments for each time slice.

Biostratigraphic data were also used to provide additional information on the environment of deposition from fossil content such as the ratio of spore-pollen to marine microfossils. Palaeoenvironments and palaeogeographies are reconstructed for selected time slices with codes representing the various depositional environments and landform elements provided in Figure 6 and Table 1.

CODE	ENVIRONMENT	WORKING DEFINITION
Land & land depositional environments		
LEU	Unclassified	Areas with no preserved sediments of time-slice age, interpreted as land, for example the Ashmore Platform. Also areas that are largely unknown that may have Jurassic sediments, such as the Queensland Plateau.
LEE	Erosional	Highland areas of sediment erosion, indicated by palaeocurrents, provenance studies, tectonic setting and the presence of igneous intrusions, for example the Arbum Arch.
LDF	Depositional, Fluvial	River deposits such as alluvial fans, braided and meandering channel deposits and coarser overbank sediments, and sand-dominated continental sequences with no evidence of aeolian or lacustrine deposition.
LDFL	Depositional, Fluvio-Lacustrine	Sediments deposited in low-energy river environments such as channels, overbanks, backswamps and shallow lakes on low-gradient floodplains; typically sequences dominated by fine-grained sediments and coal, with sheet geometry.
LDL	Depositional, Lacustrine	Deposits of deep, persistent lakes, usually in tectonically controlled basins. Distinguished from LDFL by thicker shales and more restricted distribution.
Coastal depositional environments		
CDP	Paralic	Deposits of coastal or marginal marine environments. Includes the range of environments situated at the land/sea boundary such as lagoonal, beach, intertidal, deltaic, etc., and is recognised by a variety of depositional facies ranging from coarse cross-bedded beach sand, to sand deposited in tidal deltas, to finely laminated organic sediment deposited in lagoons and estuaries (includes deltaic and intertidal-supratidal environments).
CDIS	Intertidal-Supratidal	Sediments deposited in the tidal zone, indicated by the presence of finely interlaminated fine and coarse detritus, herringbone cross-bedding, flaser bedding, evidence of periodic exposure, etc.
CDD	Deltaic	Deltaic deposits indicated by isopach patterns, upward-coarsening sequences and the map pattern of adjacent environments. Cuspate or lobate form of deltas on maps in some cases follows isopach pattern.
Marine environments		
MVS	Very Shallow (0-20 m water depth)	Marine sediments with evidence of deposition above wave base and/or occasional emergence, e.g. oolites, cross-bedding.
MS	Shallow (0-200 m water depth)	Marine sediments deposited on the continental shelf or on flanks of volcanic islands, e.g. sand, mud and limestone containing fossils that typically lived in shallow water; also includes areas along young, active spreading ridges (includes MVS).
MBA	Bathyal to Abyssal (> 200 m water depth)	Marine sediments with indicators of deep-water deposition, e.g. condensed sequences, turbidites, monotonous shale, and the presence of deeper-water organisms (includes abyssal environments).



Schematic Diagram Showing
Classifications of Depositional Environments

Figure 6 Schematic diagram showing classifications of depositional environments (Cook, 1990)

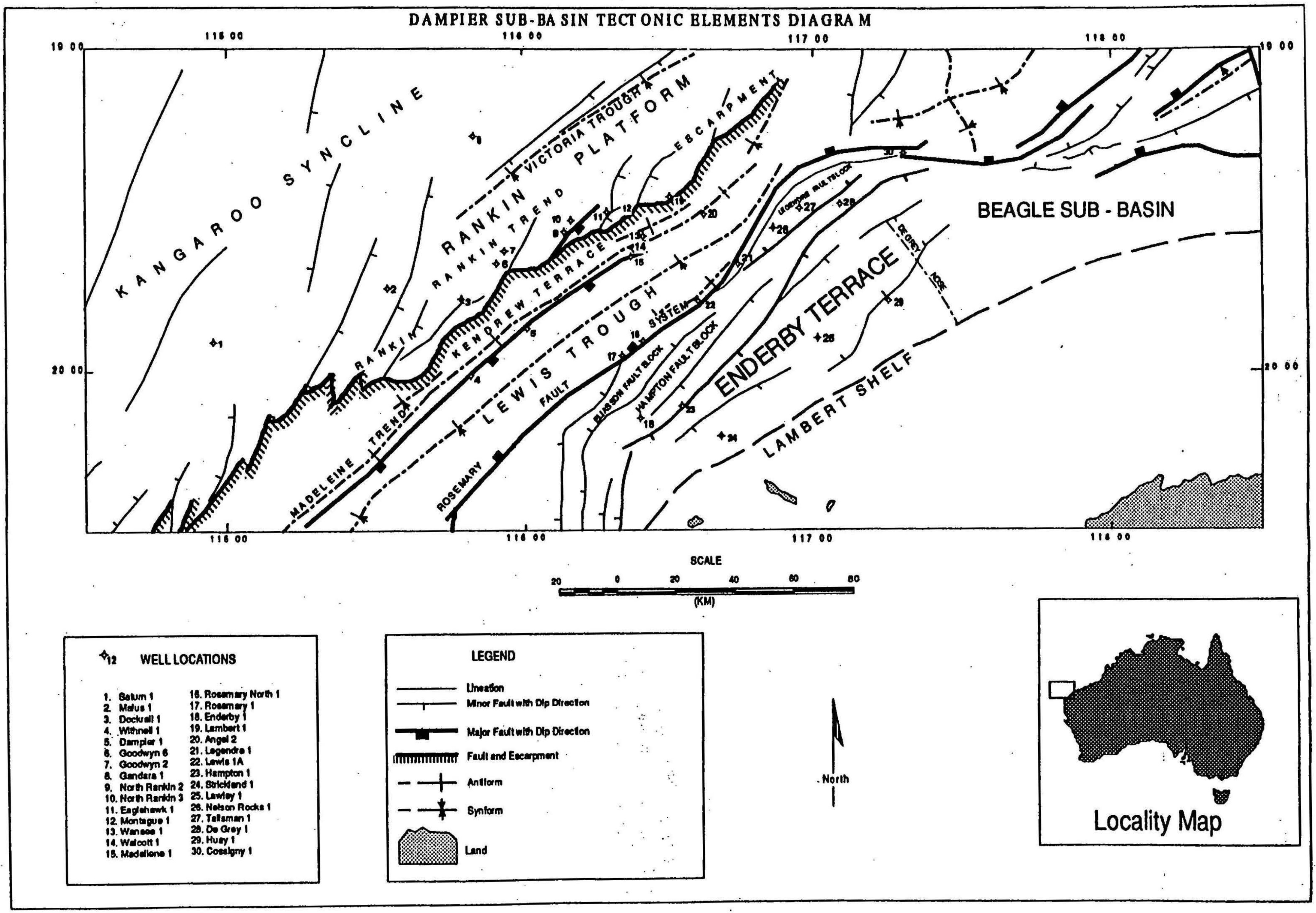
Table 1 Environment and Landform Element Codes

ENVIRONMENT CODES

LAND	LEU	Unclassified		
	LEE	Erosional		
	LUD	Unclassified Depositional		
	LDF	Fluvial	LDFB	Braided
			LDFM	Meandering
	LDL	Lacustrine		
	LDFL	Fluvial-Lacustrine		
	LDP	Playa		
	LDA	Aeolian		
	LDG	Glacial		
COASTAL	CDP	Paralic		
	CDIS	Intertidal / Supratidal		
	CDD	Deltaic	CDDU	Upper Delta Plain
			CDDL	Lower Delta Plain
			CDDP	Pro Delta
	CDE	Estuarine		
MARINE	MU	Unclassified		
	MSS	Starved Shelf		
	MS	Shallow (0 - 200m)		
			MVS	Marine Very Shallow (0 - 20m)
	MBA	Bathyal to Abyssal (>200m)		
			MA	Abyssal

LANDFORM ELEMENT CODES

V	Volcano		
LF	Lava Field		
VM	Volcanics Mixed		
C	Channel		
AF	Alluvial Fan	AFT	Fan Toe
		AFD	Debris Flow
		AFS	Sheet Flow
PB	Point Bar		
AC	Abandoned Channel		
LE	Levee		
CS	Crevasse Splay		
BS	Backswamp		
LD	Lacustrine Delta		
SF	Salt Flat		
MF	Mud Flat		
P	Pond		
D	Dune		
S	Swale		
B	Beach		
BR	Beach Ridge		
SMB	Stream Mouth Bar		
IDB	Interdistributary Bay		
SML	Submarine Levee		
CE	Chenier		
M	Marsh		
LA	Lagoon		
OB	Offshore Bar		
BI	Barrier Island		
F	Fan	FP	Fan Proximal
		FM	Fan Mid
		FD	Fan Distal
R	Reef	RT	Reef Toe
		RF	Reef Front
		RB	Reef Back
CSH	Continental Shelf		
CSL	Continental Slope		
TF	Turbidite Fan	TFP	Turbidite Fan Proximal
		TFM	Turbidite Fan Mid
		TFD	Turbidite Fan Distal
AP	[illegible]l Plai		



DAMPIER SUB-BASIN TECTONIC ELEMENTS DIAGRAM
115 00
116 00
117 00
118 00
19 00
20 00
KANGAROO SYNCLINE
RANKIN PLATFORM
VICTORIA TROUGH
ESCARPMENT
RANKIN TREND
KENDREW TERRACE
LEWIS TROUGH
SYSTEM
FAULT
ROSEMARY
MADELEINE TREND
LEGENDRE FAULT BLOCK
BUISSON FAULT BLOCK
HAMPTON FAULT BLOCK
ENDERBY TERRACE
DE GREY NOSE
LAMBERT SHELF
BEAGLE SUB - BASIN
SCALE
20 0 20 40 60 80
(KM)
WELL LOCATIONS
1. Saturn 1
2. Malus 1
3. Dockrall 1
4. Withnell 1
5. Dampier 1
6. Goodwyn 6
7. Goodwyn 2
8. Gandara 1
9. North Rankin 2
10. North Rankin 3
11. Eaglehawk 1
12. Montague 1
13. Wanaea 1
14. Walcott 1
15. Madeleine 1
16. Rosemary North 1
17. Rosemary 1
18. Enderby 1
19. Lambert 1
20. Angel 2
21. Legendre 1
22. Lewis 1A
23. Hampton 1
24. Strickland 1
25. Lawley 1
26. Nelson Rocks 1
27. Talisman 1
28. De Grey 1
29. Huay 1
30. Cossigny 1
LEGEND
Lineation
Minor Fault with Dip Direction
Major Fault with Dip Direction
Fault and Escarpment
Antiform
Synform
Land
North
Locality Map

Figure 7

REGIONAL GEOLOGY

BASIN DEFINITION

The Dampier Sub-basin lies offshore at the northern extremity of the Northern Carnarvon Basin on Australia's North West Shelf. It shares sufficient of its depositional history with the Barrow Sub-basin for them to be collectively called the Barrow-Dampier Sub-basin.

Here the Dampier Sub-basin is treated as a separate depositional entity since it has significantly thicker Lower Jurassic and in particular, a thinner Lower Cretaceous section, than the Barrow Sub-basin (Kopsen & McGann, 1985).

The Dampier Sub-basin is in the transition zone between basins to the south and south-west, including the Barrow Sub-basin, that have a predominantly north to north northeasterly trending structural grain, and basins to the northeast that have a more northeast structural grain. The northeast trending Lewis Trough, with over 15 km of mostly Triassic and Jurassic sediments is the main depocentre of the study area.

Defining the northwest margin of the Sub-basin is an elevated, complexly faulted and eroded escarpment of northwest tilted Triassic and possibly older sediments. This is the Rankin Trend. The Rankin Platform is an area further northwest, away from the immediate vicinity of the margin where these units become sub horizontal. The tectonism that formed these major features occurred during the middle Jurassic. A regional major unconformity occurs at this time and is termed the Main Unconformity. The present topography of this surface and the underlying structuring are used to define many features of the Sub-basin (see Figure 7 and Enclosure 1).

Parallel to the Rankin Trend, but stepping down into the Sub-basin proper, is the Kendrew Terrace. In some published and unpublished works this area is sometimes called the Kendrew Trough. On the Kendrew Terrace the Main Unconformity surface dips to the northwest, and is at its deepest adjacent to the base of the Rankin Trend. The Lewis Tough face of the Rankin Trend was eroded during Late Jurassic times and is called the Rankin Escarpment.

The Madeleine Trend forms a southwest plunging antiform feature between the Kendrew Terrace and Lewis Troughs. This feature is interpreted as the high end of the footwall block of a normal fault flanking the Lewis Trough. Younger sediments draped over it form the antiform feature. Together the Lewis Trough and Kendrew Terrace define the actual Dampier Sub-basin.

The southeast margin of the Lewis Trough is formed by the trans-tensional Rosemary Fault system.

To the southeast, adjacent to the Rosemary Fault System and forming a flank of the Lewis Trough is the Enderby Terrace. The shelf is approximately 25 km wide and is sub-divided into a number of elements defined by basement controlled faulting. At the immediate edge of the Lewis Trough in the southeast is the narrow Eliasson fault block. To the north is the similarly placed but separate Legendre Terrace. These terraces are bounded to the southeast by a northwest hading fault. This is a stem of, and therefore a part of, the Rosemary Fault System. Further southeast of these terraces is the Hampton fault block that is bounded by a significant down to the southeast normal fault that has a wrench component. Across these Terraces basement shallows rapidly. Further thinning occurs towards the margin until a bounding fault defines the edge of the Lambert Shelf. Here the Archaean Pilbara Block is close to the surface and sediment thickness over it is reduced to a veneer.

On the Enderby Terrace beneath the Main Unconformity significant Lower Jurassic, extensive Triassic and some possible upper Permian section rest unconformably on probable igneous or metamorphic basement. This sedimentary section thins rapidly towards the Lambert Shelf.

The northern limit of the Sub-basin occurs near Talisman 1 where the Enderby Terrace margin approaches the Rankin Trend. Here shallow pre-Main Unconformity section is onlapped by post-Main Unconformity Jurassic sediments. In this area the Rosemary Fault System starts to trend more easterly. North of this point, called the De Grey Nose, is the Beagle Sub-basin.

The southern limit of the Dampier Sub-basin is the ill-defined boundary were the dominant tectonic grain changes from the northeast, to the north or north northeast grain of the Barrow Sub-basin. This occurs a little south of Withnell 1. Coincident with this is the southern limit of the discernible syncline of the Lewis Trough. Further south this depocentre broadens from the confined Dampier to the more expansive Barrow Sub-basin. This is also coincident with a stepback to the northwest of the Rankin Escarpment.

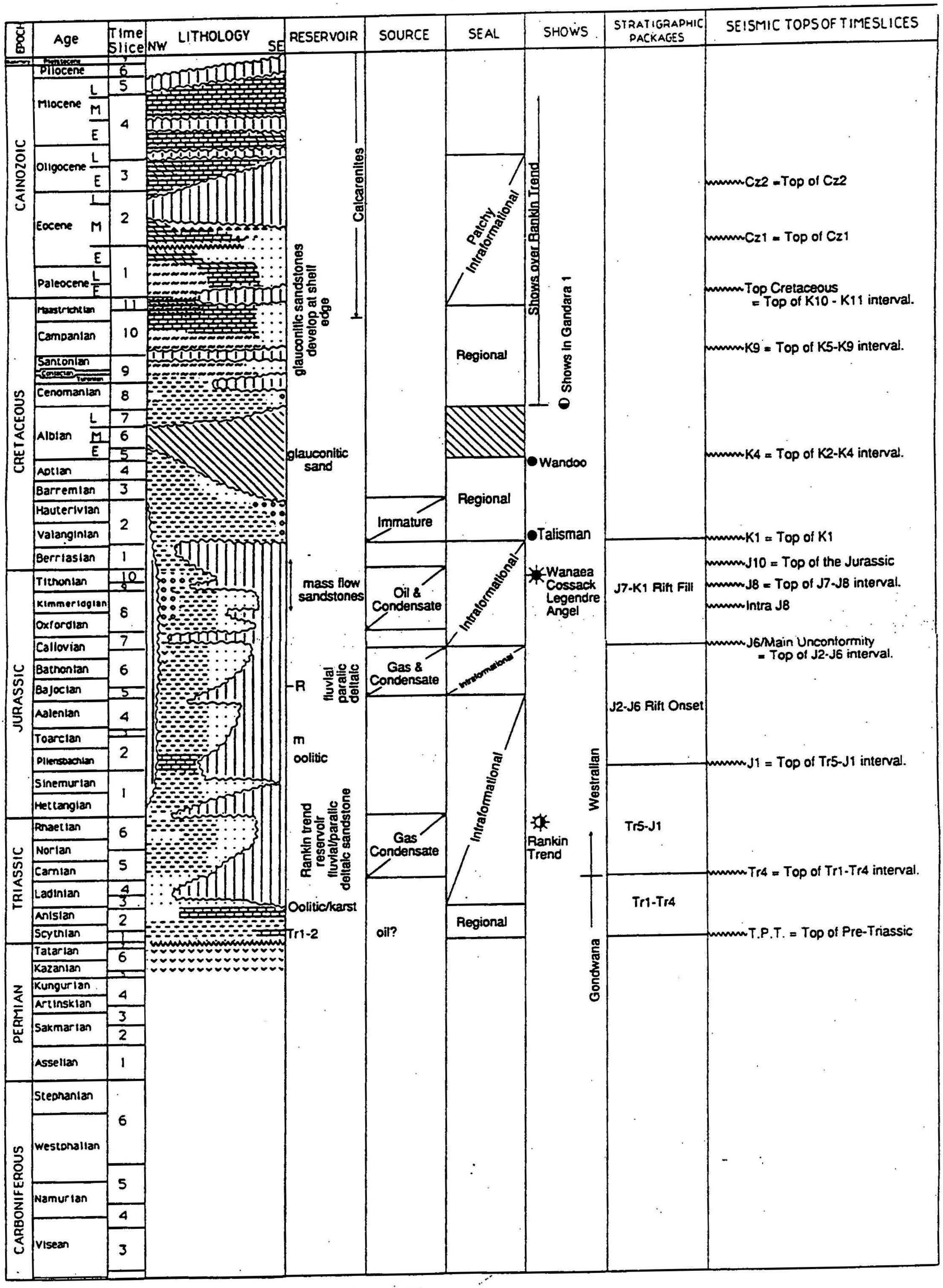


Figure 8 Summary Stratigraphic Column.

SUMMARY TECTONIC HISTORY

The Summary Stratigraphic Column shows the regional stratigraphy of the Dampier Sub-basin (see Figure 8). The Time Space Diagram, shows the relationship of regional unconformities, disconformities and 'condensed' sections (see Figure 9). An enlargement of the Time Space Diagram is provided in Enclosure 2.

The tectonic evolution of the Dampier Sub-basin can be divided into a number of major events. In the following discussion only minimal reference is made to external events or tectonic models, and the tectonic events are described as interpreted from the palaeogeographic mapping. Others have described the tectonic history in greater detail as it relates to plate tectonic models and the break up of Gondwana (Veevers 1988, Bradshaw et al 1988, Malcolm et al 1991).

1) Prior to the onset of the events that lead to the breakup of Gondwana the study area was part a north south oriented sag basin of Late Palaeozoic age (Permian and possibly Late Carboniferous). This basin underlies much of the North West Shelf area.

2) Earliest Triassic sedimentation represents the accumulations of a sag basin that developed to the east of a pre-rift arch that sourced the area (Veevers,1988). There is a pronounced angular unconformity between the basal Permo - Triassic on the Enderby Terrace and the underlying rocks that are thought to be Permian or older. This unconformity probably extends into the Lewis Trough area and further west. Basement rocks on the Enderby Terrace are igneous or metamorphic. Earliest Triassic sediments, possibly sourced from the west, (with some possible latest Permian) were then laid down on this unconformity.

3) The onset of regional extensional tectonics, resulting in the *rift onset unconformity*, commenced in the Early Jurassic, probably late in Time Slice J1. The age depth plots suggest a significant regional unconformity at or near Time Slice J2 but the interpretation is equivocal. North Rankin 3 and Gandara 1 have some evidence for an unconformity of this age, and there are suggestions from the age depth plots that it exists in all wells on the Enderby Terrace. More convincing is seismic evidence from the region of Gandara 1. An angular unconformity at this time (late Time Slice J1) provides evidence of a trans-tensional regime showing hingelines of bedding between fault block boundaries, with a resumption of sedimentation in Time Slice J2 at Gandara 1 but later nearer the Rankin Trend, manifested as onlapping beds. This marks the onset of the first significant faulting in the area. The initial subsidence of the area that would later become the Lewis Trough started in the Early Jurassic with the thick deposits of Time Slices J2 to J5. This is established on seismic evidence that shows a thickening wedge of sediment towards the Lewis Trough and with horizons truncated by the Main Unconformity becoming younger basinward of the Hampton 1 well. On the Enderby Terrace there is an extensive unconformity that developed in Time Slices J1 and eroded back to Time Slice Tr4.

4) Major *rifting* commenced in Time Slice J6, dominated initially by extension that then became more trans-tensional. There developed normal extensional listric, southeast hading faults that are seen from the Rankin Platform to the Lambert Shelf, and are

DAMPIER SUB-BASIN TIME SPACE DIAGRAM

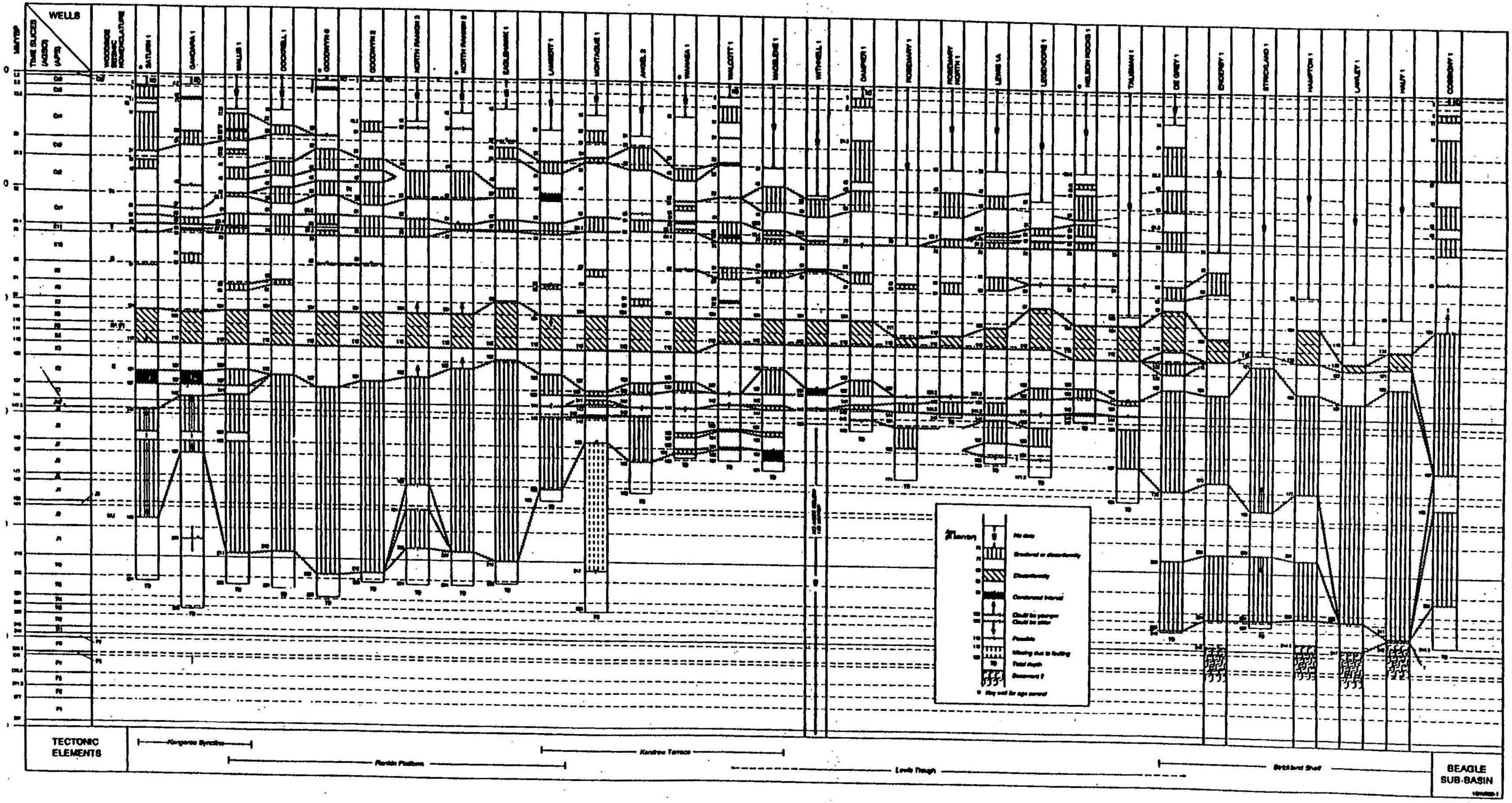


Figure 9

characteristic of the Enderby Terrace. As this rifting phase climaxed, the Rosemary Fault System developed. Associated with this event was a dramatic increase in subsidence rates in the Lewis Trough: to approximately 150m/Ma. The Rosemary Fault System is a complex of many wrench faults, with stems of the associated flower structures extending through the Early Jurassic to include basement on the Enderby Terrace and causing complex and erratic fault block orientations along the margin of the Enderby Terrace. Some of the earlier formed faults (from Time Slices J1 and J2) were reactivated at this time.

5) By the end of Time Slice J6 or during Time Slice J7 the major structural features were established. The Madeleine Trend and Kendrew Terrace may have formed simultaneously with the activity on the Rosemary Fault System during early Time Slice J7. During the remainder of the Jurassic, there was erosion on and from the Rankin Trend into the adjacent deep water Lewis Trough, which rapidly filled. The erosion resulted in formation of the Rankin Escarpment. Slumping into the Lewis Trough also occurred from the Enderby Terrace area across the episodically active Rosemary Fault System. Although sedimentation rates were high, there were a number of trough wide unconformities in the Late Jurassic. This tectonic episode marks the development of the Main Unconformity clearly seen everywhere except in the Lewis Trough. Considerable thicknesses of sediment onlap this unconformity on the northwest flank of the Lewis Trough at Time Slice J7.

6) Time Slices J8 to J10 mark the interval of infilling of the Lewis Trough. Marine circulation appears to have been restricted during this time. There is evidence of episodic tectonic activity in the form of minor fault movements but the major phase of trough formation is over. Activity on the Rosemary Fault System waned at the end of the Jurassic Time Slice J10. During Time Slice K1 marine sedimentation rates remained high in the Lewis Trough. That the Lewis Trough area remained a depocentre at this time seems to be a response to compaction of the massive accumulations of underlying Time Slice J6 to J10 claystones.

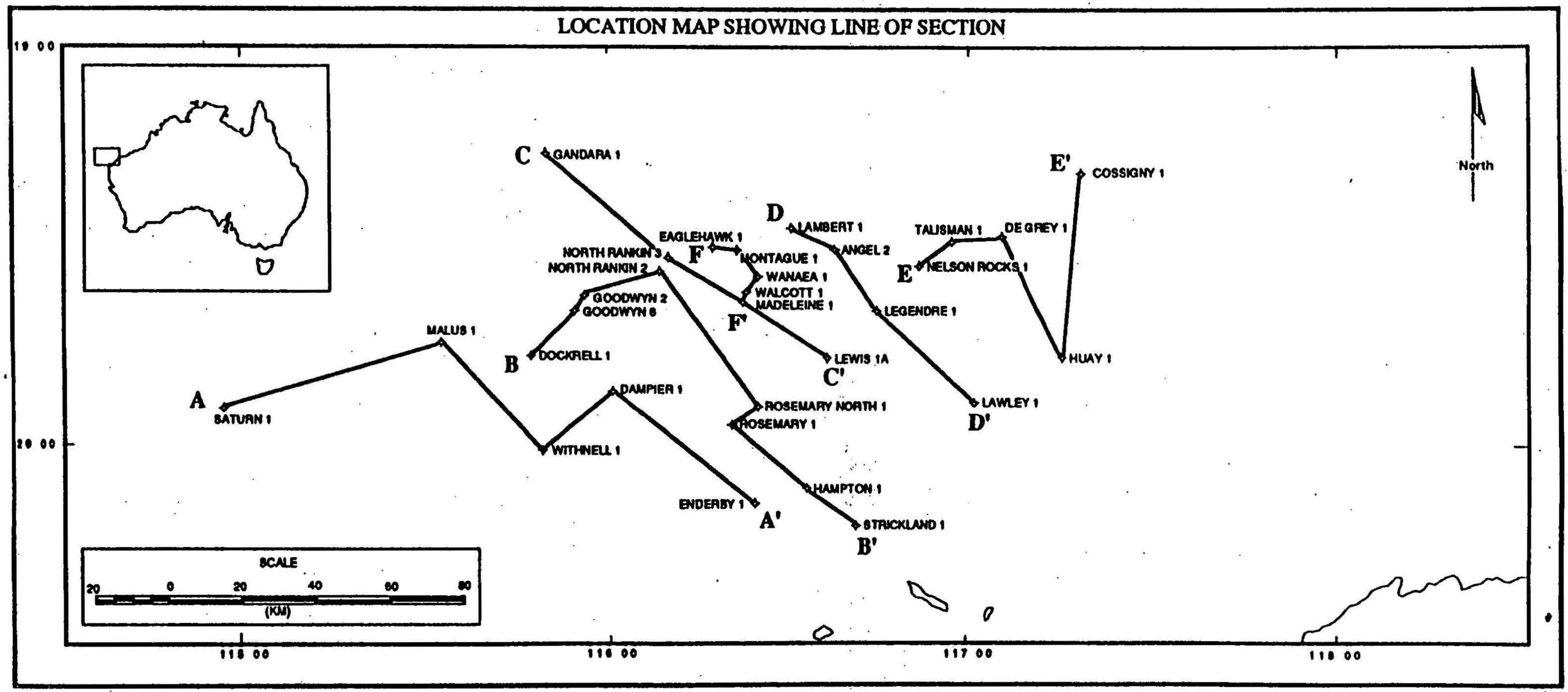
7) Time Slice boundary K1-K2 is a significant unconformity. At this time Greater India departed from Gondwana (*break-up*). Although oceanic conditions now prevailed, the area did not enter a margin sag phase but a major marine transgression did commense. This transgression and consequent retreat of the coastline toward the hinterland resulted in greatly reduced rates of deposition in the study area. The result is that Time Slice K2 to K4 is a condensed interval and Time Slice K5 is a interval of virtual non deposition.

8) When India finally cleared Australia the area entered a major margin sag phase under conditions of clastic starvation. Time Slices K5 to K11 deposits consist of mainly shallow water carbonate sediments. The Lewis Trough's differential compaction, formed a local topographic low that was infilled during this interval with thinnest deposits over the topographic sub-sea high of the Rankin Trend.

9) In the Tertiary sediment loading resulted in an acceleration of the post breakup sag phase. Thick deposits of shallow water sediments prograde across the shelf, resulting in rapid burial and significant heating of the underlying sediments. This caused the

onset of Jurassic oil generation. There was an initial pulse of deposition in Time Slice Cz1 resulting in uniformly thick (~300ms) sedimentation across the entire margin, with progrades evident and downlapping onto the base Tertiary unconformity across the Lewis and Kendrew Troughs. Over the Rankin Platform this time slice appears to be reflection free. Time Slice Cz2 is thin and bounded above and below by unconformities, suggesting a eustatic marine regression on this cooling, sagging margin. In Time Slice Cz3 there is substantial progradational outbuilding, essentially hinging on the Rosemary Fault System. Major foresets prograde rapidly across the continental shelf. This is the postulated time of onset of major oil generation.

10) In the Late Miocene (Time Slice Cz4) there was a significant regional compression caused by the collision and consequent subduction of the Australian Plate with the Eurasian Plate to the north near what is now the Java Trench. This compressional event caused the reactivation of the Legendre Trend adjacent to the Rosemary Fault System. Re-activation of older faults occured mostly recognised by reverse movement on these faults. This event accentuated some pre-existing structures and resulted in some strike slip movement.



LOCATION MAP SHOWING LINE OF SECTION
19 00
20 00
115 00
116 00
117 00
118 00
North
SCALE
20 0 20 40 60 80
(KM)
C
GANDARA 1
E'
COSSIGNY 1
D
LAMBERT 1
TALISMAN 1
DE GREY 1
EAGLEHAWK 1
NORTH RANKIN 3
F
MONTAGUE 1
ANGEL 2
NORTH RANKIN 2
WANAEA 1
E
NELSON ROCKS 1
WALCOTT 1
MADELEINE 1
GOODWYN 2
GOODWYN 6
LEGENDRE 1
F'
MALUS 1
B
DOCKRELL 1
LEWIS 1A
C'
HUAY 1
A
SATURN 1
DAMPIER 1
ROSEMARY NORTH 1
ROSEMARY 1
LAWLEY 1
D'
WITHNELL 1
HAMPTON 1
ENDERBY 1
A'
STRICKLAND 1
B'

Figure 10

PALAEOGEOGRAPHIC INTERPRETATION

METHODOLOGY

Time slice data maps and palaeogeographic interpretation maps have been constructed over a range of twenty eight time slices ranging in age from Scythian to Eocene. Twenty time slice data maps, three of which cover a composite of more than one time slice, have been drawn. Biostratigraphic control and environments of deposition have been interpreted for each time slice.

Each time slice data map shows the locations of the thirty wells used in the study. At each well location is shown a symbol to indicate wether the Time Slice is present or absence or not penetrated by the well. Hydrocarbon indications within the time slice are shown by the well symbol. For wells that intersected the time slice a shaded gamma ray log section, at a vertical scale of 1:10,000 has been posted near, and if possible immediately below, the well symbol. A table has been included that shows KB depths to the top and base of the time slice, thickness of the time slice and subsea depths to the top of the time slice, and other incidental data.

A summary of the organic chemistry is provided for each time slice map. This data was synthesised from A.G.S.O's ORGCHEM database and is shown as time slice maps of Total Organic Carbon (TOC), Hydrogen Index (HI) and Vitrinite Reflectance (VR) in Appendix 6. When referring to the stages for generation of hydrocarbons, we have followed the scheme and cut-off points used by Tobin (1991).

Palaeogeographic interpretation maps have been compiled for those time slices with sufficient information to allow an interpretation. These maps are based on the time slice data map series and are self explainatory.

Detailed descriptions for each time slice data and palaeogeographic interpretation map are provided in the following section, together with a brief discussion of prospectivity.

Six well log cross sections showing detailed time slice correlations have been constructed. Figure 10 shows the locations of these cross sections. These cross sections are Enclosures 4 to 9 and should be referred to in conjunction with the palaeogeographic interpretation maps.

PRE TRIASSIC DEPOSITION

Four wells reached total depth in rocks thought to be basement. Enderby 1 encountered greenish grey rhyolitic basement of uncertain age but is assumed to be pre Triassic. Hampton 1 encountered rocks described as medium brown grey olive green cherts that may be volcanics. Lawley 1 reached total depth within altered granitic gneiss and Hauy 1 drilled into altered basic igneous rocks.

Deposition may have commenced on the shelf in latest Permian rather than earliest Triassic as *P. microcorpus* has been identified in Hauy 1. These microfossils could be reworked, implying that only a brief interval separates the Permian and Triassic successions, that elsewhere (Barrow Sub-basin), are separated by a significant unconformity (Kirk 1985, p191).

TRIASSIC TIME SLICES: TR1 TO TR6

<u>TIME SLICE TR1 TO TR4:</u> LOWER TRIASSIC: Scythian to Ladinian (248. 0 to 231. 0 MA)
<u>ENCLOSURES 10 & 11</u>

<u>Formation Synonyms:</u> Locker Shale, Mungaroo Formation, K (See Bint and Helby 1988, p593 for a discussion of Woodside letter codes), Cunaloo Member.

<u>PALAEONTOLOGY</u>:
Spore pollen zones *L. pellucidus, P. semollovichii, T. playfordii, S. quadrifidus* and *Lower S. speciosus*

This time slice is penetrated in a total of eight wells. Seven of the eight wells are on the Enderby Terrace where the Triassic is at relatively shallow depths. Goodwyn 6 on the Rankin Trend was a deeper than usual exploration and appraisal well that reached total depth within Time Slice TR4. The other twenty-two wells reached total depth above this interval.

Age control is generally poor in the Triassic due to a number of factors. These include the coarse definition of zones afforded by the Triassic spore pollen assemblages and the oxidation of the Triassic deposits on the Enderby Terrace that have been exposed several times in their history as described in subsequent Time Slice sections.

Age control is fair to very poor over this interval. No single well has adequate age control over the entire Triassic section but North Rankin 2, provides good control of Time Slices TR6 and TR5, Goodwyn 6 of Time Slices TR6 to TR4 and Hampton 1, Enderby 1 and Lawley 1 of Time Slices TR3 toTR1. They establish a uniform high sedimentation rate for the Triassic, estimated at a minimum of 150 m/Ma. Age depth plots in more poorly constrained wells were extrapolated using this trend.

Thickness Variations:
Maximum preserved thickness occurs in Hampton 1 (897m) The limited information suggests a thickening toward the incipient Lewis Trough.

Lithology:
Earliest sedimentation on this basement is a thin very fine to coarse, dominantly fine grained, subangular to subrounded argillaceous and silty quartz sandstone that has a trace of mica, lithic grains and a trace to fair intergranular porosity. The sandstone tends to fine upward. This is commonly associated with thin beds of recrystallised limestones composed of skeletal fragments, and minor glauconite but with nil porosity.

The overlying rocks are a thick sequence of claystones with minor interbedded siltstones, sandstones and limestones. This facies is the Locker Shale. The claystone is brown to medium dark grey to dark grey tending to be darker with depth and with grey argillaceous silt layers. It contains an impoverished suite of marine benthonic forams. To the north the unit becomes sandier and thicker carbonate beds (to 40m) are encountered. These carbonates are white yellow or light grey and composed of dolomites, recrystallised limestones, calcilutites and calcarenites, the latter having a trace to fair porosity. In De Grey 1 a lost circulation zone is interpreted as an oolitic limestone. This is based on an underlying core. The limestone may have vuggy porosity that developed on an unconformity surface. In Cossigny 1 the unit is comparatively sandy. In this well the section is Time Slice TR1 to TR2 age and is thought to be unconformably overlain by Triassic or younger rocks.

The overlying Time Slices TR3 to TR4 sections are sandier, being dominantly interbedded siltstones, sandstones and claystones that, with the exception of the basal sandstone are lithologically similar to the rocks described for Time Slices TR1 and TR2.

PALAEODEPOSITIONAL ENVIRONMENT:
The earliest Triassic may have been a period of volcanic activity. In Enderby 1 a thin bed of claystone of early Triassic age, occurs within rocks described as rhyolites.

A major marine transgression across this basement, represented by either a recrystallised limestone or reworked transgressive sandstone, or both, marks the onset of Time Slice TR1 Triassic deposition. This is overlain by a thick marine shale or claystone, with minor limestone interbeds. The shale and claystone are a deeper water shelf facies. The limestones are of various ages within this time slice. To the north they become fairly thick and probably oolitic. The overall sequence also becomes sandier in this direction suggesting the area is proximal to the palaeocoastline.

A major and apparently rapid regression occurred in the middle of Time Slice TR3 resulting in deposition of paralic, deltaic and fluvial sediments across the area during the remainer of Time Slices TR3 and TR4.

Palaeogeography:
No palaeogeographic interpretation map of this time slice was attempted because of the poor spread of wells that intersected it. Deposition occurred in a shallow marine environment that possibly had restricted circulation.

PROSPECTIVITY: GOOD TO VERY GOOD

The basal Triassic limestone and transgressive sandstone are potential reservoir facies sealed by the Locker Shale (Time Slice TR2). The shale is a potential mature source rock interval on parts of the Enderby Terrace. There is potential for oil to have migrated into these reservoirs since the late Jurassic. Stratigraphic and structural traps remain to be tested.

Geochemistry (TOC, HI and Vr)

The median TOC values range from 0.19 to 1.77 with a maximum of 1.94 at Hampton 1. The median HI values range from 24 to 150 with a maximum of 194 at Hampton 1 in Time Slice TR2 (Locker Shale). Time SliceTR2 interval has good TOC values and may be a source rock. The vitrinite reflectance data which is restricted to the Enderby Terrace suggest this interval is in the early to peak stages of oil generation. However in the adjacent Lewis Trough this section reached peak maturity in the Late Jurassic - Early Cretaceous (Kaiko 1992, p 38). In the Lewis Trough Jurassic oil prone source rocks (Time Slices J6 to J10) reached peak generation, commencing in the southwest in the Late Cretaceous and progressing northeast, into the Late Tertiary. It is concluded that a continual supply of hydrocarbons, from Late Jurassic onwards, was available to migrate into the earlyTriassic reservoirs via the faults that define the Trough margin.

Shows/Porosity/Permeability:

Minor hydrocarbon indications occur in Cossigny 1, Lawley 1 and Strickland 1. These shows are thought to represent traces of migrated hydrocarbons rather than insitu hydrocarbons, although the latter is possible.

The basal Time Slice TR1 to TR2 transgressive sand has good reservoir potential, but the recrystallised limestone has poor reservoir potential where intersected. It is both feasible and likely that these limestones thicken to the northwest, towards the present Trough margin, where they may become oolitic. Carbonate dissolution, by migrating pre-maturation acidic fluids, is a possible mechanism for porosity enhancement in the carbonates in areas adjacent to the Rosemary Fault System.

Traps and Plays:

The Enderby Terrace area rises to the southeast, from the edge of the Lewis Trough, by a series of fault bounded blocks. Each of these fault blocks provides an opportunity for fault traps of the basal transgressive sandstone reservoirs and shelf carbonates. The terrace immediately adjacent to the main Rosemary Fault system is possibly the most prospective. Incised valley fill in the pre Triassic basement is an additional possible play type in this area.

TIME SLICE TR5: MIDDLE TRIASSIC: Carnian to Lower Norian (231. 0 to 222. 0 MA)
ENCLOSURES 12 & 13

Formation Synonyms: Mungaroo Formation, G, H, I & J (See Bint and Helby 1988, p593 for a discussion of Woodside letter codes).

PALAEONTOLOGY:
Upper S. specious and Lower M. crenulatus.

Eleven wells intersected sections of Time Slice TR5 age. All but Cossigny 1 were drilled on the Rankin Trend. Eight of these reached total depth within this time slice. Only Goodwyn 6 drilled through an entire Time Slice Tr5 section.

For a detailed discussion of difficulties with Triassic time slice definition see Time Slice TR1 to TR4 section.

Bint & Helby (1988, p597) show that this time slice can be subdivided further into zones, G, H, I & J along the Rankin Trend. This work has not attempted to conform to these subdivisions.

Thickness Variations:
Because only one well penetrated the entire Time Slice TR5 no isopach interpretation has been attempted.

Lithology:
Sediments comprise interbedded sandstones, siltstones, shales and coals.

The sandstones are light olive grey to dark grey, occasionally pink or brownish yellow and normally 100% quartz. They are very fine to very coarse grained, subangular to subrounded, generally being coarser in the blocker units and finer overall in the fining upward units. There are traces of carbonaceous material, minor to trace calcareous or dolomitic cement and a trace of red jasper and heavy minerals. Intergranular porosity is fair to good.

Siltstone are quartzose, olive grey to dark grey and argillaceous. The shales and claystones are olive or dark greenish grey when carbonaceous. There are occasional bluish grey to dark reddish brown varieties. Thin coals are sub vitreous and are generally brown to black and vary from brittle to soft.

PALAEODEPOSITIONAL ENVIRONMENT:
A delta system occupied the area. Fluvial fining upward point bar sequences are present, as well as coarsening upward delta distributary channels. Blocky (gamma ray signature) channel or bar sequences are common. The sequence everywhere retains a sufficiently marginal marine influence to suggest that the coastline was always in close proximity, and shallow marine facies like offshore bars, tidal ebb flood deltas can be expected in the area.

Palaeogeography:
Deposition occurred on a lower delta plain with minor marginal marine to estuarine conditions prevailing episodically. Limited dipmeter data weakly suggest a source from the southeast. Some high dips from the opposite hemisphere may indicate tidal deposits. The lowest part of the time slice section in Goodwyn 6 is dominated by lower delta or fluvial flood plain swamp deposition.

PROSPECTIVITY: FAIR TO GOOD
This is not generally the productive interval of the Triassic along the Rankin Trend being normally too deep below the main Cretaceous seal to be within the hydrocarbon column. However it could be prospective elsewhere on the Rankin Platform and Kangaroo Synclinal area.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0.54 to 1.8 with a maximum of 15.6 (coaly) at Saturn 1. The median HI values range from 100 to 138 with a maximum of 400 at Goodwyn 6. The vitrinite reflectance data suggest this interval is in the early to peak stages of oil generation. The samples all come from the Rankin Trend. The good source quality of this interval reflects the lower delta plain facies.

Shows/Porosity/Permeability:
Dockrell 1 has gas reserves, and Montague 1 has gas condensate reserves. All other wells have no shows. In the case of Montague 1 lateral seal is not provided by the Triassic but probably by Jurassic Time Slice J8 shales, and or fault plane seal. Good primary porosity and permeability are characteristic of the blockier sandstone facies.

Traps and Plays:
May be a target in structural plays on the Rankin Platform and Kangaroo Trough area where the deeper Triassic is mature and providing charge to this Time Slice.

TIME SLICE TR6: UPPER TRIASSIC: Upper Norian to Rhaetian (222. 0 to 213. 0 Ma).
ENCLOSURES 14 & 15

Formation Synonyms: Mungaroo Formation, Brigadier Formation, D, E and F. (See Bint and Helby 1988, p593 for a discussion of Woodside letter codes).

PALAEONTOLOGY:
Lower A. reducta and upper M. crenulatus.

Time Slice TR6 is penetrated in nine wells, seven wells on the Rankin Trend plus Gandara 1 and Saturn 1. Fourteen wells within the Dampier Sub-basin reached total depth before encountering this interval. In Montague 1, Cossigny 1 and the five wells on the Enderby Terrace the section is absent due to post depositional erosion.

The top of the time slice in Goodwyn 2, Goodwyn 6 and Eaglehawk 1 is the Main Unconformity. The section is conformable on the underlying Time Slice TR5 where this is penetrated.

Thickness Variations:
The thickest section occurs in North Rankin 2 (596. 5m). The isopachs are interpreted to reflect a deltaic accumulation in the vicinity of the North Rankin wells with sediments thinning offshore and away from this depocentre (see Figure 11)

Lithology
Sedimentation is dominantly claystone with interbedded sandstones and minor siltstone.

The claystones are light olive grey to olive black, grey black, dark brownish grey, greyish brown, very dusky red, moderate brown, greyish red, or brownish black. They are in part micaceous, composed of 75-100% clay minerals 0 - 25% quartz silt, 0 -15% mica, with traces of carbonaceous material and quartz sand size grains, subfissile in part and commonly soft to moderately hard.

The sandstones are argillaceous in part, light olive grey, 60 -100% quartz grains, very fine to granular, angular to subrounded, very poor to well sorted with 0 - 40% clay minerals, 0 - trace of quartz silt, 0 -10% lithic fragments, 0 -10% mica and traces of pyrite, coal, silica cement, dolomite cement and calcite cement. They are unconsolidated to hard with a trace to good intergranular porosity. Orange to rose coloured quartz occurs in the sandstones lower in the section. The sandstones commonly have sharp bases and either sharp or fining upward tops.

The siltstones are argillaceous to arenaceous dark grey, dark green or brown black when carbonaceous.

The occasional coal is black, moderately hard and sub bituminous.

Minor recrystallised limestone and dolomite occur in Saturn 1.

Dampier Sub Basin

Time Slice TR6: Isopach Map

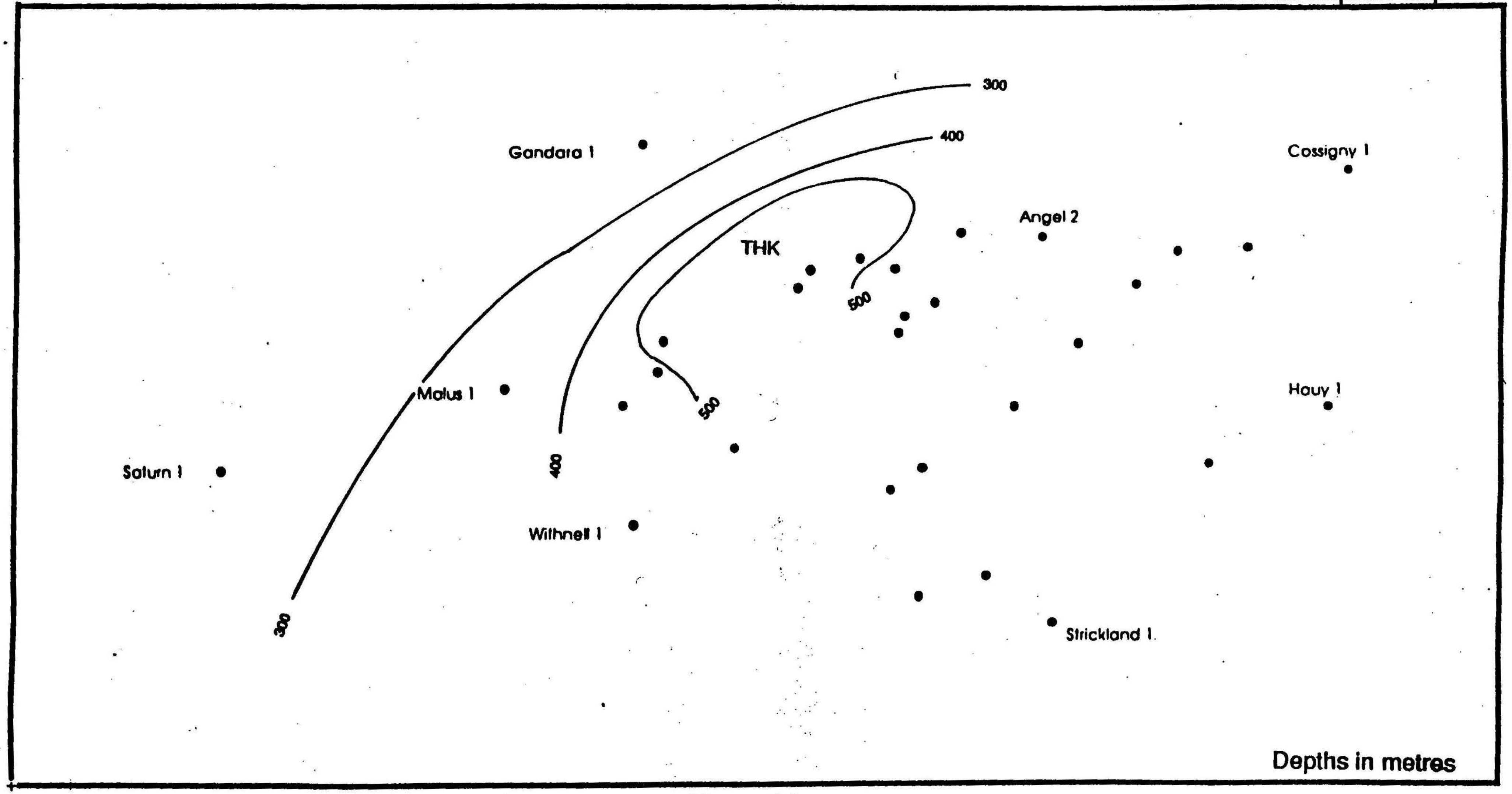


Figure 11

Palaeodepositional Environment:
Deltaic deposition on a near shore to shallow shelf environment is indicated. The sequence goes from definite fining upward fluvial point bar sequences, though a package of thicker blocky sandstone, interpreted as paralic deposits of beach or more likely tidally influenced sections of the lower delta plain, then into definite delta front coarsening upward sequences. The overall interval is interpreted as a major transgressive sequence.

The braided channel environment (referred to by Bint and Helby 1988) is more likely a tidal channel environment. Braided fluvial environments require an increase in depositional slope. This is considered to be unlikely in a sequence that otherwise shows a definite trend of gradually increasing water depth.

The Enderby Terrace was probably exposed at this time and incised river valleys are likely to have formed on it.

Palaeogeography
Within the overall transgressive cycle a deltaic depocentre in the Lewis Trough area occurs centred on the North Rankin wells. This depocentre is probably sourced from the southeast. This area is characterised by more fluvial deposits. A zone of shallow marine or paralic deposition fringed this lobe. Offshore bars, tidal channel and beach deposits are probable. Further offshore shallow shelf limestones and claystones where deposited. Minor sandstones in these areas may reflect storm deposits or distal delta front slump turbidites.

Prospectivity: Fair to Poor
This time slice contains the major reserves of the Goodwyn and Rankin Fields. It is given a fair to poor rating on the basis that most if not all the prospects within this time slice have already been tested along the Rankin Trend. However it could be reservoir elsewhere on the Rankin Platform and Kangaroo Synclinal area, in untested structures where buried sufficiently deep to be mature.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0.85 to 4.66 with a maximum of 45 (coaly) at Malus 1. The median HI values range from 100 to 159 with a maximum of 300 at Montague 1. The vitrinite reflectance data suggest this interval is in the peak stages of oil generation. The samples all come from the Rankin Trend. The good source quality of this interval reflects the lower delta plain facies.

Shows/Porosity/Permeability:
A proven oil and minor condensate accumulation occurs at Eaglehawk 1. Major gas condensate accumulations occur in North Rankin 3 and Goodwyn 2. Proven gas condensate and oil occur in Dockrell 1 and Goodwyn 6. Strong gas and oil indications occur in North Rankin 3, a gas condensate show occurs in Saturn 1 and a gas indication in Malus 1.

Porosity and permeabilities are poor to very good. Good primary porosity and permeability are characteristic of the blockier sandstone facies. Porosity enhancement has occured in this unit during periods of exposure of the Rankin Trend in the Late Jurassic to Early Cretaceous. (Warren J.,1992)

Traps and Plays:
Time Slice Tr6 could be a target in structural plays on the Rankin Platform and Kangaroo Trough area where the section is mature and providing charge to this Time Slice.

JURASSIC TIME SLICES: J1 TO J10

TIME SLICE J1: LOWER JURASSIC: Hettangian to Sinemurian:(213.0 to 200.0 Ma).
ENCLOSURES 16 & 17

Formation Synonyms: Dingo Claystone, Brigadier Beds, North Rankin Beds, North Rankin Formation, D & C.(See Bint and Helby 1988, p593 for a discussion of Woodside letter codes).

PALAEONTOLOGY:
Middle D. priscum & Lower C. torosa & Upper A. reducta.

Time Slice J1 is penetrated in a total of ten wells. It is absent, due to post depositional erosion, from four wells on the Rankin Trend, two wells on the Enderby Terrace and in Cossigny 1. In the Lewis Trough thirteen wells reached total depth before penetrating this time slice. In all of these wells the time slice is likely to be present deeper than total depth.

The palynological control is generally poor to fair over this interval. However the *A. reducta - C. torosa* boundary is often well defined and this, coupled with better palynological control from higher dinoflagellate zones, provides the control points that define the age depth plots. Extrapolation from these plots allows an estimate to be made of the time slice boundaries in the absence of precise palynological definition. The best palynological control for Time Slice J1 comes from North Rankin 2, Gandara 1 and Saturn 1. These three wells suggest that a decrease in depositional rate occurred during Time Slice J1 as compared to the underlying Triassic. The general age depth curve provided by these wells has been heavily relied upon to extrapolate Time Slice J1 in the other wells. Even so, in some cases, it is impossible to be certain that Time Slice J1 has been intersected simply because there are no palynological zones unique to this time slice.

On the Enderby Terrace the base of Time Slice J1 is a significant unconformity where it onlaps the eroded Triassic. There is no *A. reducta* recorded from the four wells on the Enderby Terrace, and lower most Time Slice J1 is almost certainly not present. In fact Time Slice J1 may not be present on the shelf at all, if the extrapolated age depth curves prove in error. There is no *A. reducta* reported for Dockrell 1 and Malus 1 and so a similar argument applies. However these two wells are on the Rankin Trend and presumably more akin to the North Rankin wells used for control.

On the Rankin Trend most of the Jurassic has been eroded but in several wells significant sections of Time Slice J1 remain. In these wells the top Time Slice J1 is an erosional unconformity. Only in Gandara 1 and Saturn 1 does a complete and conformable section of Time Slice J1 age probably exist. Inconclusive evidence from the age depth plots suggest a hiatus at the top of Time Slice J1 may occur in Gandara 1. In the Lewis Trough the Jurassic is probably conformable on the Triassic.

This time slice is thought to mark the rift onset phase of tectonic evolution with major extensional faulting occuring.

Thickness Variations:
Maximum preserved thickness occurs in North Rankin 3 (259m) but in this well the top is partially eroded. At Gandara 1 (167m) and Saturn 1 (226m) where complete sections are seen the depositional thickness is less than that remaining at North Rankin 3. On this evidence it is assumed that the original depositional thickness was thicker towards the Dampier Sub-basin and that up to 500m would constitute a maximum depositional thickness with 300m to 350m being considered more likely.

Lithology:
The dominant lithology is dark grey to medium grey, olive grey to brown, silty calcareous claystone that grades occasionally into micaceous shale. In general the claystone grades upward into minor argillaceous siltstone with occasional interbeds of minor fine grained quartz sandstone that is slightly glauconitic. In Saturn 1 the fining upward cycles average 10m thick, in Gandara 1 they are 30m thick.

In De Grey 1 the coarsening upward cycles are capped by coarser grained (range fine to granule) sandstones with minor glauconite and poor to good intergranular porosity. Here Time Slice J1 probably rests on an eroded surface of Triassic limestone.

In Strickland 1 yellow to grey, mottled black, medium to very coarse grained quartz sandstone occurs. There are zones of concentrated skeletal fragments that have iron carbonate ooids with sideritic cement. Here post depositional oxidation has resulted in yellowish claystone and iron carbonate cements within the sandstones.

In Hampton 1, Enderby 1 and Strickland 1 there is a basal light grey very fine too very coarse grained dominantly fine grained well sorted sandstone with a trace to fair intergranular porosity. This could be a basal transgressive sandstone.

PALEODEPOSITIONAL ENVIRONMENT:
In Saturn 1 sedimentation is interpreted to commence as shallow marine, overlain by deltaic and then shallow marine again, giving a regressive, transgressive cycle. The deltaic coarsening upwards cycles are up to 30m thick, with, on average a 5m sand at the top of each cycle. The stacked delta lobes are characteristic of fluvially dominated delta systems where both wave and tidal influences are minor.

The basal sand at Strickland 1, Enderby 1 and Hampton 1 is probably a reworked sand formed as the previously exposed shelf was transgressed. Deposition on the shelf may not have commenced until the later part of J1 following a sea level rise. The deltas are likely to be shelf top deltas (the area appears to have been relatively shallow throughout the entire time slice) rather than shelf edge deltas, as no major thick accumulation of prodelta clays are seen.

Palaeogeography:
Delta lobes, some coastal and lower sub-aerial delta plain environments occur in the east. In the western area the environment is interpreted as shallow shelf. The limited data suggest a very broad division of deltaic coastal sedimentation to the east and shallow marine shelf sedimentation to the west. A source area to the northeast is possible.

The transgressive sequence seen in the Late Triassic Time Slices culminates in onlap of the previously exposed Enderby Terrace. Incised valley fill may occur at this time.

<u>PROSPECTIVITY:</u> FAIR TO POOR
This is a significant time slice as major reserves are found in it. However all major plays on the Rankin Trend have been drilled. In the Lewis Trough it is probably too deep to be a viable target. Sands within fluvial deltaic environments of this type tend to be thin and of limited lateral extent.

On the Enderby Terrace the basal transgressive sand could prove a viable target but requires the migration of hydrocarbons from the Lewis Trough to be prospective.

<u>Geochemistry (TOC, HI and Vr)</u>
The median TOC values range from 0.5 to 1.9 with a maximum of 3.29 at Malus 1. The median HI values range from 18 to 130 with a maximum of 141 at Dockrell 1. The vitrinite reflectance data suggest this interval is in the early stage of oil generation on the Enderby Terrace and the early peak stages of oil generation in the Kangaroo Syncline and Rankin Platform area.

<u>Shows/Porosity/Permeability</u>:
Major gas condensate accumulations occur along the Rankin Trend sealed by the overlying Early Cretaceous; North Rankin 2, North Rankin 3 and Dockrell 1 are examples of major accumulations within this time slice. A minor oil indication in Strickland 1 suggests possible migration through the area.

Porosity in the sands is fair to good. In Dockrell 1 porosities of 14% to 19% occur and in Eaglehawk 1 they range from 15% to 22%. Permeability appears to be fair to good at these depths. (Vincent & Tilbury,1988 p 357).

<u>Traps and Plays</u>:
On the Enderby Terrace the basal transgressive sand could prove a viable target following mapping of the extent of an upper seal. Fault plays and pinchout plays based on this thin sand are possible targets. The time slice is not likely to constitute a target in the area of the Rankin Platform and Kangaroo Syncline as only claystones and siltstones are likely facies in these areas.

TIME SLICE J2: LOWER TO MIDDLE JURASSIC: Pliensbachian to Early Toracian (200. 0 to 191. 0 Ma).
ENCLOSURES 18 & 19

Formation Synonyms: Dingo Claystone

PALAEONTOLOGY:
Upper D. priscum & Lower C. turbatus to Upper C. torosa.

Six wells penetrated Time Slice J2. It is absent from eight wells on the Rankin Trend and three wells on the Enderby Terrace possibly due to post depositional erosion. Thirteen wells in the Lewis Trough did not reached this time slice but it is thought to exist at depths greater than the total depth reached.

Age control is poor to very poor over this interval as both *Upper D. priscum* and *Upper C. torosa* also extend into Time Slice J1. The boundary between these two time slices has therefore been extrapolated from the age depth plots. In Hampton 1 and De Grey 1 the Time Slice J2 boundaries are completely dependant on extrapolation from the age depth plots. Time Slice J2 deposition is apparently conformable in all wells except Saturn 1 where the upper boundary is unconformable.

Internal unconformities are difficult to detect due to the large range of the palynological zones on which Time Slice J2 is based, but there are suggestions from some of the age depth plots that Time Slice J2 is in fact missing. This is particularly seen in North Rankin 3 but here age control is again poor.

On the Enderby Terrace the section currently assigned to Time Slice J1 could possibly be Time Slice J2 age (see Time Slice J1 section for discussion)

Other workers suggest that Time Slice J2 is a time of regional unconformity associated with the the onset of rifting and subsequent creation of the Lewis Trough (Kopsen and McGann 1985). However the results of this study suggest that rifting commensed earlier in late Time Slice J1.

Thickness Variations:
Maximum preserved thickness occurs in Hampton 1 (148 m). A fairly uniform depositional thickness of 100m to 150m is indicated across the entire area, although there is thinning towards Strickland 1 and at Saturn 1, the latter due to erosion.

Lithology:
Dark grey to medium grey, olive grey to brown silty calcareous claystone or occasionally micaceous shale, is the dominant lithology in Gandara 1, Saturn 1, Enderby 1 and Hampton 1. The claystone usually grades into minor argillaceous siltstone with occasional interbeds of minor fine grained slightly glauconitic quartz sandstone.

In Gandara 1 a coarsening upward sequence occurs with shales grading into sandstones and oolitic limestones overlain by marls and claystones. The sequence is thought to indicate a transgression resulting in a gradually increasing water depth at Gandara 1. Medium to dark grey and olive grey, slightly silty soft shale grades through siltstone into light grey to light olive grey, fine to very coarse grained moderately well sorted sub angular to sub rounded silty quartz sandstone. This sandstone has a trace to good intergranular porosity. This is overlain by light brown grey oolitic (40 - 60%) medium to coarse grained calcite cemented limestone, with poor intergranular porosity. The uppermost section is marl and calcilutite

Coarsening upward cycles are developed in De Grey 1. Dark grey silty micritic shale grades through quartz siltstone into medium grained (range fine to granule) sandstone with minor glauconite and poor to good intergranular porosity. In Strickland 1 post depositional oxidation of similar deposits has resulted in yellow to black claystone and iron carbonate cements within the sandstones.

In Hampton 1, Enderby 1 and Saturn 1 recrystallised limestone composed of clays, oolites, skeletal fragments and micrite is common.

PALEODEPOSITIONAL ENVIRONMENT:
A shallow marine shelf environment is indicated, with possibly slightly deeper water than that of Time Slice J1. Deltaic environments have contracted to the northeast of the area. Marine oolitic carbonate sedimentation, possibly an offshore bar, is developed in Gandara 1, indicating fairly shoal moderate energy inner shelf conditions. In the area of De Grey 1 coastal deltaic sedimentation occurred. The time slice reflects continuation of the transgression of the previous time.

Palaeogeography:
The limited data suggest a very broad division of deltaic coastal sedimentation to the east and shallow marine shelf sedimentation to the west. An oolitic offshore bar occurs within this time slice in Gandara 1.

PROSPECTIVITY: FAIR TO POOR
There have been no discoveries within this time slice. In the Lewis Trough Time Slice J2 is probably too deep to be a viable target and would need to be sourced locally or from the deeper Triassic. Sands within this type of environment tend to be thin and of limited lateral extent. On the Enderby Terrace there is a remote possibility of a facies transition between the sandy deposits at De Grey 1 and the seal facies at Strickland 1. However hydrocarbon charge from the Lewis Trough is required to make this prospective. The Gandara area limestone - sandstone may be a more regional target but it too suffers from unproven sourcing mechanisms. Faults connecting to mature Triassic source are a possibility.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0.3 to 1.64 with a maximum of 12.5 (coaly) at Hampton 1. The median HI values range from 58 to 158 with a maximum of 188 at Hampton 1. The vitrinite reflectance data suggest the southern Enderby Terrace is in the early stage of oil generation and the northern Enderby Terrace is in the initial stage of peak oil generation.

Shows/Porosity/Permeability:
A minor oil indication occurs in Strickland 1, this may be indicative of migration into this area. In the Dampier Sub-basin the Dingo Claystone is an established source rock.

Traps and Plays:
In Gandara 1 10 -15m of sandstone and oolitic limestone with fair porosity and encased in seal and potential source facies was intersected. This is interpreted as an offshore bar but could be a more regional surface related to a relative rise in sea level. The logs show the limestone should give a good seismic reflection. The areal extent of this reflector should be mappable. It could provide subtle stratigraphic traps and be high graded wherever it is buried to sufficient levels to induce maturation or where fault migration from deep sourced hydrocarbons is feasible.

TIME SLICE J3 to J6: MIDDLE JURASSIC: Late Toracian, Aalenian, Bajocian, Bathonian and Lower Callovian (191. 0 to 167. 0 Ma).
ENCLOSURES 20 & 21

Formation Synonyms: Legendre Formation, Dingo Claystone, Learmonth Formation.

Time Slices J3, J4, J5 and J6 have been compiled into one map for reasons detailed below but which include poor palynological resolution, sparse well coverage for any individual time slice and a similar palaeodepositional environment across the time slices.

PALAEONTOLOGY:
The spore pollen zones for the different time slices are listed on the left and the dinoflagellate zones on the right.

Time Slice J6: *D. complex & C. cooksoniae*..... *W. indotata & C. halosa.*
Time Slice J5: *C. turbatus*.........................*D. caddaense.*
Time Slice J4: *C. turbatus.*
Time Slice J3: *C. turbatus.*

This composite time slice is penetrated in a total of thirteen wells. It is absent from eight wells on the Rankin Trend (including Saturn 1) and two wells on the Enderby Terrace due to post depositional erosion. Seven wells within the Lewis Trough reached total depth above this time slice. In all these wells the time slice is likely to exist beneath the total depth reached.

Palynological control is fair over this interval. The top is normally easily identified as a major basin wide unconformity (the Main Unconformity), that is identifiable everywhere except some wells in the central Lewis Trough where deposition into Time Slice J7 was probably continuous.

Where *D. caddaense* is present the boundary between Time Slice J4 and J5 is readily estimated. Normally Time Slice J5 and J6 can be constrained by the significant palynological change at this boundary. Because of the poor palynological control there is heavy reliance on the age depth plots and the good control points within Time Slice J2 to establish an estimate for the boundaries of Time Slices J3 and J4. Often the Time Slice J5 boundaries needs to be extrapolated from the above plots in those wells with particularly poor age control.

In Cossigny 1 there is a small upper section of lower most *W. digitata* (Time Slice J7). This is interpreted to be extremely thin and has been included in Time Slice J6 rather than Time Slice J7. In Angel 2 it is possible that the lower part of the section is *C. torosa* and not *C. turbatus*. This problem was essentially unresolvable so it is assumed that any conflict with a *C. turbatus* age is due to reworking.

Summary of Time slices:

Time Slice J6: Identified in eight wells. The upper Time Slice J6 marks the boundary of the commencement of the major tectonic episode that formed the Dampier Sub-basin (ie Lewis Trough and Kendrew Terrace). Everywhere but within the Dampier Sub-basin the top of Time Slice J6 is a major erosional unconformity (the Main Unconformity). In the Lewis Trough, at Rosemary 1, Madeleine 1 and Legendre 1, the overlying Time Slice J7 is present and the wells reached total depth within Time Slice J6. Hence nowhere in the Trough was a full section of Time Slice J6 encountered.

Gandara 1 has the most complete section over this interval. However the upper most 30m is mixed siltstone/sandstone facies assemblage different from the claystone of the rest of Time Slice J6. Age control of this upper section is poor (*C. dampieri* superzone) and so it could be as young as Time Slice J8. The section is here interpreted as a syntectonic deposit, either late Time Slice J6 to early J7, (see Figure 9 and Enclosure 2) possibly shed from the uplifted flank of the rapidly forming Lewis Trough, (ie the Rankin Trend). Such a model implies that these sediments might be the distal edge of a clastic wedge.

Time Slice J5: Identified in seven wells.

Time Slice J4: Identified in eight wells

Time Slice J3: Identified in six wells

Thickness Variations:

Only relatively thin deposits of Time Slices J3 and J4 are seen. By Time Slice J4 there is no doubt that major subsidence preceding the establishment of the Dampier Sub-basin has commenced. At Angel 2 well 810m of Time Slice J6 is deposited; as the top is unconformable this is not a maximum figure. In the Lewis Trough up to 2000m of Time Slice J6 may have been deposited.

Uplift did not commence on the Rankin Trend until at least post Time Slice J4 and on the evidence of Gandara 1 probably did not commence until the latest Time Slice J6. It is possible that at this time the Rankin Trend area was a half graben with southwest striking faults hading to the northwest, so that another shallow half graben trough would have existed on what is now the Rankin Platform. This would mean that Gandara 1 was likely isolated from the easterly depositional sources supplying the rest of the basin.

Lithology:

Five lithologies dominate the composite time slice, dark claystone, dark siltstone, fine grained sandstone, coal and limestone.

Claystone: Olive black to olive grey, grey brown to brownish black and medium grey moderately hard claystone, composed of 50-100% clay minerals, nil- 50% quartz silt, nil 10% micrite and with traces of carbonaceous matter, pyrite and mica. At Legendre 1 and Rosemary 1 white kaolinitic clays are found. These may be seat earths beneath coals. In North Rankin 3 traces of glauconite and foraminifera occur.

Siltstone:Very light to medium grey, olive black to dark grey siltstone is composed of 55-70% quartz silt, 20-40% clay minerals and nil to 15% quartz sand. The siltstone is often pyritic and carbonaceous. At Madeleine 1 it is significantly felspathic.

Sandstone: Colourless to very light grey, very fine to granule, dominantly fine, moderate to well sorted, subangular to subrounded, 60-90% quartz, unconsolidated to hard sandstone, with nil to good porosity. Along the Enderby Terrace area several variations are notable. Silica cement is common and calcite cement is frequent. Traces of chert are seen in Cossigny 1 suggesting a source from this area. Enderby 1 and De Grey 1 both have significant glauconitic content.

Coal: Is mostly black, hard and vitreous but occasionally brown and clayey. Up to 2. 5m thick coals are recorded in Legendre 1. These coals are not regionally extensive and appear to be fluvio-lacustrine deposits.

Limestone is common within Time Slice J3. Recrystallised medium grey or yellow grey oolitic (to 80%) and skeletal (to 10%), calcite cemented limestone is found in Time Slice J3 in the wells on the Enderby Terrace. Crinoid fragments and sponge spicules have been identified. Time Slice J3 is defined solely on the age depth plots. That the method has selected units so lithologically unique is a reflection of the general accuracy of the age depth plots as a means of defining the time slices when age control is poor.

PALAEODEPOSITIONAL ENVIRONMENT:
All the time slices are interpreted to be the result of fluvial, to deltaic, near shore and shallow marine shelf deposition. Delta distributary channels, beaches and offshore bars are possible. The overall pattern is of a low to moderate energy system. The trend throughout this interval is a continuation of the transgressive phase of previous time slices up till the middle or end of Time Slice J5. Late Time Slice J5 and all of Time Slice J6 mark the onset of a regressive phase.

Palaeogeography:
Time Slice J3: The evidence of the limestones in wells on the Enderby Terrace indicate a relative sea level high. The environment is marine shallow continental shelf. Possible volcanic activity may be occurring at this time based on the feldspar content of some of the sands.

Time Slice J4: Deltaic in the eastern half of the area. Offshore shallow marine in the western area.

Time Slice J5: Deltaic in the eastern half of the area. Offshore shallow marine in the western area. Peak of transgressive event and possible start of regression.

Time Slice J6: Deltaic in the eastern half of the area. Offshore shallow marine in the western area. Marine regression continues slowly. Onset of major tectonism.

PROSPECTIVITY: FAIR
The prospectivity of this interval is fair. Good mature source rocks are present. However stratigraphic trapping situations, though likely to be numerous, are difficult to predict. In structural traps these Time Slices would be good secondary targets.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0.29 to 2.53 with a maximum of 63 (coaly) at Angel 2. The median HI values range from 18 to 244 with a maximum of 906 (coal) at Angel 2. The vitrinite reflectance data suggest this interval is in the initial to middle peak stages of oil generation except at Hampton 1 which is in the early stage of oil generation. There is a clear correlation between the better TOCs and the prodelta facies in Time Slices J5 and J6, however the HI values are not as conclusive.

Shows/Porosity/Permeability:
There are gas indications in Madeleine 1, North Rankin 3 and Lambert 1 and oil indications in Talisman 1, Cossigny 1 and Strickland 1. There are oil and gas indications in Rosemary 1 and strong oil and gas indications in Angel 2. The Angel 2 section may be the source for the Angel Field accumulation within the overlying Time Slice J10, though it is unusual that no stratigraphically controlled accumulations occur within this well given the obviously good stratigraphic trapping possibilities.

Traps and Plays:
Stratigraphic traps in this interval are highly likely particularly in the transition zone between shallow shelf and lower delta plain. Distributary channel sands and distributary mouth bar sands would be likely reservoirs.

Time Slices J4 and J3 are seal facies at North Rankin 3 and Gandara 1. It seems probable that this seal facies was extensive over a large area of the Rankin Platform and Kangaroo Syncline. Cretaceous seal rocks are also regionally extensive but between these two seals is a possible thin reservoir lithology. It is the lithostratigraphic equivalent of the small K8 interval seen in Malus 1, the conglomeratic interval in Saturn 1 and the sandier section discussed above from Gandara 1. This means there is a strong possibility that reservoir quality sands could be stratigraphically isolated between lower Jurassic seal rocks (potential source rocks) and overlying Cretaceous seals. Traps in this reservoir could be strucural, isolated fault blocks or stratigraphic pinchout. Hydrocarbons could also enter via faults from deeper mature source.

TIME SLICE J7: MIDDLE JURASSIC: Middle Callovian to Lower Oxfordian (167. 0 to 162. 0 Ma).
ENCLOSURES 22 & 23

Formation Synonyms: Dingo Claystone

PALAEONTOLOGY:
Dinoflagellate Zones: *W. digitata and R. aemula.*

The Time Slice J7 was penetrated in six of the study wells. Time Slice J7 is a syntectonic deposit limited to the Dampier Sub-basin (Lewis Trough and Kendrew Terrace) into which it was deposited during the Sub-basin's formation. It is absent from the twenty wells not in the Sub-basin. Four of the wells in the Lewis Trough reached total depth above this time slice which is believed to be present at greater depths.

There is a possibility of a wedge of sediment of Time Slice J7 age on the northwestern flank of the Rankin Trend (see Traps and Plays discussion in Time Slice J3 - J6 section).

At Madeleine 1, Walcott 1 and Wanaea 1 only the *W. digitata* (lower Time Slice J7) is definitely present. The upper surface in this area is a minor unconformity. In the wells adjacent to the Rosemary Fault System *R. aemula* is present as well as the *W. digitata* zone.

Thickness Variations: (see Figure 12)
Of the six wells, three reached total depth within the time slice. Isopach mapping is controlled by the seismic with only limited well input. The depocentre for this time slice is the Lewis Trough. The thickest section occurs in Rosemary 1 (500m). There seems to be an asymmetry to the trough and the thickest section appears to occur adjacent to the Rosemary Fault System. The absence of *R. aemula* from the Madeleine 1 and Wanaea 1 area suggests that the Madeleine Trend came into existence at this time, resulting in non deposition and erosion onto this feature.

Lithology:
The dominant lithology is olive grey to olive black to brown black highly silty claystone with a trace of mica and pyrite. This is gradational into and interbedded with olive grey argillaceous siltstone that in turn grades into light grey to light pinkish grey to olive grey, very fine to fine grained, well sorted, sub angular to rounded, 40-60% quartz sandstones, with calcite and dolomite cement. The sandstone have only a trace of intergranular porosity. Microcline (to 40%) and lithic fragments become more pronounced to the northeast and in Legendre 1 the sandstones are felspathic arkoses. As a rule bioturbation is intense in all cores taken in this time slice.

PALAEODEPOSITIONAL ENVIRONMENT:
A source area to the northeast, as in Time Slice J6 time is indicated. Acid volcanic detritus is probably derived from this direction. Deposition was restricted to the now rapidly subsiding fault bounded Dampier Sub-basin. The likely existence of the Madeleine Trend, at the end of Time Slice J7 suggests that the basic division of the

Dampier Sub Basin

Time Slice J7: Isopach Map

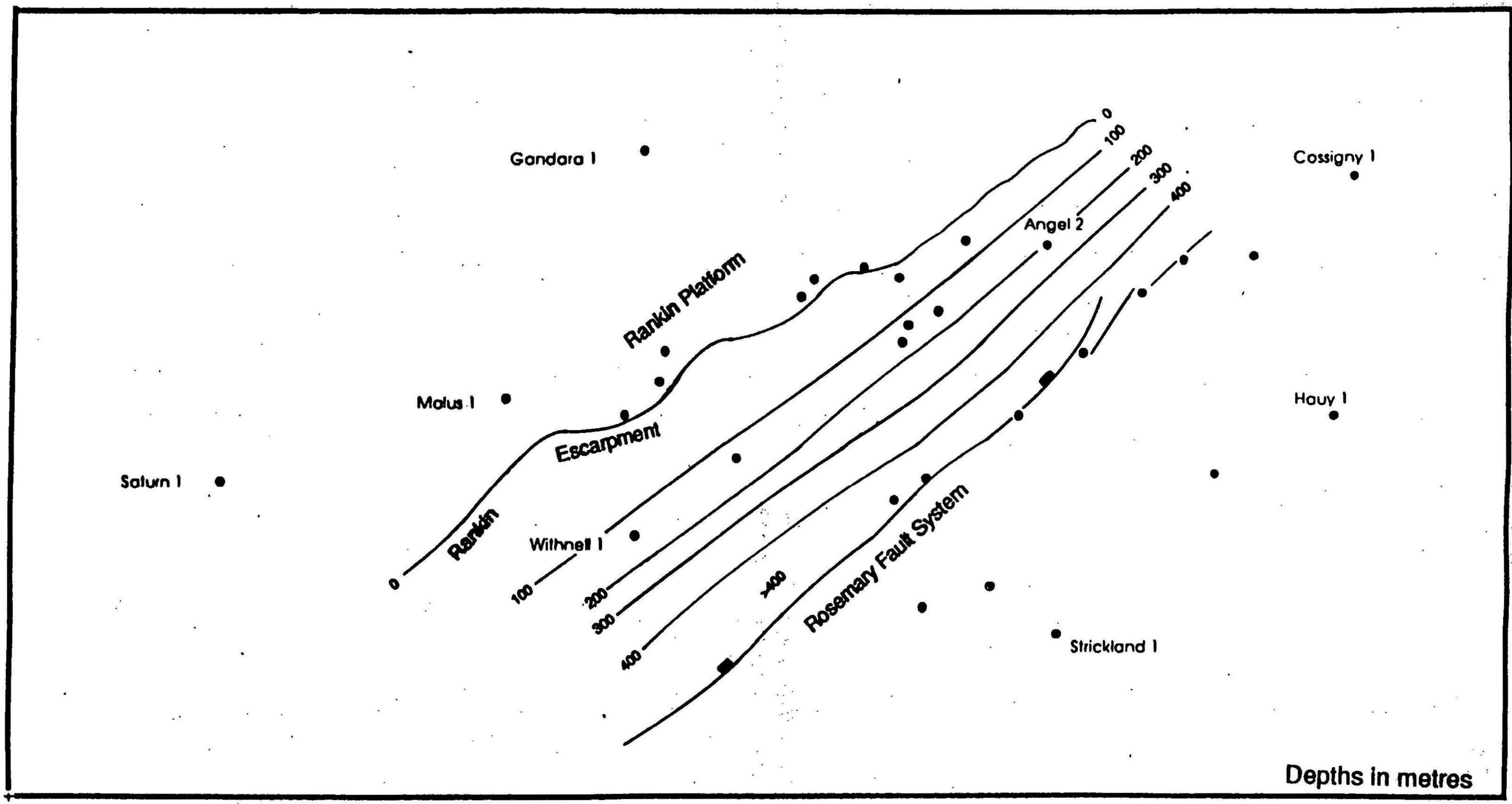


Figure 12

Sub-basin into the Lewis Trough and Kendrew Terrace, had occurred by the middle of the *R. aemula* zone.

Palaeogeography:
Marine nearshore environments are indicated to the northeast. It is interpreted that a shelf edge delta system built out to the edge of the rapidly subsiding trough from the east and northeast. Uplift of the Enderby Terrace provided an additional source of sedimentation into the Sub-basin and it is assumed that much of the erosion of the Lower Jurassic on the flanks of the Rankin Trend occurred at this time leading to the development of the Rankin Escarpment. The deposits in the Sub-basin represent distal offshore sedimentation and slumping and flows from the edge of the deltas.

The sequence at Rosemary 1 is interpreted to commence as a series of stacked prodelta lobes (30-50m thick). Water depth rapidly increases as the Sub-basin subsidence accelerates and slump deposits off this faulted margin accumulate.

PROSPECTIVITY: POOR
The prospectivity of is considered poor, mainly due to poor porosity and permeability in the discontinuous sands. Time Slice J7 is possibly a significant source rock interval though the better source quality may be limited to the eastern half of the Sub-basin.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0.9 to 2.02 with a maximum of 3.98 at Legendre 1. The median HI values range from 48 to 147 with a maximum of 294 at Rosemary 1. The vitrinite reflectance data suggest this interval is in the initial stage of peak oil generation. Very low HI values in Madeleine 1 and Walcott 1 may reflect reworking and oxidation of sediment sourced from the west, as opposed to Rosemary 1 and Legendre 1 which receive sediment from the east.

Shows/Porosity/Permeability:
Time Slice J7 is believed to be a major source rock interval. Mixed oil and gas shows occur in all the wells except Legendre 1. The shows are attributed to both local maturity in the source shales and locally sourced migrated oil in the siltstone and sandstones. Porosities in the fine sandstone are everywhere described as intergranular, trace to poor and permeabilities are thought to be low.

Traps and Plays:
Reservoir quality is very poor in this unit and this reduces the play potential significantly. A detrital source area from the northeast is indicated and reservoir quality could improve in this direction.

TIME SLICE J8: UPPER JURASSIC: Early Oxfordian to Kimmeridgian: (162. 0 to 150. 0 Ma).
ENCLOSURES 24 & 25

Formation Synonyms: Dingo Claystone, Biggada Formation Equivalent, Eliasson Formation, Lauchie Member(a shale interval within the Eliasson Fm)

PALAEONTOLOGY:
D. swanense, W. clathrata, W. spectabilis.

Ten of the study wells encountered Time Slice J8. Rosemary North 1 and Nelson Rocks 1 reached total depth before encountering this time slice. In the remaining eighteen wells it is absent, probably due to non deposition.

Age control is fair to good over this interval. Both Dampier 1 and probably Withnell 1 reached total depth within this time slice. In Dampier 1 only the *D. swanense* zone is recognised. In Withnell 1 technical problems prevented age dating below 3750m. The well is assumed to be near the base of Time Slice J8 at total depth. The top of Time Slice J8 was positioned just below an identification of *C. perforans.*

In Malus 1 a thin interval of *W. spectabilis* is found. (see also Gandara 1 Time Slice J3 - J6)

A distinct unconformity at the mid *W. clathrata* time occurs in the vicinity of Madeleine 1 and Wanaea 1, though not necessarily elsewhere and may be related to movement on the Madeleine Trend.

The wells in the Lewis Trough that are adjacent to the Rosemary Fault system lack section younger than *W. spectabilis.* It is possible that this unconformity is the mid *W. clathrata* unconformity seen at Madeleine 1 but it could also be a younger (*D. swanense*) separate event.

Thickness Variations:(see Figure 13)
Deposition is restricted to the Dampier Sub-basin. The thickest section is in Withnell 1 (534m) near the trough axis. The isopachs suggest this trough was closed to the north and open to the south. A lobe of sandy sediment interpreted to be a submarine depositional lobe centred on Legendre 1 occurs within the *W. spectabilis* interval. A depositional lobe geometry has been considered when interpreting the contours.

Lithology:
Deep basin deposition is dark grey-black, poorly fissile, moderately well compacted shale with varying amounts of quartz silt. It has traces of glauconite and pyrite, is fossiliferous, has rare bituminous stringers and thin beds of argillaceous dolomite and siltstone. Where the shale is not deeply buried it is referred to as a claystone. This claystone is gradational into and interbedded with olive grey argillaceous siltstone that commonly grades into light grey to olive grey, very fine to fine grained, well sorted, sub angular to rounded, 40-60% quartz sandstone. This sandstone commonly has calcite and dolomite cement and a trace of intergranular porosity. In Montague 1 a dark

Dampier Sub Basin

Time Slice J8: Isopach Map

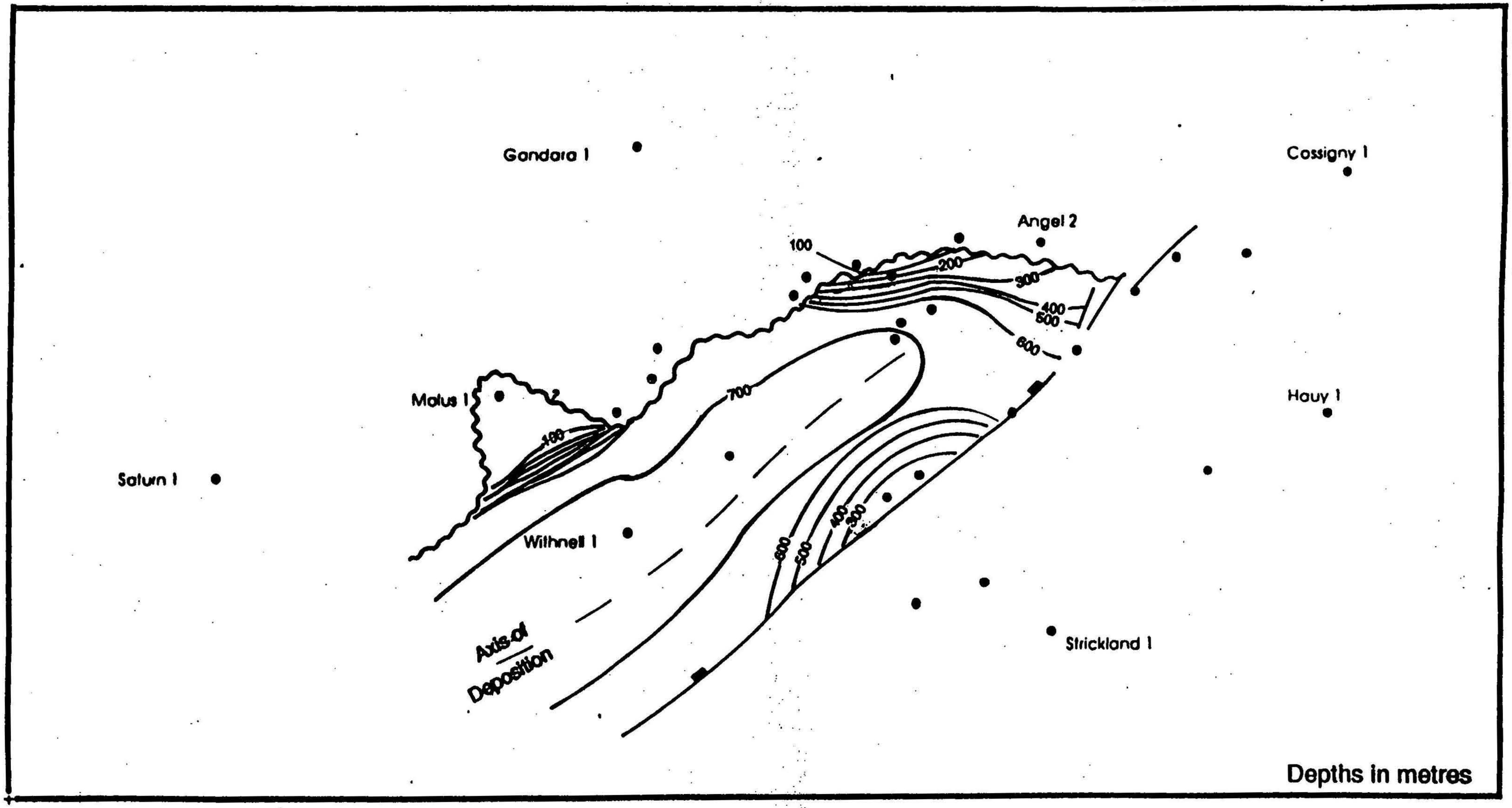


Figure 13

yellowish brown to brown black claystone occurs, possibly indicating a nearby exposed and thus oxidised source area.

At Malus 1 a light grey coarse grained (very fine grained to granule) quartz sandstone with good intergranular porosity occurs.

At Montague 1 the sandstones are light olive grey, very fine to medium grained, moderately well sorted, sub angular to rounded, calcite and silica cemented and have trace accessories as for the claystone. The sandstones have sharp basal contacts, and are normally part of fining upward cycles.

In Legendre 1 is a massive section of light grey, silty to very coarse grained dominantly quartzose, very pyritic cemented sandstones. These sandstones are interbedded with, and overlain by, thin beds of argillaceous siliceous and dolomite cemented sandstone, brown siltstone and dark grey slightly calcareous organic shale. Minor glauconite content increases up the section. The uppermost sand is very coarse grained to granule with abundant cloudy frosted quartz.

Bioturbation, bivalves, belemnites fragments, faecal pellets and other indicators of open marine circulation are plentiful. Ripple marks are common in cores.

<u>PALEODEPOSITIONAL ENVIRONMENT:</u>
Deposition was into the rapidly subsiding Dampier Sub-basin. The environment is marine, though circulation may have been restricted at times. Sediment was sourced dominantly from the east. The uplifted Rankin Trend acting as a dam to this source. The Rankin Trend flank of the Sub-basin may also have sourced material by slumping.

The Rankin Trend and Rankin Platform areas may have been partially emergent or possibly shallow marine. These area do not appear to a major source of sediment supply to the west although the sand at Malus 1 is possibly reworked from this area. Sandy mass flow deposition commences in some places along the Rosemary Fault System.

<u>Palaeogeography:</u>
In early Time Slice J8 sources of relatively clean sand developed. The sands appear to be mass flow deposits that fed into the Sub-basin from point sources on its margins. The finer material that accumulated in the Sub-basin has no apparent preferential source location. An interpretation is that the sand is being moved along feeder channels whilst the finer sediment moved directly across the shelf edge into the basin down minor feeders or by shelf edge slumping. The sand is possibly sourced by reworking in a distance coastal zone and moved by longshore drift into the proximal end of the feeder channels that cross the shelf. The sandy depositional lobes built up on the Sub-basin floor beneath the termination of the feeder channel at the Sub-basin margin. This model implies that the Enderby Terrace was not necessarily emergent at this time.

During *W. spectabilis* time a feeder channel near Legendre 1 supplied sediment to a depositional lobe that appears to nose into the trough striking west southwest. The sandy deposits of this depositional lobe do not extent far into the Sub-basin a feature characteristic of depositional lobes (Shanmugam and Moiola 1991.)

In Withnell 1 the top of Time Slice J8 (late *D. swanense* time) occurs just above a very badly caved section of hole assumed to be a sandstone. This sand is likely to thicken towards its source area, speculated to be from a feeder channel near Malus 1 but could be from a feeder to the south of Rosemary 1.

A small submarine depositional lobe or delta lobe has accumulated near another minor source area adjacent to Montague 1,

The sand at Malus 1 is of uncertain affinity. It may relate to the Lewis Trough but it is possible that it is part of a package of post-Main Unconformity reworked sands with affinities to other sands seen in Gandara 1 and Saturn 1.

PROSPECTIVITY: FAIR TO GOOD
This is a major source rock interval particularly in the deeper Lewis Trough. There is potential for good reservoir quality sands at the base of the fault bounded eastern flank of the Lewis Trough. These would be top sealed and sourced by the adjacent shales. The target is however fairly deep in most areas of the Sub-basin and all easily mappable structures appear to have been tested though it is not certain that the wells are crestal at this level.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0.65 to 2.9 with a maximum of 4.63 at Withnell 1. The median HI values range from 77 to 301 with a maximum of 484 at Montague 1. Montague 1 has consistently higher HI values than any of the other wells that may be due a possible northerly source area, distinct facies associated this shelf edge delta, contamination from the pay zones in this well or restricted circulation at the northern end of the trough resulting in improved organic matter preservation. The vitrinite reflectance data suggest this interval is in the initial peak stages of oil generation in the northern Lewis Trough. Both Dampier 1 and Withnell 1 are in the later peak stage of oil generation.

Shows/Porosity/Permeability:
Throughout this interval strong shows are found in most wells and gas condensate reserves are present in Montague 1. Malus 1 and Legendre 1 are the only wells without shows. Most of the shows are interpreted to reflect actively generating source rocks. This section would likely have fair to good reservoir characteristics similar to the Time Slice J10 section though perhaps slightly poorer due to deeper burial.

Traps and Plays:
The mass flow sands of the Legendre area have been unsuccessfully tested at this level. Intraformational clay seals exit and additional stacked traps are possible, if closure exits at these levels. An additional trap includes incised valley fill on the shelf, top sealed by the intraformational clays.

Possible bypassed pay occurs in Withnell 1 which had a very strong oil and gas show over a a probable caved and overpressured sandstone in uppermost Time Slice J8. On the assumption that this sand is distal to a thicker sequence, possibly centred to the southwest of Rosemary 1, (or towards Malus 1) then a lead may exits in this area. The sand is estimated to be 10m thick and is encased in seal rocks. Even minor faults could isolate large areas on the dip slope and these could also provide additional traps.

TIME SLICE J9: UPPER JURASSIC: Early Tithonian:(150. 0 to 147. 5 Ma).
ENCLOSURES 26 & 27

Formation Synonyms: Dingo Claystone, Angel Formation

PALAEONTOLOGY:
C. perforans, O. montgomeryi. The Time Slice J9 - J10 boundary occurs within the *O. montgomeryi* zone.

Time Slice J9 was penetrated in twelve of the study wells. Rosemary North 1 and Nelson Rocks 1 reached total depth before encountering this time slice. In the remaining fifteen wells it is absent, probably due to non deposition. All wells, except Saturn 1, are within the Dampier Sub-basin.

Palynological control is poor to excellent over this interval. Extensive palynological work has been undertaken on selected wells within this time slice, the effort related no doubt, to the oil discoveries made in the overlying units.

A basal unconformity or hiatus appears in wells adjacent to the Rosemary Fault System and in the northern Lewis Trough wells, were *C. perforans* appears to be absent. Only a comparatively thin *C. perforans* zone is seen in Dampier 1.

Saturn 1 presents some difficulties. In this well Time Slice J9 is based on extrapolation from the age depth plot and inferred to be beneath overlying Time Slice J10 sediments. However the interval in question, 3016m-3022m sub-sea, is a fossiliferous glauconitic calcite cemented sandstone, that rests unconformably on Time Slice J2 age sediments. It can be any age between Time Slices J2 and J10. It is thought be related to post Time Slice J6 deposits as seen in Gandara 1 and Malus 1 (see Figure 9 and Enclosure 2).

A characteristic of some of the deposits is an extremely well preserved shallow water species assemblage. This is considered indicative of anoxic conditions, that prevented corrosion of the carbonate remains. Reworking of immediately older units into Time Slice J9 sediment is also a common occurrence adjacent to the Enderby Terrace.

In Lewis 1A there may be a thin basal section of Time Slice J9 age. Heavy reworking of *W. spectabilis* (ie. Time Slice J8) is interpreted and this complicates the identification of immediately younger zones.

Thickness Variations: (see Figure 14)
The thickest section is encountered in Withnell 1 (534m). Deposition is restricted to the Dampier Sub-basin. The isopachs suggest that this trough was closed to the north and open to the south.

Lithology:
In the deep basin area dark to very dark grey brown, poorly fissile to moderately well compacted shale dominates the sedimentation with varying amounts of quartz silt. This lithology grades into silty shale, with traces of glauconite and pyrite. In Madeleine 1 minor ripple cross-bedded highly bioturbated sandstones and siltstones grade down

Dampier Sub Basin

Time Slice J9: Isopach Map

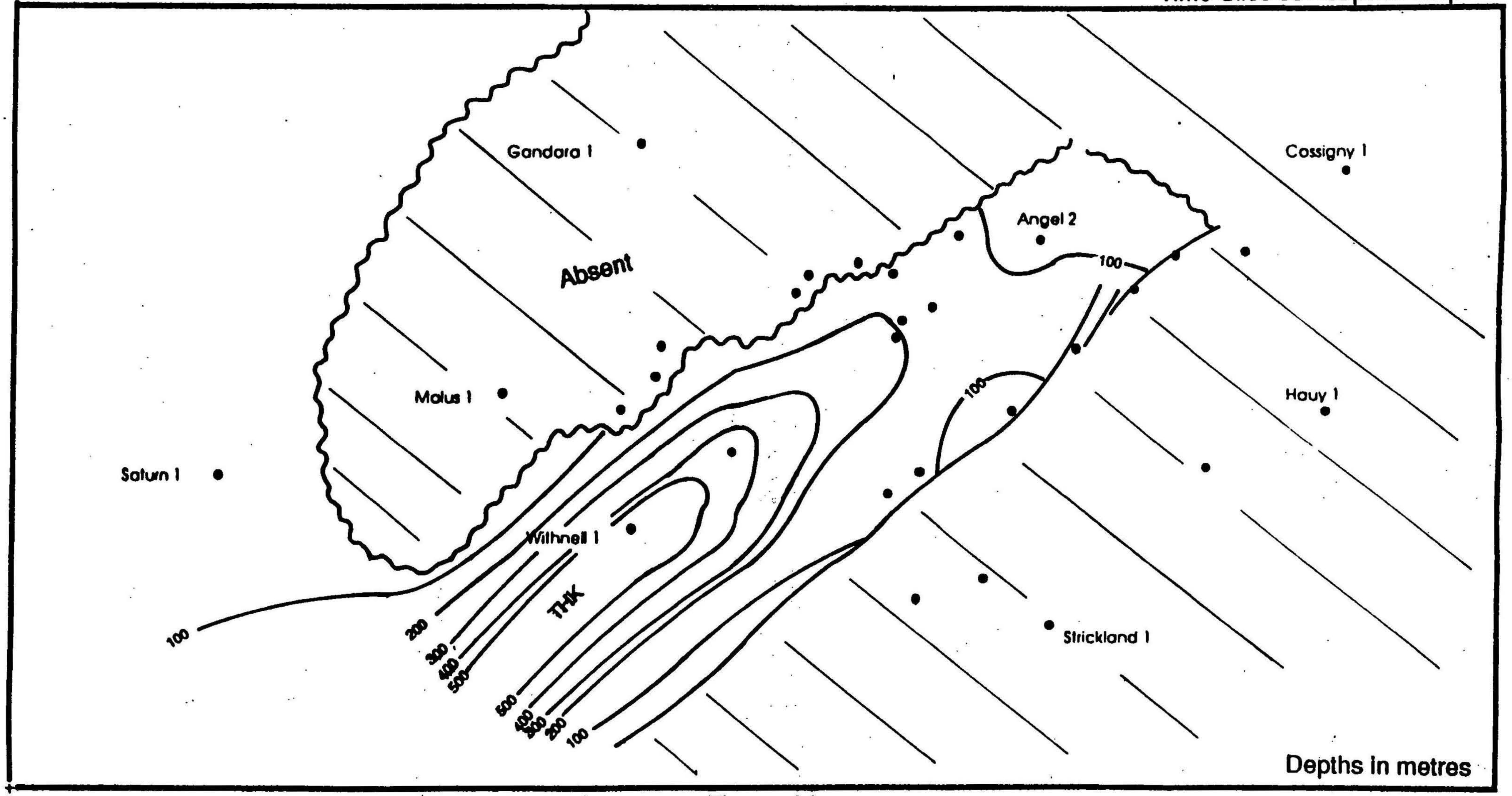


Figure 14

into non bioturbated black shales this lithology being indicative of local or perhaps basin wide anoxic conditions.

Towards the trough margins the shale becomes a soft to hard, dark olive grey claystone that is slightly silty and micaceous, with traces of dolomite, pyrite, glauconite and carbonaceous fragments. Occasionally there is a trace of siderite and minor argillaceous dark grey siltstone laminae.

At Legendre 1 the siltstones are light brown to medium dark greyish brown, soft to friable locally grading to fine and medium grained non-glauconitic slightly calcareous sandstones.

Mass flow sands are seen in wells immediately adjacent to the Sub-basin's edge. In composition and texture they vary from well to well.

> Montague 1: Light olive grey, very fine to medium grained, moderately well sorted, subrounded, with calcite and silica cement and trace accessories as for the claystones. The sandstones have sharp basal contacts and generally fine upward. Porosity is poor.
>
> Angel 2: Sandstones are mostly upward fining, clear to medium light grey, very coarse to granule, dominantly coarse grained, subangular to subrounded well sorted with trace glauconite, pyrite and jasper. Silica cement is common but generally the sandstones are moderately consolidated with good to fair porosity.
>
> Legendre 1: White to light brown with a greenish tinge due to aggregates of glauconite, fine to coarse grained and poorly sorted. The coarser grains are frosted and slightly pitted. There are thin beds of conglomerate. These lithologies have good porosity. The lowest sandstone is highly argillaceous below 2280m resulting in zero effective porosity.
>
> Rosemary 1: sands are very light grey white and medium dark grey, very fine to very coarse grained but dominantly fine to medium grained, becoming coarser grained with depth, sub angular to sub rounded, moderate to well sorted unconsolidated to moderately hard with good porosity.
>
> Saturn 1: A basal conglomerate of very fine to pebble quartz and minor heavy minerals grades up into argillaceous fossiliferous glauconitic calcite cemented greensands. This is probably not a mass flow deposit.

PALAEODEPOSITIONAL ENVIRONMENT:

This time slice is characterised by the initiation of mass flow deposition into the deep water, narrow fault bounded Dampier Sub-basin. This style of deposition continues into Time Slice J10 when the source of the sands was terminated.

The basin appears to have been anoxic in part. Morgan (1991) has found a "lean darkened and superbly preserved assemblage" of microfossils at 2361m in Rosemary 1. He attributes this to a "starved anoxic environment".

Palaeogeography:
Three feeder channels, one near Legendre 1, one north of Angel 2, and one just to the south of Rosemary 1, fed submarine depositional lobe deposits throughout Time Slice J9. The largest depositional lobe is probably the Legendre lobe, followed by the Rosemary lobe and then the Angel lobe. Sand may have been sourced from a distant shore zone, eg bars, beaches (a possibile causitive mechanism to explain the quartz grain frosting), followed by long shore drift into the heads of feeder canyons that crossed the shelfs. Temporary sand damming within the submarine canyons followed by episodic discharge of the feeder onto the depositional lobes can explain many of the characteristic of these deposits.

Some of the thick deposits of clays and siltstones in the trough axis may be the result of escarpment erosion and slumping from the Rankin Trend.

PROSPECTIVITY: FAIR TO POOR.
This is a major source rock interval particularly in the deeper trough axis. None of the good reservoir quality sands at the base of the fault bounded eastern flank of the Lewis Trough are sealed and any hydrocarbons entering the sequence can be expected to migrate upward into the overlying beds.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 1.01 to 1.58 with a maximum of 3.15 at Dampier 1. The median HI values range from 74 to 203 with a maximum of 308 at Withnell 1. The vitrinite reflectance data suggest this interval is in the initial peak to middle peak stages of oil generation. The northern area, as was seen in Time Slice J8, has apparently better HI values. This is possibly a function of the northern source area or restricted circulation resulting in better organic carbon preservation. Maximum TOC values occur in Madeleine 1, Dampier 1 and Withnell 1 associated with basin floor deep water deposits possibly also related to restricted circulation and consequent poor oxygenation of bottom waters within the trough.

Shows/Porosity/Permeability:
Potential reserves are present in Montague 1. Oil indications are found in Rosemary 1 and Talisman 1. Strong shows in occur in Withnell 1 and Dampier 1 where the sediments are probably within the oil window. Saturn 1 has what could be described as a strong gas condensate show over this interval, with a log calculated 30-50% water saturation. The interval was cased off but not tested.

Traps and Plays:
No plays are obvious. The Montague 1 sands could have a significant stratigraphic component and so the reservoir cover a large area. The mass flow sands have been unsuccessfully tested in several places at this level. Intraformational clay seals exit so intraformational traps are possible.

There is possible by-passed pay in Saturn 1.

TIME SLICE J10: UPPER JURASSIC: Late Tithonian:(147. 5 to 144. 0 Ma).
ENCLOSURES 28 & 29

Formation Synonyms:: Angel Formation, Dingo Claystone

PALAEONTOLOGY:
Lower P. iehiense, D. jurassicum and *upper O. montgomeryi.*

Time Slice J10 has been penetrated in a total of fifteen wells and all, except Saturn 1, are within the Dampier Sub-basin. Time Slice J10 is absent from the remaining fifteen wells due to non deposition.

Palynological control is poor to excellent over this interval. Extensive palynological work has been undertaken on selected wells within this time slice, the effort related, no doubt, to the oil discoveries made in it.

Those wells in the northwestern half of the Dampier Sub-basin appear to have complete sections with evidence of only a minor hiatus occurring at the top in a few of the wells. In contrast the wells adjacent to the Rosemary Fault System all appear to have parts, or all, of the *P. iehiense* zone missing. In some cases it is not clear wether the missing section is actually within Time Slice J10 or the overlying Time Slice K1. Nevertheless a minor unconformity is considered to be present at or near the top of Time Slice J10 in this area.

Talisman 1 is the exception to the above. In this well *P. iehiense* is present but the lower zones of *D. jurassicum* and *O. montgomeryi* have not been recognised. They are assumed to be present based on extrapolation from adjacent wells. However in Lewis 1A the *O. montgomeryi* zone is missing so it is possible that it is absent in Talisman 1 as well.

The deposits have an extremely well preserved shallow water species assemblage. This is considered indicative of anoxic conditions that prevented corrosion of the carbonate remains. Reworking of immediately older units into Time Slice J10 is also common.

Thickness Variations: (see Figure 15)
The maximum preserved thickness occurs at Montague 1 (579m), and the minimum at Saturn 1(27m). Saturn 1 is outside the Lewis Trough and not representative of the general depositional pattern. The isopach map attempts to reflect the existence of several distinct submarine depositional lobes.

Dipmeter:
The dipmeter was examined in several wells to see how it might aid in the interpretation.

The motivation for collecting dipmeter data in exploration wells (ie most of the wells used in this study) is usually for structural interpretations such as the recognition of fault zones or major unconformities. It is also a method to verify the general

Dampier Sub Basin

Time Slice J10: Isopach Map

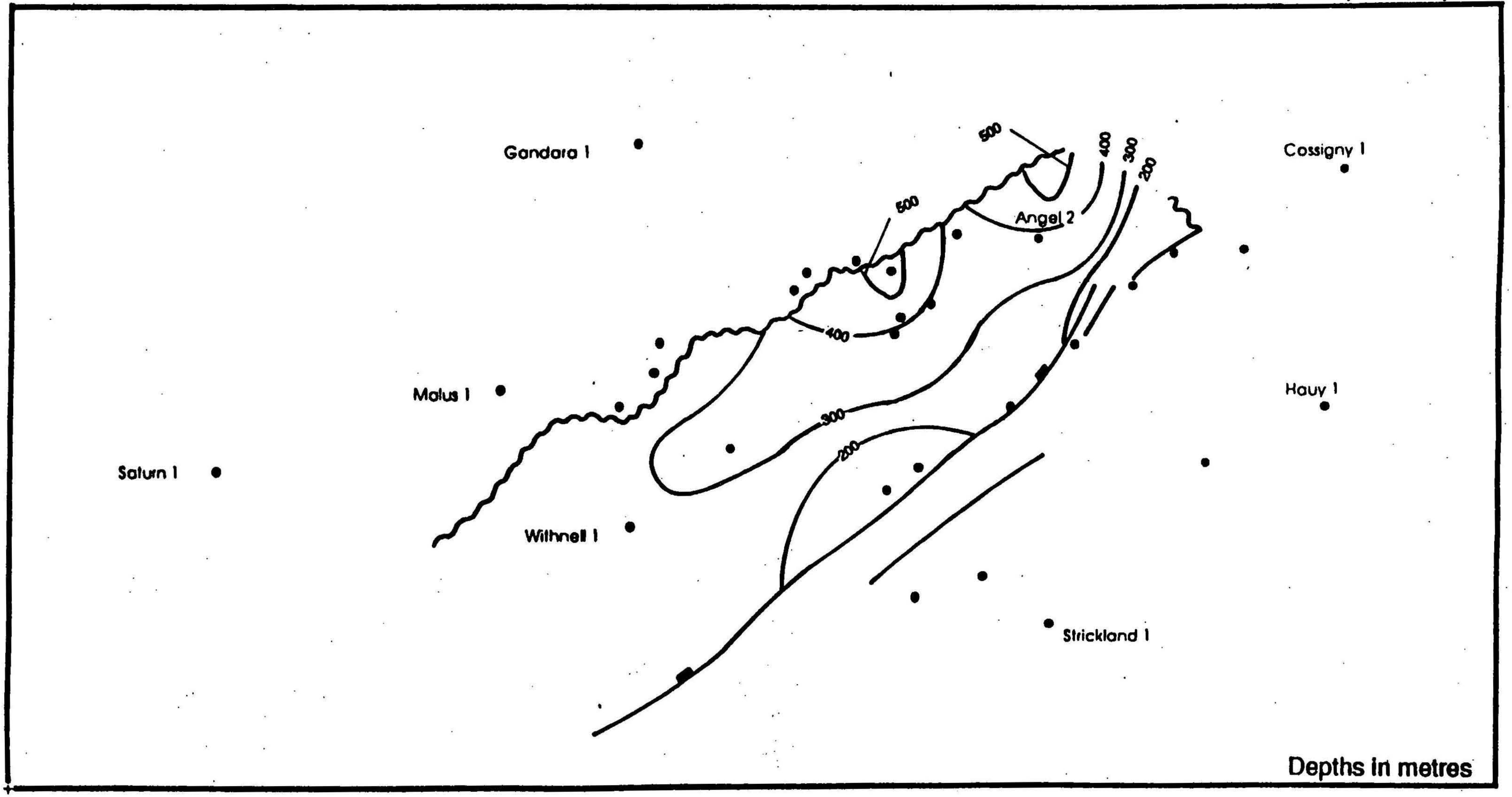


Figure 15

correctness of the seismic interpretation on which the well was drilled. Both the tool used (generally Schlumbergers HDT) and the style of processing are not necessarily aimed at facilitating stratigraphic studies. Nevertheless some useful stratigraphic indications can be interpreted from the available dipmeters.

Angel 2: The dipmeter was not run below 2834m. Random dips. The higher dips show a very weak south to south southwest trend. Not really useful but could indicated the destructured nature of the sandstones.

Wanaea 1: No dipmeter

Rosemary North 1: No dipmeter

Madeleine 1: There are few consistent patterns throughout the sequence. Using the highest dips as possible indicators of forset bedding (not a necessarily valid assumption) the spread indicates a depositional slope to the southeast with an arc from north northeast to west southwest dominant.

Montague 1: The dipmeter shows dip patterns that are interpreted to indicate channel like features. These have an azimuth consistently to the east southeast between 3250m and 3715m. Lack of significant dip spread is indicative of an apex position proximal to a point source. Below this depth the dip quality is poor. The lower section is possibly bioturbated, or slumped.

Walcott 1: The dipmeter is difficult to interpret being an HDT processed mainly for structural interpretation. The upper sands may possibly thicken slightly to the northwest and pinch out to the southeast. Below 3320m the dipmeter plot is highly scattered and may represent bioturbated or slumped deposits. At 3320m there is evidence of a boundary from both the dipmeter and the lithology. Below this depth the lithology is brownish black to greenish black silty claystone. Dips are few (bioturbated??) and what dips there are are to the south or southeast at 20- 30 degrees. It is uncertain what these represent.

TABLE 2: SUMMARY DIPMETER INTERPRETATION OF NELSON ROCKS 1 FOR TIME SLICE J10

FROM	TO	DIP	POSSIBLE INTERPRETATION
2056	2068		Feeder channel on mid depositional lobe
2068	2080	5/NNW	
2110	2122	10/W	Stacked grain flows
2110	2122	Chaotic	Debris flow general westerly trend
2122	2145	NW	
2145	2155	10/NW	Stacked units, with asymmetric surface ripples
2155	2170	None	Debris flow
2170	2190	chaotic	Slump

Nelson Rocks 1: There are several dip patterns that suggest different depositional mechanisms for various packages within the sand. In general the dips show the sands to be bedded, with a dip azimuth, interpreted as palaeodepositional slope, ranging from north to west with a mean northwest trend, and up to 10 degrees dip. Normal to this trend is another dip set that may be the due to asymetrical ripples produced by alternating tidal currents. The lower dips (10 - 20 degrees) have an azimuth to the southwest, the higher dips (20 - 40 degrees) have an azimuth to the northeast.

Rosemary 1: The sequence can be divided into three units: The upper zone from 2205m - 2237m is a very coarse grained to granular, rounded to angular, white to clear quartz sandstone, that is interpreted to have a component of reworked middle Jurassic sediments. The dips are generally to the south southwest. From 2237m - 2395m is dominantly a medium to coarse grained unconsolidated sandstone with trace glauconite. Individual sandstone units are estimated to be 3-10m thick. The dipmeter shows consistently low (< 10 degree) dips all with an azimuth to the southwest and a narrow azimuth spread of approximately 10 degrees. From 2395m - 2503m is similar to the above but has higher dips and a generally broader azimuth spread. Red patterns of upward decreasing dip dominate and the interpretation is that the sands are proximal feeder channel deposits. The channel axis palaeoslope is to the southwest and strikes northwest.

Saturn 1: Not interpreted.
Withnell 1: Not interpreted.
Dampier 1: Not interpreted.
Lambert 1: Not interpreted.

Lithology:
Rosemary 1 and Rosemary North 1: A light to dark grey sandstone sequence that overall fines upwards. The sandstones range from very coarse to fine grained, but are dominantly medium grained. They are mainly quartz, rounded to angular, but with common glauconite, jasper and traces of pyrite. The sequence is poorly consolidated with good visual porosity.

Nelson Rocks 1: Medium bluish to dark greenish grey, granule to fine grained, dominantly medium grained, rounded to sub angular, well sorted sandstones. Mainly quartzitic but with traces of glauconite and pyrite. The sequence is poorly consolidated to consolidated with good visual porosity. There are minor brown black to olive black calcareous claystones.

Lewis 1A: Light to dark black grey, pebble to very fine grained, dominantly fine to medium grained, rounded to angular, poor to well sorted sandstones. Mainly quartzitic but with common glauconite, shell fragments, traces of pyrite and traces of calcite cement. The sequence is poorly consolidated to consolidated with good visual porosity. There are minor brown black to olive black glauconitic argillaceous claystones.

Madeleine 1: An interbedded and gradational sequence of sandstones, siltstones and claystones. The section shows a well defined coarsening upward trend defined by increasing sand bed thickness. Both the base and top of the sands have abrupt contacts. The thickest sandstone beds are up to 8m thick and the thinnest units are below the resolution of the wireline logs. These sandstones are light to medium grey, fine to medium grained, rarely coarse grained, subrounded, moderately well sorted and massive. They are dominantly quartzose (50 - 75%, mainly clear), glauconitic and slightly micaceous. The thicker units are without apparent cement, others have a calcareous aragonitic matrix. Finer grained subangular argillaceous quartz sandstone occurs as laminations and thinner beds within the siltstone. In cores convoluted bedding is seen at basal contacts. The bulk of the sands are generally massive but ripple cross-bedding occurs higher in the sands. They are therefore graded and fine upward. There exists a whole spectrum of silty sandstone and argillaceous sandy siltstones. They are medium grey, generally sandy and argillaceous, very fine grained and tight. These are normally highly bioturbated by both horizontal and vertical burrowing organisms. Ichnofossil assemblages include chondrites, rhizocorallum and helminthoides.

Walcott 1: An interbedded and gradational sequence of sandstone, siltstones and claystone. The section shows a well defined coarsening upward trend. This is reflected in increasing sand bed thickness towards the top of the section. Both the base and top of the sands have abrupt contacts. The thicker units are up to 10m thick. The cleaner thicker sandstones are light olive grey to medium greenish grey, fine to medium grained, rarely coarse grained, subrounded, moderately well sorted and massive. They are dominantly quartzose (50 - 75% mainly clear), glauconitic and slightly micaceous. The thicker units are without apparent cement but the remaining sandstones have a calcareous aragonitic matrix. A generally finer grained dark greenish grey subangular argillaceous quartz sandstone occurs as laminations and thinner beds within the siltstone. This sandstone is not readily distinguishable on simple log characteristics such as gamma ray where its response is identical to the siltstones and shales. Siltstones are medium grey, generally sandy, very fine grained, gradations of the sandstone. They tend to be argillaceous and lack effective porosity. There exists a whole spectrum of silty sandstone and argillaceous sandy siltstones. These are normally highly bioturbated by both horizontal and vertical burrowing organisms and have an ichnofossil assemblage of chondrites, rhizocorallum and helminthoides. A thin section from 3237m is described as an immature sublitharenite. It is dominantly a very fine grained to medium grained, subangular, poorly sorted quartzose sandstone, with minor felspar and lithic fragments in a loosely packed sericitised clay matrix. Grains of glauconite are present as well as fragments of skeletal carbonate. Clay and pyrite are the main cements, with minor silica, dolomite, and chlorite.

Lambert 1, Montague 1, Wanaea 1 and Angel 2 have similar lithology descriptions to those of Walcott 1 and Madeleine 1 except that Angel 2 has noticeably more glauconite (5-15%) and is occasionally conglomeratic. No jasper is described from the upper sandstone of the Angel 2 section.

Dampier 1 and Withnell 1 are characterised by medium grey to dark grey, brown to dark olive black claystone, commonly sandy and silty with thin beds of siltstone and sandstone.

<u>Discussion</u>:
The wells Montague 1, Lambert 1, Wanaea 1, Walcott 1 and Madeleine 1 form a group of related deposits. This can be seen from basic log correlation (see Enclosure 9).

There is a very strong lithostratigraphic correlation of individual sandstones between Madeleine 1 and Walcott 1. It is this characteristic which means these systems cannot be deltaic in the sense of coastal deposition. They are submarine episodic mass grain flow deposits best described as depositional lobes (Shanmugam, G. and Moiola, R. J., 1991). The wells can be correlated on gross features which establish that three sequences exist. The dipmeter interpretation suggests that Montague 1 is close to a channel system and hence near the probable point source that created these deposits. Montague 1 is also the thickest section.

The section at Angel 2 is not easily correlated with the adjacent deposits. An almost one to one correlation of sands can be made between Montague 1 and Lambert 1. Angel 2 which is apparently slightly more distal than Lambert 1 has a completely homogeneous upper zone. This does not fit with the definite episodic nature of the deposits on the Montague depositional lobe. Angel 2 deposits are probably sourced from a separate though similar type of feeder system to the Montague sequence. The persistent location of the sources through time suggests entrenched valleys and or submarine canyons are feeders for the depositional lobes.

PALAEODEPOSITIONAL ENVIRONMENT:
This time slice is characterised by mass flow deposition into the deep water narrow fault bounded Dampier Sub-basin. The basin appears to have been anoxic at different times.

Palaeogeography:
Three feeder channels, one near Montague 1, one north of Angel 2, and one just to the south of Rosemary 1, fed submarine depositional lobe deposits throughout Time Slice J10. The largest depositional lobe is probably the Montague lobe, followed by the Angel lobe and the Rosemary lobe. To the northwest of Rosemary 1 their appears to have been multiple feeders for several types of mass flow deposits.

The Montague depositional lobe appears to have at least two stages. The lower sandy lobe is abruptly terminated in mid *D. jurassicum* time by a thick claystone. Either there is a change in source character, or a change in relative sea level. Weaker indications of this event are seen in other wells, notably Rosemary 1, Angel 2 and Lewis 1A so the break is interpreted to indicate a relative sea level rise. Following this is a major coarsening upward sequence, in which the sandstone bodies get systematically thicker up the section, indicating a major progradation. Most of the sands are probably episodic grain flows. Some of the sands may cover significant areas particularly the upper sands of the upper Montague depositional lobe sequence. This is inferred from Dampier 1 where several thin sands exits. These sands are most readily correlated back to the Montague lobe and so interpreted to be the distal edges of these grain flows.

PROSPECTIVITY: GOOD TO VERY GOOD.
Apparently highly prospective except that almost all of the low risk structural closures at the top of these sands have already been drilled. Time Slice J10 is productive from several fields. In all cases the uppermost sand sealed by the overlying Cretaceous claystone is the productive unit. Nowhere are there stacked reservoirs. Internal

claystone seals appear to be of good quality and it is possible that stacked traps with structural closure offset from the upper most closure might exist. Source rocks of the underlying mature Time Slices J9 and J8 sections are dominantly oil prone.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0.49 to 1.30 with a maximum of 2.38 at Legendre 1. The median HI values range from 67 to 201 with a maximum of 365 at Lambert 1. The vitrinite reflectance data suggest this interval is in the early stages of oil generation. Despite the range of facies present in this Time Slice there is no major apparent variation in the source rock quality that is of fair quality but not good.

Shows/Porosity/Permeability:
Numerous oil, and gas condensate deposits are reservoired in this time slice which is regionally sealed by the overlying Cretaceous claystones. Lewis 1A, Withnell 1, Nelson Rocks 1, Talisman 1 and Rosemary 1 all have minor oil indications and Montague 1 a minor oil and gas indication. Rosemary North 1, up dip from Rosemary 1 has a residual hydrocarbon leg. Dampier 1, Madeleine 1 and Walcott 1 all have strong oil and gas shows. Lambert 1 has a major oil accumulation and Angel 2 is an appraisal well for the major gas condensate Angel Field. Wanaea and Cossack are major oil fields at this level (Bint 1991).

Traps and Plays:
Clastic sands entered from mainly point source locations from both flanks of the trough. The sands appear to be episodic deposits that formed depositional lobes. Background sedimentation was mainly organic rich shales. The implication is that the reservoir sandstones are likely to be adjacent to mature source rocks. The Lewis Trough is a known source of oil for the Wanaea-Cossack, Talisman and Legendre fields and a probable source for the Wandoo accumulation. The early Jurassic is also the probable source for the Angel gas/condensate field and may also be a significant contributor to the reserves of the Rankin Trend gas condensate fields. Any reservoir (in a trapping configuration) within the trough, at a temperature below oil cracking is thought likely to contain liquid hydrocarbons. (see Play Concepts section).

Several stratigraphic type plays are discussed below

(i) distal sandstone lobes that cross the present trough axis would have updip pinch out. Stacked reservoirs would be possible, but reservoir quality might be reduced in the thinner sands.

(ii)parallel to trough axis reservoir bodies with up dip pinch out, evident on seismic but not mapped out.

(iii)unconformity related traps appear possible from seismic evidence.

(iv)intra lobe traps formed beneath intraformation regional or local claystone seals.

(v)feeder channel traps sealed by overlying Cretaceous clays particularly in the Montague area.

CRETACEOUS TIME SLICES: K1 TO K11

Time Slice K11 is present in only a few wells, is part of a condensed interval and is essentially a continuation of Time Slice K10 style of deposition. No separate interpretation was deemed justified for this time slice.

TIME SLICE K1: LOWER CRETACEOUS: NEOCOMIAN: Berriasian to Early Valanginian: (144. 0 to 137. 0 Ma).
ENCLOSURES 30 & 31

Formation Synonyms: Talisman Member, Forestier Claystone, Barrow Group Equivalent.

PALAEONTOLOGY:
E. torynum, B. reticulatum, D. lobispinosum, C. delicata, K. wismaniae, P. iehiense. The Cretaceous Jurassic boundary falls within the *P. iehiense* zone.

Eighteen wells penetrated Time Slice K1. It is absent from the other twelve wells due mostly to non deposition. The palynology control is very good to fair over this interval.

Time Slice K1 shows onlap and burial of the Rankin Trend progressively with time (see Figures 16 to 19). Major Time Slice K1 deposition is confined to the Lewis Trough and Kendrew Terrace areas. Time Slice K1 is bounded by a significant unconformity on both upper and lower surfaces. Deposition across the *P. iehiense - K wismaniae* zones may have been essentially continuous in the Lewis Trough axis in the south, as both zones are recognised in Dampier 1 and Withnell 1. Nevertheless there is normally a log signature at the appropriate level that can be inferred to indicate a minor change in depositional style across a small hiatus. Along the Rosemary Fault System the *P. iehiense* zone is absent suggesting possible fault movement at this time.

Deposition of the *K. wismaniae* dinoflagellate zone appears to be restricted in the northeastern Lewis Trough. From this it is interpreted that the Lewis Trough area was open to the ocean in the southwest with the major source of clastic sedimentation being from this direction at this time.

By *C. delicata* time a major transgression has onlapped most of the Rankin Trend, the *C. delicata* zone appears to be missing in Dampier 1, possibly due to movement on the Madeleine Trend that made the Dampier 1 area a basin floor topographic high. Parts of *D. lobispinosum* may be absent in some wells but this is difficult to accurately assess. In the wells where *D. lobispinosum* is not recognised there is usually a section in which it could be developed. *B. reticulatum* is present in all wells.

E. torynum is absent from the northwestern end of the Lewis Trough. This may be due to erosion related to uplift or non deposition related to reduction in source area input.

The Rankin Trend and De Grey areas were positive features at the commencement of Time Slice K1 deposition. High points on the Rankin Trend appear not to have any Time Slice K1 sedimentation but it is worth noting that a thin upper or condensed Time

Dampier Sub Basin

Extent of *P.iehense*

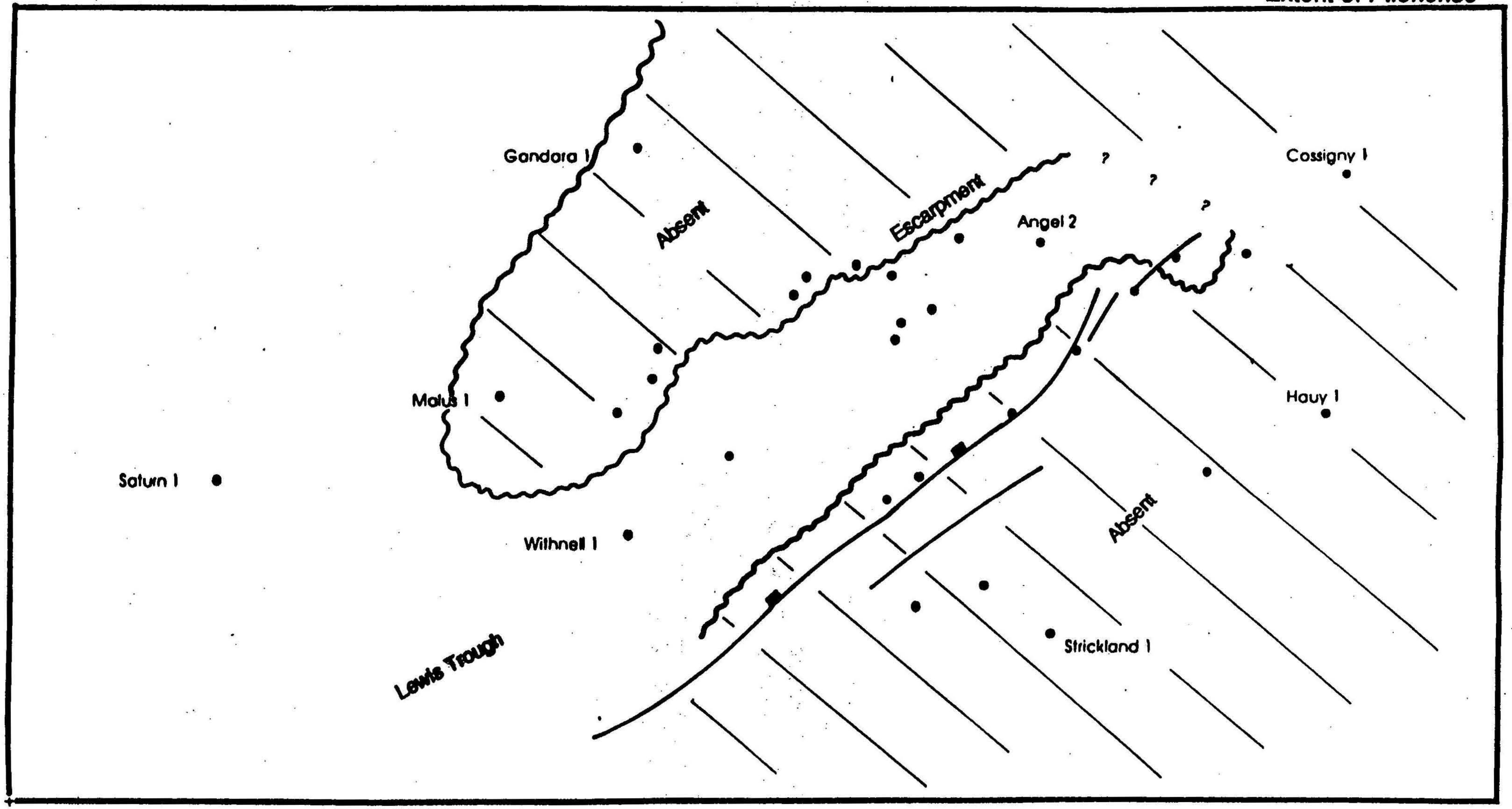
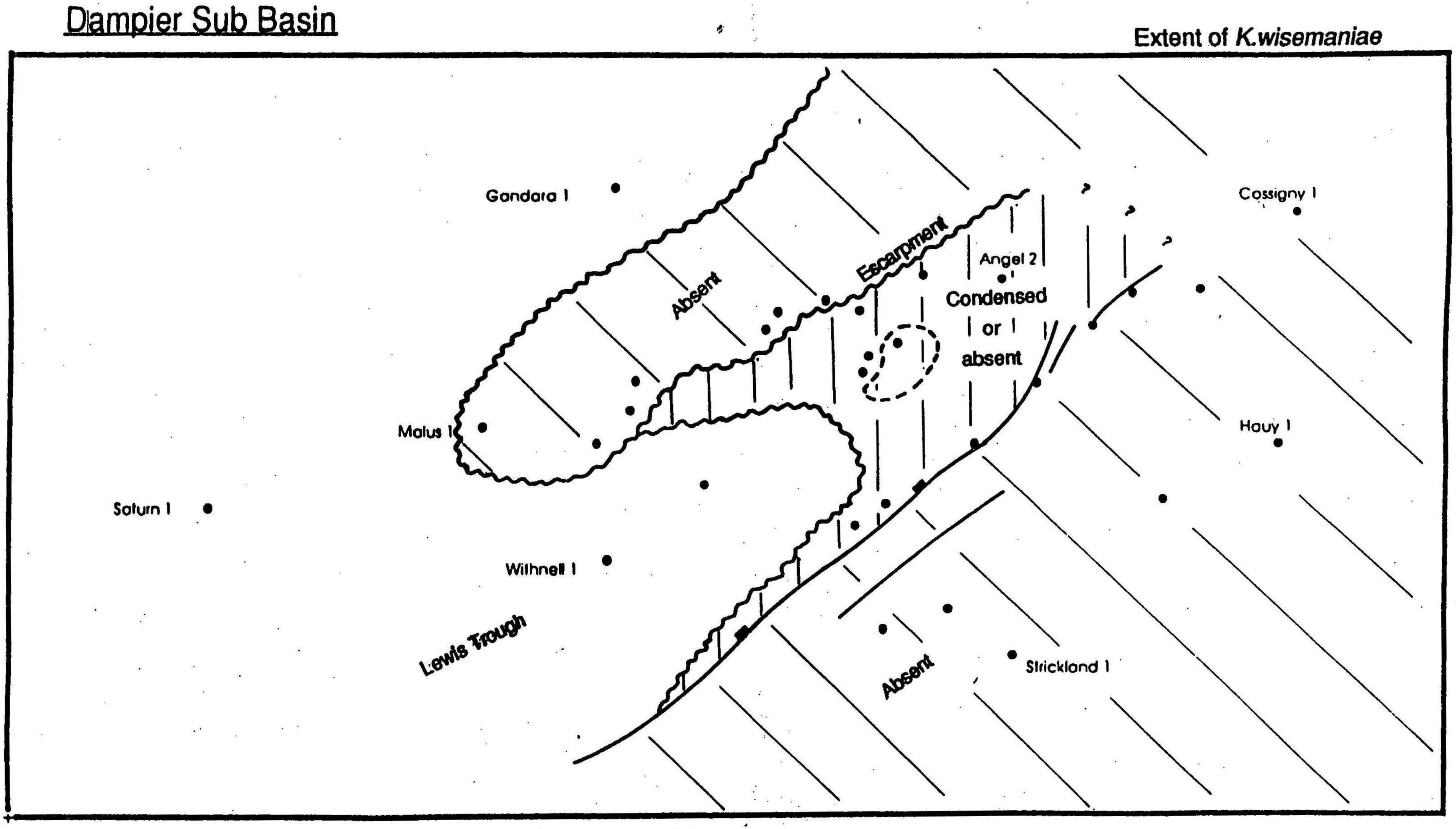


Figure 16



Dampier Sub Basin
Extent of K.wisemaniae
Gandara 1
Cossigny 1
Escarpment
Angel 2
Absent
Condensed
or
absent
Malus 1
Houy 1
Saturn 1
Withnell 1
Lewis Trough
Absent
Strickland 1

Figure 17

Dampier Sub Basin

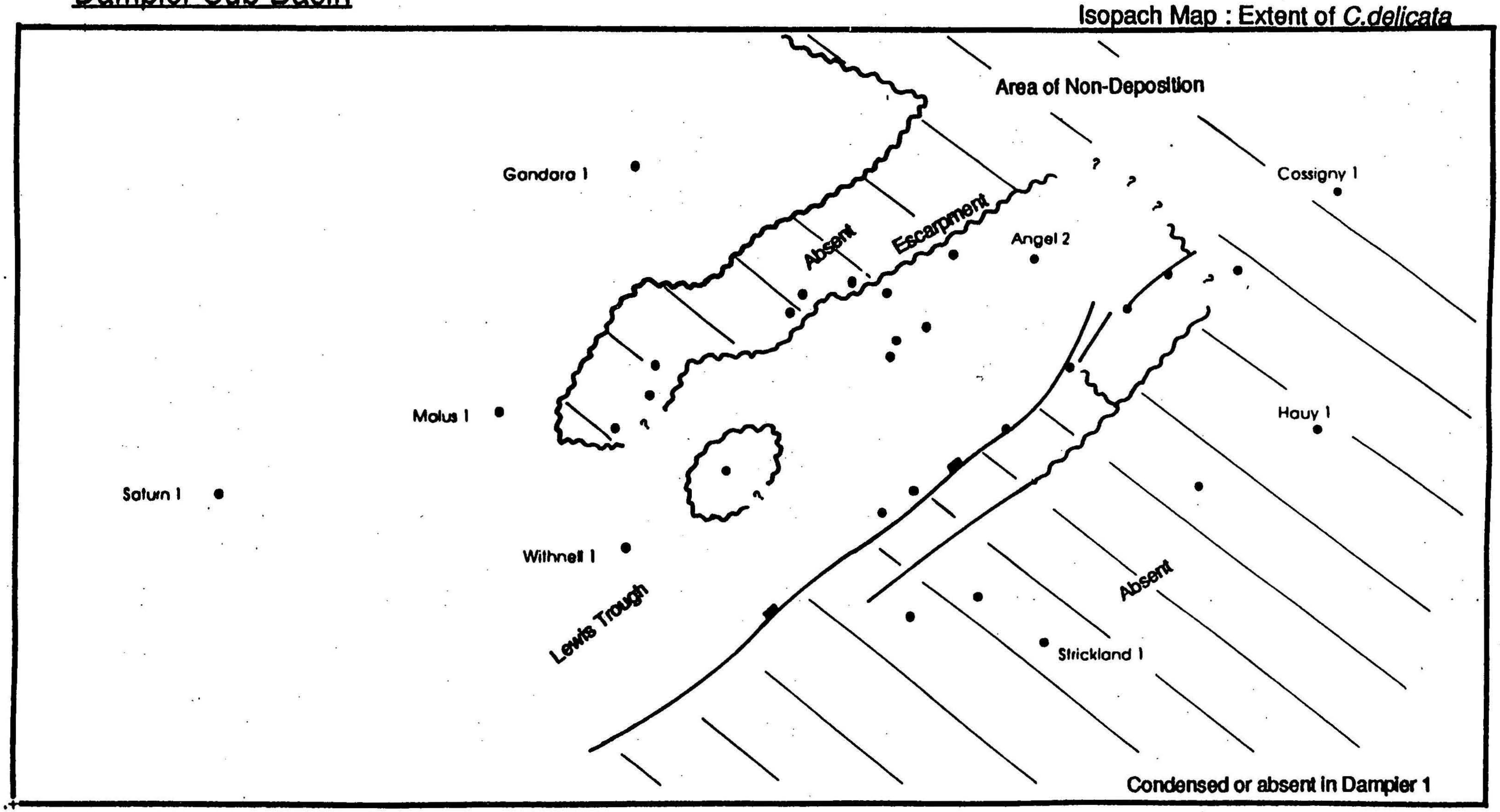


Figure 18

Dampier Sub Basin

Extent of *E.torynum*

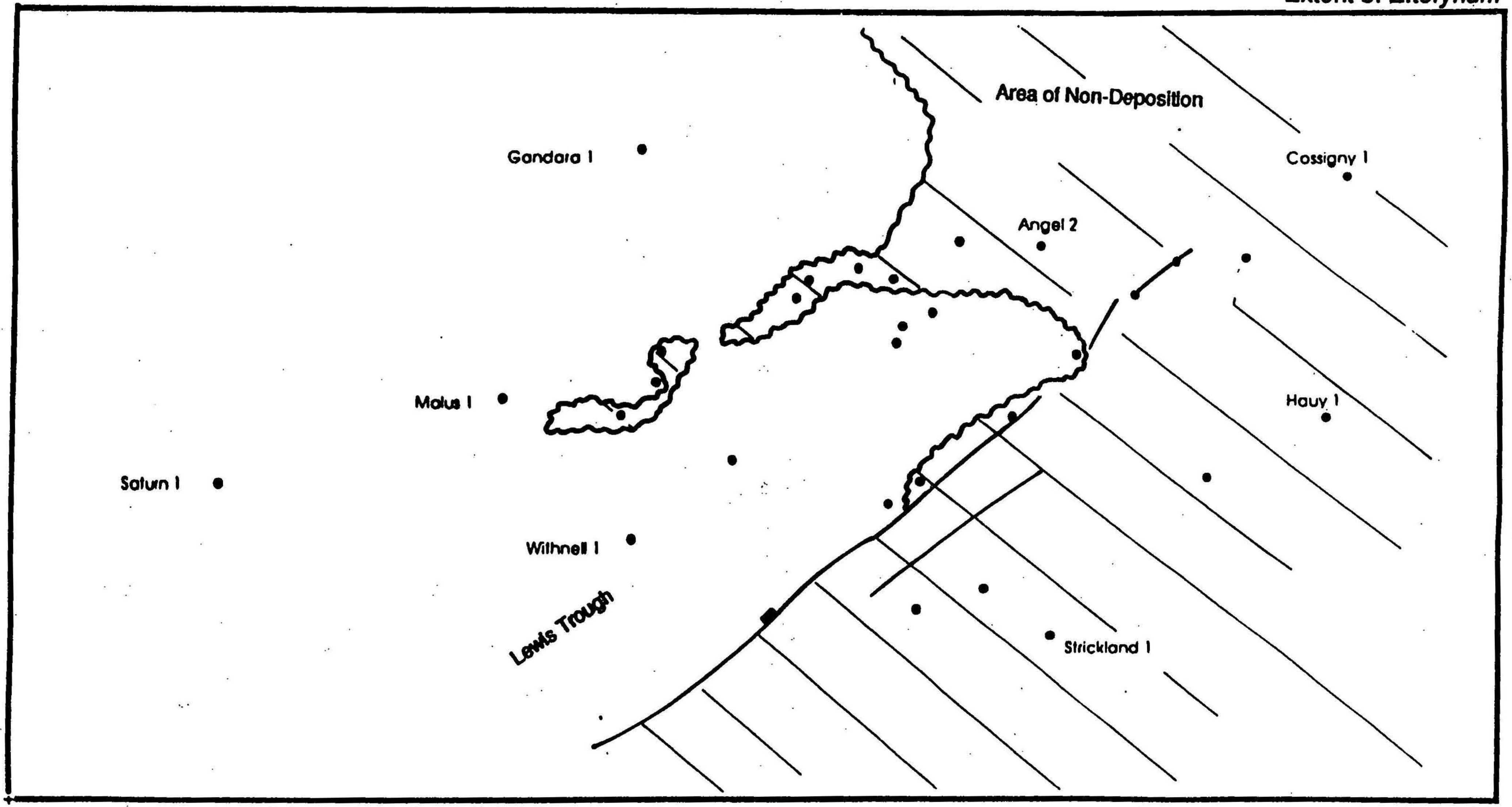


Figure 19

Slice K1 section is possible in both Dockrell 1 and Goodwyn 2. Several internal hiatuses appear possible within Time Slice K1 but these are suspected short lived events (~1 Ma or so) and not readily resolved with the available palynology.

Lithology:
The background basinal deposition is medium grey or more commonly dark olive grey to olive black claystone, generally firm, mostly non calcareous with traces of glauconite. This is mixed with minor quartz silt. There could be a minor source of clastics from the Rankin Trend, that has resulted in siltstone and minor argillaceous sandstones in the vicinity of Montague 1, Lambert 1 and Wanaea 1. An alternate explanation is that these facies are the distal portion of sandy clastic deposits from a secondary source area that is focused on Legendre 1 and Talisman 1 or the last vestiges of the submarine feeder system of Time Slice J10. Another source of quartz silt may be from the southwest, as both Dampier 1 and Withnell 1 have basal siltstone layers.

In Talisman 1, Time Slice K1 sedimentation is dominated by glauconitic quartz sandstone. The lowest sandstone in the section is felspathic, medium grained, with up to 10% glauconite. The upper sands show strong coarsening upward cycles from fine to medium to coarse grained being subrounded to rounded and moderately well sorted. Glauconite content decreases upward from 20% to 5% (Ellis 1988 p 239). Pyrite cemented layers are associated with palaeo or present day oil water contacts. In Legendre 1 the sandstones are off white, fine to medium grained quartz sandstones, subangular to subrounded, moderately sorted, with minor glauconite and abundant pore filling kaolinite. Minor dolomitic layers are present.

Between the sands are thick (to 20m) silty dark grey claystones. In Nelson Rocks 1 the section although dominantly a fine grained claystone appears to be part of the Talisman-Legendre sourced units, having traces of jasper and minor limestone and dolomite layers. The claystones are thought to be depositional lobe top, drape deposits or submarine channel levees.

There are altered volcanic ash beds at the base of Time Slice K1 recognised in Wanaea 1(Bint 1991, p28).

Thickness Variations: (see Figure 20)
Maximum preserved thickness occurs in Withnell 1 (358m). The Lewis Trough is the controlling factor. The thickest deposits occur in the axis of this feature. The general trend is for the sediments to thin towards the northeastern end of the trough.

PALAEODEPOSITIONAL ENVIRONMENT:
A major change has occurred between the top of Time Slice J10 and the base of Time Slice K1. The major sand source feeding the Lewis Trough during Time Slice J10 terminates abruptly. This maybe related to a major relative sea level rise. The termination of sand supply from the north is absolute and it appears that for a while in the early Time Slice K1 sediment source may have been dominantly from the southwest with minor input from the Rankin Trend.

Dampier Sub Basin

Time Slice K1: Isopach Map

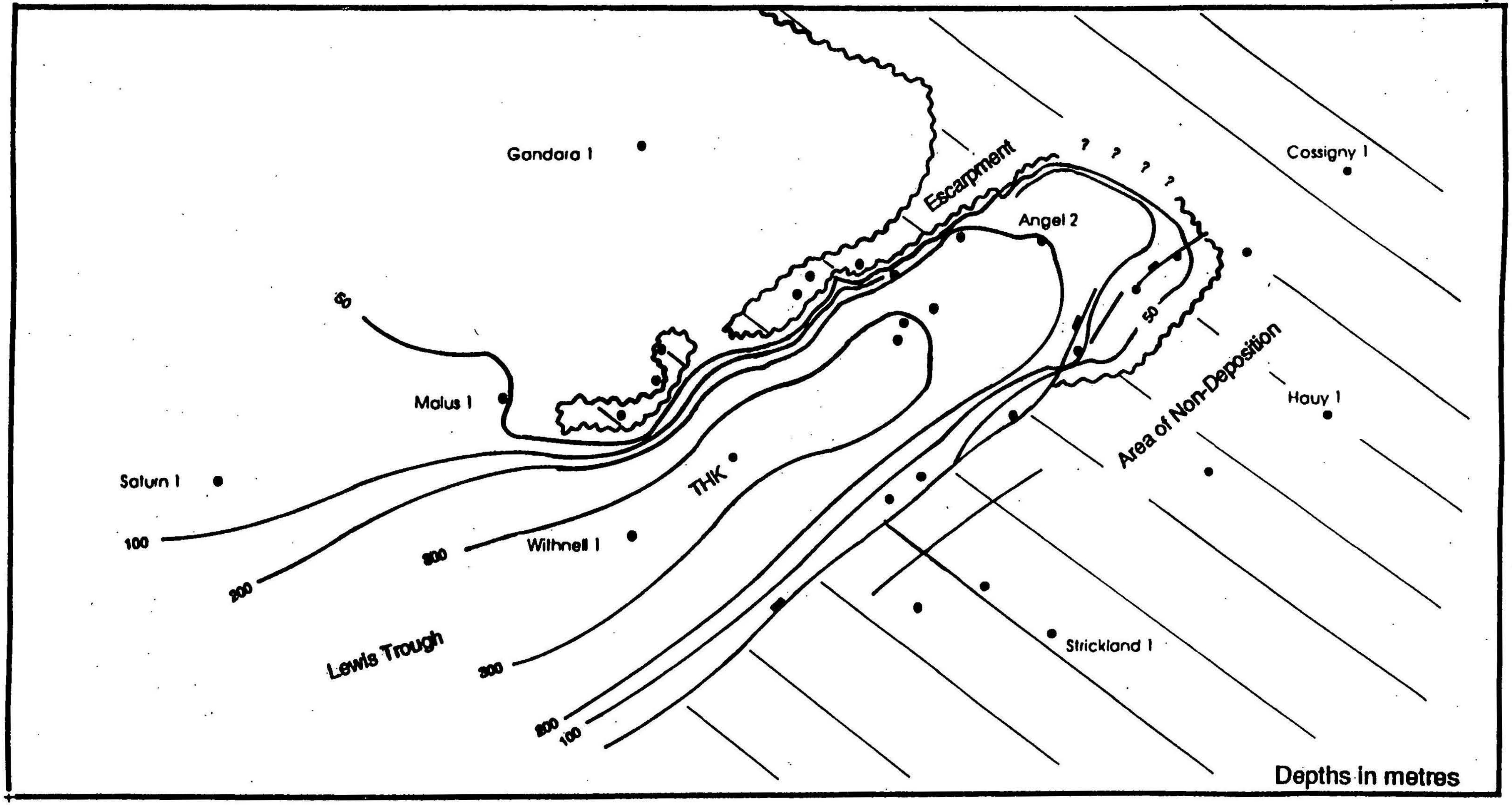


Figure 20

Sandy deposition is restricted to a minor source of mass flow deposits at the northeastern end of the trough in the area of Talisman 1 and Legendre 1. The sandstones are probably mass flow deposits perhaps strongly channelled, and likely associated with a small shelf edge delta system, that did not encroach into the area until the later part of Time Slice K1.

Palaeogeography:
The Lewis Trough was a relatively deep graben that received basinal (continental slope or basin floor) deposition sourced mainly from the southwest during the earliest Time Slice K1. In this sense the northeastern end of the Lewis Trough contains distal deposits. Later in Time Slice K1 a deltaic system encroached from the east or southeast. In the vicinity of Nelson Rocks 1 and Talisman 1 a shelf edge delta system formed, and some mass flow deposits accumulated. It is the high glauconitic content that distinguishes these deposits from the underlying Time Slice J10 units.

PROSPECTIVITY: FAIR TO GOOD
This sequence is a seal facies on Time Slice J10. It is generally unprospective. In the southeastern area around Talisman and Legendre there is potential for traps in reservoirs of good quality.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0.39 to 1.75 with a maximum of 3.71 at Withnell 1. The median HI values range from 72 to 553 with a maximum of 553 at Walcott 1. The vitrinite reflectance data suggest this interval is in the earliest stages of oil generation. There are fair to good source rocks in the deep marine basin floor area of the Lewis Trough were more rapid sedimentation rates appear to have enhanced the preservation of organic carbon.

Shows/Porosity/Permeability:
Talisman 1 and Legendre 1 both made significant oil discoveries within this time slice. Legendre 1 was the first discovery in the area, but it appears to be uncommercial. Talisman Field was brought on stream and produced. A pattern of better source quality too the south in the vicinity of Withnell 1 and Rosemary 1 is apparent on all the early to middle Cretaceous Time Slices.

Shows are also seen in Rosemary North 1 and Rosemary 1 and are thought to reflect oil migrated up the Rosemary Fault System from deeper Jurassic sources, similar to the proposed sources for the Talisman & Legendre accumulations. Rosemary North 1 show is likely related to the residual oil accumulation seen in the underlying Time Slice J10. In Legendre 1 the porosity of the oil zone is approximately 14%. At Talisman 1 porosity ranges from 16-25% with permeabilities from 1 to 3 darcies.

Minor shows in Withnell 1 and Dampier 1 are thought to be due to early maturation of the basinal shales that have source rock quality. Shows are also recorded in Lambert 1 and Wanaea 1. These shows probably reflect vertical migration from the immediately underlying accumulations in Time Slice J10.

Traps and Plays:
The more obvious major structural traps on the Legendre Trend have been drilled. More subtle traps need assessment. The sands at Talisman 1 and Legendre 1 both appear to pinch out laterally into claystones at Nelson Rocks 1 giving potential stratigraphic plays in this area.

TIME SLICE K2: LOWER CRETACEOUS: NEOCOMIAN: Early Valanginian to Hauterivian: (137. 0 to 125. 0 Ma).
ENCLOSURES 32 & 33

Formation Synonyms: Winning Group, Barrow Group Equivalent, Muderong Shale, Mardie Greensand, Birdrong Sandstone.

PALAEONTOLOGY:
M. testudinaria, P. burgeri, S. tabulata and S. aureolata.

Note: mid Valanginian/ late Hauterivian breakup of Culvier Abyssal Plain and formation of the Cape Range Fracture Zone.

The palynology control is very good to poor over this interval. Time Slice K2 is penetrated in a total of twenty five wells. It is absent from the other five wells. Three of these on the Rankin Trend may have very thin condensed intervals of Time Slice K2. In the other two wells, Strickland 1 and Cossigny 1, it is probably absent due to post depositional erosion.

Time Slice K2 is bounded by a significant hiatus on the lower surface. This defines a basin wide sequence boundary.

The Rankin Trend was a positive submerged feature during Time Slice K2, and progressive onlap of the feature is certain. However Time Slice K2 section is not definitely established in North Rankin 2, North Rankin 3 and Eaglehawk 1. A thin Time Slice K2, or condensed Time Slice K2 section, is however possible in these wells.

On the Enderby Terrace where age control is poorest there is difficulty assigning an undated sandstone unit to a definite time slice. Lithostratigraphic considerations suggest the sandstone, in Hauy 1 and Lawley 1 is best assigned to Time Slice K3, as has been done, however this not a compelling reason and the sand could be Time Slice K2 age. Possible missing intervals within Time Slice K2 are suspected to be characteristic of the shelf area, but because of the poor age control are difficult to resolve.

Thickness Variations: (see Figure 21)
Maximum preserved thickness occurs in Withnell 1 (150 m) and in general the sediments thin towards the northeastern end of the Lewis Trough. The Lewis Trough was still a distinct topographic feature during this time, probably as a result of compaction of the underlying sediment package. The Rankin Trend was a positive submarine topographic feature. The Madeleine Trend is also reflected in the isopachs.

Lithology:
The background basinal deposition is medium dark grey, black brown or olive black claystone, generally firm to hard, with nodules of glauconite, traces of pyrite, traces of mica and minor quartz silt. The claystone is occasionally carbonaceous. The claystone tends to become greenish black towards the east and northeast, possibly due to increasing input of glauconite. Quartz content and grain size also increase in this

Dampier Sub Basin

Time Slice K2: Isopach Map

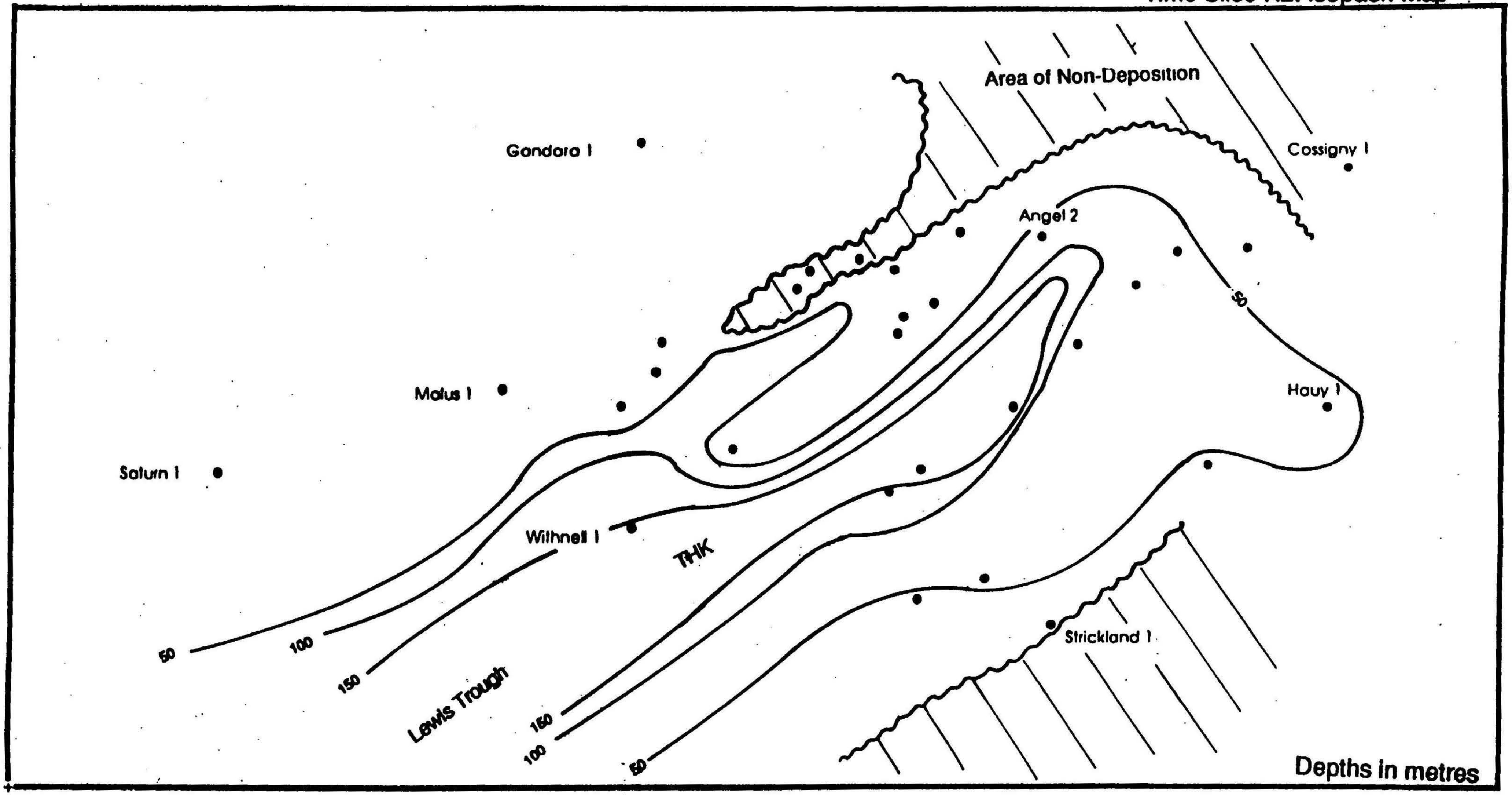


Figure 21

direction. In Wanaea 1 there is an increase to 10-25% quartz silt or very fine grained quartz sand in the claystone.

At De Grey 1 the sands are colourless to grey, very fine grained to granule, but dominantly coarse grained, subangular to rounded, moderately well sorted, quartz sandstones with minor glauconite. In Talisman 1 a fining upward cycle is present. The base of the unit is coarse grained well sorted subrounded to rounded quartz sandstone with up to 45% glauconite. (Ellis 1988, p 239). This fines upward into an argillaceous glauconitic quartz sandstone. The cycle terminates in a silty arenaceous claystone. The cycle may represent rising relative sea level.

Elsewhere on the Enderby Terrace greensands dominate. At Hauy 1, Lawley 1, Hampton 1, Enderby 1, Rosemary 1 and Rosemary North 1 the dominant lithology is greensand. Generally the high radioactivity associated with the glauconite makes it difficult to distinguish this facies on the gamma ray log. The sandstones are glauconitic, fine to very coarse grained, subrounded and well sorted.

PALAEODEPOSITIONAL ENVIRONMENT:
Time Slice K2 is characterised by an extreme reduction in clastic input. This time slice marks the commencement of a major transgression following the separation of Greater India from Australia (Veevers, 1988).

Palaeogeography:
Greensands developed in situ on a shallow, moderate to low energy, marine middle to outer shelf environment and clays were deposited offshore in deeper water on the shelf edge and continental slope. The pattern of facies suggests a minor clastic quartz source to the east or northeast of De Grey 1. Occasional storm action deposited limestone and dolomite layers in deeper water adjacent to the shelf or these may be insitu deposits.

PROSPECTIVITY: GOOD
The greensand and clastic facies must be considered highly prospective. It is believed that at Talisman hydrocarbons migrated into the Time Slice K1 sands during the Late Cretaceous to Early Tertiary, and that remigration into the Time Slice K2 unit occurred following Miocene fault reactivation (Ellis, 1988). The oil is thought to be sourced from deeper mature Jurassic.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0.44 to 2.62 with a maximum of 3.19 at Legendre 1. The median HI values range from 83 to 173 with a maximum of 214 at Rosemary North 1. The vitrinite reflectance data suggest this interval is in the early stage of oil generation. Fair to poor TOC values occur in the outer shelf and slope facies with good to very good TOCs occuring in the middle to outer shelf facies possibly associated with the shelf break.

Shows/Porosity/Permeability:
Talisman 1 made a significant oil discovery within this time slice. Shows are seen in Nelson Rocks 1, Gandara 1 and Dockrell 1. Porosity in the greensands ranges from nil

to approximately 25% in Talisman 1, and indications are that the where porosity is good permeability is also good. Wandoo Field is believed to be productive from this or the overlying interval. A pattern of better source quality to the south in the vicinity of Withnell 1 and Rosemary 1 is apparent in this and all subsequent early to middle Cretaceous Time Slices.

Traps and Plays:

Subtle traps appear to be highly favourable in this area. Wandoo Field discovery establishes that major hydrocarbon migration onto the Enderby Terrace has occurred. In Rosemary North 1 a thick (21m) very fine to coarse grained glauconitic sandstone is seen. This sand is absent in adjacent wells, unless it is the equivalent of the sand in Lawley 1 and Hauy 1, that, as discussed previously has been assigned to Time Slice K3. Pinchout traps are therefore feasible. However the internal stratigraphy is very complex, and it will be necessary to conduct a program of stratigraphic drilling across the shelf to establish the detailed stratigraphy of the area.

TIME SLICE K3: MIDDLE CRETACEOUS: NEOCOMIAN: Barremian: (125. 0 to 119. 0 Ma).
ENCLOSURES 34 & 35

Formation Synonyms: Winning Group, Muderong Shale, Mardie Greensand, Strickland Member, Windalia Sand Member, Nanutarra Formation (see Hocking and van der Graaff 1977 for discussion of this onshore equivalent).

PALAEONTOLOGY:
M. australis and lower *A. cinctum.*

Twenty-eight wells penetrated this time slice. It is absent from the other two wells, De Grey 1 and Cossigny 1, due to non deposition or subsequent erosion. Age control is good to poor over this interval.

The Rankin Trend that had been a positive feature since the beginning of the Cretaceous, was finally completely onlaped by a thin, or condensed section during Time Slice K3.

On the Enderby Terrace, where age control is poorest, there is uncertainty about the boundaries of the time slice in most wells. At Enderby 1 an *M. australis* age is definite. In the adjacent Hampton 1 age control is poor so the Time Slice K3 range is based on direct lithostratigraphic correlation to Enderby 1. In Strickland 1 there is no certain Time Slice K3, but the lower section, dated as *A. cinctum* is interpreted as upper Time Slice K3. A sandstone interval in Lawley 1 is undated and it is possible that Time Slice K3 is absent in this well. However the section is between definite Time Slice K2 and K4 and is lithostratigraphically similar to a sandstone in Hauy 1. The Hauy 1 sandstone is also undated but lies immediately below definite Time Slice K3 and above definite Time Slice K2. Lithostratigraphic considerations suggest the sandstones, in Hauy 1 and Lawley 1 are best assigned to Time Slice K3. This interpretation is followed here, but it is not compelling and the sandstone could belong to Time Slice K2.

Thickness Variations: (see Figure 22)
The general trend is for the sediments to thin towards the northeastern end of the Enderby Terrace. Maximum preserved thickness occurs in Hampton 1(163 m).

Lithology:
The background deposition is medium dark grey, black brown, olive black or occasionally light greenish grey claystone. It is generally firm but can also be soft and plastic, and has traces of glauconite, pyrite, minor quartz silt and up to 20% mica. The claystone tends to become darker towards the east and northeast, possibly due to an increased glauconite content.

On the Enderby Terrace area greensands and glauconitic sandstones dominate. The glauconitic sandstones are light grey, greenish grey, dark greenish, grey olive black or green black, fine to coarse grained, dominantly coarse grained, well to moderately well sorted, subrounded to subangular quartz sandstones with up to 30% glauconite. Glauconite contents higher than 30% (up to 60%) are greensands. These sands are

Dampier Sub Basin

Time Slice K3: Isopach Map

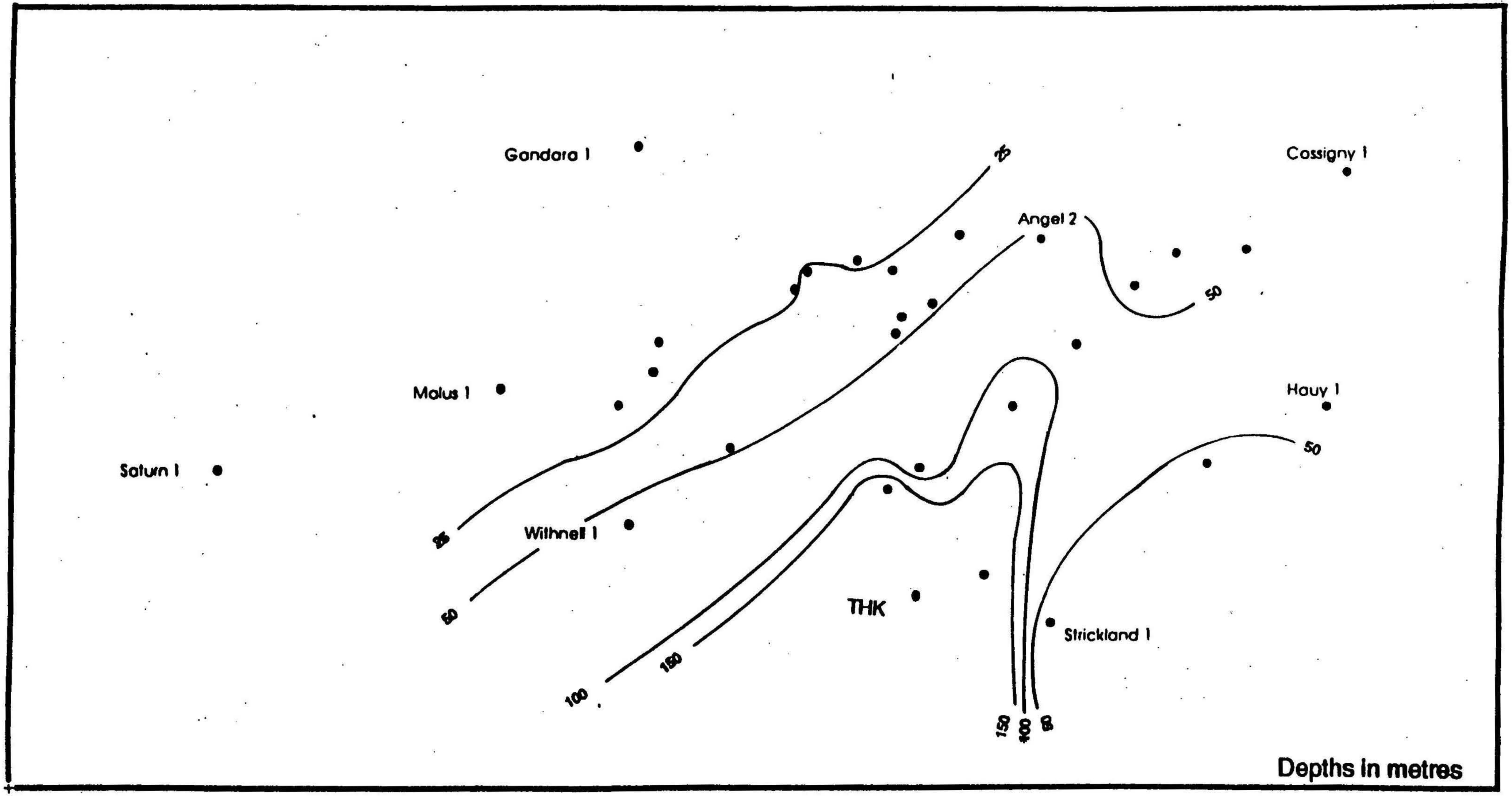


Figure 22

interbedded with argillaceous glauconitic siltstones or fine sandstones and medium dark grey glauconitic claystones.

The high radioactivity associated with the glauconite makes it difficult to distinguish this facies from claystone on the gamma ray log.

PALAEODEPOSITIONAL ENVIRONMENT:

The interpreted shoreline location is a long way east of the map area throughout the time slice. Time Slice K3 depositional system is essentially a continuation of Time Slice K2 except that the influence of the Lewis Trough on deposition is reduced, although the Rosemary Fault system still controls the location of the shelf edge.

Palaeogeography:

An extreme reduction in clastic input is the main characteristic of this time slice. Greensands developed insitu on a shallow, moderate to low energy, outer marine shelf. Cleaner sandstones were deposited in the area of Enderby 1 and Hampton 1. Clay deposition occurred offshore in deeper water on the shelf slope. Occasional storm action deposited thin sandstones and silty layers in deeper water adjacent to the shelf.

PROSPECTIVITY: GOOD

The mixed greensand and quartz sandstone facies is highly prospective. Wandoo Field is probably reservoired within this time slice. The Jurassic of the Lewis Trough is thought to be the main source of the hydrocarbons.

Geochemistry (TOC, HI and Vr)

The median TOC values range from 0.31 to 2.11 with a maximum of 2.43 at Madeleine 1. The median HI values range from 8 to 189 with a maximum of 189 at Rosemary North 1. The vitrinite reflectance data suggest this interval is in the earliest stage of oil generation. Generally TOC values decrease seaward. The small set of HI samples are poor. A pattern of better source quality too the south in the vicinity of Withnell 1 and Rosemary 1 is apparent on all the early to middle Cretaceous Time Slices.

Shows/Porosity/Permeability:

Minor oil indications occur in Gandara 1, Enderby 1, Rosemary North 1 and Nelsons Rocks 1. Minor gas indications occur in Rosemary 1, Talisman 1, Wanaea 1 and North Rankin 3. Hampton 1 has a good gas show. Wandoo Field (200 million barrels in place) is believed to produce from this interval, but to be sourced from the Jurassic of the Lewis Trough. Porosities are fair to good with many sands being unconsolidated. Permeability is probably high due to the general lack of consolidation.

Traps and Plays:

Wandoo Field establishes that major hydrocarbon migration onto the Enderby Terrace has occurred. A possible fairway may be the interpreted incised feeder channels of Time Slices J8 to J10. The Wandoo Field is in the vicinity of an interpreted lobe of thick clastic deposits. The extent and geometry of these deposits is uncertain. The overlying deposits are claystones that act as a seal. Fault plays are possible in addition to the standard four way dip closed plays. Pinchout of the greensands to the north and east of Hauy 1 are another trapping possibility.

TIME SLICE K4: MIDDLE CRETACEOUS: Aptian (114. 0 to 110. 0 Ma).
ENCLOSURES 36 & 37

Formation Synonyms: Winning Group, Muderong Shale.

PALAEONTOLOGY:
D. davidii, O. operculata and *Upper A. cinctum.*

The palynology control is fair to poor over this interval. Time Slice K4 is penetrated in a total of thirteen wells. It is absent from the other seventeen wells due probably to post depositional erosion.

An undated sandstone in De Grey 1 lies above definite Time Slice K4 claystone. Because sandstone is generally absent from this Time Slice the sandstone is thought to belong to Time Slice K6. However it could be any age from Time Slices K4 to K8.

Upper Time Slice K4 is a major unconformity except at Lawley 1 and possibly in Strickland 1. Strickland 1 section is not plotted on the map because of poor age control but the equivalent stratigraphic section is a claystone.

Thickness Variations: (see Figure 23)
The thickest section occurs in Rosemary 1 (282m) and this area appears to be a depocentreTime Slice K5 is a major period of sea level fall that appears to have significantly eroded intoTime Slice K4.

Lithology:
Sedimentation is marine silty claystones that are medium brown, olive grey to olive black, greenish grey to greenish black, dark grey to light grey claystone, generally firm but also soft and plastic. They have rare traces of mica, glauconite, micrite, pyrite and quartz silt to 30%. On the shelf area the claystone becomes more glauconitic and arenaceous. In Dampier 1 minor very fine grained thin sandstones are present.

PALAEODEPOSITIONAL ENVIRONMENT:
The marine transgression of Time Slice K3 continues during Time Slice K4 when it reaches a peak. Sediment starvation of the area is pronounced and claystones dominate deposition.

Palaeogeography:
Time Slice K4 is characterised by the progradation of claystones over the greensands and sandstones of the underlying Time Slice K3. It is interpreted to represent the marine slope or outer shelf deposits of a major marine transgression on a sediment starved margin.

PROSPECTIVITY: VERY POOR
This is a major seal facies and is therefore non prospectivity. Its significance lies in it sealing the underlying sandstones of Time Slice K3.

Dampier Sub Basin

Time Slice K4: Isopach Map

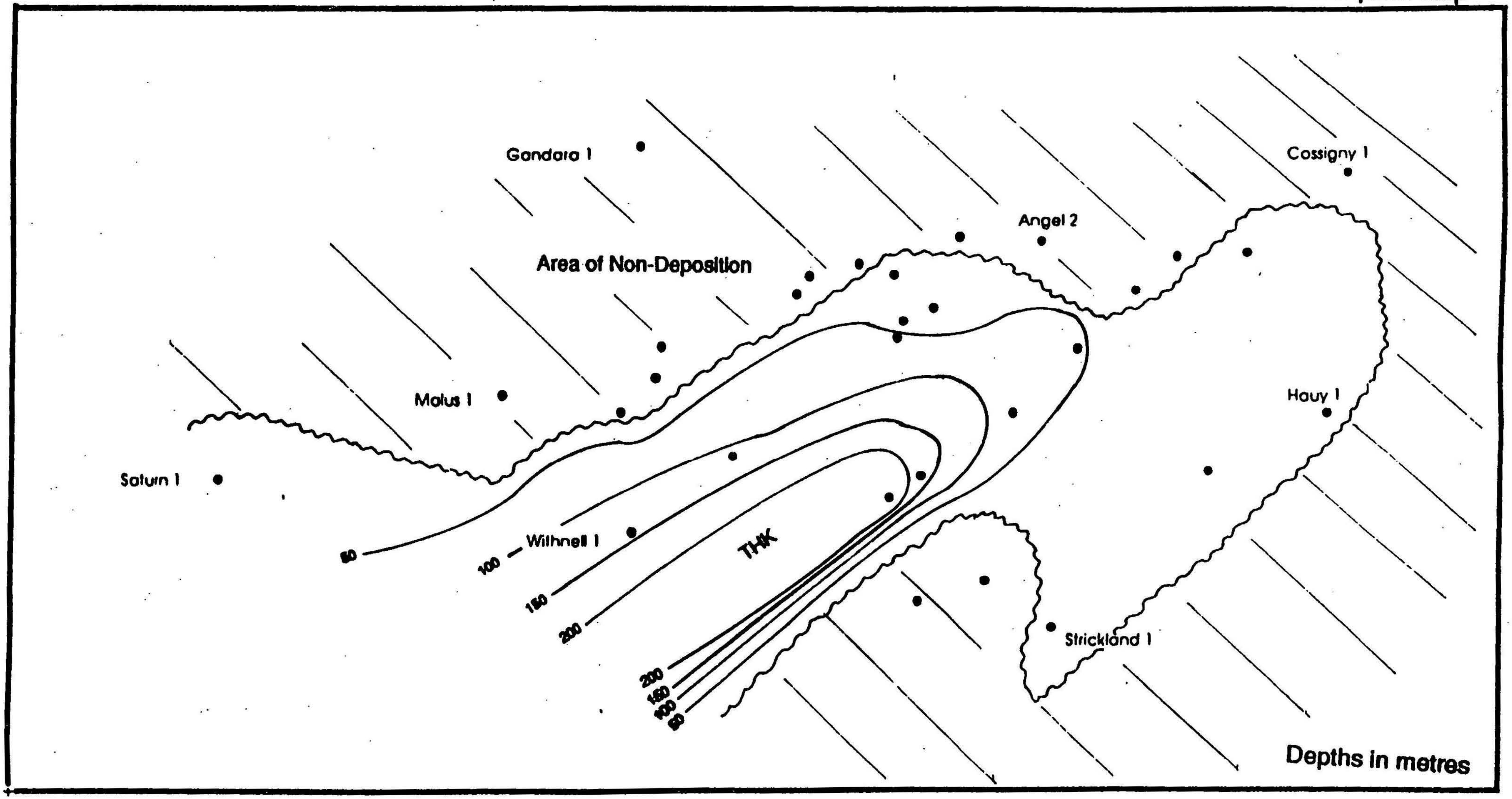


Figure 23

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0.29 to 1.29 with a maximum of 1.43 at Withnell 1. The median HI values range from 15 to 130 with a maximum of 130 at Rosemary North 1. The vitrinite reflectance data suggest this interval is in the earliest stages of oil generation. Generally TOC values decrease seaward and the small set of HI samples are poor. A pattern of better source quality too the south in the vicinity of Withnell 1 and Rosemary 1 is apparent on all the early to middle Cretaceous Time Slices.

Shows/Porosity/Permeability:
There is a minor gas indication in Wanaea 1. There is no effective porosity or permeability in this unit.

Traps and Plays:
No obvious traps or plays.

TIME SLICE K5 to K7: MIDDLE CRETACEOUS: Late Aptian to Late Albian: (114.0 to 99.0 Ma).

ENCLOSURES 38 & 39

Formation Synonyms: Windalia Radiolarite

PALAEONTOLOGY:

M. tetracantha, C. denticulata and *P. ludbrookiae.*

Age control is fair to very poor over this interval. It is particularly poor on the Enderby Terrace. This is a combined interval as few wells have any Time Slice K5 section and west of the Rosemary Fault System the interval is a condensed section.

Time Slice K5 to K7 is recognised in twenty six wells. It may be present in at least two of the remaining wells as a thin condensed interval; in Legendre 1 from 1635m to 1655m and in Eaglehawk 1 from 2740m to 2747m. Age control is poor and these sections are currently assigned to other Time Slices.

De Grey 1 section is difficult to assign, as it is undated. It must be Time Slice K4 to K8 age. It has been assigned to Time Slice K6 on lithostratigraphic grounds.

The base of this combined time slice is a major disconformity.

Thickness Variations: (see Figure 24)

The Rosemary Fault System may have been active during this period as evidenced by the absence of section and thickness variations along the fault. The Rosemary 1 area was a depocentre during this time.

Lithology:

Sedimentation is dominated by marine calcilutites and marls.

Radiolarites are referred to in the well completion reports of Withnell 1 and Enderby 1 although the criteria used to identify the radiolarites are difficult to assess. Overlying this is marl. Often a calcareous claystone overlays the marl.

Time Slice K6 is dominated by glauconitic sandstone sedimentation on the Enderby Terrace. These sandstones are light olive grey to dark medium grey 85-95% quartz, up to 40m thick, very fine to coarse grained, dominantly medium grained, poorly to well sorted, angular to subrounded, with up to 30% glauconite, trace mica, trace pyrite and trace to very good intergranular porosity and unconsolidated to hard.

In Lewis 1A sandstones are similar to the above but only 3m thick, generally fine grained and mostly well sorted.

A thick undated glauconitic sand in De Grey 1 is assigned to this time slice on the basis of lithological similarities with other sandstones of Time Slice 6 on the Enderby Terrace.

Dampier Sub Basin

Time Slice K5-7: Isopach Map

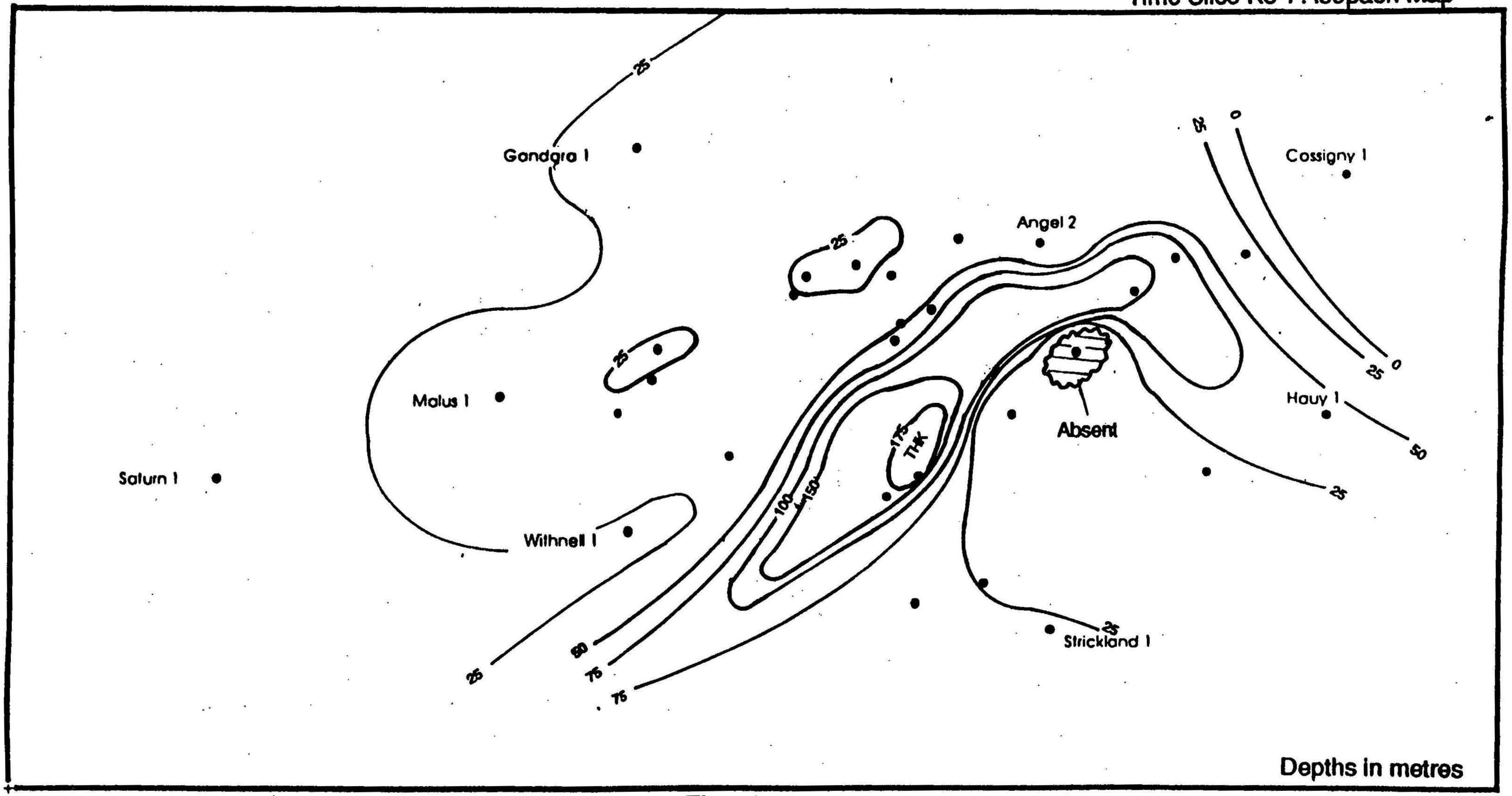


Figure 24

Landward of these sandstones the sedimentation appears to become silty.

PALAEODEPOSITIONAL ENVIRONMENT:
Time Slice K7 represents the commencement of sedimentation following the major regional disconformity of Time Slice K5. At this time India finally drifted clear of Australia and significant margin sag commenced. Time Slice K6 sediments are thin or condensed off the Enderby Terrace. On the Enderby Terrace area, Time Slice K6 sedimentation is glauconitic quartz sandstone that becomes more silty easterly. Time Slice K7 sediments are invariably fine grained claystone, marls or calcilutities.

Palaeogeography:
Open marine starved shelf to slope deposition associated with margin sag.

It is possible the basal greensand facies was developed during the lower sea level by a winnowing process associated with shoaling of wave base. The overlying claystone marl facies is a product of the transgressive phase associated with virtually zero clastic deposition.

Deposition recommenced on an extremely starved shelf after continental margin sag began, following on from continental breakup. Time Slice K6 is interpreted to represent reworked shallow marine shelf deposits. It is the first interval to show the influence of significant carbonate sedimentation.

PROSPECTIVITY: FAIR TO POOR.
Sands on the shelf area have good potential for pinchout and fault plays, sourced by faults from the deeper Jurassic. The remaining areas are non prospective.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0.31 to 0.97 with a maximum of 1.03 at Rosemary North 1. There are no HI values and one vitrinite reflectance measurement at Hauy 1 of 0.31. The poor TOC values are a result of clastic starvation coupled with good oceanic oxygenation. The section is immature. A pattern of better source quality to the south in the vicinity of Withnell 1 and Rosemary 1 is apparent on all of the early to middle Cretaceous Time Slices.

Shows/Porosity/Permeability:
There is a minor oil indication at Gandara 1 and minor gas shows at Talisman 1 and North Rankin 3. The sandstone on the Enderby Terrace have nil to very good intergranular porosity.

Traps and Plays:
Depending on the correctness of the assignment of the sandstone in De Grey 1 to the Time Slice K6, a major sand trend may exist along the edge of the Enderby Terrace. The sand could pinchout updip into shaly sands and siltstones. It is only 40m thick in Rosemary North 1 and fault offsets would generate potential plays within it. Hydrocarbons would need to migrate from the Jurassic source beds into this time slice and faults are the only obvious means to achieve this.

TIME SLICE K8: MIDDLE CRETACEOUS: Late Albian to Cenomanian:(99. 0 to 91. 0 Ma).

ENCLOSURES 40 & 41

Formation Synonyms: Gearle Siltstone

PALAEONTOLOGY

Lower *P. infusoroides, D. multispinum, X. asperatus.*

Time Slice K8 is recognised in all thirty wells but in four wells on the Enderby Terrace and in Talisman 1 the deposits are not mapped out due to poor age control.

Sedimentation appears to be continuous with the underlying time slice, except in Wanaea 1, Walcott 1, Madeleine 1, Angel 2 and Legendre 1, where the basal *X. asperatus* zone is missing.

Most of these wells are on a regional high (the Madeleine Trend) and the section may be missing due to onlap perhaps influenced by minor uplift along the trend. Eaglehawk 1 is also unconformable but this may be more apparent than real due to the possibility of an unidentified condensed section of Time Slice K5-K7 age being present.

The top of Time Slice K8 is marked by a regionally identifiable log signature called the Turonian spike. The spike is a combined log signature of a high gamma ray and associated high sonic. It is the log response to an organic rich layer of carbonaceous claystone deposited during a period of oceanic anoxia (pers comm A. Partridge). The degree of expression of the spike on the logs varies. Montague 1 is perhaps the best expressed and here the layer is up to 5m thick. In Rosemary 1 it is associated with what was described as a coal. The age of the spike is consistent at top C3b and defines the boundary between Time Slices K8 and K9.

In several wells there is a hint of a second spike at the C2/C3a boundary, possibly indicating an early less pronounced oceanic oxygen minimum.

Poor age control on the wells of the Enderby Terrace precludes certain recognition of this time slice although the claystone facies appears to be present in these wells.

Thickness Variations:

The Madeleine Trend may have been tectonically active during this depositional period as evidenced by the absence of the lowest dinoflagellate zones of this time slice along this trend. The same result could occur without tectonic action due to onlap of a submarine topographic feature or currents over such a feature preventing deposition.

Lithology:

Sedimentation is dominated by marine calcilutites and marls. Radiolarites are referred to in Enderby 1, although the criteria have been used to identify them are difficult to assess. Inshore the marls and calcilutites grade into claystones with minor quartz silt (to 10%) and minor glauconite.

The marls are medium grey, green grey to dark grey or bluish white and soft to moderately hard. They tend to become darker to the southeast. The calcilutites are similar to the marls in colour and compaction. They are 70 - 90% micrite and 10 - 20% clay minerals with occasional quartz silt. The claystone is generally olive grey to olive black, brown black to dark grey brown, light green grey to dark green 70 - 80% clay minerals, 20 - 30% quartz silt, calcareous. Most of the lithologies contain traces of forams and *Inoceramus sp.* fragments. Corals, and crinoid fragments are seen in Saturn 1.

PALAEODEPOSITIONAL ENVIRONMENT:
Time Slice K8 sediments overlap the boundaries of the Time Slice K5-K7, particularly to the northwest where they form a seal facies on the Time Slice K6 sandstones in De Grey 1 and Cossigny 1. Deposition is on a continental shelf extremely starved of clastic sediments. It is the first interval to show the influence of major carbonate sedimentation to the exclusion of almost any clastic sediments.

Palaeogeography:
Open oceanic continental shelf deposition. The interval represents a continuation of continental shelf and slope sedimentation that was initiated in Time Slice K5-K7. There is a continuation of relative sea level rise caused mostly by margin sag. The coastline is thought to be a long way to the east of the area.

PROSPECTIVITY:
This is a seal facies and is not considered highly prospective. It is significant in that the claystone facies probably extends across the shelf and forms a regional seal facies.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0.24 to 1.54 with a maximum of 1.54 at Hampton 1. The median HI values range from 36 to 184 with a maximum of 280 at Rosemary North 1. The vitrinite reflectance data suggest this interval is immature. A pattern of better source quality to the south in the vicinity of Withnell 1 and Rosemary 1 is apparent on all the early to middle Cretaceous Time Slices.

Shows/Porosity/Permeability:
There is a minor oil indication at Gandara 1 and Goodwyn 2, and Rosemary 1, the latter associated with the Turonian spike. A minor gas shows occurs in North Rankin 3.

Traps and Plays:
There are no obvious plays or traps in this time slice. It forms a regional seal on the sandy facies at Cossigny 1 and would also form a good seal unit on the Enderby Terrace.

TIME SLICE K9: UPPER CRETACEOUS: Turonian, Coniacian, Santonian: (91.0 to 83.0 Ma).
ENCLOSURES 42 & 43

Formation Synonyms: Toolonga Calcilutite, Winning Group, Windalia Sandstone Equivalent.

PALAEONTOLOGY
Zones *C4* to *C8*.

Time Slice K9 was penetrated in twenty five of the study wells. Time Slice K9 is not recorded in four wells on the Enderby Terrace these being Hampton 1, Strickland 1 Lawley 1 and Hauy 1 where the section is not recognised due to poor age control; it may in fact be absent due to erosion. In Talisman 1 the time slice is not recognised due to poor age control but appears to be developed based on log signature.

A lot of this time slice is absent along the Rosemary Legendre Fault Zone and Enderby Terrace. It appears that deposition was continuous into at least C4 time in all but the northernmost wells along this zone. C5 and C6 zones are absent in all wells except Legendre 1 and Nelson Rocks 1. Deposition had recommenced by C6 time in all wells except those on the Enderby Terrace.

In Lambert 1 and Saturn 1 Time Slice K9 is a condensed section.

Thickness Variations: (see Figure 25)
The depocentre for this time slice is the Lewis Trough where a maximum 385m is recorded in Rosemary 1. The depocentre axis parallels, and is adjacent to, the Rosemary Fault System.

Lithology:
Calcilutite, calcareous claystone and marl are the dominant lithologies. The calcilutite (Toolonga Calcilutite) forms the uppermost section and calcareous claystones and marls are the lowermost older deposits. In general the marl dominates the section on the ocean side of a hingeline defined approximately by the Rosemary Fault System. At all levels the deposits become more calcareous, lighter in colour and generally thinner further offshore. Colour ranges from dark olive green black to light bluish white and compaction from moderately hard to very soft plastic. Glauconite traces are common inshore and foraminiferal and *Inoceramus sp.* fragments are also common.

Argillaceous very fine grained thin sandstone beds and arenaceous claystones occur in Rosemary 1

PALAEODEPOSITIONAL ENVIRONMENT:
Deposition occurred on an open marine continental shelf and slope in an environment starved of clastics, that becomes totally carbonate dominant offshore.

Dampier Sub Basin

Time Slice K9: Isopach Map

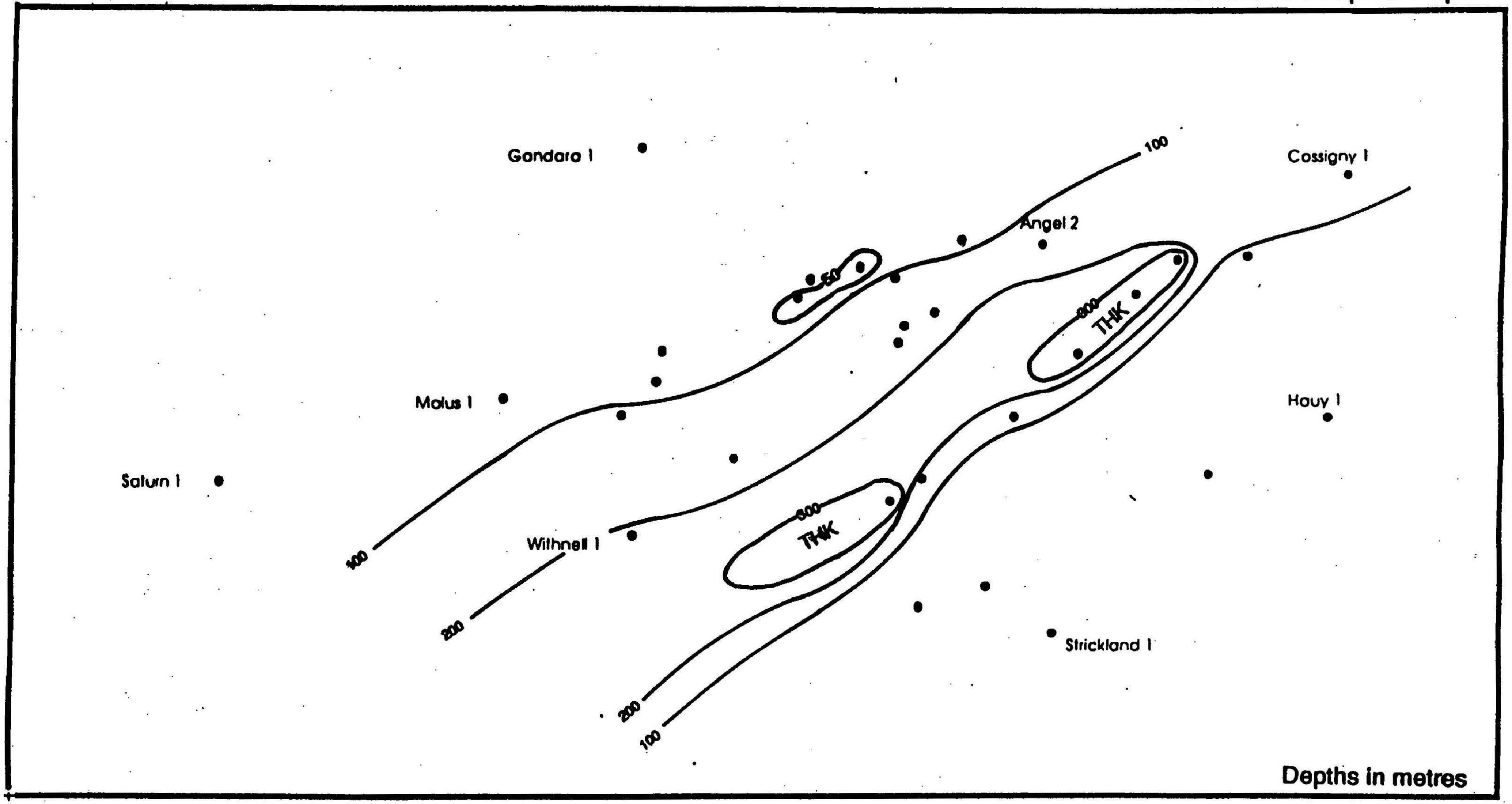


Figure 25

Palaeogeography:
The southeastern margin of the Lewis Trough forms a hinge line that divides the upper continental slope and outer shelf edge deposits from the deeper water base of slope deposits. The shore line is a long way to the east, but a minor finger of outer to middle shelf edge sands may exist in the vicinity of Rosemary 1

PROSPECTIVITY: POOR
The prospectivity of Time Slice K9 is considered poor. The thin sands at Rosemary 1 could provide potential to the southeast or east if reservoir quality and thickness were to improve. Hydrocarbon migration into any of these sands would rely on faults but is difficult to envisage a feasible pathway through such soft and plastic sediments.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0. 35 to 0. 96 with a maximum of 1. 25 at Rosemary North 1. There is one HI value of 134 at Rosemary North 1. The vitrinite reflectance data suggest this interval is immature. Withnell 1 and Rosemary 1 again show better source rock quality than elsewhere, as has been seen in preceding Cretaceous Time Slices.

Shows/Porosity/Permeability:
Minor gas and oil indications occurred in wells along the Rankin Trend; Goodwyn 6, North Rankin 2, North Rankin 3 and Eaglehawk 1 that may indicate upward migrating hydrocarbons. Any porosity is non effective and permeability is zero. This is a major seal facies.

Traps and Plays:
No traps or plays. There is a minor reservoir lead near Rosemary 1.

TIME SLICE K10: UPPER CRETACEOUS -Campanian to Lower Maastrichtian: (83.0 to 70.0 Ma).
ENCLOSURES 44 & 45

Formation Synonyms: Withnell Formation, Toolonga Calcilutite, Miria Marl, Miria Formation.

PALAEONTOLOGY:
Zones *C9* to *C11*

Time Slice K10 was penetrated in twenty five of the study wells. Time Slice K10 is not recorded in five wells on the Enderby Terrace. In Enderby 1 a section with identifiable Time Slice K10 was recorded however the top of Time Slice K10 is very poorly controlled in this well. In Rosemary 1 age control over this interval is also poor.

The Top Cretaceous is marked by a regional unconformity in the Dampier Sub-basin. This unconformity has partially or completely removed the overlying Time Slice K11, but has not removed any significant amount of Time Slice K10.

There also appears to be a regional disconformity or unconformity or condensed section at the base of Time Slice K10. The age depth plots do not allow an exact time estimate and the event may range from middle Time Slice K9 to lower Time Slice K10.

Thickness Variations: (see Figure 26)
The depocentre for this time slice is the Lewis Trough to the southwest of Rosemary North 1, where a maximum 549m accumulated at Withnell 1.

Lithology:
The sequence is marl offshore, interbedded with calcareous claystone inshore. On the southern Enderby Terrace quartz sandstone deposition occurs. In the southwest basal calcilutite occurs. This is a diachronous continuation of the calcilutite (Toolonga Calcilutite) of Time Slice K9.

The marl is commonly light greenish grey occasionally dark grey and slightly glauconitic. The claystone is most commonly dark olive grey, dark green to black, and calcareous. Calcilutite is medium grey green, greenish white. The marls claystones and calcilutites are generally very soft to soft but more deeply buried sections are moderately hard. Pyrite, glauconite and foraminifera are common and *Inoceramus sp.* fragments are abundant.

In Rosemary 1, thin olive grey to olive black to dark green grey, very fine to medium grained, dominantly very fine to fine grained, subangular to subrounded argillaceous glauconitic sandstones occur. They have poor intergranular porosity. Similar though less abundant sandstones occur in Lewis 1A and Legendre 1

Dampier Sub Basin

Time Slice K10: Isopach Map

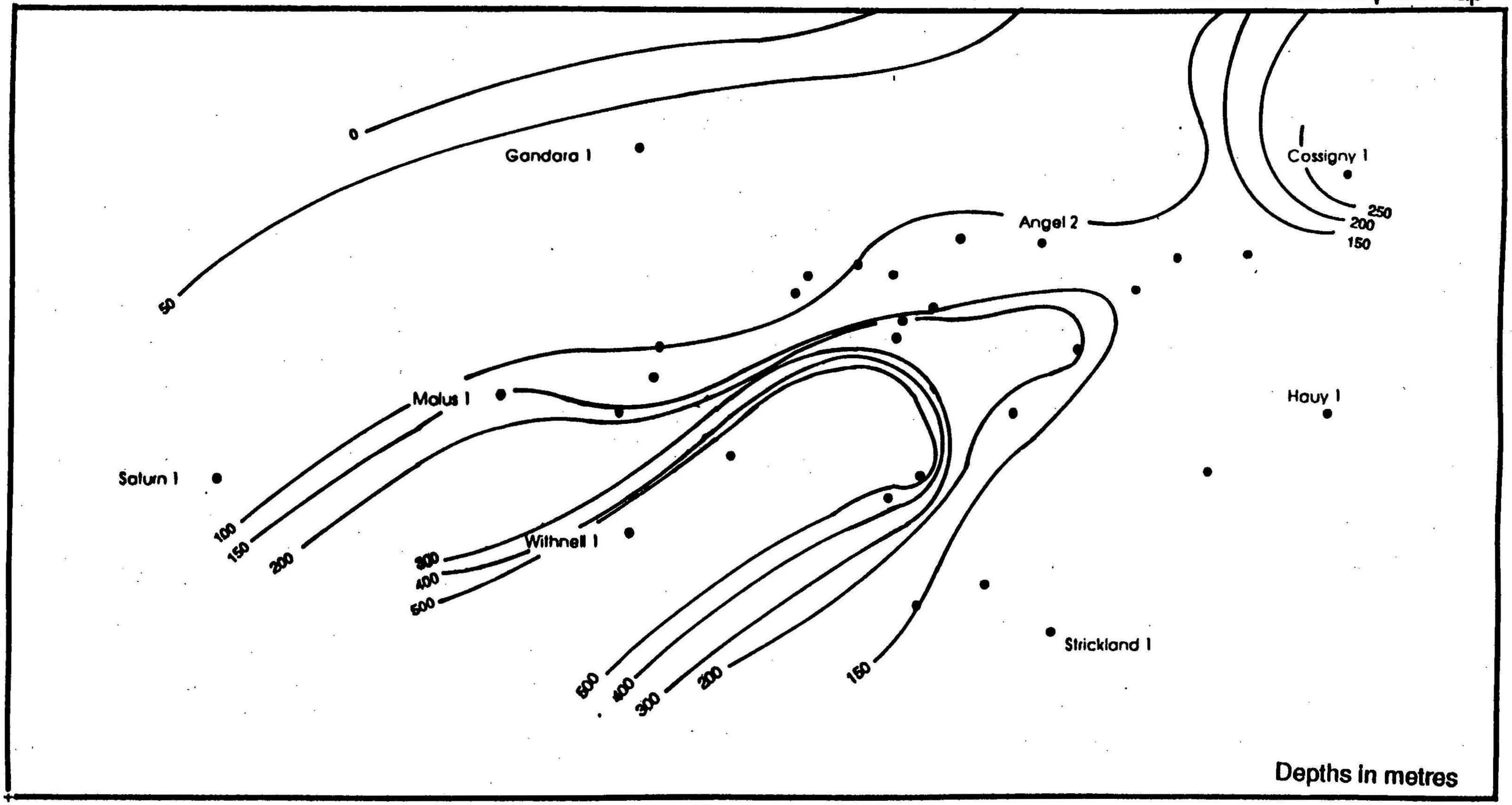


Figure 26

PALAEODEPOSITIONAL ENVIRONMENT:
Time Slice K10 is a continuation of Time Slice K9 style of deposition with evidence of minor regression and shallower water or more energy in the vicinity of Rosemary 1. Fragments of *Inoceramus sp.* are abundant and foraminifera are common.

Palaeogeography:
These are open oceanic continental shelf and slope carbonate dominated deposits on a starved shelf. Middle shelf sands encroach onto the slope break near Rosemary 1.

PROSPECTIVITY: POOR TO FAIR
The prospectivity of time slice Time Slice K10 is considered poor.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0.39 to 2.8 with a maximum of 2.8 at Legendre 1. The median HI values range from 34 to 52 with a maximum of 96 at Rosemary North 1. The vitrinite reflectance data suggest this interval is immature. The general trend for TOC values is to decrease offshore. Because the sediments are carbonates and the above figures are indicative of fair quality source rocks.

Shows/Porosity/Permeability:
Minor oil shows occurred in Withnell 1, Dockrell 1, Goodwyn 6(minor gas as well), North Rankin 3 and North Rankin 2. This is repeated in Time Slice K9 and this suggests the shows are leakage from the underlying accumulations. Porosity is non effective and permeability is zero in what is a major seal facies. Fine grained sandstones in the vicinity of Rosemary 1 may have reservoir potential to the east on the assumption that they might become coarser, thicker and cleaner in this direction.

Traps and Plays:
There are no particularly good obvious traps within this unit. A clastic source area from the southeast quadrant is indicated. Sands from this source are found in Legendre 1, Lewis 1, and Rosemary 1. They are not well described and may be of poor quality. Lateral facies pinchout traps are possible, and faulting could provide a migration pathway for underlying hydrocarbons to enter these reservoirs.

TERTIARY TIME SLICES: Cz1 and Cz2.

Age control above Time Slice Cz2 is extremely poor so no attempt has been made to interpret above this level.

TIME SLICE Cz1: TERTIARY: Paleocene to Lower Eocene. (66. 4 to 52. 0 Ma)
ENCLOSURES 46 & 47

Formation Synonyms: Cardabia Group, Dockrell Fm., Walcott Fm. Lambert Fm, Wilcox Fm.

PALAEONTOLOGY:
Zones *T1* to middle *T10*. *T6* is generally considered to be absent and a time of submarine disconformity (Apthorpe 1988).

Time Slice Cz1 was penetrated in 23 of the study wells. Time Slice Cz1 is not recorded in seven wells, these being the five wells on the Enderby Terrace plus Talisman 1 and Rosemary 1. In some of these wells Time Slice Cz1 may be absent due to erosion, but poor age control is more likely the primary cause of non recognition of Time Slice Cz1 deposits.

The base of Time Slice Cz1 is a major unconformity in all but the three most southern wells in the Lewis Trough; being Saturn 1, Withnell 1 and Dampier 1 where sedimentation was continuous. A general trend of deposition commencing later in the north with progressive onlap of the palaeohighs can be interpreted from the data. From this it is interpreted that the Lewis Trough area was an embayment open to the ocean in the south with the Rankin Trend and De Grey areas being positive features at the commencement of Time Slice Cz1.

The upper surface of Time Slice Cz1 is an unconformity over areas of the Lewis Trough, particularly in the vicinity of the Rosemary Fault System and on the Rankin Trend. This unconformity is probably due to erosion.

In wells without upper and lower unconformities a complete succession of palynology zones is found. Several wells along the Rankin Trend have either a condensed interval or an erosional unconformity at palynological zone T7.

Thickness Variations:
The Rosemary Fault System forms a hinge line to the margin sag accumulations. The trend is to thicken rapidly from the Enderby Terrace into the Lewis Trough across this hinge line and then to thin gradually seaward. The thickest section is encountered in Dampier 1 (464m). There may be subtle thins over older buried topography in the vicinity of Wanaea and Madeleine and along the Rankin Trend. This suggests that some of the depositional space has been provided by compaction of the underlying units.

Lithology:
In four wells, North Rankin 2 and 3, Eaglehawk 1 and Madeleine 1 there are basal glauconitic marine sandstones. These are described as dark greenish grey, very fine

grained, well-sorted glauconitic sandstones with up to 60% quartz. Porosity ranges from good to poor.

In Dampier 1 a thick sequence of light grey fine to very fine silty quartzose sandstone accumulated. In places this grades into glauconitic sandstone. There are traces of chert, siderite and dolomite as well as recrystallised limestone lenses. Near Nelson Rocks 1 and Legendre 1 are olive grey to olive black very fine grained glauconitic sandstone that are thinly interlaminated with dark brown glauconitic siltstone. *Inoceramus sp.* prisms are a found within these accumulations. These sands are interpreted as inner continental shelf deposits.

A broad band of claystone, marl and calcilutite trends northeast from Saturn 1 to Lambert 1 and probably continues northward. The dominant lithology is dark olive grey to olive black moderately hard to soft claystone, or olive grey or dark brown to light grey soft marl. Light grey calcilutite is less common. Foraminifera, skeletal fragments, pyrite and glauconitic siltstone are common within these lithologies. Gandara 1 sequence commences as a light grey claystone and grades upward through marl into calcilutite.

PALAEODEPOSITIONAL ENVIRONMENT:
Deposition was on an open marine continental shelf to slope environment.

Palaeogeography:
Initial sedimentation followed on from a probable major sea-level fall and resulted in basal greensand deposition. It is interpreted that the greensands could form a belt generally paralleling the palaeobathymetry. The palaeobathymetry is in turn thought to be most likely a reflection of compaction in the Lewis Trough: ie the Trough was a seafloor low and the Rankin Trend a sea floor high.

Following from this Time Slice Cz1 sediments were deposited on a marine continental shelf. A simple zonation of inner to outer shelf is seen paralleling the present coastline, finer grained sediments being deposited further offshore. Minor clastic input occurs in the southeast of the Enderby Terrace.

Palaeo-water depths are not directly indicated but generally thought to reflect in broad terms the modern shelf trends.

PROSPECTIVITY: POOR TO FAIR
The speculative zone of basal greensands in the Lewis Trough provides a reservoir facies. Wherever faulting allows possible hydrocarbon migration from deeper pre-Main Unconformity accumulations a play may exist.

Geochemistry (TOC, HI and Vr)
The median TOC values range from 0.28 to 1.79 with a maximum of 1.79 at Lambert 1. There are no HI data. The vitrinite reflectance data suggest this interval is immature. There appears to be a general increase of TOC values to the north.

Shows/Porosity/Permeability:

Three minor gas shows occur, in Goodwyn 6, Withnell 1 and North Rankin 3. The two on the Rankin Trend may be associated with vertical migration from underlying accumulations. Withnell 1 however is a shallow accumulation (~1000m) in the middle of the Lewis Trough and may be early phase biogenic rather than thermogenic gas.

The top to the deepest burial of Time Slice Cz1 is only 2504m sub sea in Gandara 1. Porosity degradation by compaction is therefore not likely to be a major problem.

Traps and Plays:

The sequence is essentially a seal facies. Reservoir quality facies are possible where glauconitic sands of sufficient thickness accumulate. As explained earlier there is a possibility that the basal glauconitic sands form a band parallel to the palaeoshoreline at the commencement of Time Slice Cz1 deposition. It would be necessary to migrate hydrocarbons into these reservoirs from underlying source rocks. Faults provide the only obvious mechanism for this. Hence any plays would require the coincidence of faults through the underlying sequences and potential to be on a migration pathway. High resolution seismic might highgrade such prospects.

TIME SLICE Cz2: TERTIARY: Middle to Late Eocene (36.5 to 52.0 Ma)
ENCLOSURES 48 & 49

Formation Synonyms: Giralia Calcarenite, Walcott Fm.

PALAEONTOLOGY:
Zones *P10* to *P17* and *T10* to *T14*

Time Slice Cz2 is penetrated in a total of 24 wells. Time Slice Cz2 is the uppermost timeslice for which an interpretation has been attempted. This is due to the poor age control of the upper boundary in many wells.

Due to poor age control Time Slice Cz2 is not recorded in six wells, these being the five wells on the Enderby Terrace and Rosemary 1. In the wells on the Enderby Terrace Time Slice Cz2 may be absent due to erosion. As well, Talisman 1 lacks age control, but lithological and log correlation allow fairly certain identification of the time slice in this well. Poor age control on the upper boundary of Time Slice Cz2 occurs in Withnell 1, Madeleine 1, North Rankin 2, Rosemary North 1 and Legendre 1, and in these wells lithological correlations have been used to estimate a top.

The base of the Time Slice Cz2 is a significant unconformity in many of the wells. The top of Time Slice Cz2 is also an unconformity surface but erosion does not appear to have significantly cut down into the actual timeslice except in Dampier 1, Goodwyn 2, Goodwyn 6 and Lambert 1.

Where good age control is seen zone T12/T13 is often missing. The missing zone is almost always associated with a lithological break and/or a peak in chert concentration. This lithology break can be seen in wells with poor age control. The above observations confirm a regional time break, either erosional or non depositional, centred on the T12 zone at about 43-42 Ma. Whether this break has a diachronous component is unclear. This interpretation is not reflected in the Time Space Diagram which shows the direct age depth plot interpretations.

Thickness Variations:
The general trend is to thicken rapidly from the Enderby Terrace across the Rosemary Fault System into the Lewis Trough with the thickest section occurring in Wanaea 1 (251m) and then to thin gradually seaward.

Lithology:
In five wells, Dampier 1, Madeleine 1, Walcott 1, Wanaea 1 and Lewis 1 there are basal light grey glauconitic calcareous quartzose fine to medium grained marine sandstones with indications of good to fair porosity.

The pre T12 hiatus sediment package has inner shelf deposits of coarser grained material, dominated by calcarenites, siltstones and sandstones. A clastic source area centred on Legendre probably fed the area from the southeast across the Enderby Terrace. Further offshore the clastic input is reduced and minor quartz silts and clay minerals are mixed with dominant marls and calcilutites.

The post T12 hiatus package has similar zonation to the above except for a notable reduction in clastic input but an abundance of chert. The actual hiatus surface may have been exposed to silicification processes or winnowing that could have concentrated the chert.

PALAEODEPOSITIONAL ENVIRONMENT:
Deposition was on an open marine clastic starved, carbonate dominated shelf. Palaeo-water depths are not directly indicated but generally thought to reflect in broad terms the modern shelf trends.

Palaeogeography:
Three depositional episodes can be distinguished. A basal marine transgressive sand deposit, followed by two episodes of marine continental shelf progradation on a clastic starved continental shelf.

The basal sandstone deposits developed initially in deeper water as the transgression advanced north. This is a pattern seen in underlying Time Slice Cz1 (see Time Slice Cz1 section for a more complete discussion of palaeobathymetry).

PROSPECTIVITY: POOR
The sequence is essentially a seal facies and no reservoir facies are thought to occur within it.

Geochemistry (TOC, HI and Vr)
There is insufficient geochemical data for this Time Slice.

Shows/Porosity/Permeability:
The only show for this timeslice is recorded from Gandara 1 where a weak gas oil indication occurred. As it is from a non reservoir unit it is not thought to be particularly significant. In five wells, Dampier 1, Madeleine 1, Walcott 1, Wanaea 1 and Lewis 1 there are sandstones with indications of good to fair porosity.

Traps and Plays:
Reservoir facies are possible where glauconitic sandstones or calcarenites of sufficient thickness accumulate. It would also be necessary to migrate hydrocarbons into these reservoirs from underlying source rocks. Faults provide the only obvious mechanism for this.

EXPLORATION HISTORY OF STUDY WELLS

INTRODUCTION

The Dampier Sub-basin has a drilling history that dates back to 1968. The exploration history of the area has been summarised in Kopsen & McGann (1985) and Table 3 below summarises the most basic data of the wells used in this study.

TABLE 3: WELLS USED IN STUDY

WELLNAME	OPERATOR	SPUD DATE	COMPLETE
Angel 2	Woodside/Burmah Oil NL	7-MAR-72	2-JUN-72
Cossigny 1	Woodside/Burmah Oil NL	15-OCT-72	8-NOV-72
Dampier 1	Burmah Oil Co of Aust Ltd	22-NOV-68	9-MAY-69
De Grey 1	Burmah Oil Co of Aust Ltd	10-SEP-71	18-OCT-71
Dockrell 1	Woodside/Burmah Oil NL	30-JUN-73	28-AUG-73
Eaglehawk 1	Woodside/Burmah Oil NL	10-NOV-72	24-DEC-72
Enderby 1	Burmah Oil Co of Aust Ltd	10-SEP-70	12-OCT-70
Gandara 1	Hudbay Oil (Aust) Ltd	9-MAY-79	15-JUL-79
Goodwyn 2	Burmah Oil Co of Aust Ltd	27-MAR-72	7-JUN-72
Goodwyn 6	Woodside Petroleum Ltd	28-SEP-81	31-JAN-82
Hampton 1	Woodside/Burmah Oil NL	22-MAR-74	24-APR-74
Hauy 1	Woodside/Burmah Oil NL	25-NOV-72	14-DEC-72
Lambert 1	Woodside/Burmah Oil NL	13-NOV-73	3-FEB-74
Lawley 1	Hudbay Oil (Aust) Ltd	10-AUG-81	29-AUG-81
Legendre 1	Burmah Oil Co of Aust Ltd	7-JUN-68	17-NOV-68
Lewis 1A	Burmah Oil Co of Aust Ltd	24-DEC-75	4-MAR-76
Madeleine 1	Burmah Oil Co of Aust Ltd	15-MAY-69	15-DEC-69
Malus 1	Woodside/Burmah Oil NL	7-OCT-72	11-NOV-72
Montague 1	Woodside Offshore Petroleum	29-OCT-84	31-MAY-85
Nelson Rocks 1	Woodside/Burmah Oil NL	30-JUN-73	1-AUG-73
North Rankin 2	Woodside/Burmah Oil NL	9-JUN-72	20-AUG-72
North Rankin 3	Woodside/Burmah Oil NL	3-AUG-72	28-SEP-72
Rosemary 1	Woodside/Burmah Oil NL	13-NOV-72	25-APR-73
Rosemary North 1	Woodside Petroleum Ltd	19-OCT-82	25-NOV-82
Saturn 1	Phillips Aust Oil Co	1-DEC-80	5-FEB-81
Strickland 1	Hudbay Oil(Aust) Ltd	10-MAR-82	25-MAR-82
Talisman 1	Marathon Petroleum Aust Ltd	14-JUN-84	28-SEP-84
Walcott 1	Woodside Petroleum Limited	13-JUL-79	24-NOV-79
Wanaea 1	Woodside Offshore Petroleum	8-NOV-88	20-JUN-89
Withnell 1	Burmah Oil Co of Aust Ltd	5-MAR-76	23-JUN-76

WELL POST DRILL AUDIT SUMMARIES

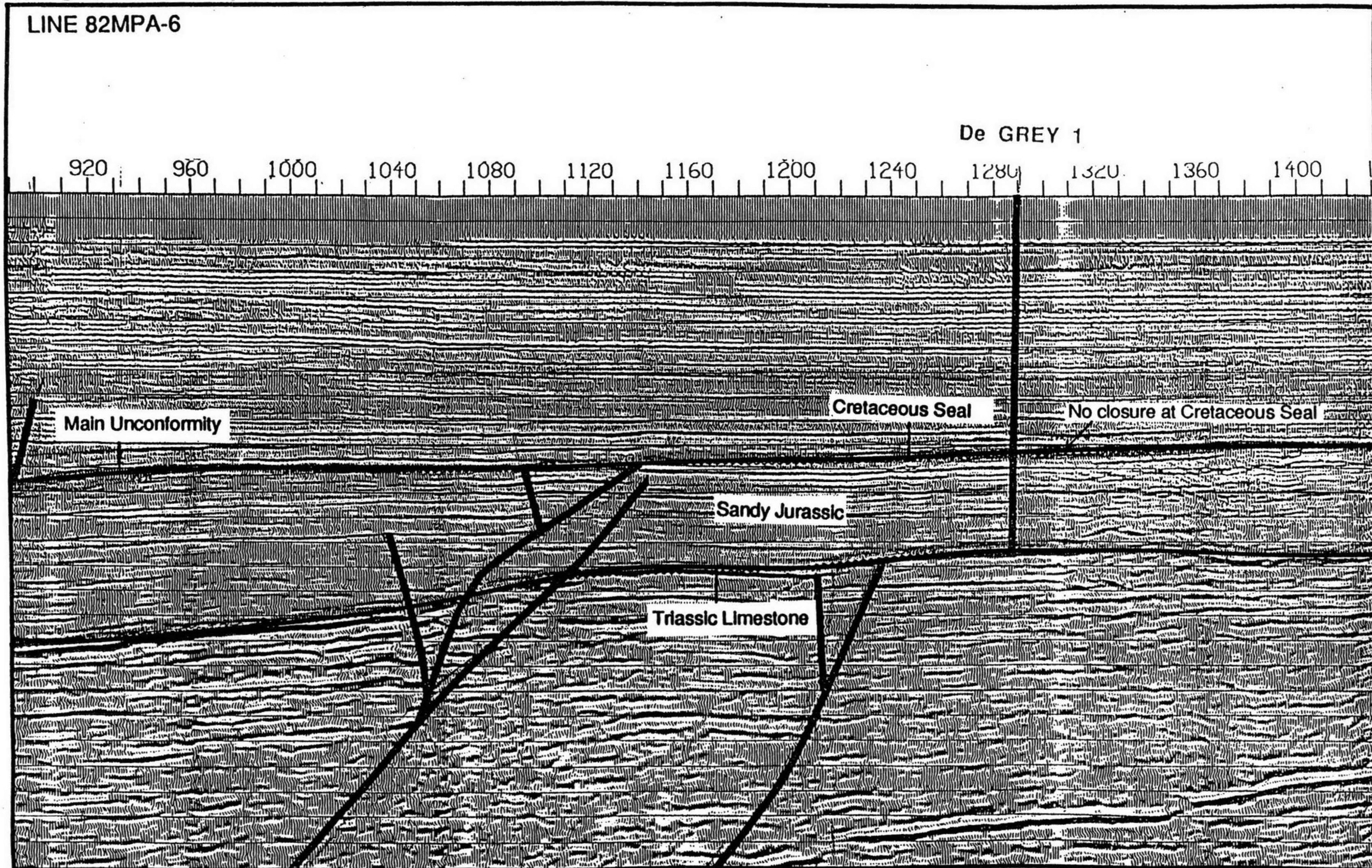
The wells used in this study are all exploration or early post discovery appraisal wells. An excellent summary of most of the successful wells has been compiled by Vincent and Tilbury (1988, p367) and the detail will not be repeated here. Talisman 1 results are adequately covered by Ellis (1988). Bint (1991) describes the Madeleine 1, Walcott 1 and Wanaea 1 wells. Table 4 summarises the post drill audit results for the study wells.

TABLE 4: WELL POST DRILL AUDIT SUMMARY TABLE

WELLNAME	SUCCESS-FAILURE SUMMARY	PROVINCE
Angel 2	Gas Condensate Discovery	Lewis Trough
Cossigny 1	No trap	Beagle Sub-basin
Dampier 1	No reservoir at target levels	Lewis Trough
De Grey 1	No trap	Enderby Terrace
Dockrell 1	Gas Condensate & Oil Discovery	Rankin Trend
Eaglehawk 1	Oil Field	Rankin Trend
Enderby 1	Not on migration pathway	Enderby Terrace
Gandara 1	Immature within small drainage area	Kangaroo Syncline
Goodwyn 2	Gas Condensate Discovery	Rankin Trend
Goodwyn 6	Gas Condensate Discovery	Rankin Trend
Hampton 1	Minor gas, off target at depth	Enderby Terrace
Hauy 1	No trap	Enderby Terrace
Lambert 1	Oil Discovery	Lewis Trough
Lawley 1	No major closure & no migration path ?	Enderby Terrace
Legendre 1	Oil Discovery - first discovery	Lewis Trough
Lewis 1A	Possibly no trap	Lewis Trough
Madeleine 1	Outside closure	Lewis Trough
Malus 1	Uncertain, outside closure??	Rankin Platform
Montague 1	Minor discovery - retest J10 warranted	Lewis Trough
Nelson Rocks 1	structuring post oil migration	Lewis Trough
North Rankin 2	Gas Condensate Discovery	Rankin Trend
North Rankin 3	Gas Condensate Discovery	Rankin Trend
Rosemary 1	Outside closure	Lewis Trough
Rosemary North 1	Residual oil column	Lewis Trough
Saturn 1	Bypassed pay & outside closure	Kangaroo Syncline
Strickland 1	Breached closure at K - deeper play ?	Enderby Terrace
Talisman 1	Oil Discovery	Lewis Trough
Walcott 1	Outside closure	Lewis Trough
Wanaea 1	Major Oil Discovery	Lewis Trough
Withnell 1	No major reservoir. Possible pay.	Lewis Trough

The emphasis in the following discussion is on the general exploration implications of the successful wells and a brief examination of what the most probable reasons are for failure in unsuccessful wells. This is not a complete detailed well audit as only limited information is available to us. However it is necessary to see what general conclusions can be made about the Dampier Sub-basin petroleum system based on current well results. The interpretation and inferences from this audit are discussed under the play concepts and recommendations section of this report.

The wells have been drilled in five main tectonic provinces (See Figure 7 & Enclosure 1). Within each province the tested play types remain similar. The exception to this generalisation is Cossigny 1 which was drilled in the Beagle Sub-basin. This well is apparently not within closure (J. Blevin pers comm) and will not be discussed here.



Seismic Line over De Grey 1. Figure 27

The Dampier Sub-basin tectonic provinces are

- Enderby Terrace
- Dampier-Sub-basin: Kendrew Terrace and Lewis Troughs
- Rankin Trend
- Rankin Platform
- Kangaroo Syncline Area

ENDERBY TERRACE

The Enderby Terrace area is broadly defined as the area to the southeast of the Lewis Trough. It has acted as a tectonically more stable block throughout development of the adjacent areas. The southeastern flank of the Lewis Trough is a tectonically complex wrench fault zone called the Rosemary Fault System. On the Enderby Terrace basement (or pre Triassic) shallows by a series of fault defined terraces to the southeast. The overall trend is for down to the northwest normal faulting, but superimposed on this is a secondary system of horsts and grabens developed by a series of associated listric faults of opposite throw.

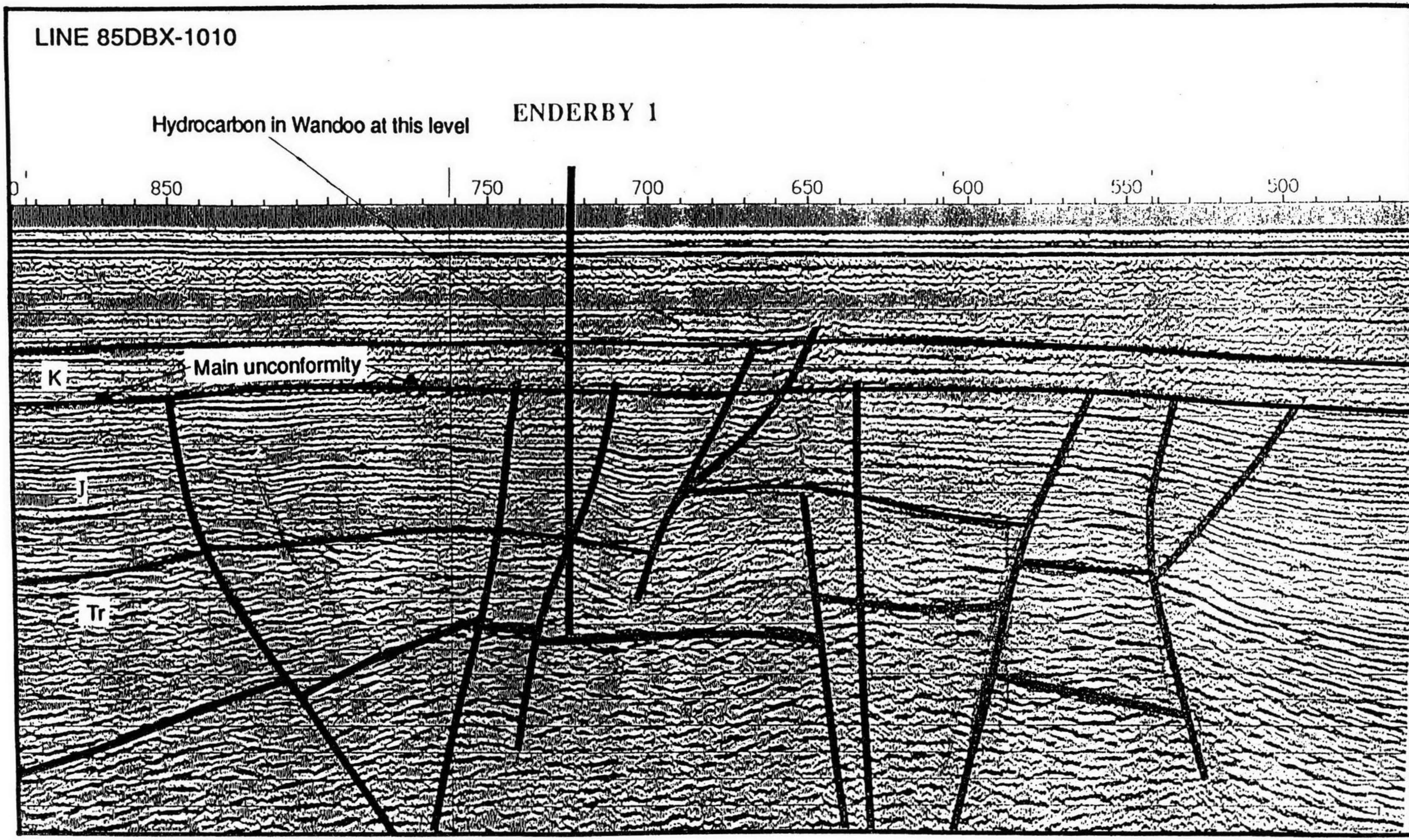
The area has been upgraded following the discovery of the Wandoo Field. It is currently interpreted to be sourced from Jurassic hydrocarbons migrating from the Lewis Trough.

TABLE 5: ENDERBY TERRACE WELL AUDIT SUMMARY

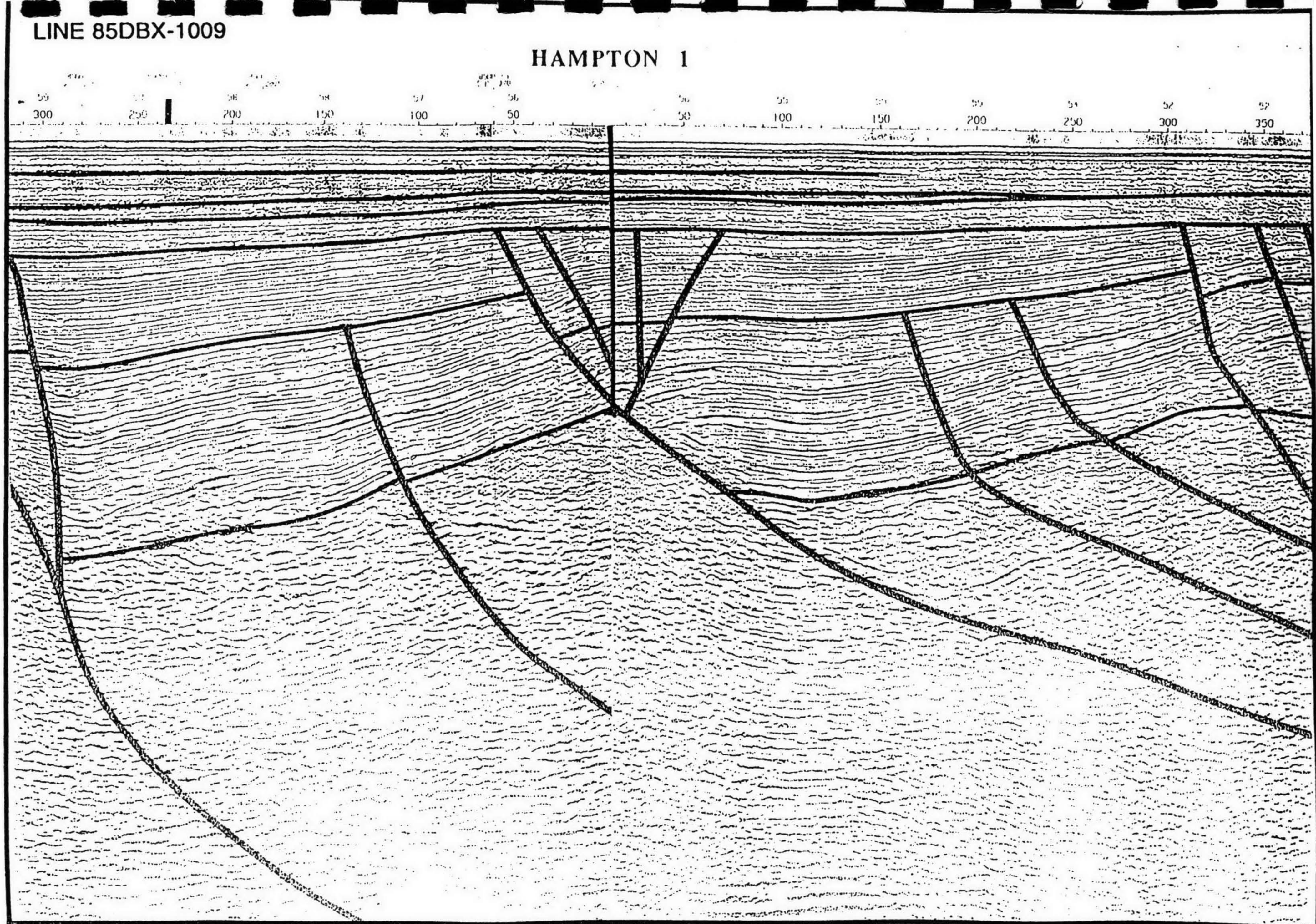
WELLNAME	COMMENTS
De Grey 1 (1971)	Not a valid test -- no closure at top of reservoir section
Enderby 1 (1970)	Very close to Wandoo-- possibly not on migration pathway or downdip or in different fault compartment.
Hampton 1 (1974)	Valid test of Cretaceous with minor closure probable. Gas show in basal Cretaceous sandstones. Not a valid test of earlier section as no closure seen on recent seismic
Hauy 1 (1972)	Stratigraphic play - probably not a valid test.
Lawley 1 (1981)	Valid test - possibly not on migration pathway.
Strickland 1 (1982)	Cretaceous breached by faulting or thin seal. Major rollover not apparent on modern lines at Cretaceous level. A possible basal Triassic rollover target was not tested as the well terminated above this. Migrated oil is present.

De Grey 1 (see Figure 27)

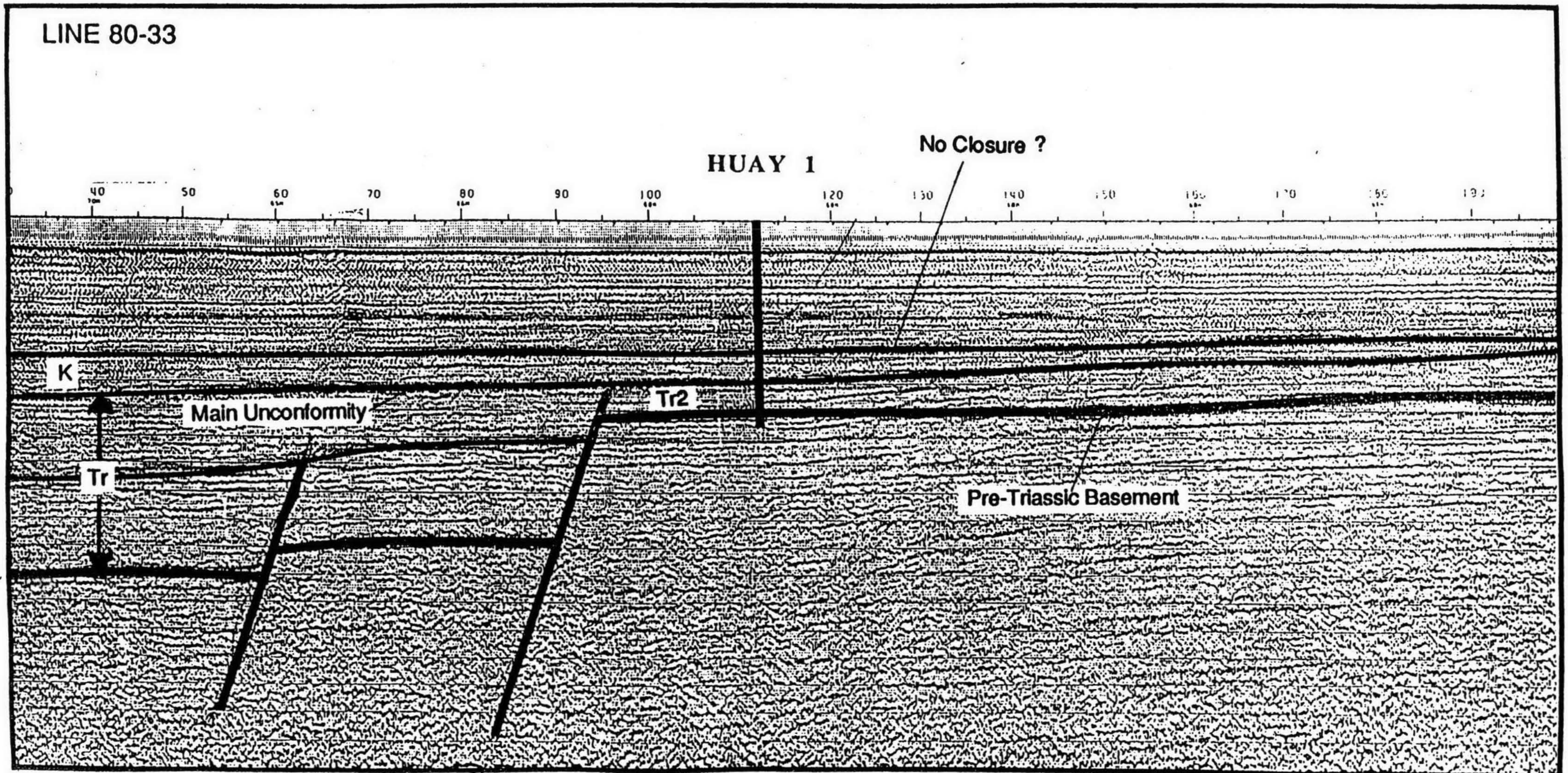
For purposes of post drill auditing, the well can be divided into two sections. Above 1297m KB (the Main Unconformity) the well section is a seal facies consisting of marls, siltstones and claystones that were deposited in a starved or restricted continental shelf environment. Below this is a reservoir facies of clastics, deposited in a shallow marine or lower deltaic environment with abundant sand supply. Because of the high sand to shale ratio only a structural play immediately below the regional seal at 1297m KB appears viable. Provided four way dip closure can be established at this level then De Grey 1 was a valid test. No map at this level is available to us but an examination of



Seismic Line over Enderby 1.   Figure 28

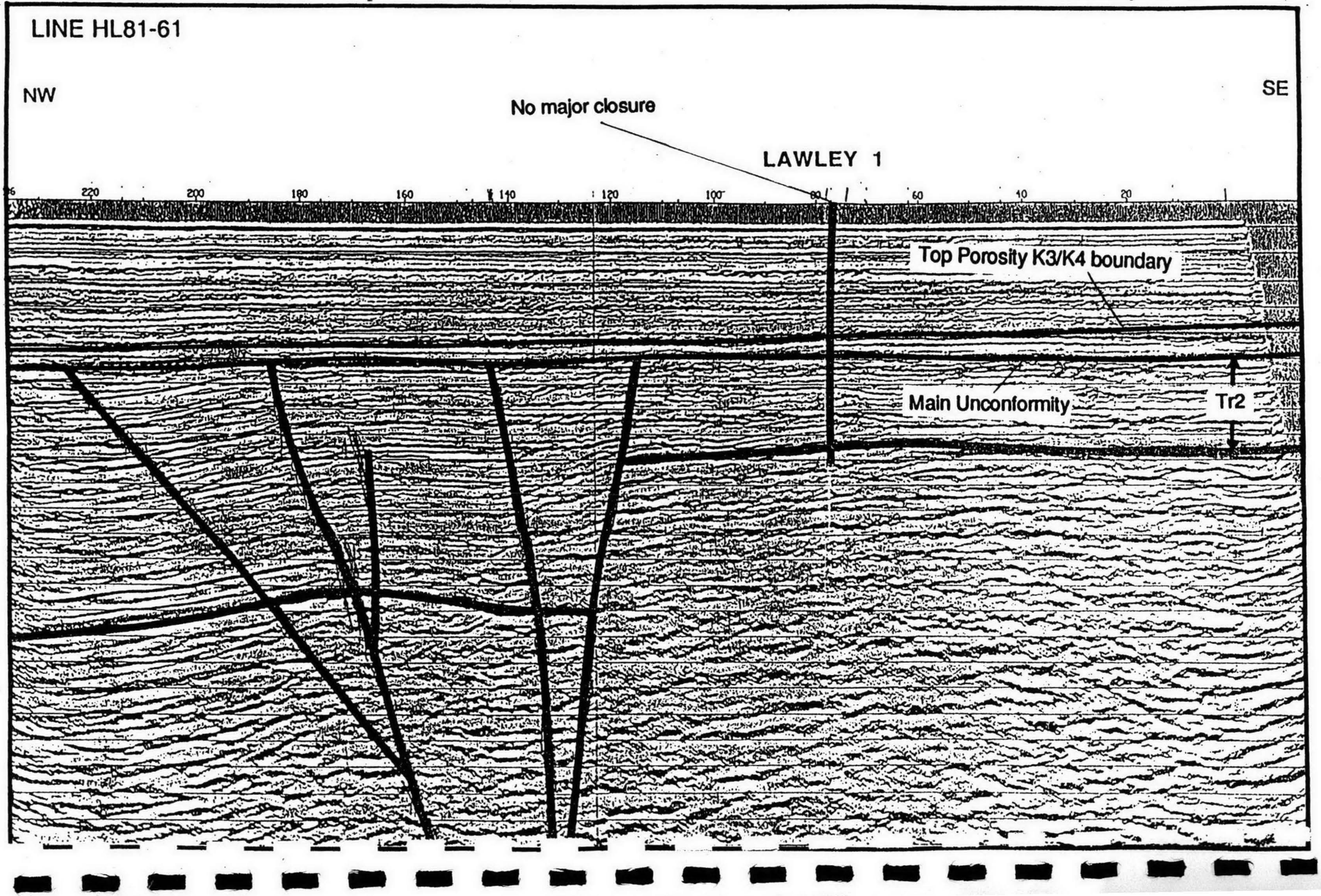


Seismic Line over Hampton 1 Figure

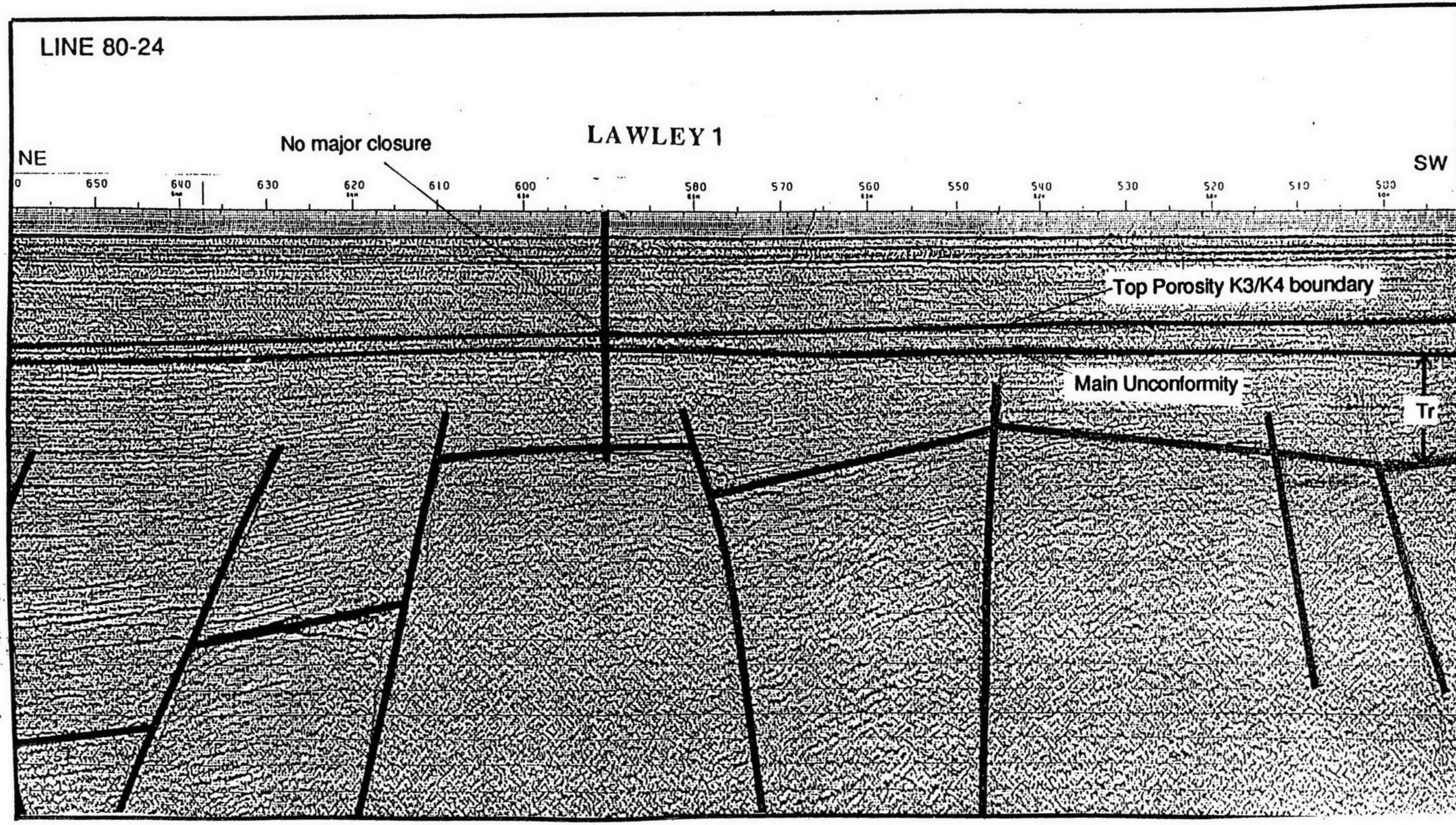


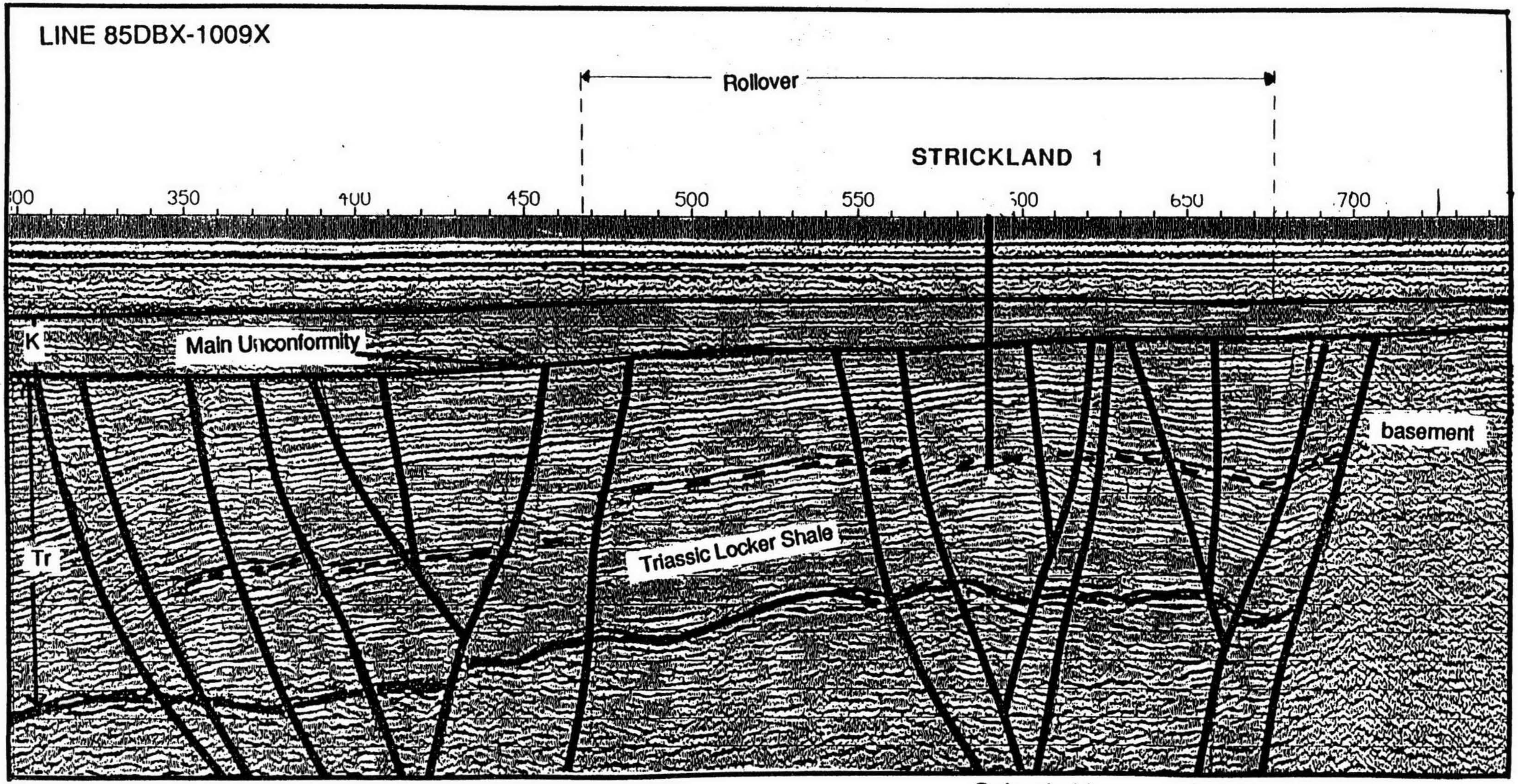
Seismic Line over Hauy 1Figure

Northwest to Southeast Seismic Line over Lawley 1.Figure 31

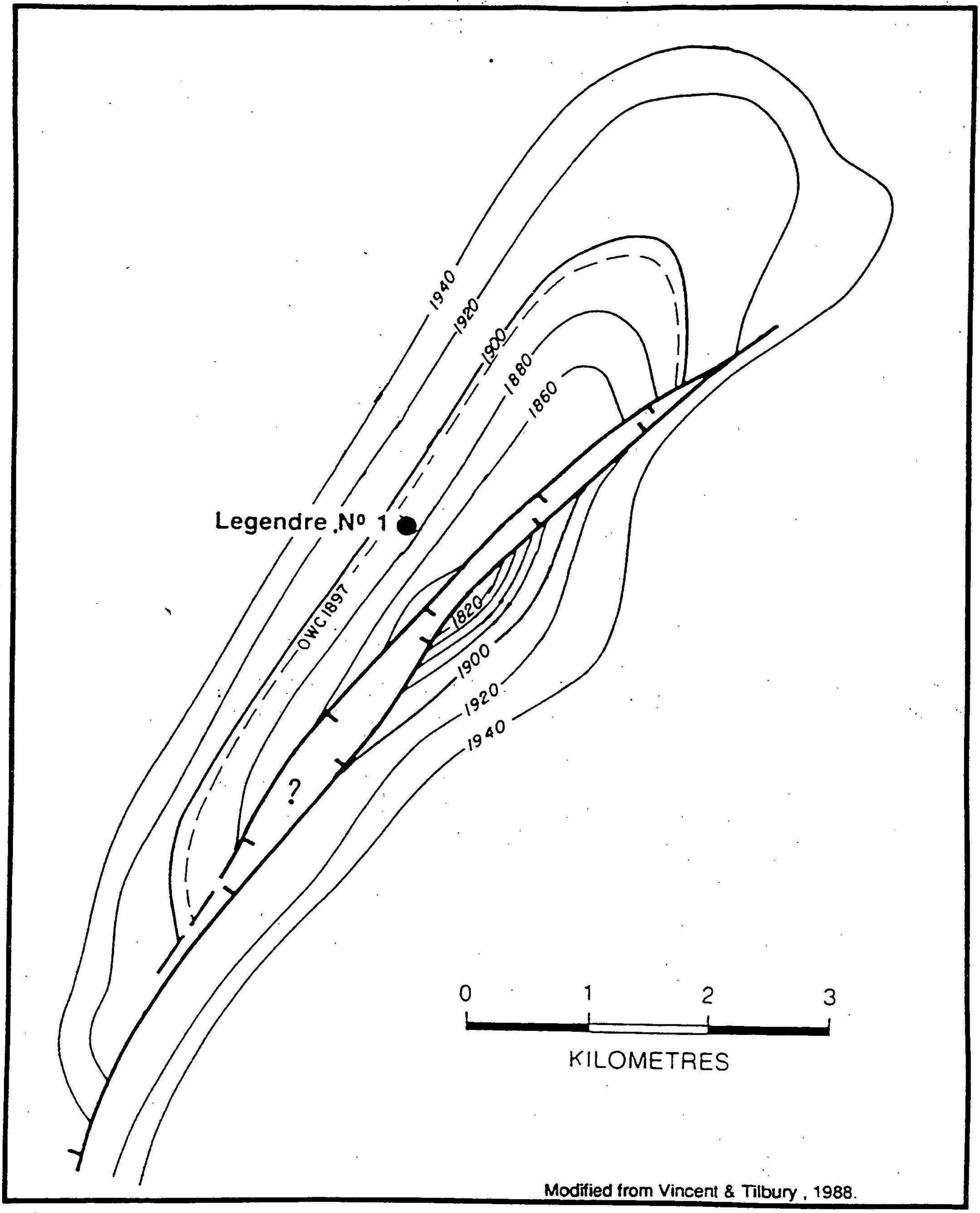


Southwest to Northeast Seismic Line over Lawley 1 Figure 32





Seismic Line over Strickland 1. Figure 33



Structure map at top reservoir level (Neocomian) showing the Legendre oil accumulation trapped against an antithetic fault. (Contours in metres subsea.)

Figure 34

possibly breached by faults. Indications of migration in the form of numerous shows high grade this area. The well did not drill to the original proposed total depth. A possible trap in basal Triassic Time Slice TR1 sandstones and or limestones beneath the Locker Shale remains untested.

DAMPIER SUB-BASIN

LEWIS TROUGH

All the Lewis Trough wells have been primarily targeted on what was mapped as four way dip closure on a reflector near the Cretaceous - Jurassic boundary. This is normally the contact between the upper Jurassic Tithonian aged sandstone reservoirs and the overlying Lower Cretaceous claystone seal rocks. Source for these traps is now recognised as most likely to be the underlying mid to late Jurassic marine anoxic claystones.

Two anticlinal trends exist within the Dampier Sub-basin; the Legendre Trend adjacent to the Rosemary Fault System and the Madeleine Trend, adjacent to the Rankin Trend. The Rankin Trend defines the northwestern margin of the Lewis Trough and the Rosemary Fault System defines the southeastern margin. All major closures on these trends have been tested, and several major fields have been found.

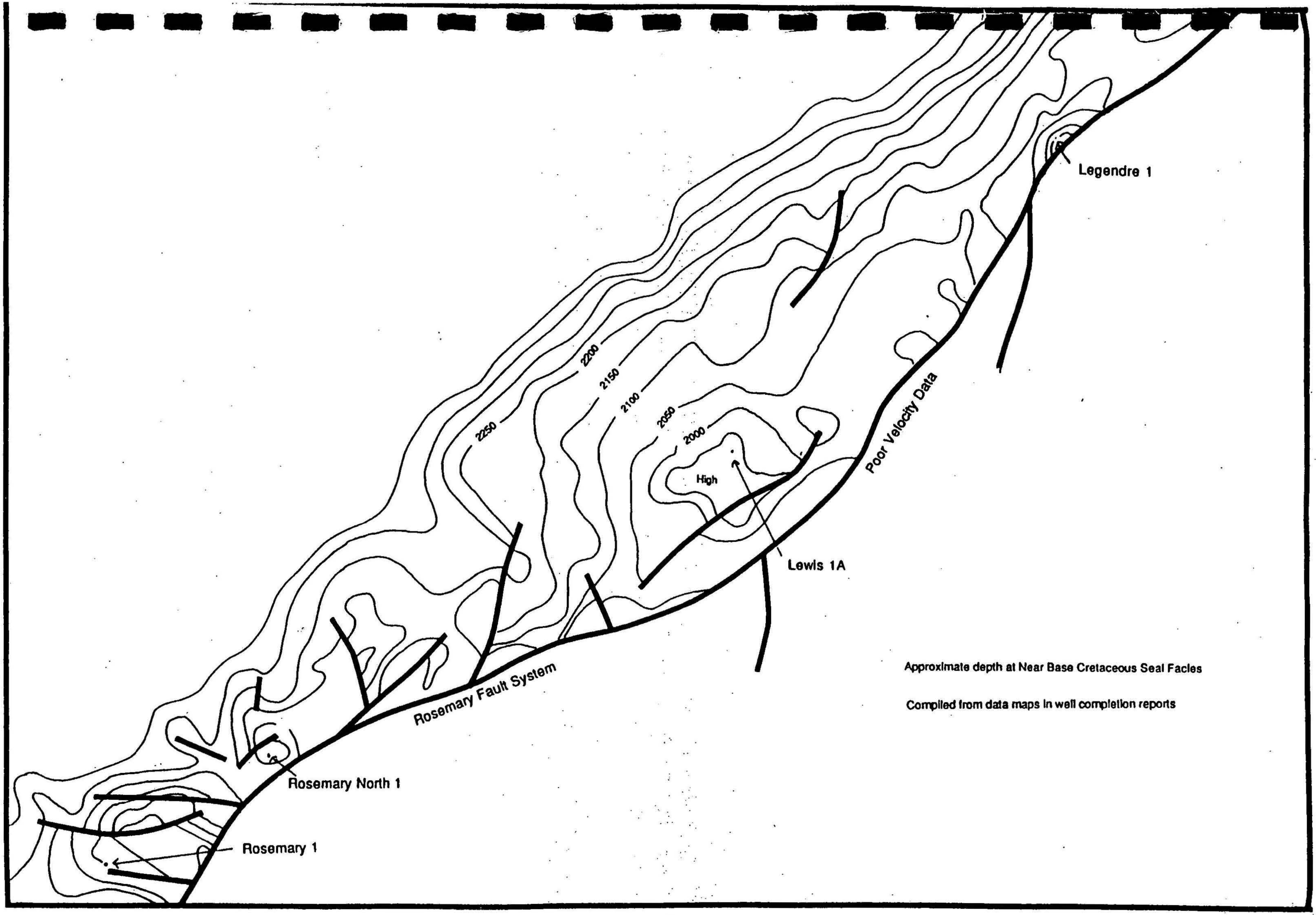
LEGENDRE TREND

To the north of the Legendre Trend, sandstone deposition continued through the upper Jurassic into the lower Cretaceous, but the essential play concept of reservoir facies sealed beneath a regional lower Cretaceous seal facies remains the same.

TABLE 6: LEGENDRE TREND WELL AUDIT SUMMARY (See Figure 35)

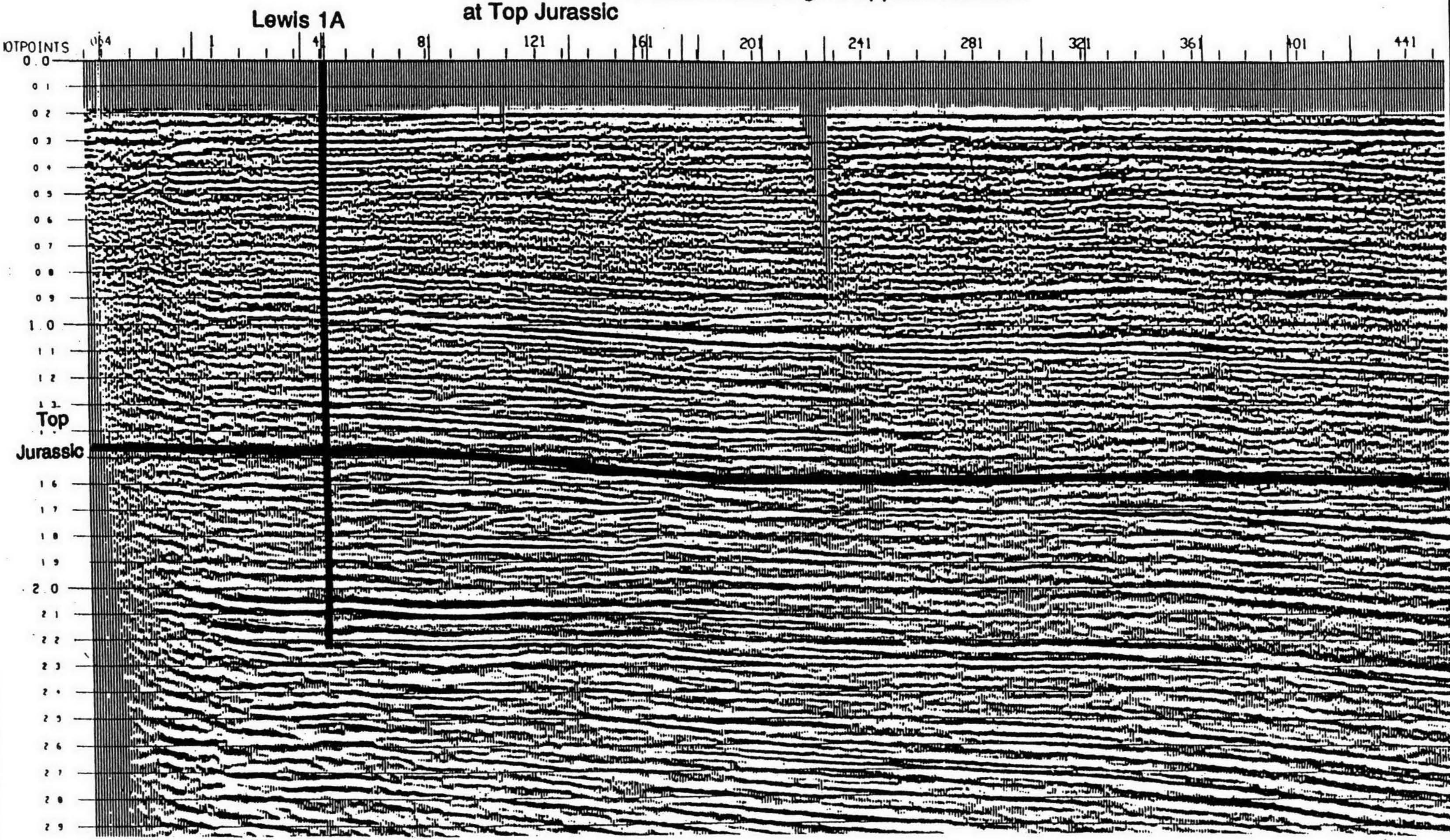
WELL	FIG	COMMENT
Legendre 1	34	First oil discovery appears to be non commercial
Lewis 1A	36	Minor shows - possibly no closure. Original mapping based on poor quality seismic.
Nelson Rocks 1	37	Minor shows - closure not present until Miocene suggests main oil generative phase is pre Miocene
Rosemary 1	35	Not at apex of mapped closure.
Rosemary North 1	35	Residual oil leg - up dip of Rosemary 1. Miocene fault reactivation or Tertiary tilting may have allowed oil to escape.
Talisman 1	38	Minor field put on stream.

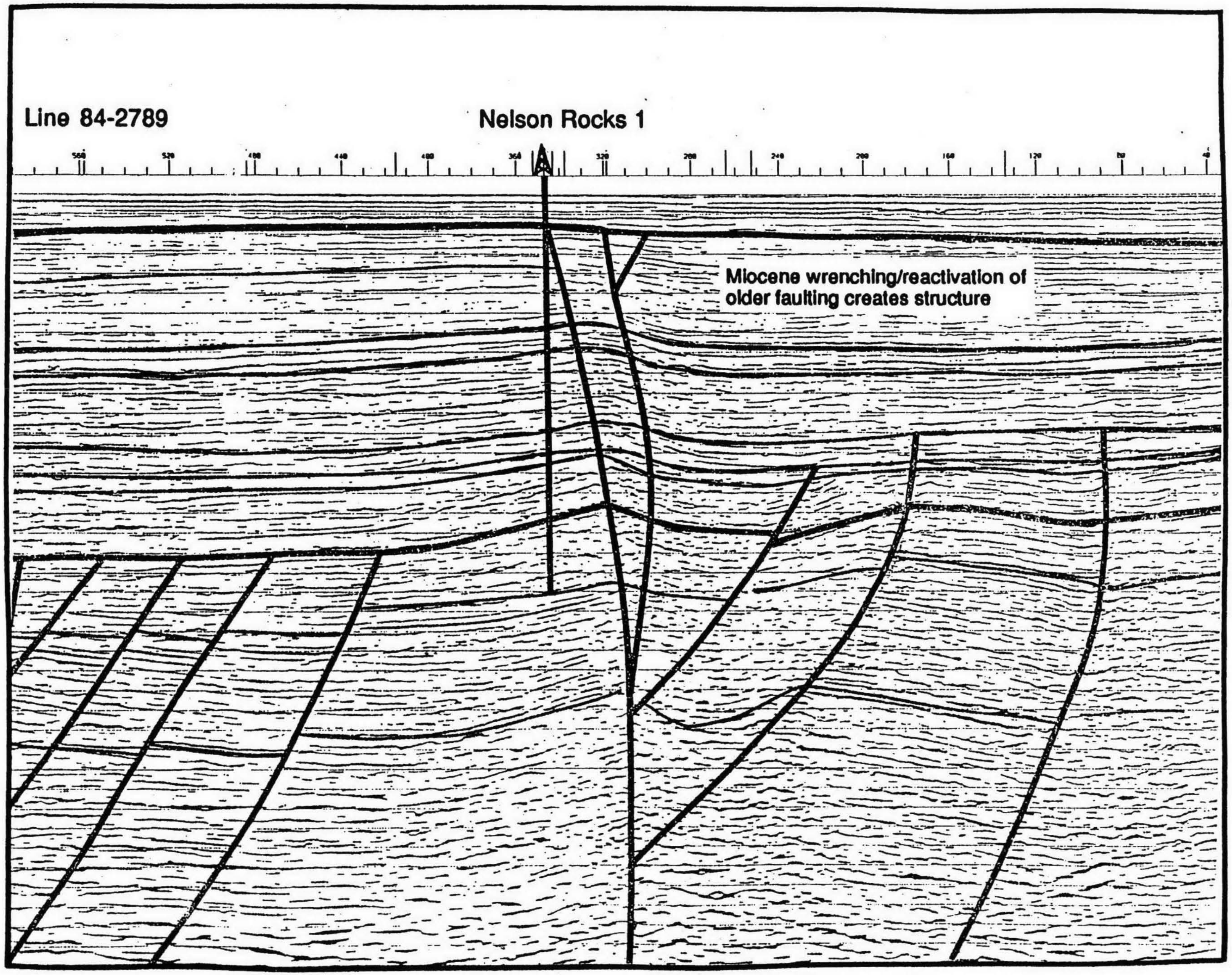
The Legendre Trend antiform appears to have been initiated at Main Unconformity time. Compaction has helped maintain the structure that was further enhanced during Time Slice K1 when additional movement occured. Late Oligocene and Miocene compression has reactivated and reversed the Middle Jurassic trans-tensional faulting resulting, in some places, in an enhancement of the anticlinal trend.

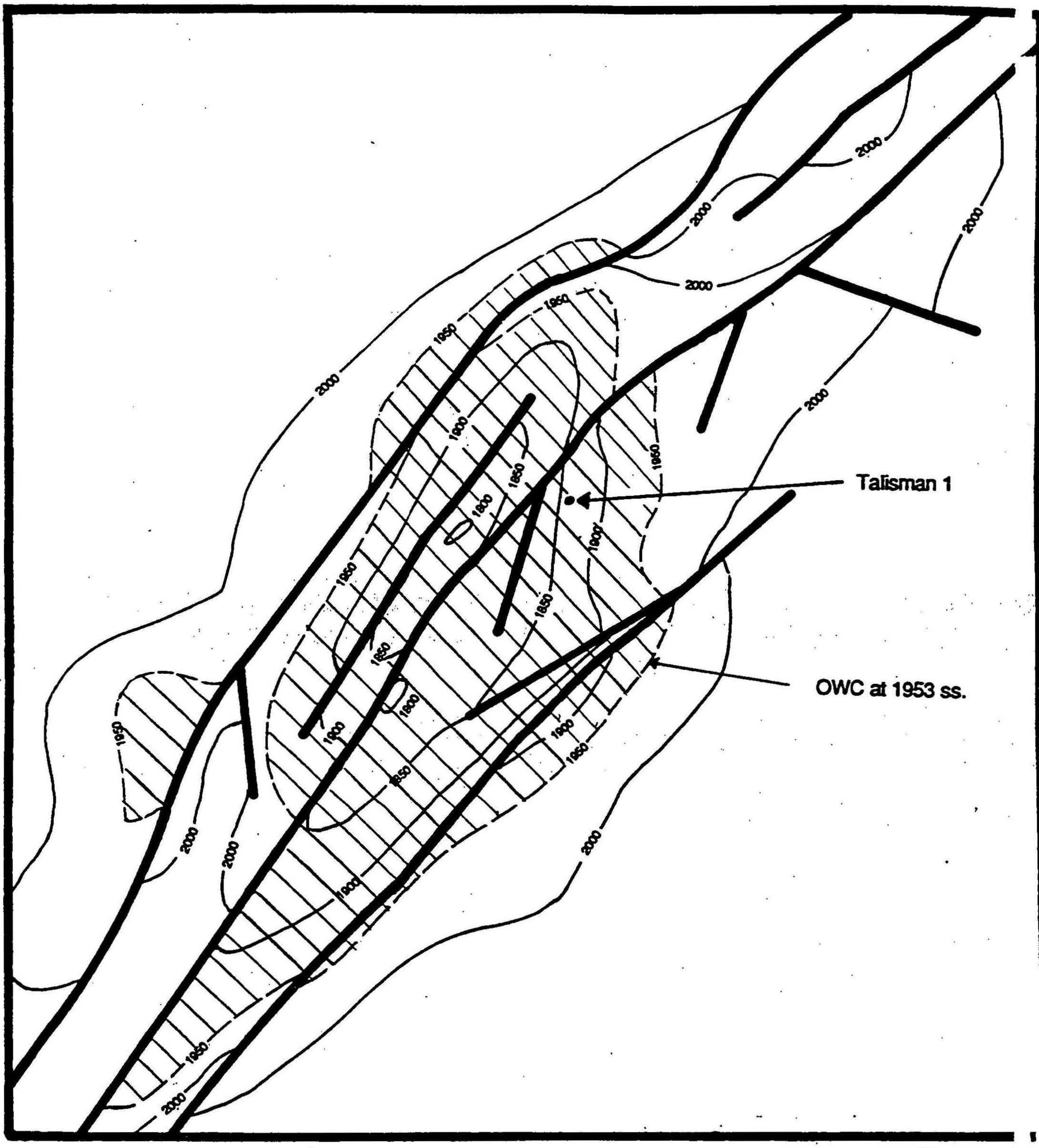


Structure Map at Depth Near Base Cretaceous Seal Facies Along the Legendre Trend. Figure 35

Lewis 1A Seismic section showing no apparent rollover at Top Jurassic



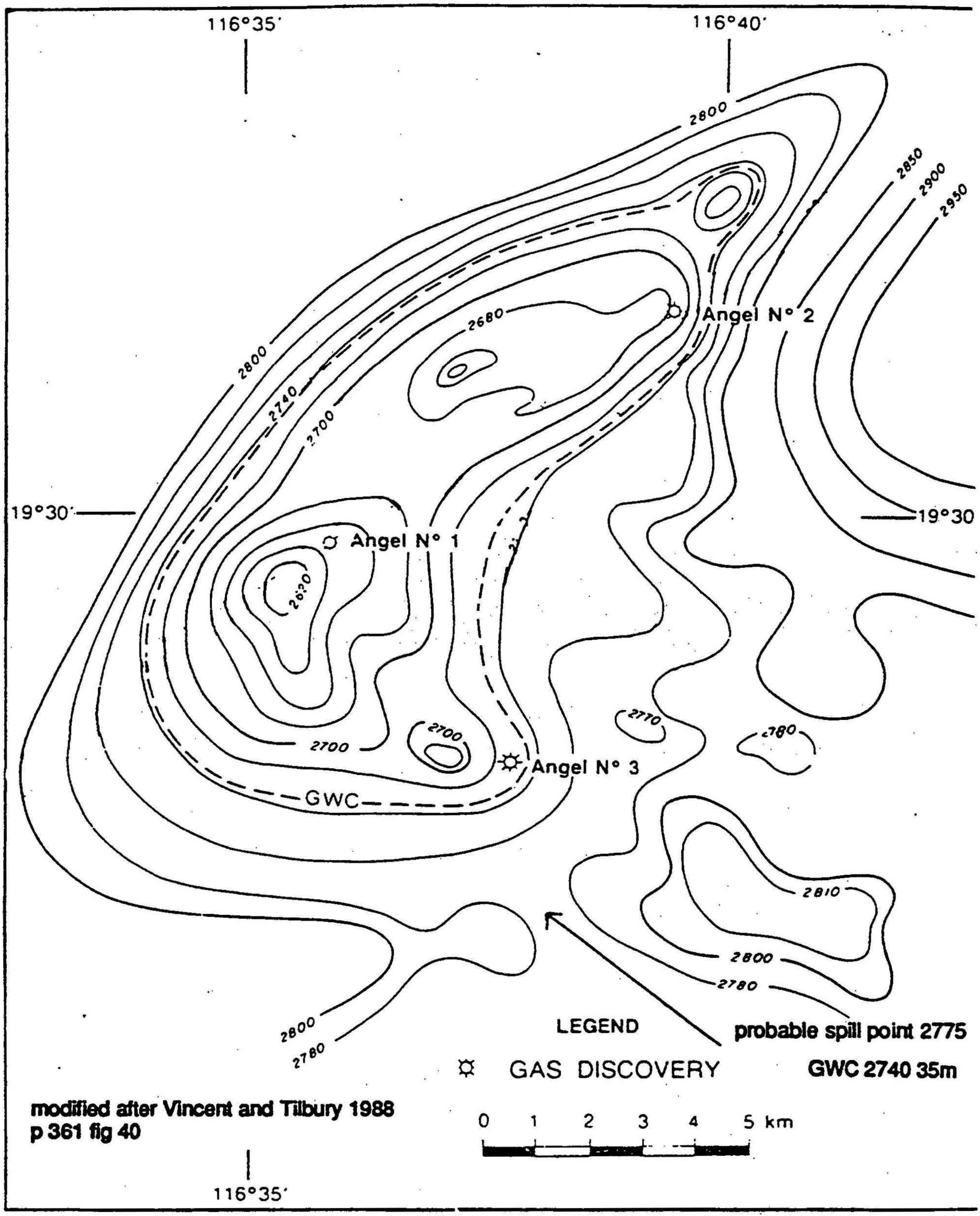

Line 84-2789
Nelson Rocks 1
Miocene wrenching/reactivation of older faulting creates structure



Structure Map at Base Cretaceous Seal of the Talisman Field.

Figure 38

Modified from data map in WCR.



(Contours in metres subsea.)

Figure 39

Structure Map at Base Cretaceous Seal of the Angel Field.

There is little detailed information available to make concrete assessments of the reasons for well failure. A map on the base Cretaceous seal suggests Lewis 1A is poorly constrained by the available seismic and may be on a nose rather than a closure. Each of the wells has a figure associated with it (See Table 6) and that figure is self explainatory.

MADELEINE TREND

The Madeleine Trend is formed by Jurassic trans-tensional faulting similar to that which initiated the Rosemary Fault System. Late Tertiary reactivation however appears to have been very minor. At depth the trend is above the apex of tilted pre Main Unconformity fault blocks that hade to the southeast. The apex of the tilted fault blocks form a half graben that deepens towards the Rankin Trend. Between the apex of the fault blocks and the Rankin Trend is the Kendrew Terrace, which is to the east of the Lewis Trough. Closure on the structures is the result of drape and compaction of the upper Jurassic and younger sediments across the tilted fault blocks. Associated listric faulting is a result of the same mechanism. Closures along the trend must have been affected by Tertiary margin sag.

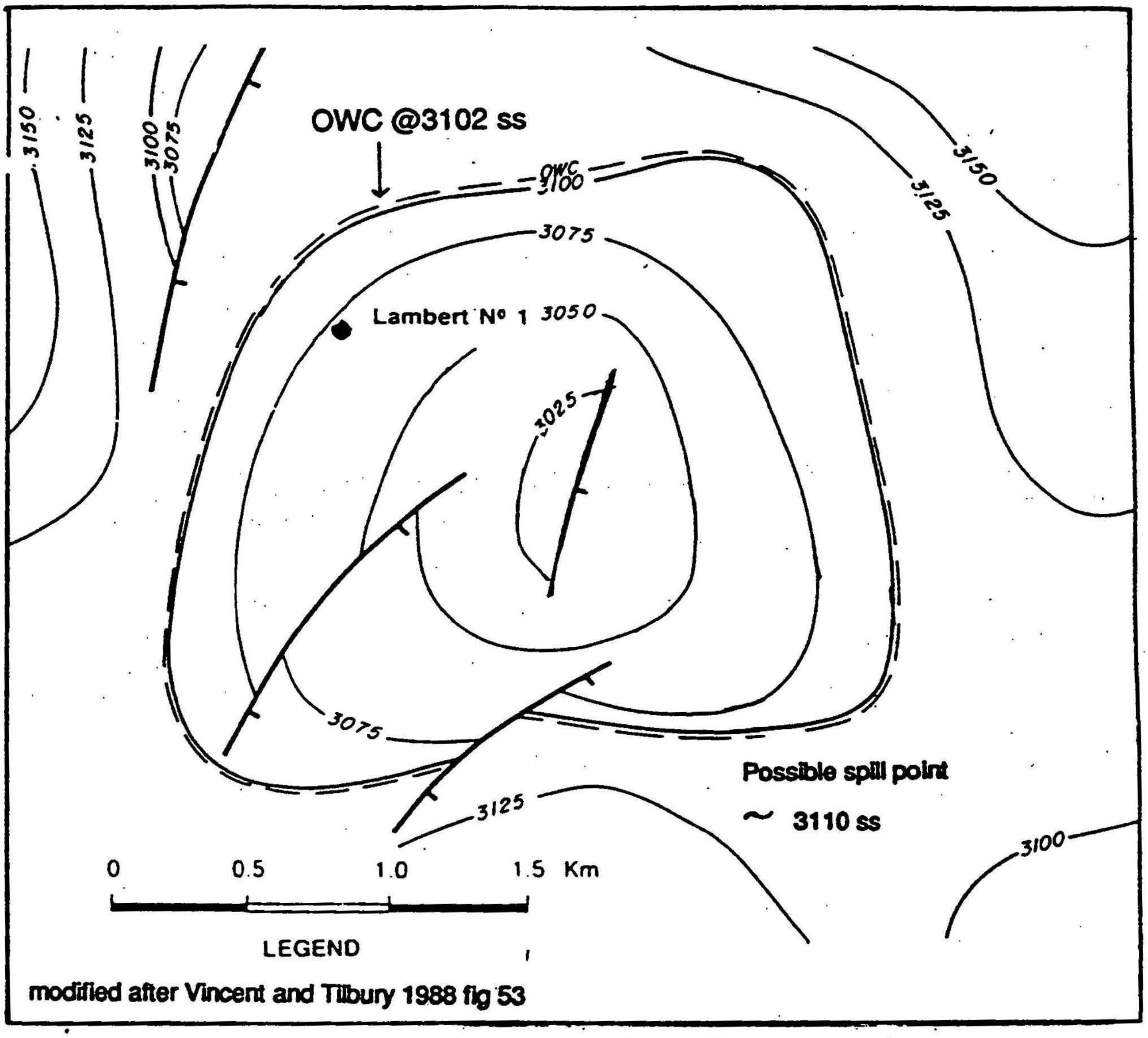
All plays are based on closure in the basal Cretaceous seal rocks above the top Jurassic sandstone. Montague 1 and Lambert 1 have been drilled on structures developed by a similar mechanism but associated with fault blocks linked to the Rankin Trend rather than the Madeleine Trend.

TABLE 7: MADELEINE TREND WELL AUDIT SUMMARY

WELLNAME	FIG	COMMENT
Angel 2	39	J6 directly beneath Time Slice J9/J10 reservoir sandstones. J6 sequence sources gas condensate in to the Angel Gas Condensate Field. Published mapped spillpoint is within 35m of the GWC. This is within mapping accuracy so the likely spillpoint is the GWC.
Dampier 1	no fig	No reservoir in Time Slice J10 -- deeper Time Slice J8 is generative. Drilled on structural closure.
Lambert 1	40	See below: Time Slice J10 oil well discovery. Filled to published spillpoint.
Montague 1	41 42	See below: Time Slice J10 dry; Time Slice J8 & Time Slice Tr6 gas condensate recoveries.
Madeleine 1	43	Outside Wanaea closure.
Wanaea 1	43	96m oil column. Major discovery. 49° API oil sourced from underlying Time Slices J9/J8 source rocks. Is updip of Cossack Field spill point.
Walcott 1	43	Outside Wanaea closure.
Withnell 1	no fig	No reservoir in Time Slice J10 -- deeper Time Slice J8 generative - possible pay at top of Time Slice J8.

Lambert 1 (see Figure 40)

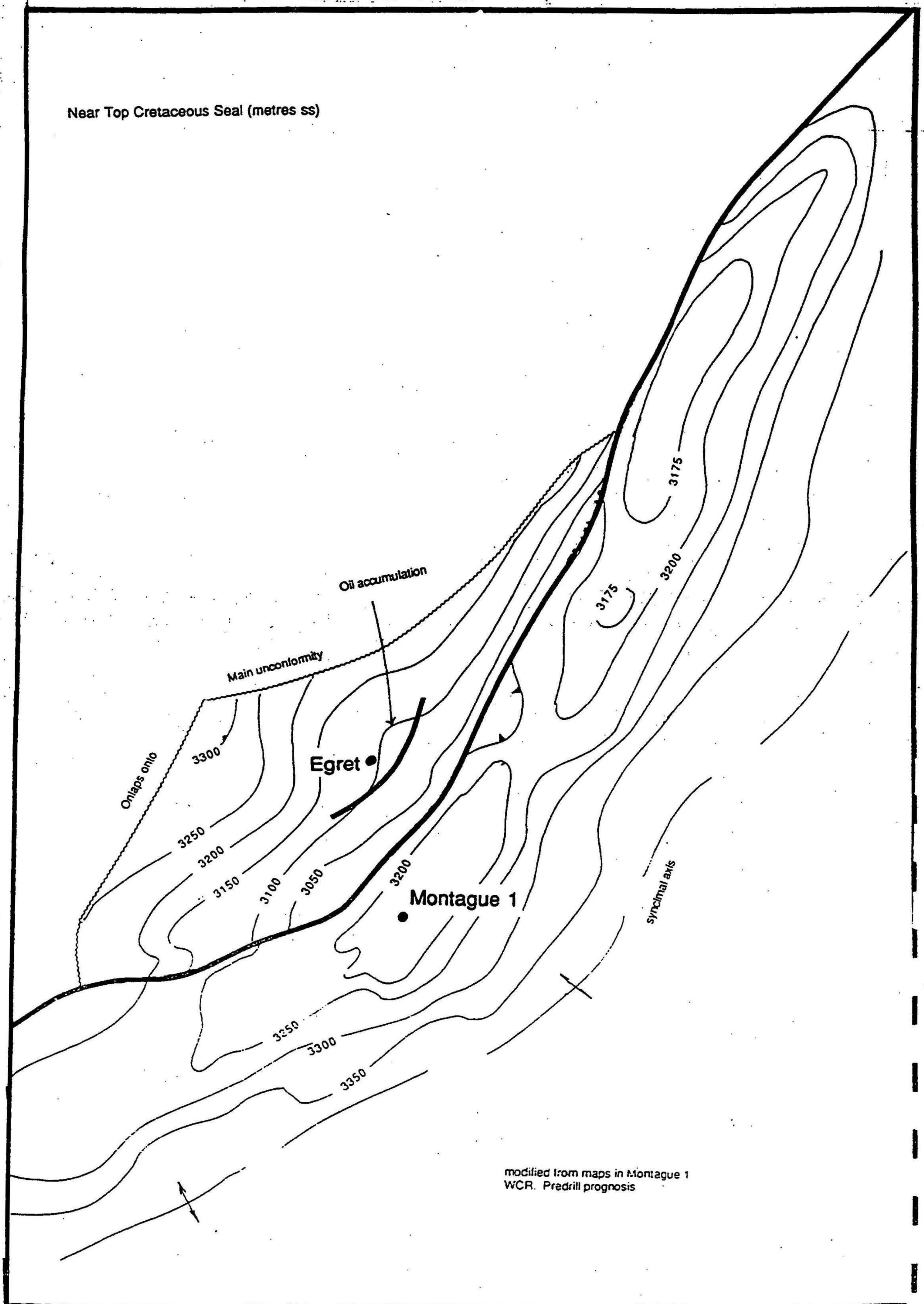
Lambert 1 tested a closure at the Cretaceous Jurassic boundary and encountered a gross oil column of 10m of 45° API oil in upper Tithonian sands. Oil flowed at 375 BPD



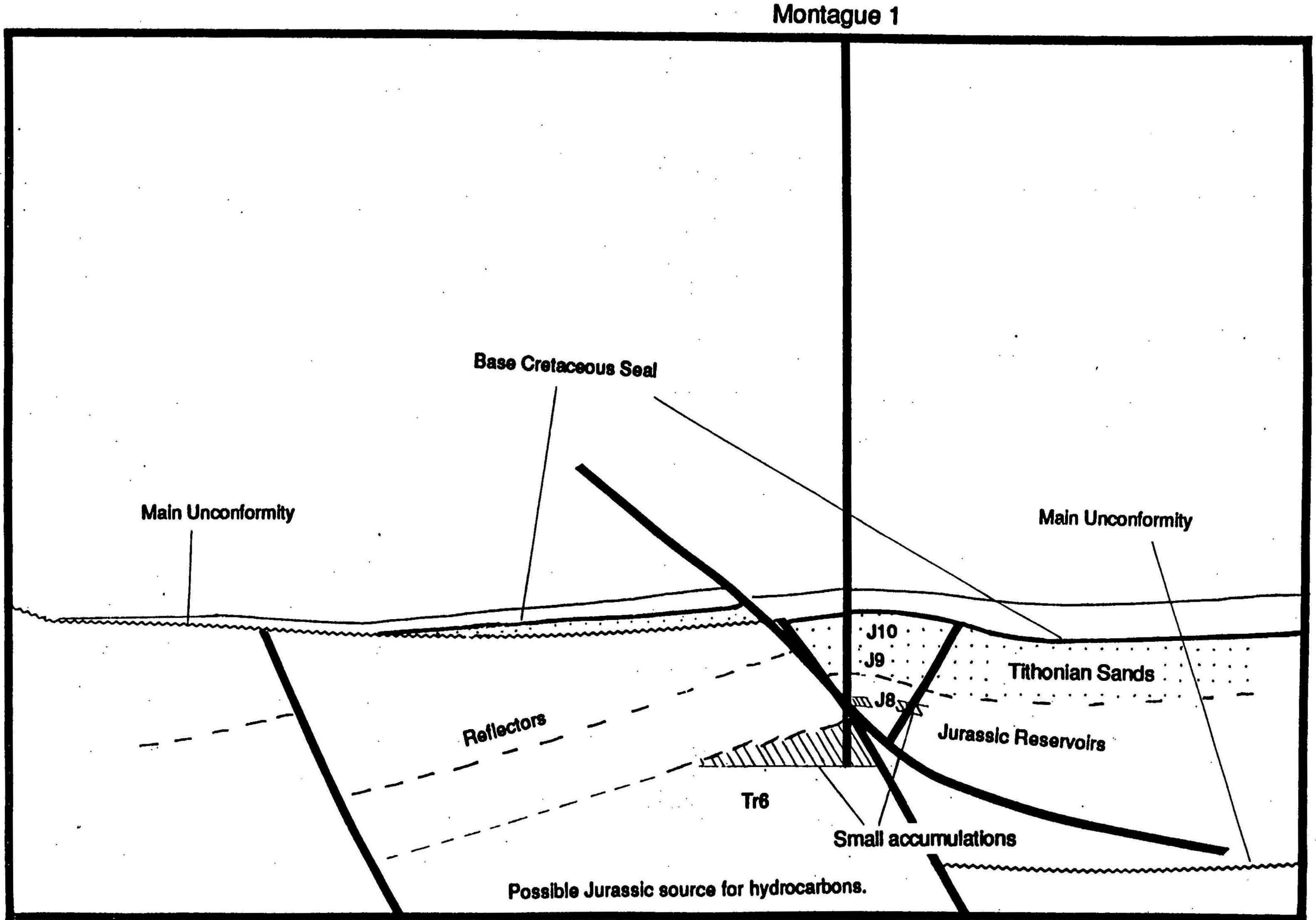
(Contours in metres subsea.)

Structure Map at Base Cretaceous Seal of the Lambert Field.

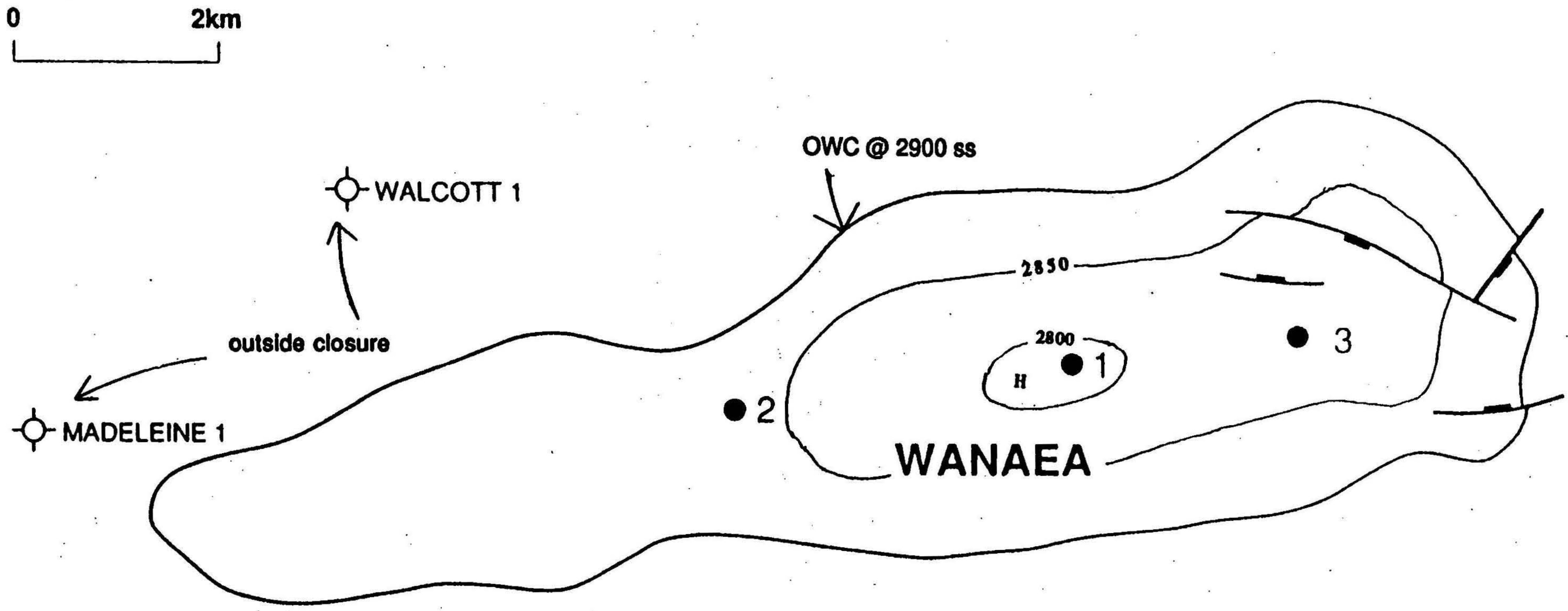
Figure 40



Structure Map at Base Cretaceous Seal of Montague 1 Prospect. Figure 41



Post Drill Geological Section across Montague 1 Prospect Figure 42



Structure Map at Base Cretaceous Seal in the Wanaea 1, Madeleine 1 and Walcott 1 Area. **modified after Bint 1991 fig 7**

Figure 43

and reservoir porosity was estimated at 17% and permeability at 300-700 mD. This structure appears to be filled to spillpoint.

Montague 1 (see Figure 41 and 42)
Montague 1 was drilled on the primary objective of a Tithonian aged reservoir which showed anticlinal closure at the Jurassic/Cretaceous boundary (at the top Time Slice J10 seismic reflector). The well is downdip from Egret 1 which encountered a 9.4m oil column within Tithonian aged sandstones. It is a closure associated with a Triassic Fault block related more to the Rankin Trend than the Madeleine Trend. At Montague 1 this target was dry, although significant gas and condensate shows were encountered within Time Slices J8 and Time SliceTR6 sandstones. The well was plugged and abandoned after being side tracked twice, once from 3724 m when the bit became stuck after reaching a depth of 3979m and again from 3526m after the well kicked whilst drilling at 4000m and the drill pipe became differentially stuck.

Montague 1 presents some interpretation difficulties. It appears to have drilled through a fault that separates the Jurassic and Triassic sections at 4050m KB. The interpretation of this boundary is critical for assessing the meaning and implications of the well. This interpreted fault is based on palynological evidence but there is no lithological or log break associated with the contact. Neither dipmeter nor SWC's were collected in this interval due to drilling difficulties. Originally the boundary was picked at the top of a sandstone interval implying that the Triassic species in the overlying interval were reworked.

The top of the Triassic reservoir section occurs at 4123m and a hydrocarbon water contact occurs at 4216m. Residual hydrocarbons (23%) were interpreted down to the base of the sandstones at 4297m. Within the Triassic section only thin shale bands separate a relatively continuous sandy section and it appears that a gross hydrocarbon column of 93m was encountered. On the basis of the residual hydrocarbons a column of at least 174m may once have existed. Production data and log interpretation suggests that a gas condensate contact may exist at 4170m. The production test was over the interval 4147m to 4180m. It flowed 2.6 MMCFD and 60 BCPD. The reservoir pressure was 8965 psi at 4176 KB. This pressure is higher than the pressure calculated from a zone below but this is most likely due to instrument, procedure or interpretation error. A permeability of 0.37 mD - 1.2 mD was calculated for the formation, but this might be lower than average as the test was conducted in what is interpreted as the finer grained part of the sandstone. A water bearing zone below the hydrocarbon column flowed over 6000 BPD indicating good flow rates are possible. The estimated permeability of the lower test interval was 26 mD and reservoir pressure 8910 psi at 4256m KB. Minor associated gas production was probably solution gas being mostly methane (97%).

On the hanging wall of the fault are thin Jurassic (Time Slice J8) sandstone reservoirs within a thick shaly section. Pressure measurements were difficult to obtain but the permeability was < 1 mD and the reservoir was tight. A reservoir pressure of at least 7400 psi at 4252m KB was estimated. The test interval seems to have been within the worst reservoir and cleaner intervals in the sandstone above could be expected to flow better.

Modified from Tilbury & Barter 1992

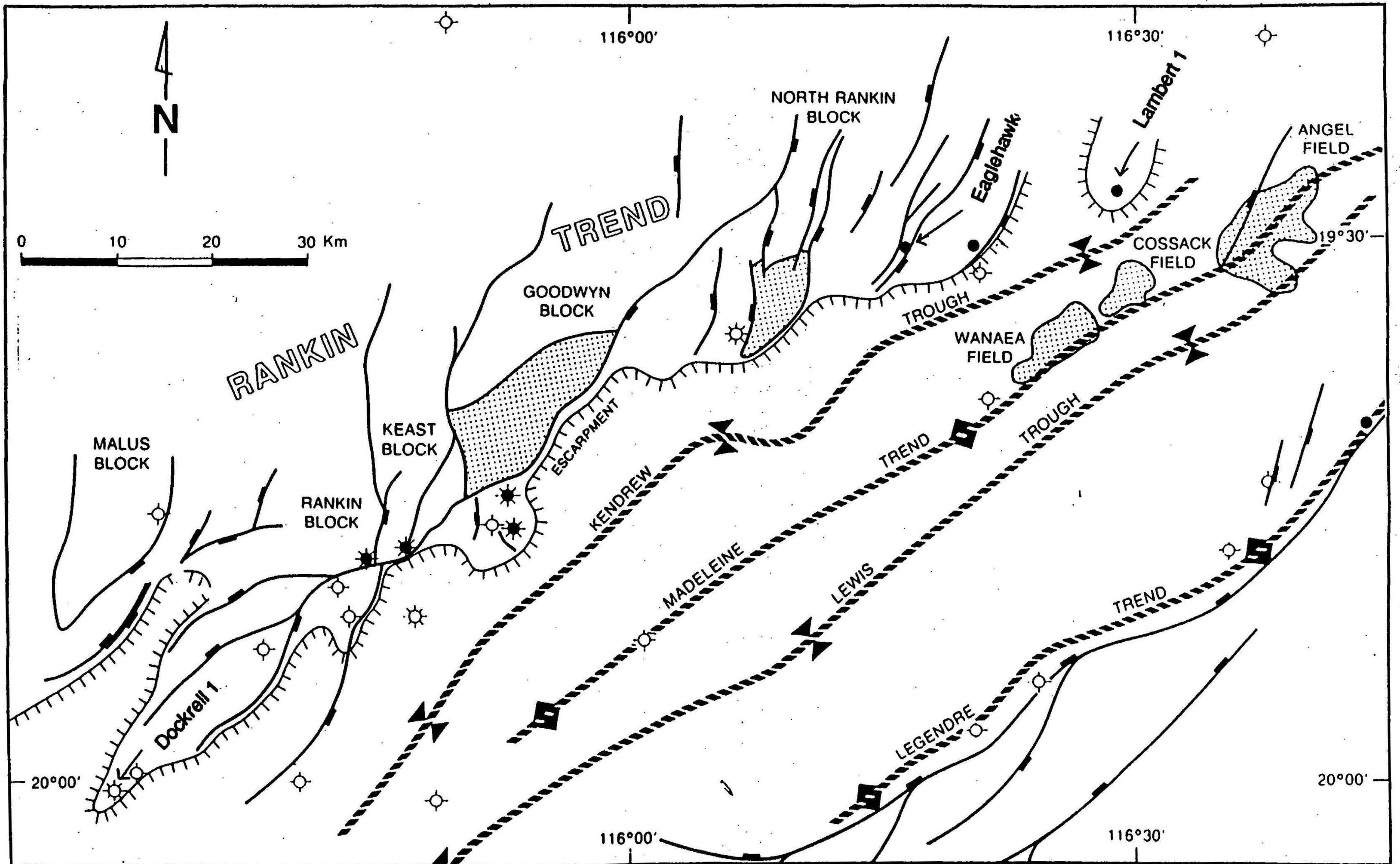


Diagram of Rankin Trend Discoveries Figure 4a

The oil from the production test in the Triassic is a typical light paraffinic oil with no significant post migration biodegradation. It is derived from thermally mature source beds. Biomarkers show that the source beds are similar to those which produced the Angel Field light oils (reservoired in Upper Jurassic sandstones), and similar to source rocks in Madeleine 1 cores 5 & 7 (which are lower Time Slice J8 age). This result suggests a Jurassic source for the oil, probably face loaded into the Triassic across the fault plane.

The upper Tithonian was the main target in this well, but was dry. It is not clear why the well failed but it could be due to one or a combination of the following

(i) Major fault independent closure is 20 msec (mapped as 30 to 40m). Minor associated listric faulting due to drape compaction penetrates through the basal Cretaceous seal and it is possible these faults provide a migration pathway out of the structure. In this scenario hydrocarbons might be found in the post Cretaceous section.

(ii) The upper 50m of the Tithonian is a siltstone rather than the anticipated sandstone. With only 30m of closure the first reservoir is effectively beneath any possible hydrocarbon contact. This assumes the siltstone is a waste zone. Lack of shows suggests this is unlikely. Alternately, the well may have encountered a facies variant in the upper 50m and nearby lateral facies change could provide reservoir and the structure is effectively filled.

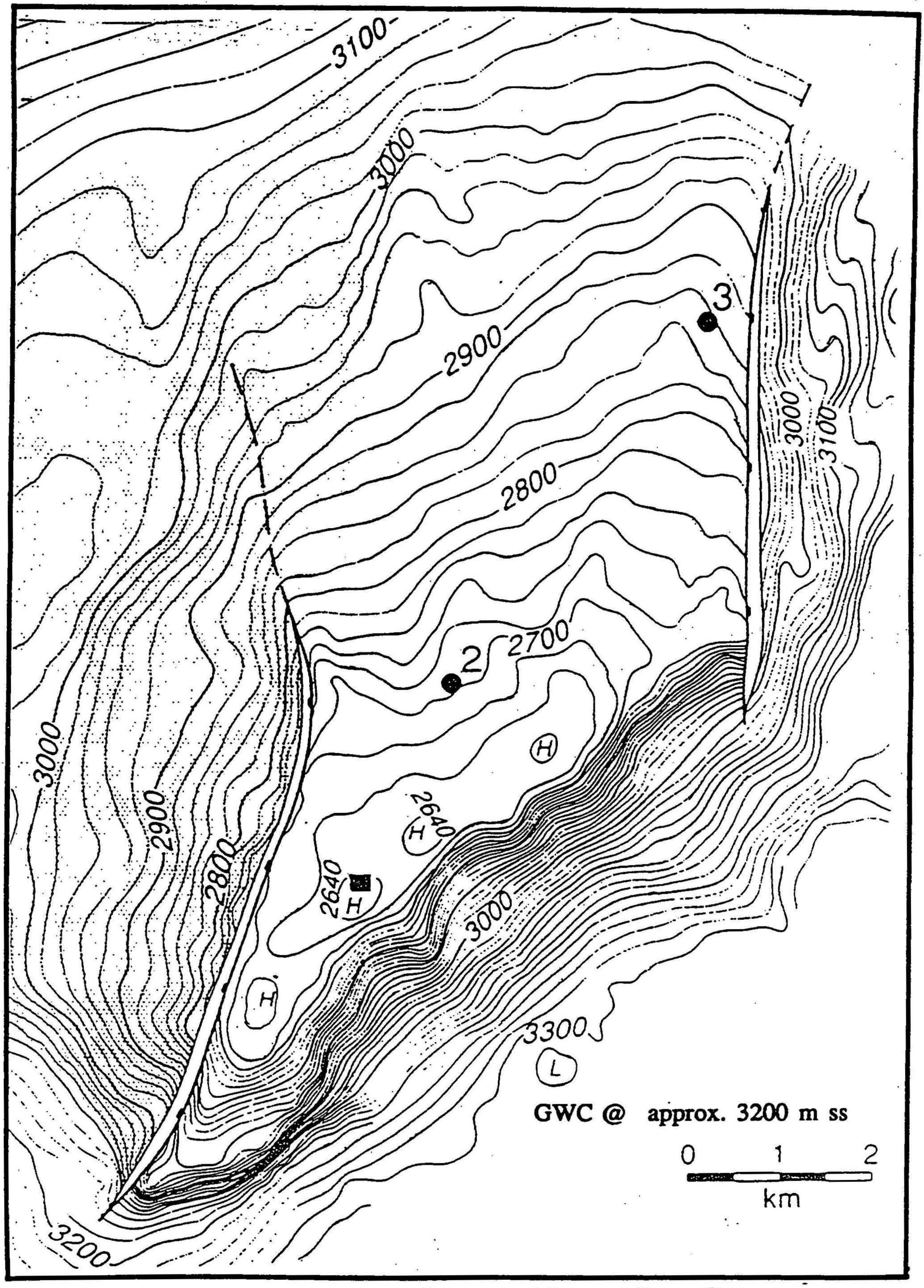
(iii) The main fault is sealing all the way up so that no hydrocarbons have leaked upward. This assumes only a Triassic source is possible. Two factors against this possibility are (1) geochemistry which infers a Jurassic source for the hydrocarbons and (2) the existence of a residual oil column. It is likely that this oil escaped up the fault plane.

(iv) Insignificant drainage area of mature Jurassic source. A synclinal axis immediately adjacent to the structure means that only a limited area of Jurassic is actually draining into the feature.

(v) It is possible that the 30m closure at the Cretaceous/Jurassic boundary is only a very recent event associated with Tertiary margin sag. The major component of the sag is Time Slice Cz3 age, implying pre-Oligocene oil migration.

The results of Montague 1 are sufficiently ambiguous that retesting of this structure may be warranted.

RANKIN TREND (See Figure 44)
The Rankin Trend is defined by a series of tilted horst blocks. The major fault trend strikes northeast and defines a margin of the Kendrew Terrace. This trend is cut by a series of approximately north striking faults. The whole has a regional tilt to the northwest.



Structure Map on Base Cretaceous.

(Main Unconformity across the North Rankin Field

Figure 45

Faulting was mostly late Time Slice J6 and early Time Slice J7 age. The Rankin Trend margin retreated by slumping to form an escarpment, the Rankin Escarpment. Erosion stripped back sediment to the Late Triassic - Early Jurassic. The eroded surface across the trend is called the Main Unconformity. It is onlapped by late Jurassic, and onlapped and buried by early Cretaceous claystones which form a regional seal. The original northwest tilt has been enhanced by the Tertiary margin sag. Beneath the Main Unconformity Triassic and Lower Jurassic fluvial to marginal marine clastic sediments tilt at 6 to 10 degrees to the north. Gas condensate is reservoired within these tilted beds and top sealed by the Cretaceous claystones deposited on the Main Unconformity.

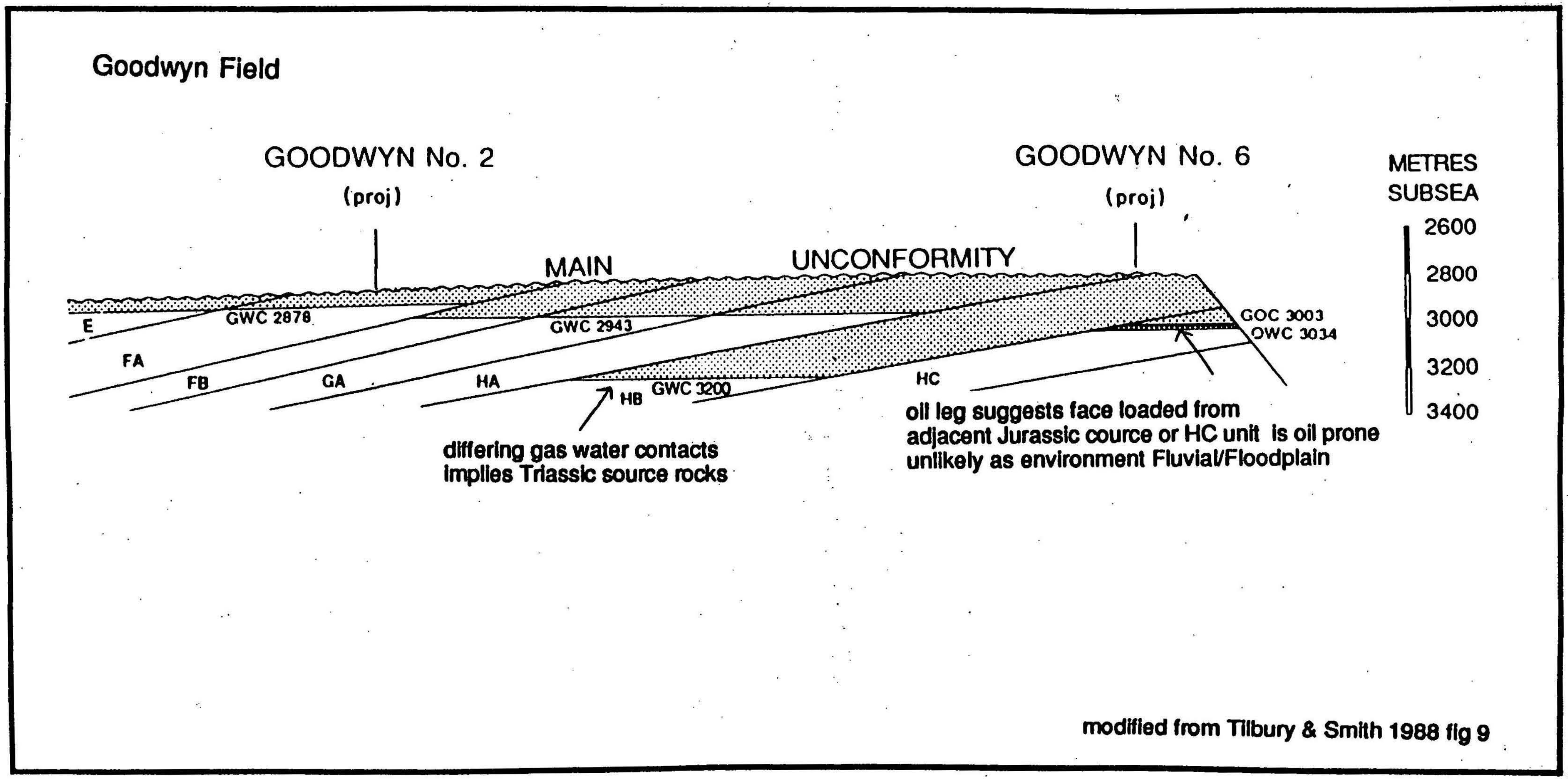
TABLE 8: RANKIN TREND WELL AUDIT SUMMARY

WELL	COMMENT
North Rankin 2	570 m gross column. Uncertain if structure is filled to spill point. GWC @-3220m. Estimated 11 TCF in place. Internal faults non sealing resulting in field wide GWC.
North Rankin 3	As above.
Goodwyn 2	Internal faults act as seals. Several GWCs. Triassic source rocks inferred.
Goodwyn 6	370 m gross column 31m oil column in southern block.
Dockrell 1	GOC @ 2971 OWC @ 2987m. Stacked reservoirs with major shale breaks.
Eaglehawk 1	29° API oil in upper sand. Probable Jurassic source, but biodegraded.

North Rankin 2 and 3 (see Figure 45)
The North Rankin Field
There is a common gas water contact at 3220m (ss) across this field. This may be related to extensive faulting within the field. Recent work has established that most faults are not effective barriers (Tilbury and Barter, 1992; p27)

Goodwyn 2 and 6 (see Figure 46)
The Goodwyn Field
Goodwyn 6 near the crest of the accumulation discovered an oil leg. Fields in down dip fault blocks eg Goodwyn 3, Tidepole and Rankin also have oil legs. The Goodwyn Field provides some empirical evidence for a Triassic source for the gas condensate. In general there is a relatively constant gas water contact across the field at approximately 3000m. A deeper contact at 3165m in thin isolated sand is indirect evidence of gas migrating up dip from a lower Triassic source.

Dockrell 1
The main accumulation is in sands beneath the Main Unconformity and has an oil leg. This field has two minor gas condensater sands within thick shales beneath the main accumulation. These lower sands require stratigraphic or fault sealing.



Schematic Cross-Section of the Goodwyn Field Illustrating Variable Hydrocarbon Water Contacts.

Figure 46

Eaglehawk 1
A very small oil accumulation that occurs in a narrow fault bounded block. The source of the oil is probably down dip Jurassic sediments.

RANKIN PLATFORM
The Rankin Platform is a faulted but broadly flat area of Triassic and Early Jurassic sediments contiguous with the uplifted Rankin Trend. It formed in the Mid Jurassic and is related to the formation of the Dampier Sub-basin. From its inception the Sub-basin acted as a dam to sediments from the southeast preventing them from reaching the Rankin Platform area. Minor reworking of the sediments on the Platform occurred in the interval following its formation (Time Slices J6 to J8) and prior to its burial. Major sedimentation recommenced and onlapped onto the Rankin Platform following the sedimentary filling of the Lewis Trough during the Late Jurassic / Early Cretaceous (Time Slices J10 to K3).

TABLE 9: RANKIN PLATFORM WELL AUDIT SUMMARY

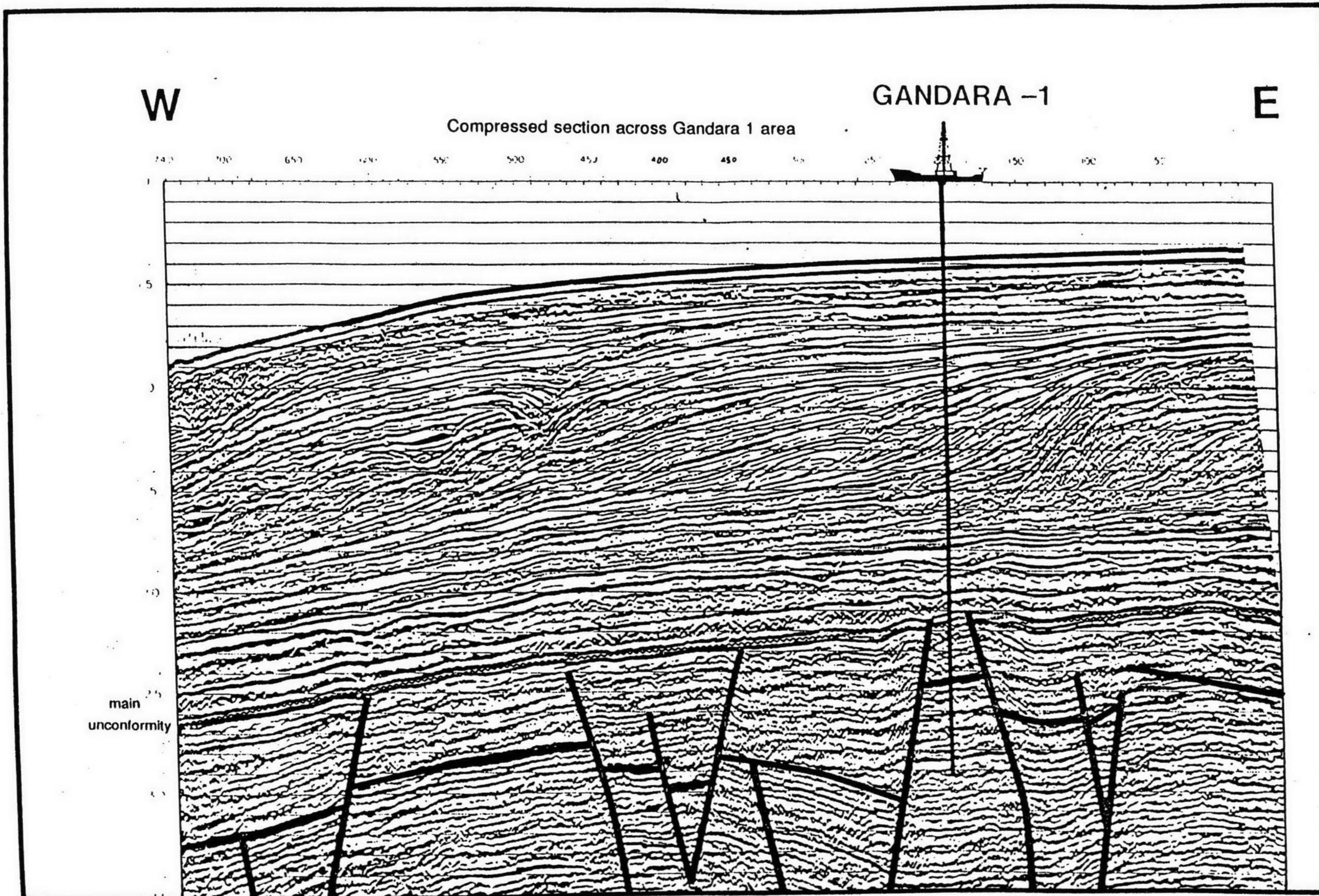
WELLNAME	COMMENT
Malus 1	Plugged and abandoned very minor shows - No obvious reason for failure - may be downdip of closure in broad pre-Main Unconformity rollover.

Malus 1
Malus 1 was drilled on a tilted Triassic fault block sealed by Cretaceous and Tertiary claystones and marls. It was thought to be similar to Rankin trend plays. The lithology of the Cretaceous/Tertiary suggests that an exceptionally good seal is developed. Either there is no source or the original structural interpretation is in doubt. This well needs to be carefully assessed to determine valid reasons for its failure.

KANGAROO SYNCLINE AREA
The Rankin Platform is separated from features to the west by a synclinal area, generally unnamed but in the vicinity of Gandara 1 called the Victoria Syncline. Further west again is the Kangaroo Synclinal trend which is defined by the axis of a broad downwarp within the pre-Main Unconformity section. Saturn 1 and Gandara 1 are drilled in an uplifted plateau area between these two more clearly defined synclinal trends. The features of the Kangaroo synclinal area may have commenced development in the Late Triassic. Major fault block structuring culminated in the mid Jurassic. Tested prospects in the area were based on similar concepts to the Rankin Trend traps.

TABLE 10: KANGAROO SYNCLINE WELL AUDIT SUMMARY

WELL	COMMENT
Gandara 1	Tilted Fault block. Reached Total depth above mature section
Saturn 1	Tilted Fault block. Reached Total depth above mature section. Has probable by passed pay in sands on the Main Unconformity.



Seismic Section Across Gandara 1. Figure 4

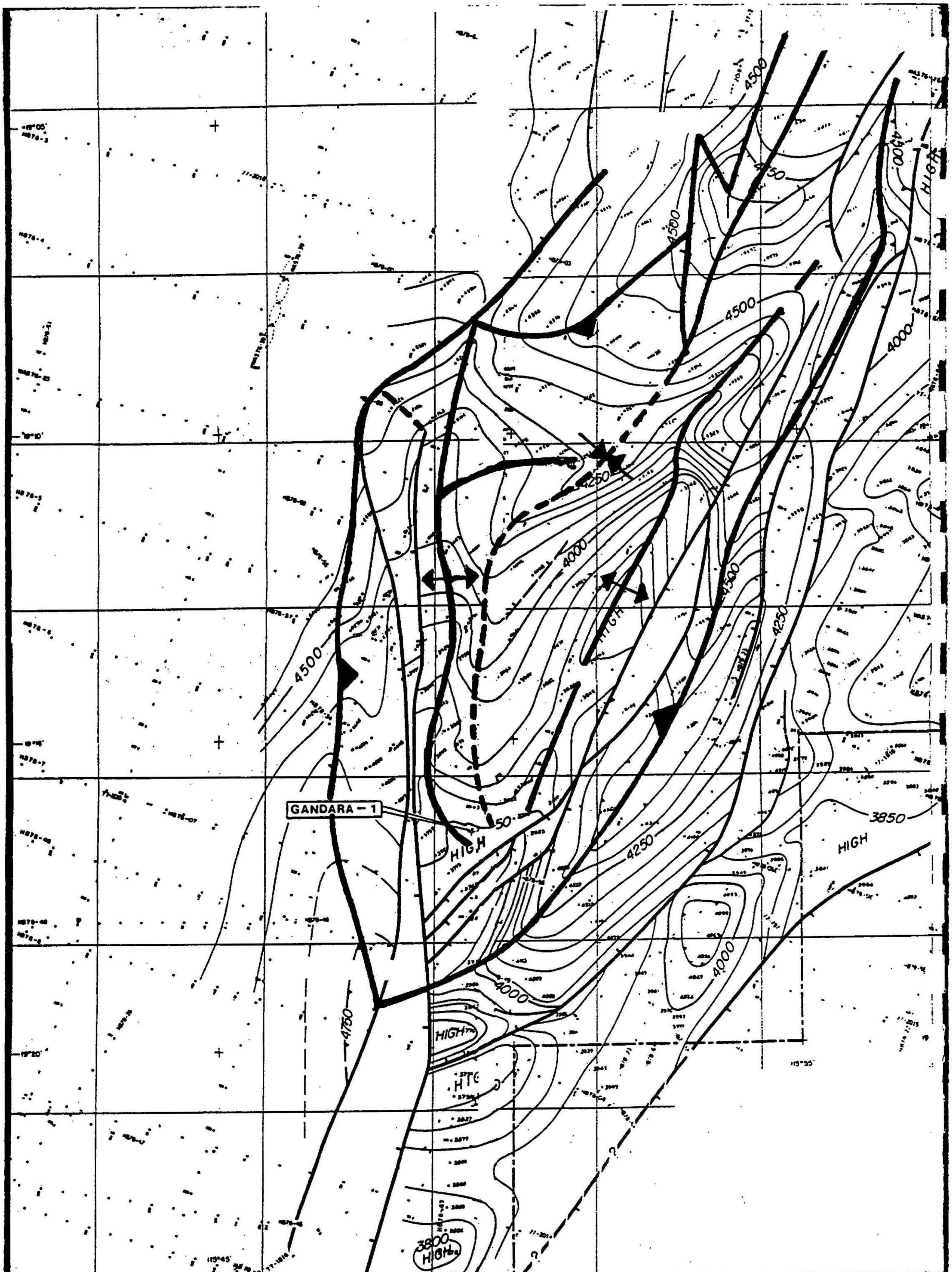
Gandara 1 (see Figures 47 & 48)
Gandara 1 was drilled at the apex of a fault bounded tilted horst block. Initial faulting of the block probably occurred earlier than Time Slice J6 possibly at the very end of the Triassic. The fault structuring reached a climax in the Callovian (Time Slice J6 and J7). The Triassic was the target, sealed beneath Jurassic shales of the Dingo Claystone. The trap relies in part on fault sealing of the flanks of the horst block by the Dingo Claystone and/or sealing by the overlying Cretaceous shales. This would appear to be effective as there are no reservoirs within the Jurassic into which hydrocarbons could migrate. Faulting does not appear to extend through the seal lithologies and so no effective migration pathway out of the Triassic exists. The Triassic dips north at 3 degrees.

Good porosities (up to 22% log) exist at a total depth of 4361m. However the bottom hole temperature of 115 °C means the section is currently, and perhaps only recently, entered the hydrocarbon generative window. Most of the main source rock in this area is above this depth and so is immature within the drainage area of the structure. Drainage from adjacent probably mature source areas appears to be away from the structure. This would be the prime reason for well failure. Shows are found throughout the upper Cretaceous section drilled perhaps indicating hydrocarbon migration.

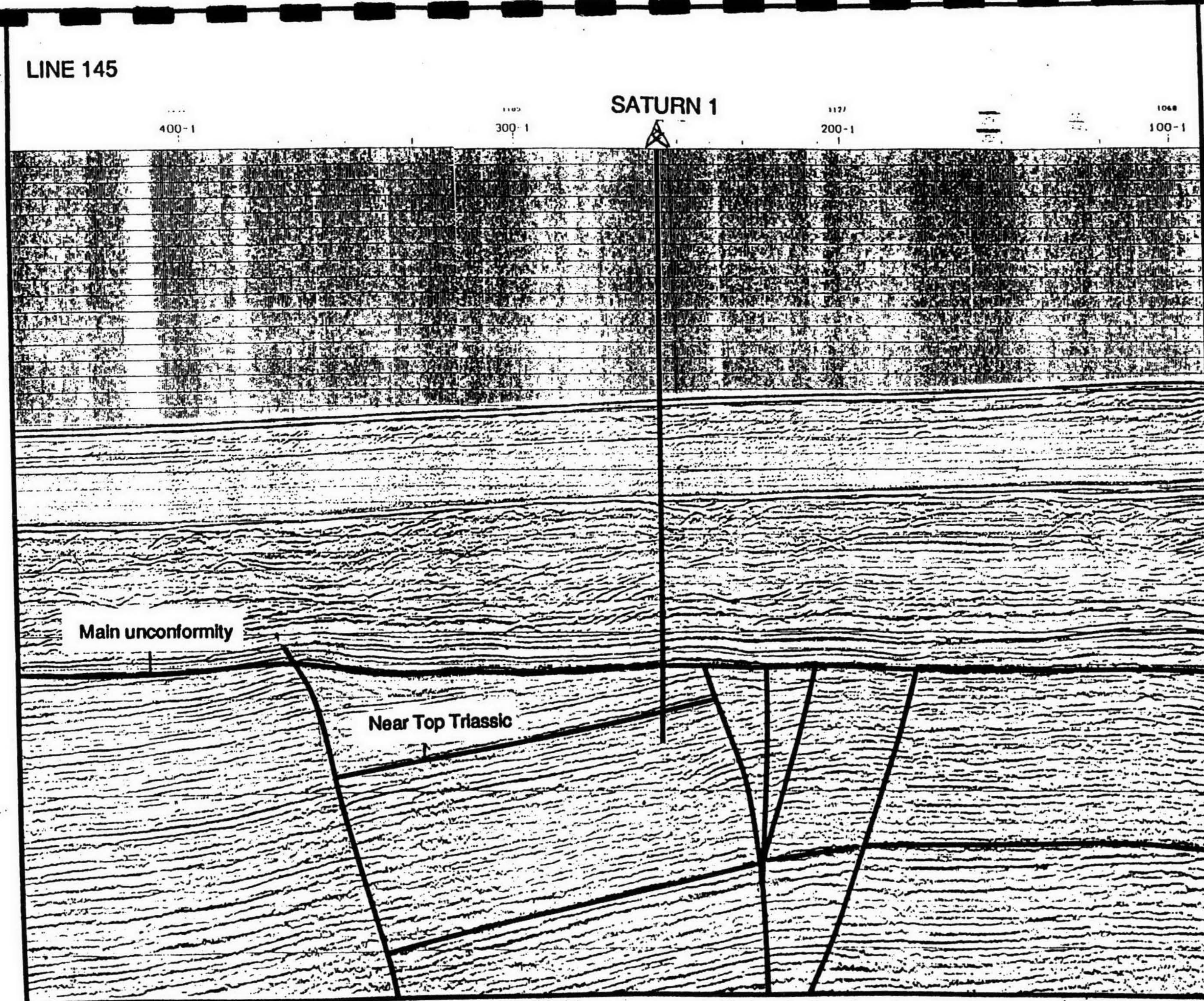
Saturn 1 (see Figures 49, 50 & 51)
Saturn 1 was targeted on closure beneath Cretaceous seal on the Main Unconformity. This horizon is clearly defined on the seismic and there is little doubt about the veracity of the interpretation. The target was Triassic reservoirs within tilted fault blocks sub cropping beneath this seal. When viewed regionally the structure at the Main Unconformity level is greater than 500 km^2. On the original interpretation, closure independent of major faulting is approximately 100m over an area of 75 km^2. The Saturn structure is related to the formation of the Rankin Trend in middle Jurassic (Time Slice J6 time). An intra pre Main Unconformity fault block reflector was mapped and showed Saturn 1 at the apex of closure with the fault block.

The well drilled through Cretaceous seal rocks and encountered a sandstone beneath these seal rocks and immediately above the Main Unconformity. This sand of uncertain age, but between Time Slices J2 and J10, occurs over the interval 3016-3022m (ss). It is a glauconitic conglomeratic sandstone possibly a reworked basal transgressive sandstone. The chromatograph was non operational over this interval but headspace gas analysis showed 73% methane, 10% ethane, 8% propane 5% butane and 4% pentanes. The Sw is calculated at 31-55% and porosity average of 15%. This sand could thicken off structure and based on similar sandstones in Gandara 1 and Malus 1 is likely to be regional. The sand was not tested and should be classified as by-passed pay.

Reservoir beds where not encountered immediately beneath the Main Unconformity as hoped. Instead approximately 500m of lower Jurassic and upper Triassic non reservoir facies was encountered prior to intersecting the top of the first good regional Triassic reservoir sandstone. The operator considers this to be the main cause of well failure at the primary reservoir objective, ie no reservoir beneath the regional post-Main

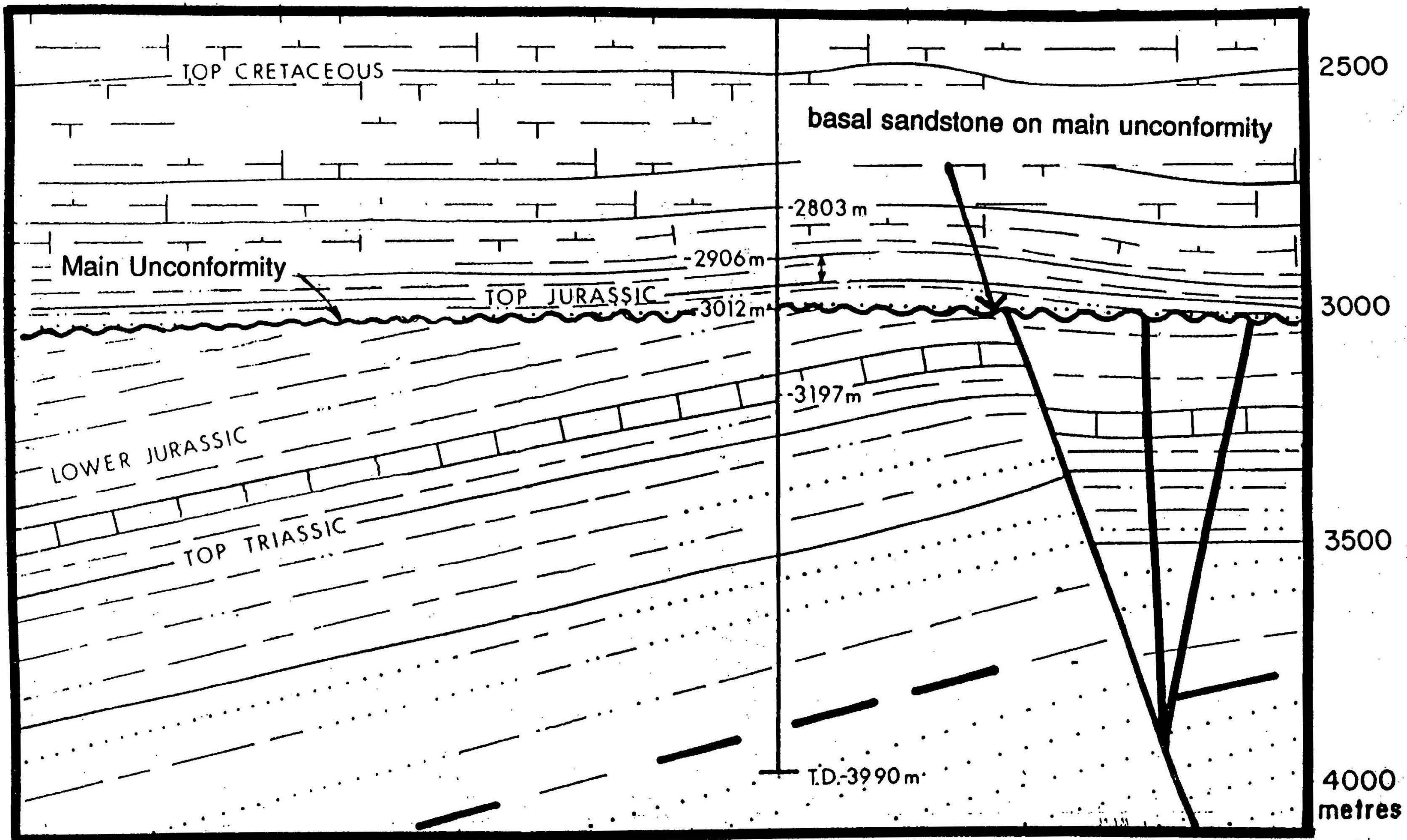


Structure Map at top Triassic of Gandara 1 Prospect Showing Drainage. Figure 48

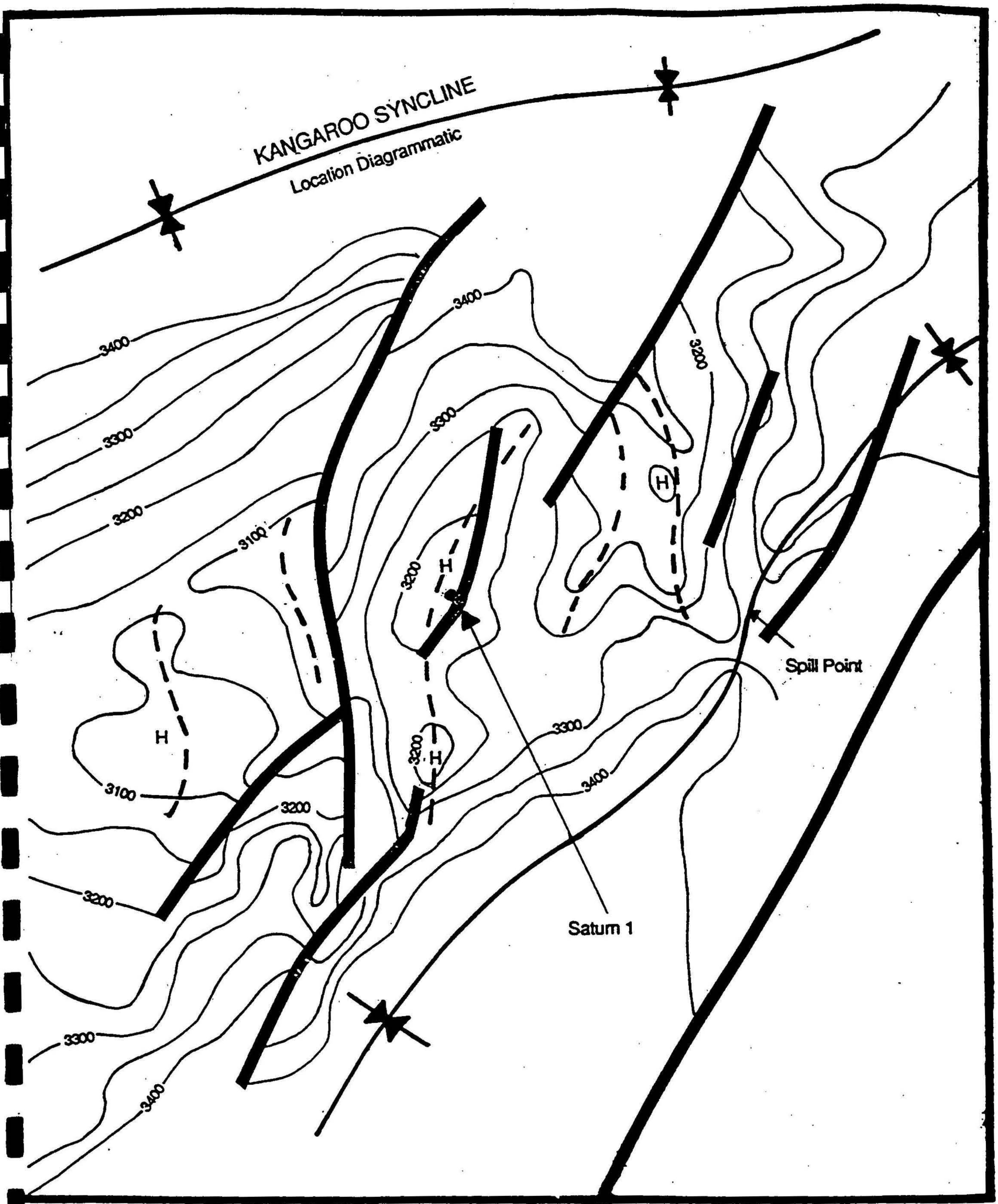


LINE 145
SATURN 1
400-1
300-1
200-1
100-1
Main unconformity
Near Top Triassic

SATURN 1



Geological Section Across the Saturn 1 Structure. Figure 50



Structure contour on main unconformity.
Triassic structure is similar but dips to north west at 3° to 6°.
(Modified from WCR)

Structure Map on Base Cretaceous (near Main Unconformity) at Saturn 1. Figure 51

Unconformity seal. Minor up dip potential is possible in the tilted fault block and gas in the basal post-Main Unconformity sandstone was suggested to have been sourced by leakage up the east bounding fault plane.

A re-examination of the seismic on line 145 suggests wrench faulting rather than normal faulting. At the level of the first thick Triassic reservoir sand (approx 3500m sub sea) there is no closure at the well site, but potentially a 50 msec rollover occurs approximately 5 km to the southeast. The magnitude of the lateral offset caused by the wrench nature of the faulting that created the pre-Main Unconformity trap is unknown. It follows that there are difficulties with mapping the juxtaposition of reservoir and seal across these fault boundaries.

Porosities in the Triassic sandstones are from 18-25% in medium to coarse grained units at 4000m which is total well depth. The well has a present day extrapolated BHT of 103 °C which is consistent with a basal vitrinite reflectance of 0. 7% Rv. This is just below the commonly accepted temperature of 110 °C for the onset of peak generation from continental fluvial source rocks. There is no reason to suspect that higher temperatures existed in the past.

Although the well did not intersect the prognosed section it was successful at the level of the Main Unconformity closure. A 6m basal transgressive sand of good porosity sits on the Main Unconformity. It is probably by passed pay. The sand could be sourced from sub-cropping Triassic or sub-cropping Jurassic mature downdip and within the drainage radius. There is fair potential for thickening of this sand unit as well as an oil leg beneath a gas cap. Potential also exists for a large Triassic closure to the southeast of this location. Good reservoir characteristics are preserved at depth to at least 4000m (sub sea).

DAMPIER SUB BASIN PETROLEUM SYSTEM & PLAY CONCEPTS

INTRODUCTION

The following section gives an overview of some of the features considered when assessing the petroleum system of the Dampier Sub-basin as inferred from the results of the well audits, palaeogeographic interpretations and geochemistry. Play concepts are additional to these more regional considerations and are detailed later.

REGIONAL EXPLORATION RESULTS OVERVIEW

Exploration Success Rate

Irrespective of the accuracy of the post drill well audits it is established that most wells on valid trapping situations have been successful in that they encountered hydrocarbons. Considering this the success rate for valid trap exploration wells is greater than 50% and may be as high as 80%.

Inadequately Tested Previously Drilled Structures

As a result of the post drill audits several wells are candidates for retesting or re-evaluation .

Hampton 1 was not on structure at the pre-Main Unconformity level. Significant rollover is seen to the east and a play may exist in this area sourced by mature Triassic or possibly migrated Jurassic.

Montague 1Their is sufficient ambiguity associated with the results of this well to suggest that the Montague closure be re-examined in detail. If any closure does exist the probability of oil fill is quite high.

Withnell 1 drilled through a 9.0m unit at the top Time Slice J8. The unit was heavily caved. The gamma ray suggests the unit is a sand, but extensive SWC shots failed to recover any sample. The interval was oil stained, This unit is encased in overpressured source rock quality shales at a depth of 3794 m KB. The caving of the sand was believed due to overpressure stresses. The unit is significant as it is most likely to be the distal toe of a mass flow sand deposit and would almost certainly become thicker towards its source.

Saturn 1 probably has by passed pay in the sand which sits on the Main Unconformity. The actual area of closure over which this sand could be filled is in excess of 500 square kilometres. It is possible the untested 6m sand could have an oil leg and increase in thickness off structure.

Source Rocks

There is geological evidence to indicate a Triassic, or older, source for the gas condensate discoveries. It is not established from purely geological criteria whether the Jurassic is a source of gas condensate but it is certain that the Jurassic is a source of oil. The Triassic section could also be a source of oil although there is no conclusive geological evidence for this. These conclusions are based on the following:

Triassic Gas Condensate

Deeper GWCs in discontinuous sands in the Goodwyn Field provide the necessary evidence to infer hydrocarbon migration from down dip mature source rocks. It is extremely difficult to envisage a migration pathway from the Jurassic of the Lewis Trough (the only other mature source rock in the area) that could produce such an effect, so a Triassic source is logically necessary. The common GWCs of the North Rankin Field are due to the intersecting fault sets in this field that effectively interconnect all the reservoirs (Tilbury and Barter 1992). This highly complex internal faulting beneath the Main Unconformity provides good vertical communication across the North Rankin Field. The faulting may also be a conduit to deeper source, possibly Permian, but it is not thought that it is necessary to invoke the Permian to explain these accumulations. Geochemical and maturation results suggest the Triassic section along the Rankin Trend is mature and generative. The Angel Field is in a situation where the gas condensate accumulation could be sourced from underlying Triassic via fault migration pathways. So on purely geological grounds, Angel Field is not irrefutable evidence for a Jurassic source for gas condensate .

Jurassic Gas Condensate

The Angel gas condensate Field overlies Time Slice J6 (pre-Main Unconformity) aged rocks. These rocks may be the source of the gas condensate in the overlying field. However at Montague 1 geochemical analysis (Montague 1 WCR) has concluded that the light oil and condensate, found in the Triassic reservoirs, has biomarkers the same as those from the Angel Field gas condensate. These are similar to Jurassic (Time Slice J8 cores) source rocks found in Madeleine 1. This suggests but does not prove a Jurassic source for the Angel Field condensates.

Triassic Oil

Trap formation and maturation timing on the Rankin Trend allow for the possibility that an early oil phase may have preceded the gas condensate phase, but the oil escaped because no seal was in place. An oil leg in Triassic rocks at Goodwyn 6 is within a fluvial floodplain sequence not thought to be a particularly oil prone facies. It is interpreted that the oil is Jurassic sourced. Other oil legs along the Rankin Trend are all in situations that allow for short distance migration from mature Jurassic source rocks in the Lewis Trough. On the basis of the wells examined there is no conclusive geological evidence for a Triassic oil source. This is discussed more fully in the next section.

Jurassic Oil

Oil only discoveries are restricted to the Lewis Trough or its flanks. Along the Rankin Trend oil legs are only found in sections of those Fields that are adjacent to the Dampier Sub-basin. In Goodwyn 6, immediately adjacent to the Dampier Sub-basin an oil leg was encountered, which is not found in other sections of the field. The lack of an oil leg across the entire Goodwyn Field is difficult to explain if the Triassic is sourcing this oil. If the Field is being face loaded from the Jurassic of the Lewis Trough then the oil leg is much more easily explained. Fields in Triassic fault blocks downdip of the Rankin Trend for example Rankin, Goodwyn 3 and Tidepole all have oil legs beneath their gas cap. This pattern is consistent with a Jurassic source for the oil but does not disprove a possible Triassic oil source.

All discoveries along the Legendre Trend are oil. The Wanaea and Cossack Fields are oil fields immediately underlain by mature Time Slice J9 and J8 source rocks. This establishes the general oil prone nature of the Lewis Trough Jurassic section. Oil in Wandoo Field is almost certainly sourced from the Jurassic of the Lewis Trough although there is a remote possibility of a Triassic source from mature Time Slice Tr1 and Tr2 sediments (Locker Shale).

Cretaceous and Tertiary:
There is little evidence for significant accumulations charged from Cretaceous or Tertiary source rocks. Hampton 1 has a dry gas accumulation in Time Slice K3 aged reservoirs. This is possibly sourced from the Cretaceous but could just as easily be from deeper Triassic source possibly Time Slice TR1 and Time Slice TR2 aged Locker Shale.

TIMING OF TRAP FORMATION
Time Slice J6 to J7 defines the major structuring event of the Dampier Sub-basin In many areas this is the time of formation of many of the major structural traps, eg on the margin of the Enderby Terrace, on the Rankin Platform, Kangaroo Syncline area and Legendre Trend. Other areas notably the Rankin Trend and Lewis Trough required either regional seal and or drap compaction to form traps.

Regional Seal Facies
A feature of the Dampier Sub-basin is the striking effectiveness of the regional lower Cretaceous seal rocks and the apparent absence of significant effective intraformational seals beneath them. Significant stacked reservoirs are unknown. The timing of the emplacement of these regional seals is therefore important as it puts a maximum age to hydrocarbon accumulation. In the low areas of the Lewis Trough and Rankin Platform effective seal was in place by middle Time Slice K1 but a regional seal on the Rankin Trend and Enderby Terrace was not in place until Time Slice K7. In the Kangaroo Syncline area an effective seal on the major Triassic reservoirs was in place by Time Slice J1 and over the sands which rest on the Main Unconformity by Time Slice J10.

The Muderong Shale facies and younger rocks are critical for trapping most of the known reservoirs. They form the seal on the Rankin Trend pre-Main Unconformity Triassic reserves, the Lewis Trough Tithonian reservoirs and the Enderby Terrace early Cretaceous reservoirs.

Rankin Trend
The Triassic reservoirs beneath the Main Unconformity were not buried until the end of Time Slice K3 time, but the first significant thickness of seal was not until the middle of Time Slice K7.

Lewis Trough
The uppermost Jurassic (Tithonian) reservoirs Time Slice J10 are immediately sealed by overlying Time Slice K1 claystones. There is a possible small time break at the top Tithonian but otherwise sedimentation across the boundary was

continuous. In the Talisman area reservoir deposition continued into the early Cretaceous and seal rock deposition is similar to that described for the Enderby Terrace below.

Enderby Terrace:
Enderby 1 is sufficiently close to Wandoo Field to use it to make some inferences regarding the Wandoo accumulation. The Wandoo Field reservoir is known to be shallow (less than 2000m sub sea). Top porosity at a similar level in Enderby 1 is in section of *M. australis* age (Time Slice K3). A significant section of Time Slice K7 seal rocks was deposited over the Time Slice K3 reservoir.

Kangaroo Syncline
The Triassic reservoirs do not always subcrop the Main Unconformity. A seal facies on the major reservoirs has existed since at least lower Jurassic Time Slice J1). The seal may have been broken by Time Slice J6 aged tectonics. In this area onlap of a regional sealing facies occurred in the Late Jurassic (Time Slice J10) and by early Cretaceous the area was effectively sealed above the Main Unconformity.

Madeleine Trend Closures
The Wanaea, Cossack and Angel Fields lie along the Madeleine Trend. These traps formed by drape compaction of upper Jurassic and lower Cretaceous over the tilted pre Main Unconformity fault blocks. Bint (1991, p. 24) states that the structures did not substantially develop until the late Cretaceous.

TIMING OF HYDROCARBON GENERATION
Triassic
Time Slices TR1 and TR2 (Locker Shale) are possibly an oil source rock, particularly the basal section. Burial history modelling suggests that for the earliest maturation of the lowest Triassic, these models assume an initial generative phase coincident with an Rv 0. 5% Rv. (Swift et al 1988, p550), which would have occurred at a depth of 2. 0 km (Kaiko 1992). The basal Triassic reached this depth in the earliest Jurassic at the Dampier 1 location and by the end of the Jurassic the entire Triassic in the Lewis Trough would have been mature.

The upper Triassic on the Rankin Trend is currently mature but on the Kangaroo Synclinal area the upper Triassic is still immature. At Hampton 1, on the Enderby Terrace, the basal Triassic reached 1. 5 km in Early Jurassic and is currently deep enough to be mature.

These considerations suggest that any Rankin Trend Triassic oil would have been formed prior to seal rock emplacement. The margin of the Enderby Terrace is estimated to have been mature for early Triassic oil since the Late Jurassic.

Jurassic
The bulk of the Lewis Trough oil generation from Time Slice J8 source rocks must have occurred after the middle of Time Slice K1 time (seal in place) and probably before the end of the Time Slice Cz3 (the major burial event). Trap formation on the Madeleine

Trend (discussed above) suggests the earliest accumulation to be not prior to Time Slice K10. Ellis (1988) suggests that the Miocene migration of hydrocarbons into shallow reservoirs has occurred at Talisman Field and implies an early Oligocene Time Slice Cz3 age for the main oil phase in the Lewis Trough. Obviously the deeper Jurassic would have matured earlier. Elsewhere the Jurassic appears to be in the earliest generative phase.

Cretaceous & Tertiary
There is no empirical evidence of significant maturation of Cretaceous and younger rocks

Kangaroo Syncline
Post drill well audits suggest that the wells drilled in the Kangaroo Syncline area reached total depth above mature section in situations where the trap accessed only minimal drainage from adjacent more mature source areas. Neither of the examined wells had mature Jurassic source. It is likely that at slightly greater depths mature source would be encountered that would be just as prolific as that on the Rankin Trend. Because trapping of the early phase of generation is likely this area is considered to have Triassic oil potential.

VOLUME OF HYDROCARBON GENERATED

Many of the accumulations show evidence, none of it conclusive however, of being filled to spill point (see the well audit section). Although not as indicative as the larger Lambert and Angel Fields spill points, there is evidence that the smaller accumulations along the Legendre Trend could be filled to spill point as well, but here it is necessary to invoke fault control of the trap spill point.

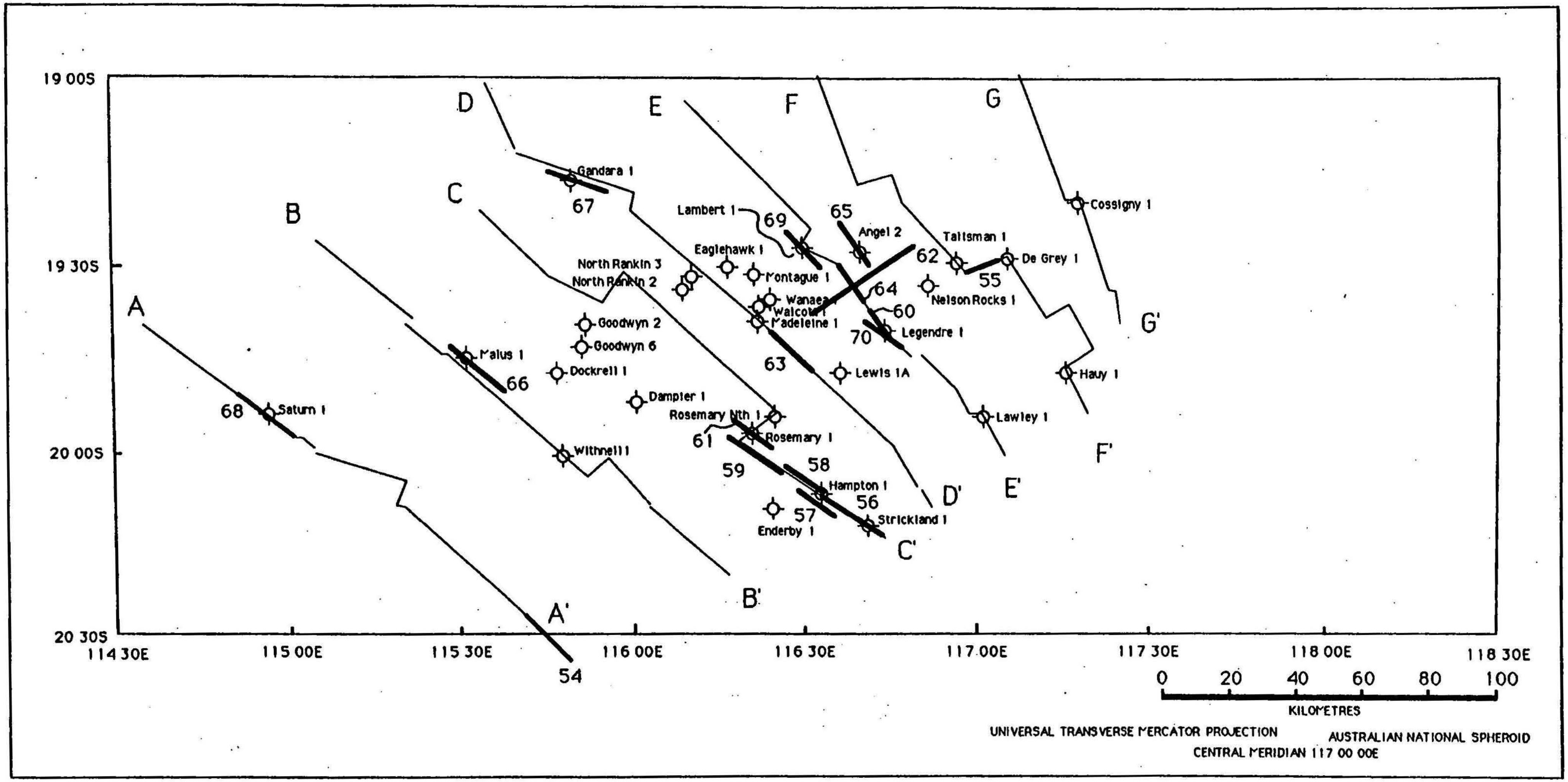
It is interpreted that sufficient hydrocarbons have been generated in the Lewis Trough to allow for the major migration onto the Enderby Terrace resulting in the accumulation of the Wandoo Field. On the Rankin Trend enormous volumes of hydrocarbons are in place. North Rankin Field supports a gross hydrocarbon column of approximately 570m.

Montague 1 has a large residual oil leg beneath the Triassic accumulation. Rosemary North 1 and Hampton 1 have residual or possibly residual hydrocarbon legs and there is evidence of residual oil legs in Talisman 1 (Ellis 1988).

The point emphasised is that the evidence suggests an abundance of hydrocarbons for the available traps particularly from the Lewis Trough and Rankin Trend.

CONSEQUENCES OF MARGIN SAG

All structural closures have been in a continual state of adjustment in response to Tertiary margin sag particularly since Time Slice Cz3. This sag effect may have exploration consequences that are possibly very significant. Montague 1 could have failed because closure is a result of very recent margin sag that may post date the main oil migration phase.



Location Diagram for Figures 54 to 70. Figure 52.

RESERVOIR QUALITY:
Reservoir quality varies but as a general statement there does not appear to be a significant cut off depth yet established for the basin and factors such as overpressure and expense appear to be controlling drilling depths rather than reservoir quality.

Good initial depositional porosity appears to be maintained at depth and this generalisation appears to also be valid for permeability.

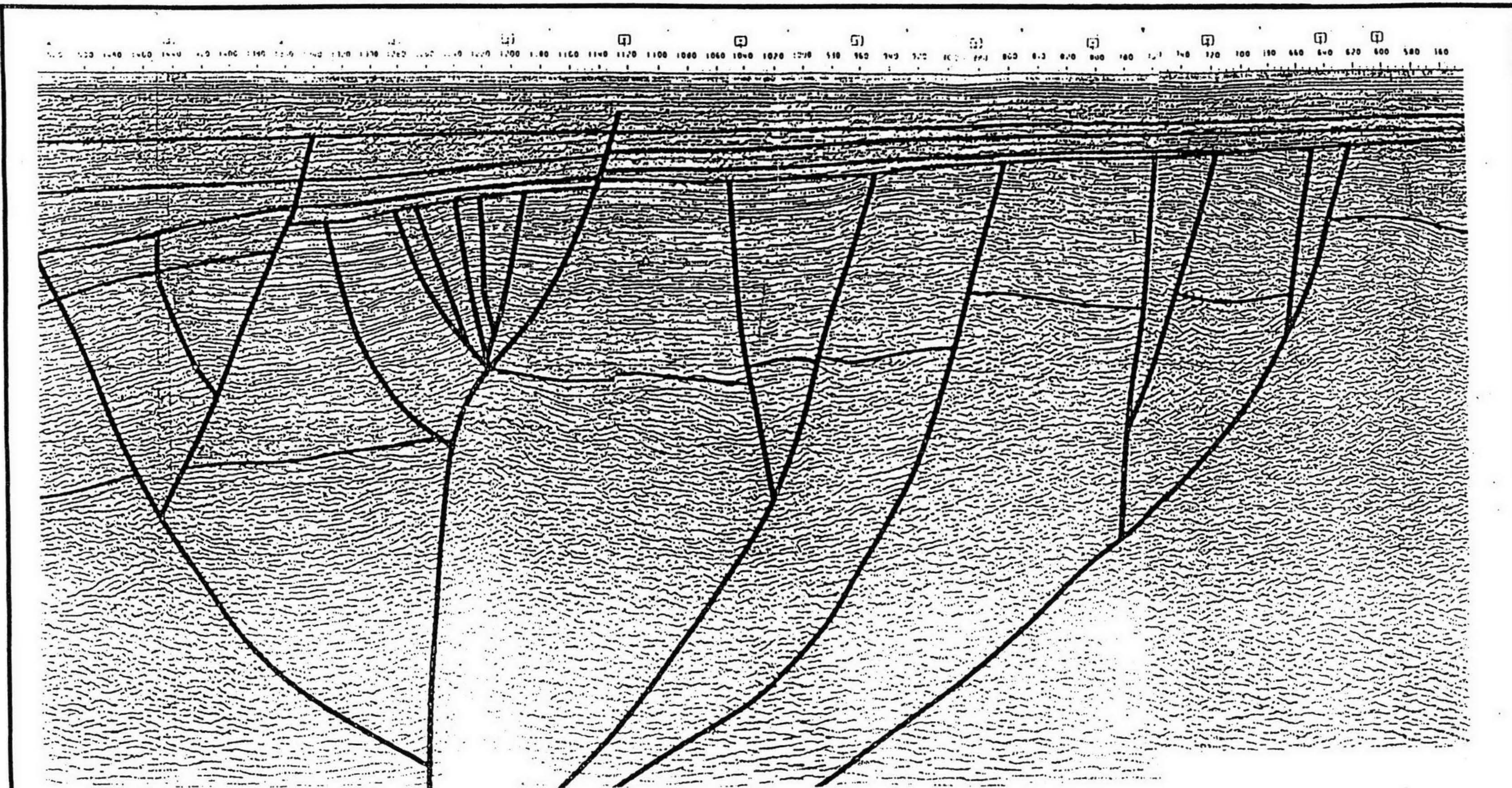
Triassic Reservoir
Both Gandara 1 and Saturn 1 had good porosities (22-25% log) in clean thick Triassic sandstones at depths of 4000 to 4200m. These are relatively cool wells and it may be that diagenesis is reduced under these circumstances.

Jurassic Reservoirs
Reservoir quality in the thicker mass flow sandstones is good. In Wanaea porosities are 16 -17 % and permeabilities average 300 mD, in Angel Field porosities average 14-20% and permeability ranges from 150 to 727 mD. In Madeleine 1 similar sands have poor reservoir quality due to depositional matrix in sands which are mainly grain flows. Porosity preservation coincident with hydrocarbon emplacement could occur making deep middle Lewis Trough plays attractive.

PLAY CONCEPTS
The play concepts are discussed by tectonic provinces. These are the
- Enderby Terrace
- Dampier-Sub-basin: Kendrew Terrace and Lewis Troughs
- Rankin Trend
- Rankin Platform
- Kangaroo Syncline Area.

Figure 53 is a schematic diagram based on seismic interpretation. It is a composite which illustrates the main play ideas recognised. The numbering on this figure (1 to 15) is used below with additional seismic to detail each concept. The location of the seismic figures used to illustrate this section is shown on Figure 52.

ENDERBY TERRACE (INCLUDES THE ROSEMARY FAULT ZONE)
(1) Hanging Wall Anticlines on the Enderby Terrace
Major listric faults with hanging wall anticlines occur on the Enderby Terrace. These faults generally parallel the Rosemary Fault System and define potential closure on the downthrown side. Figure 57 shows that Triassic dip closure was not present in the Hampton 1 well, but that critical dip reversal occurs updip from this location and down through the Triassic to the Top of the Pre-Triassic reflector. Figures 56-59 amalgamate to form one cross-section across the Enderby Terrace from the Lambert Shelf (near Strickland 1) to the Lewis Trough. These and other recently acquired deep seismic data indicate that the shallower listric faulting is attached to deep master detachment faults. The listric faults are evidently simple minor extension faults that occured at Time Slice J1, that were followed by more complex wrench tectonics, probably on older faults reactivated at the Main Unconformity time. Other hanging wall anticlines (similar to Hampton 1) can be expected in this setting.



Seismic Line 82-38 Part of Cross-Section A-A' Figure 54

(2) Rosemary Fault System-Legendre Trend

The Rosemary Fault System created the Legendre Trend along which several significant oil discoveries have been made. This fault system is interpreted to be a transtensional wrench, that has branches or stems that extend both into the Lewis Trough and marginward to include the fault which bounds the Eliasson Fault Block. Wrenching on the Rosemary Fault System appears responsible for the structuring seen at Time Slice K1. The complex and variable nature of the Rosemary Fault Zone is shown in figures 54,59,60,61 and 70. Reservoirs of Time Slice J10 or Time Slice K1 age sealed by Time Slice K1 claystones are the main targets. The reservoirs generally have good porosity and permeability characteristics but may be variable due to diagenesis including heavy pyritisation. The structure of the Rosemary Fault System is very complex and early vintage seismic poorly images the zone. The wrench component to the system has only recently been recognised. This complexity suggests that remapping will continue to be required as seismic resolution and quality improve with time and that untested closures may still exist along the trend.

(3) Rotated Blocks on the Enderby Terrace

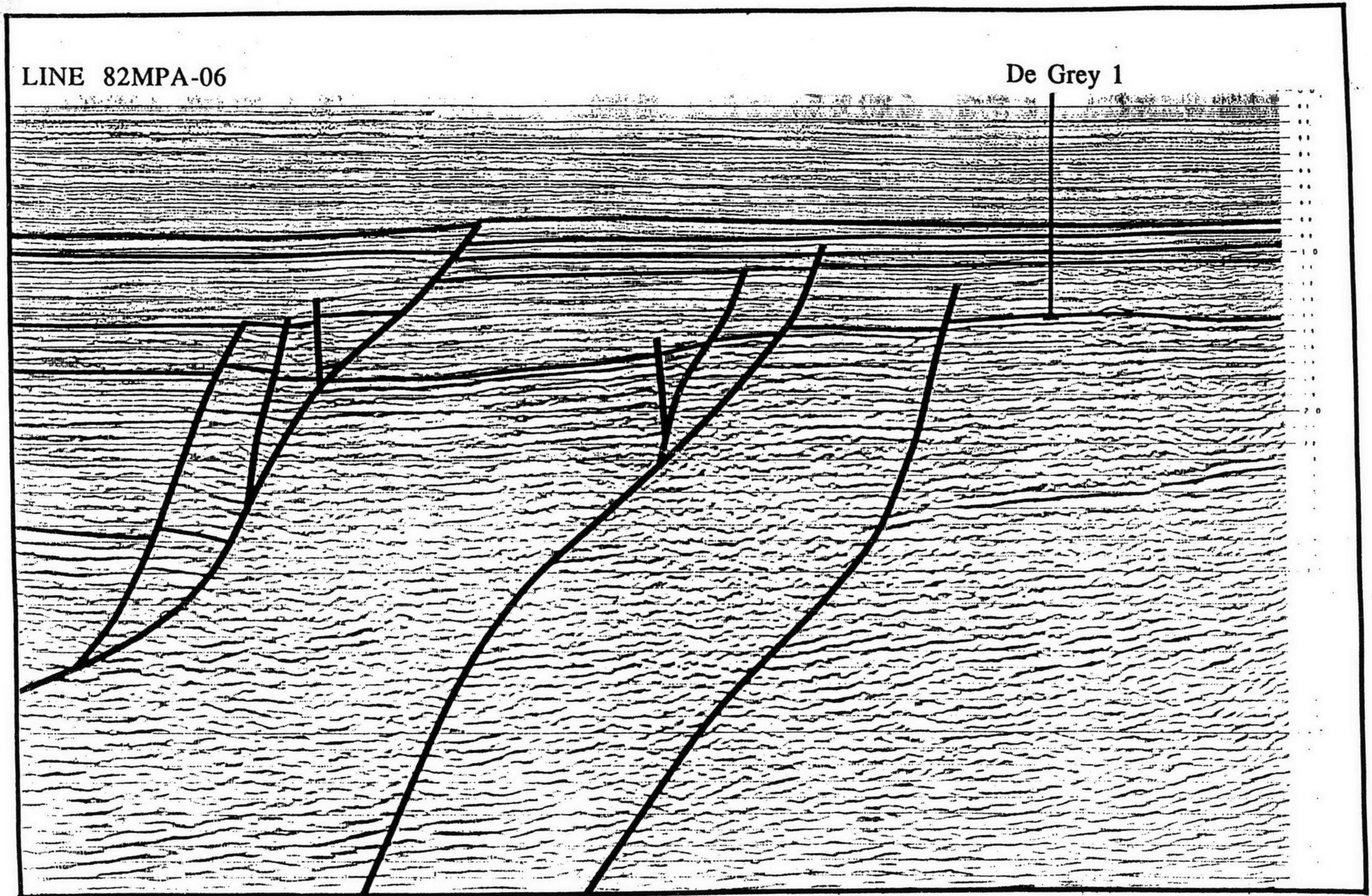
Time Slice J6-J7 aged movement along the Rosemary Fault System has resulted in rotation of large blocks of probable Triassic and Lower Jurassic sediments. The fault bounded block seen in the overlap area of figures 58 and 59 is over 7 km across and dip within it, is in the opposite sense to that in the adjacent section. Dip segment mapping shows major rollover on this regional dip line. Four way dip segment closure would exist if rollover occurs along strike and both fault plays and dip segment plays appear possible within these blocks. Top seal appears to be the main risk on trap integrity.

(4) Faults Providing Pathways into Shallower Reservoir Facies on the Enderby Terrace

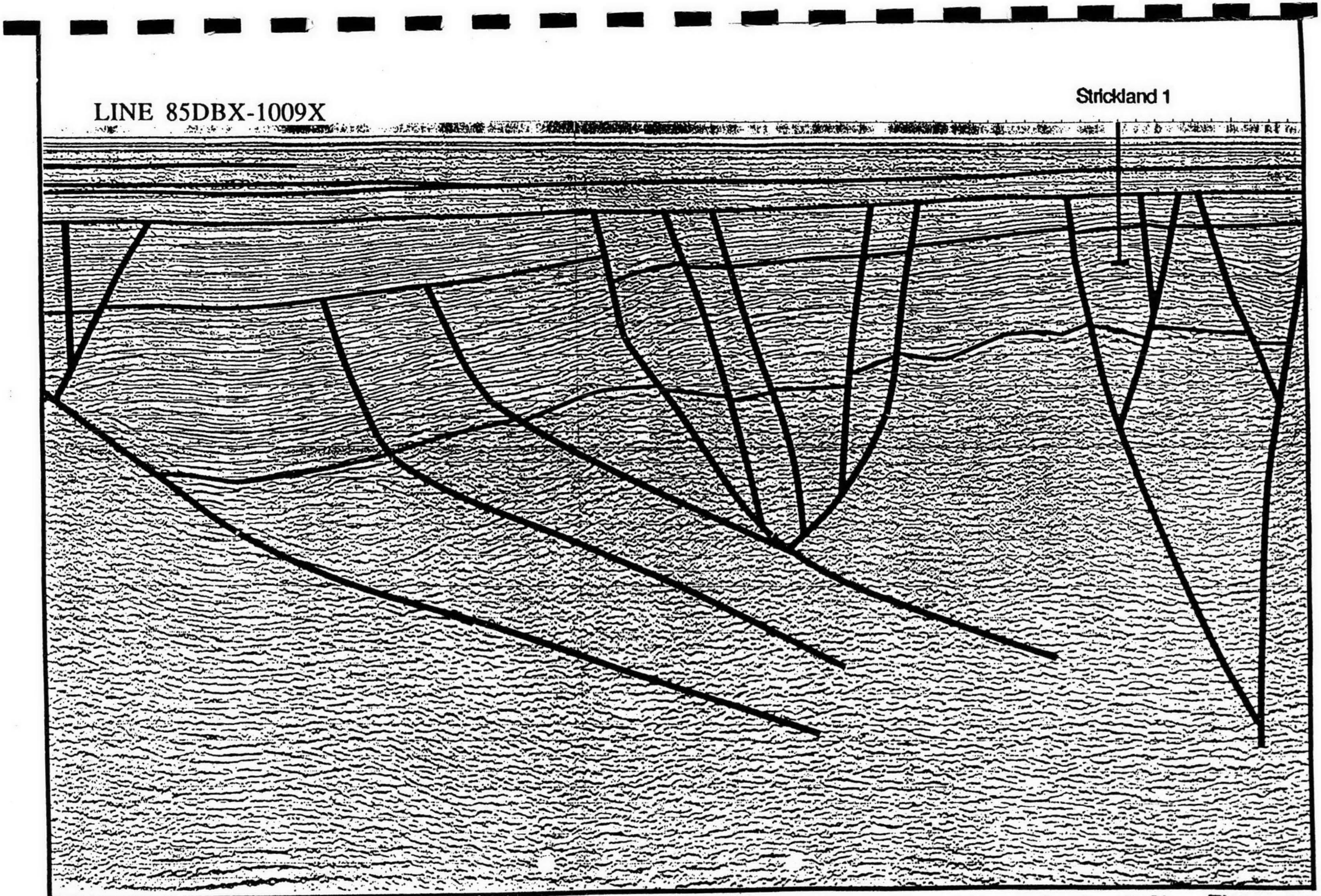
Along the Rosemary Fault System minor recent reactivation or differential compaction has caused some faults to penetrate into Tertiary aged sequences. At these locations it is possible that hydrocarbons have migrated up the fault plane into shallower reservoirs. Figure 59 illustrates this effect.

(5) Basal Triassic Transgressive Reservoir Plays on the Enderby Terrace

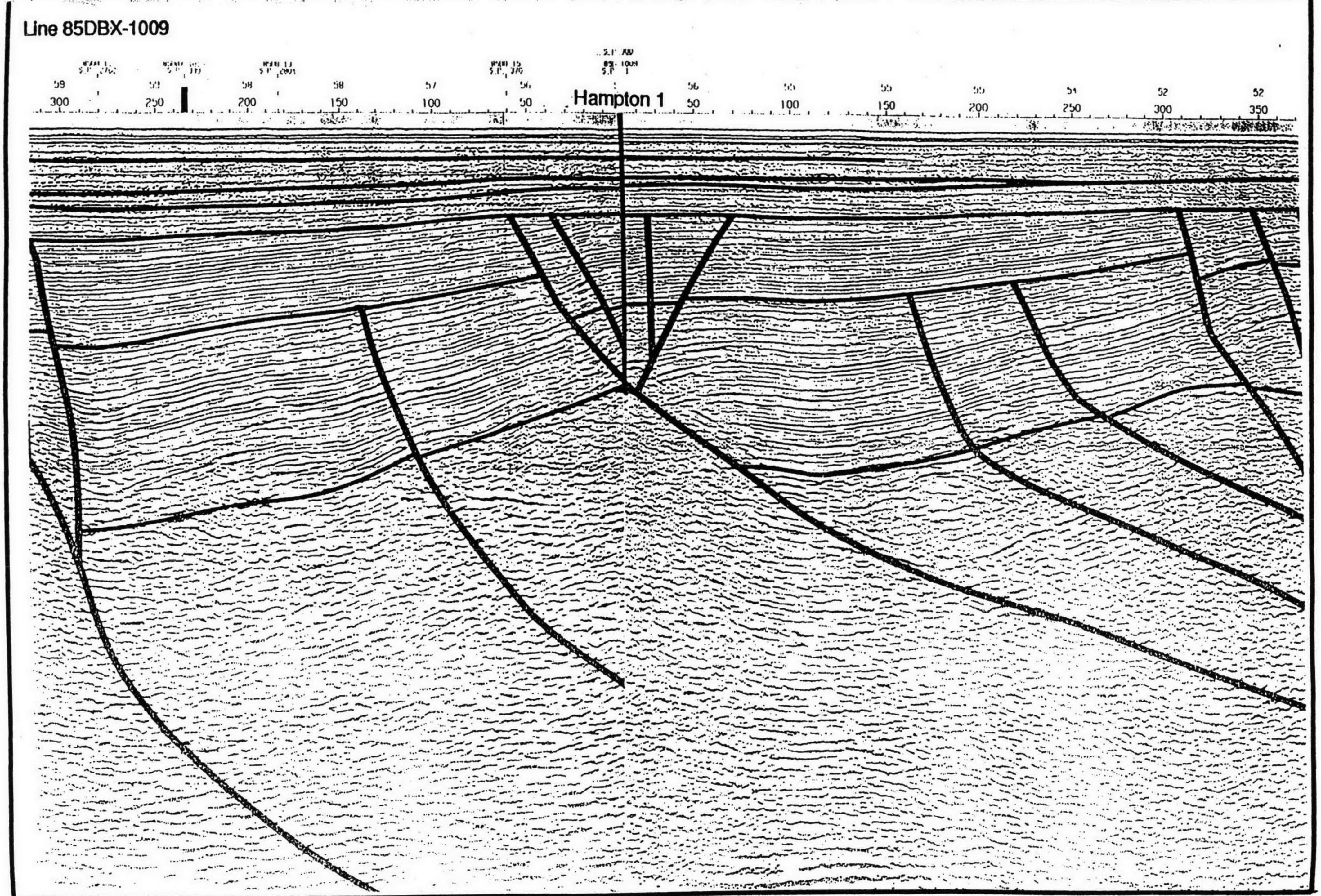
See Time Slice Tr1-Tr4 section for a detailed description. In essence a basal transgressive sequence of sandstone and limestone unconformably rests on pre-Triassic basement. It is regionally developed across the Enderby Terrace and possibly becomes thicker towards the Lewis Trough. In the south the unit is sealed by a thick regional shale (the Locker Shale) but to the north there is a facies change to sandy clastics and seal integrity is lost. There is potential for the basal shale facies to be oil prone and close to the Lewis Trough this unit should be at a depth and temperature sufficient to cause maturation. It is also possible that sourcing from the mature Jurassic in the Lewis Trough could occur in some places. Plays are based on flank sealing of these basal reservoirs by faults (Locker Shale or basement) with top seal by Locker Shale. Figure 58 illustrates this play.



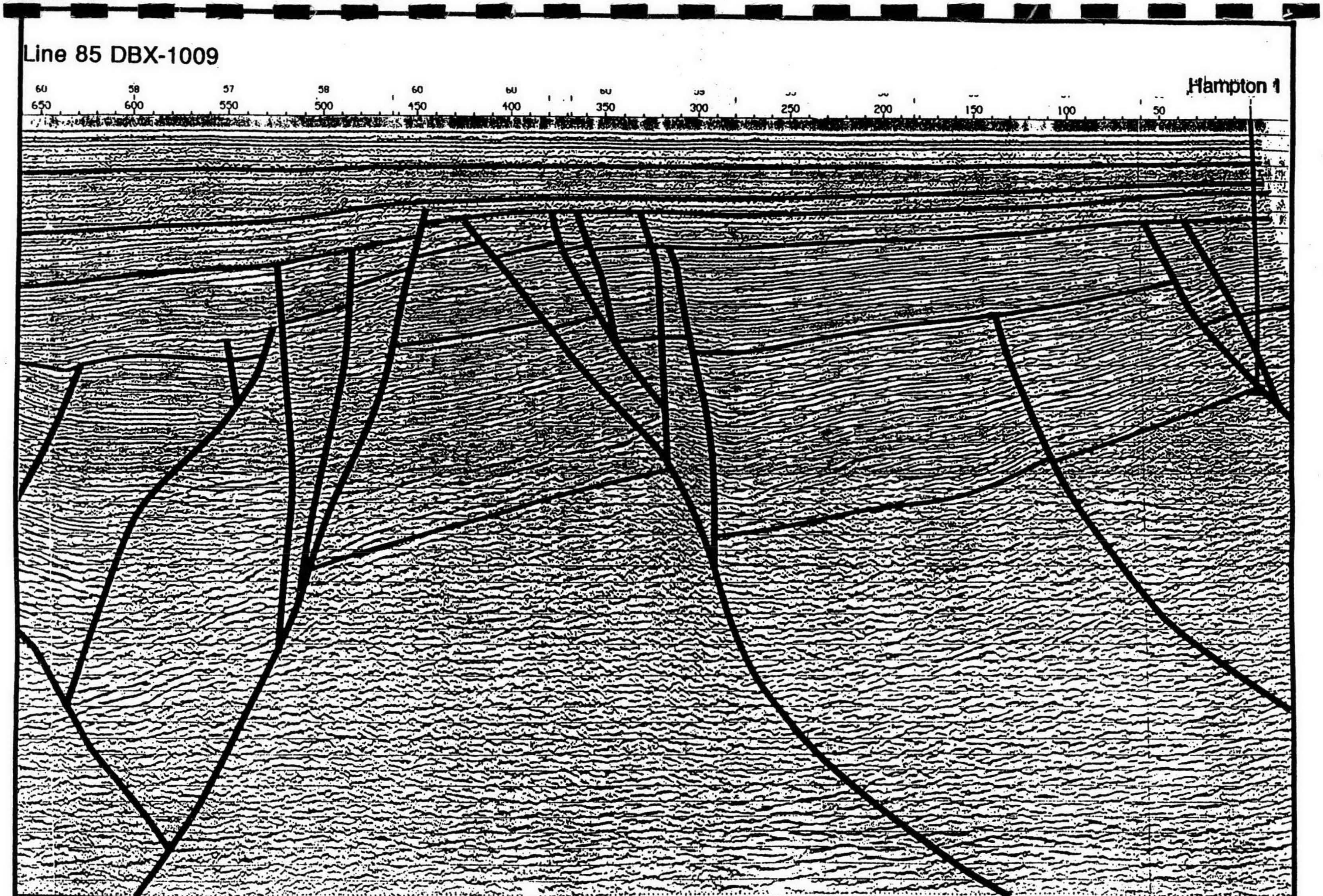
Seismic Line 82MPA-6 Part of Cross-Section F-F'. Figure 55



Seismic Line 85DBX-1009X Part of Cross-Section C-C'. Figure 56



Seismic Line 85DBX-1009 (A) Part of Cross-Section C-C'. Figure 57



Seismic Line 85DBX-1009 (B)   Part of Cross-Section C-C'   Figure 58

(6) Lower Triassic Intra Time Slice TR2 Limestone Reservoirs on the Enderby Terrace
This play concept is similar in all respects to the preceeding play concept except the position of the reservoir. Oolitic limestones are developed at various levels throughout Time Slice TR2 (see Time Slice Tr1 - Tr4 section). The lost circulation zone in De Grey 1 is probably a limestone unit. A thick limestone unit is also developed in Cossigny 1. It is probable that thick limestone units exist on the Enderby Terrace adjacent to the Lewis Trough. An elongate area adjacent to the Lewis Trough on the Eliasson and Hampton Fault Blocks is high graded. Figures 58 illustrates this play.

(7) Incised Valley Plays - Triassic and Jurassic (not illustrated in Figure 53)
The Enderby Terrace has been exposed several times in its geological evolution. During these intervals incised valleys are likely to have formed. As an example during Time Slice J10 depositional lobes were deposited at the base of the fault defined margins of the Lewis Trough. These depositional lobes are believed to have been fed from feeder channels, envisaged to be of order of 1-2 km wide, which were most likely incised river valleys or shelf canyons. It is possible that the sand supply, during periods of high sealevel was supplied to the canyon head by near coastline longshore currents. The general locations of the major feeder channels are shown on (see Enclosure 29). These channels may provide the major pathway onto the shelf for oil migrating up the Rosemary Legendre Fault zone and also could have internal trapping mechanisms.

(8 A, B and C) Dampier-Sub-basin; Kendrew Terrace and Lewis Troughs
Time Slice J8 to Time Slice J10 is characterised by marine mass flow sandstones interpreted to be depositional lobes. The sandstone facies of these lobes are episodic deposits separated by mainly organic rich shales. The lobes have only been tested in structural locations beneath the main regional seal. Several other trapping mechanisms have been seen on seismic or can be inferred but have not been tested, these include

A--Onlap plays including pre Main Unconformity and, in particular, post Main Unconformity (Time Slices J8 and J9) sediments, where they onlap the Main Unconformity. Figure 64 illustrates these onlaps as the Madeleine Trend is approached. In addition where the Main Unconformity shallows towards the northern margin of the Dampier Sub-basin, sediment of Time Slices J7 and J8 are seen to onlap it (see Figure 62).

B--Possible reservoir sandstones that parallel the trough axis and have potential up dip pinch out are interpreted from seismic sections. Various possible sand bodies are seen in figure 64 primarily within Time Slices J8 and J9, all associated with unconformities. Figure 63 shows an interpreted isolated mound within timeslice J10 thought to be a mass flow deposit, probably a sandstone. At the time of it's deposition it would have been located at the axis of the Lewis Trough.

C--unconformity (onlap)related traps.
Part of this feature is an onlapping wedge of Time Slice J10 or Time Slice J9 sediments which are thought to be probably sands (see Figure 60). The K1 timeslice shows a possible mass flow deposit or an erosional margin at this location. The Sub-

basin is an established mature oil source rock area. The lobes would be charged from adjacent source rock.

(9) Migration Updip from Angel Field
As discussed previously the Angel Field may be filled to spill point. Evidence available to us indicates that the speculative spill point is on the eastern flank of the axis of the Lewis Trough. The implication is that excess hydrocarbons would be migrating along the base Cretaceous seal from this spill point in an approximate north east direction. Any structural or stratigraphic closures along the conjectured migration pathway have the potential to be charged. If an oil charge did precede the gas condensate phase in Angel Field then there is a possibility for oil in the speculated updip traps. Figure 64 shows that the spill point at base Time Slice K1 in the Angel Field is close to the low axis at the level of this horizon.

RANKIN TREND

(10) Fault Conduits to Shallower Reservoir Facies
Their are a significant number of shows within seal facies in section above the major accumulations in wells along the Rankin Trend (Time Slice K1 and younger). A possible interpretation is that hydrocarbons are migrating upward from the underlying accumulations. There are some faults above and adjacent to the Rankin Trend which penetrate through the regional seals. These faults provide the only possible route for hydrocarbons to enter the overlying units. Time Slices Cz1 and Cz2 have possible glauconitic reservoir facies which could be charged by such a mechanism. (see Figure 53)

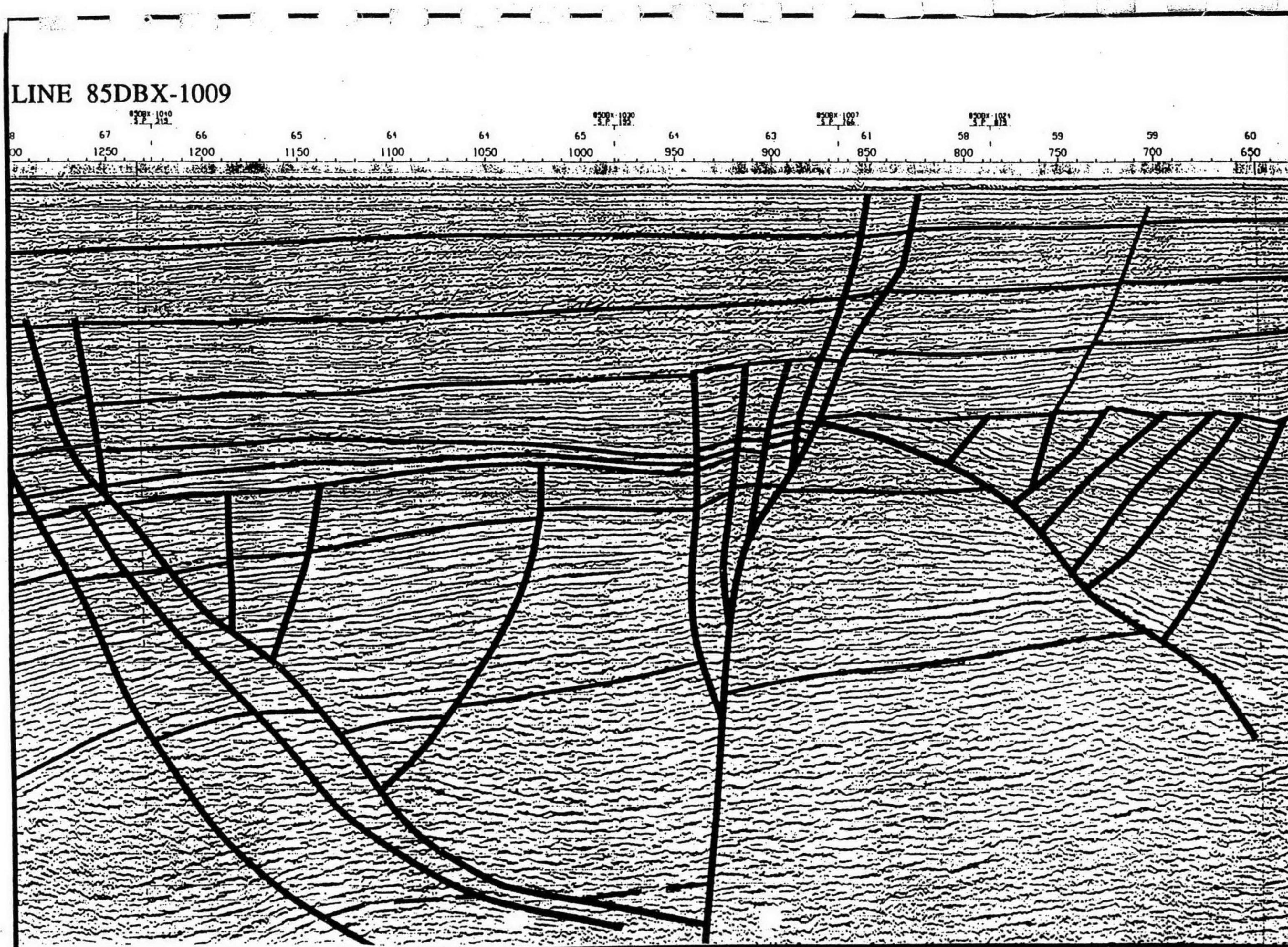
(11) Face loading of Jurassic from Triassic source
The Rankin Trend escarpment is onlapped by Jurassic sediments. These sediments dip into the Kendrew Terrace axis and it is possible that face loading of the Jurassic by Triassic source can occur and vice versa. (see Figure 53).

KANGAROO SYNCLINE AREA

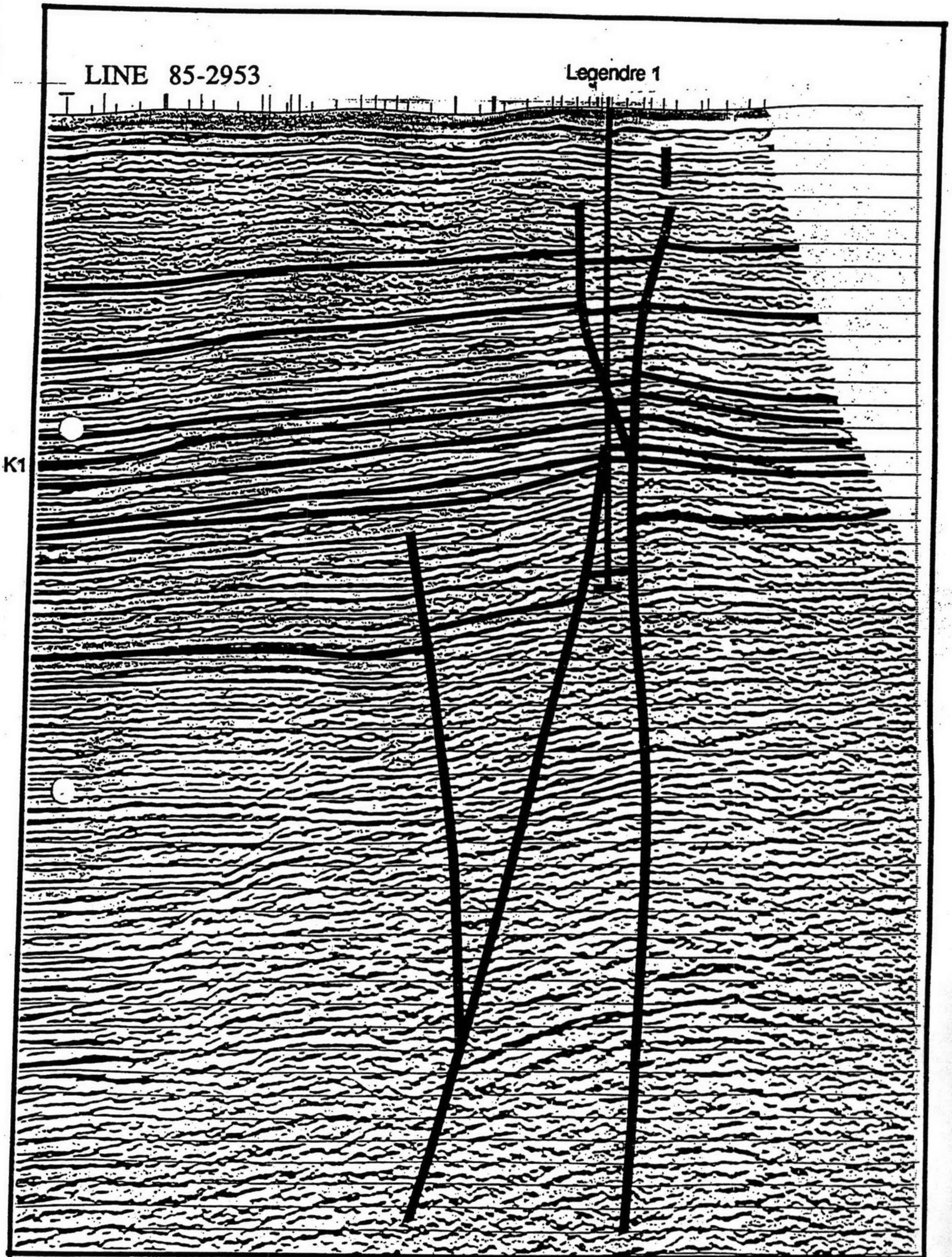
(12) Large Rollovers with Potential Closure (not illustrated in Figure 53)
There are major rollovers seen on dip lines in the area although major closure has not been established by this study. (see Figure 68).

(13) Structure Draining Mature Source
Gandara 1 appears to be drilled on a valid structural play (tilted fault block) but the structure is peculiar in that it drains a completely immature source area (see Figure 67). Saturn 1 is located off structure below the level of the Main Unconformity.

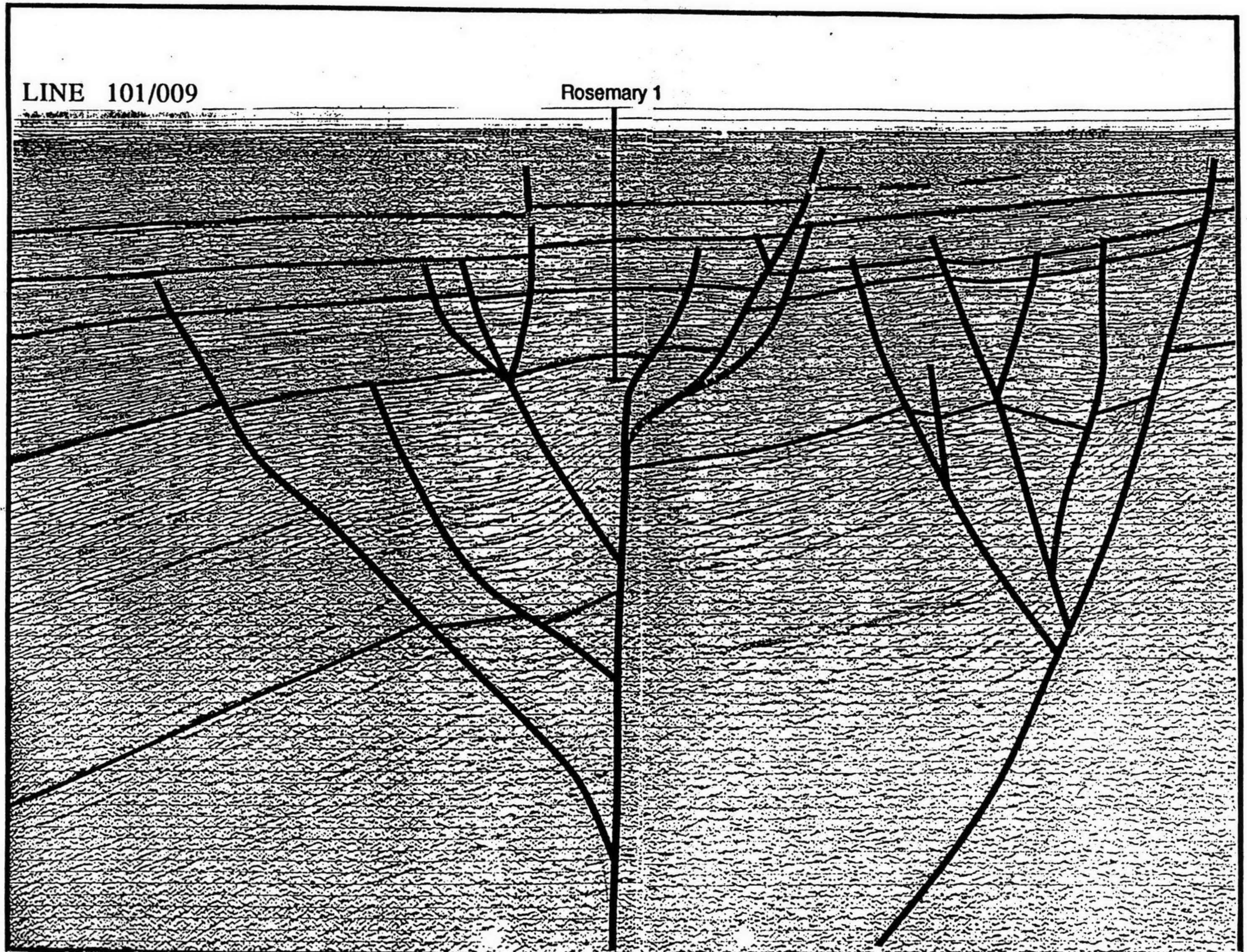
(14) Transgressive Sand on the Main Unconformity (not illustrated in Figure 53)
Three wells to the west of the Rankin Trend have reservoir sections, generally undated, which rest probably on the pre-Main Unconformity section. These wells are Gandara 1, Saturn 1 and Malus 1. (see Enclosure 2)

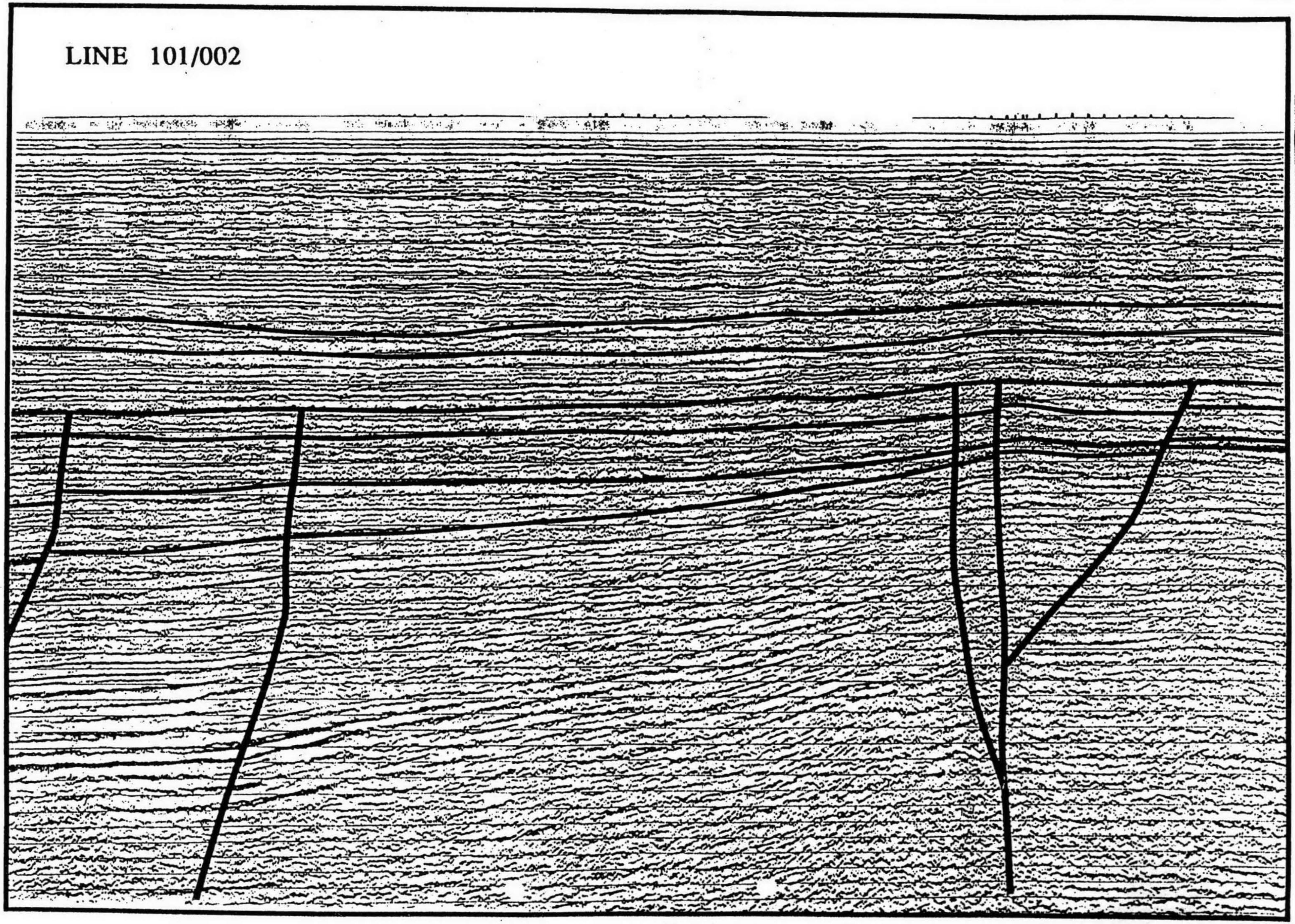


Seismic Line 85DBX-1009 (C) Part of Cross-Section C-C'. Figure 59

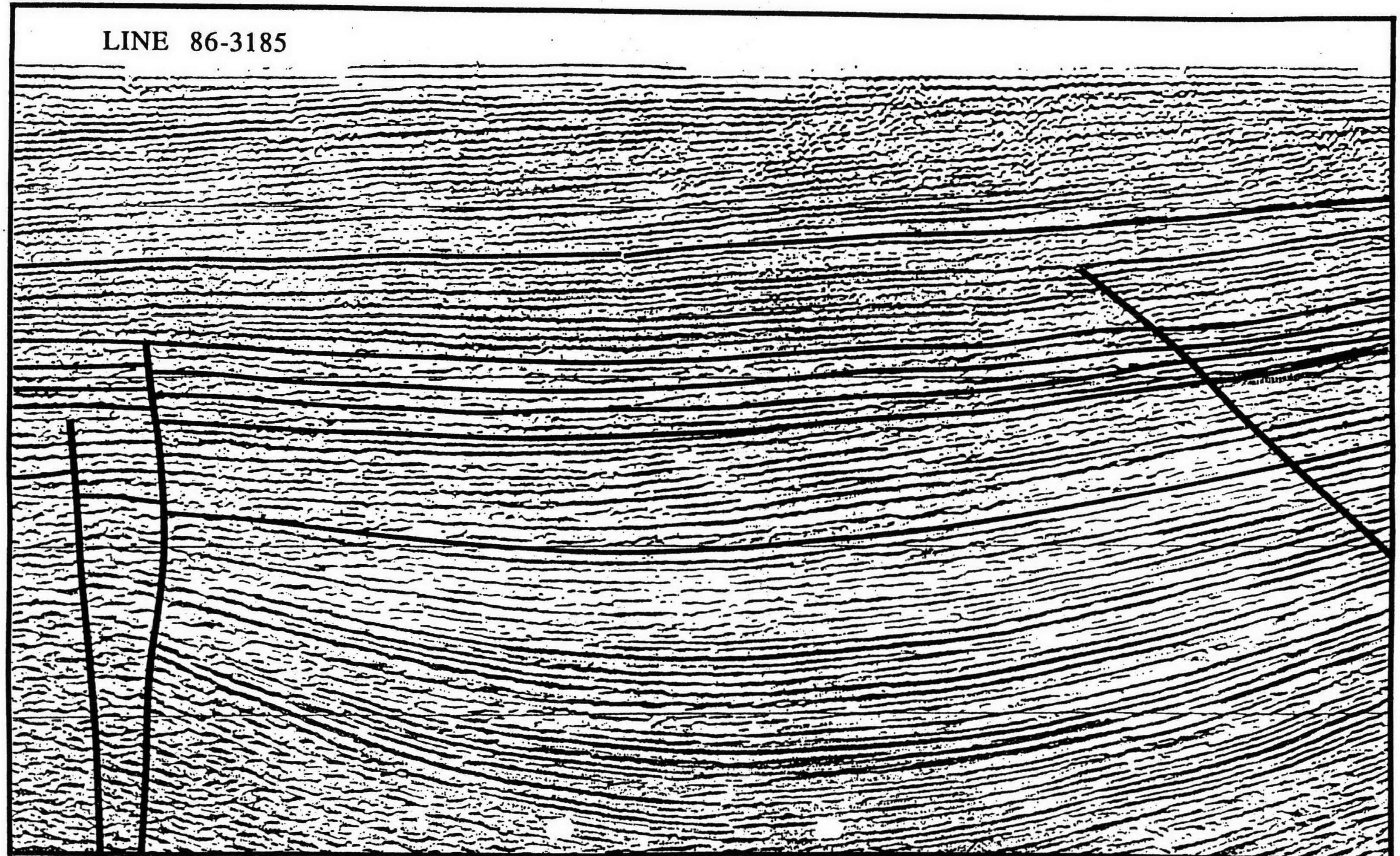


Seismic Line 85-2953 (A) Part of Cross-Section E-E'. Figure 60

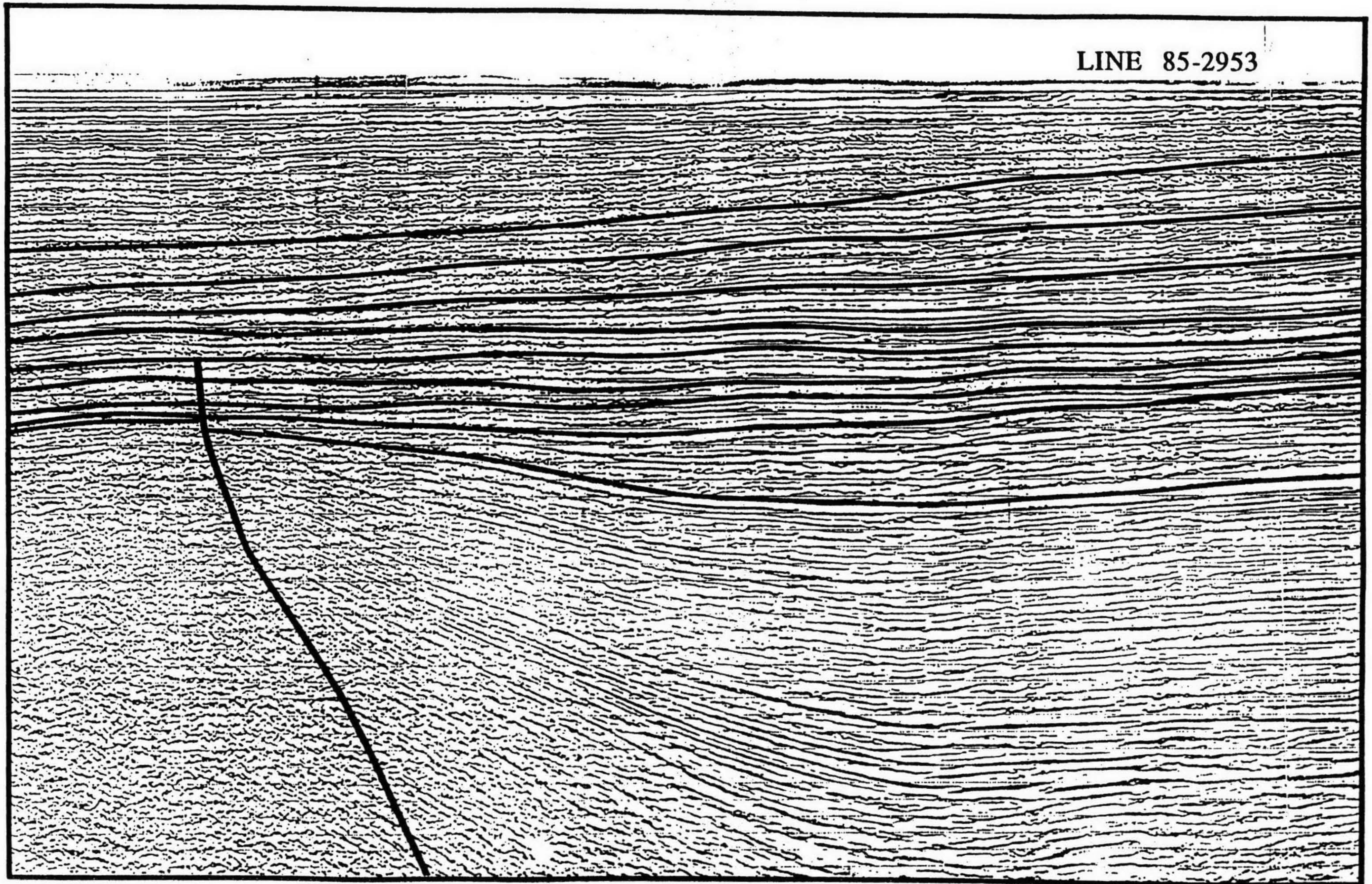

LINE 101/009
Rosemary 1



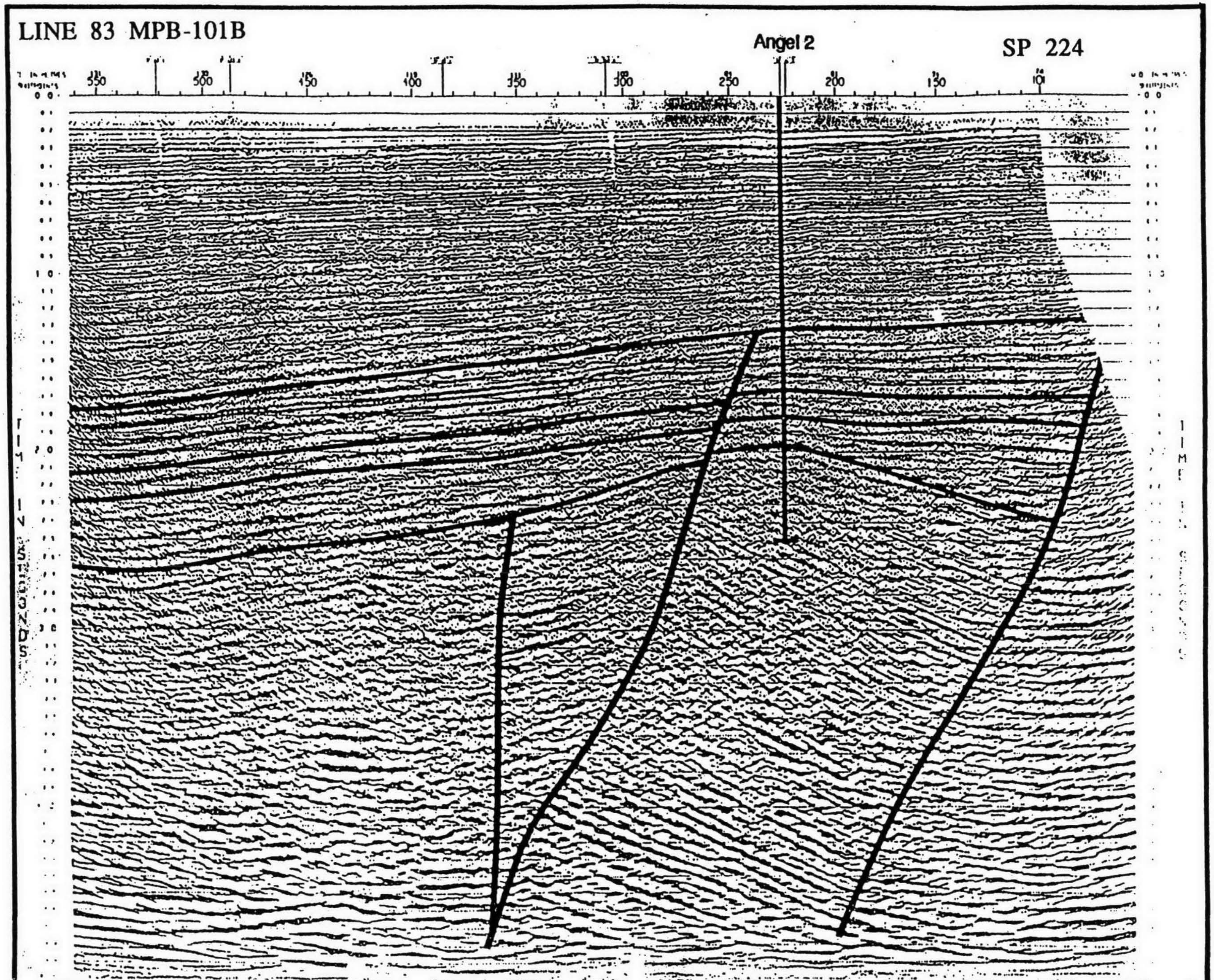
Seismic Line 101/002 AGSO Line. Figure 62



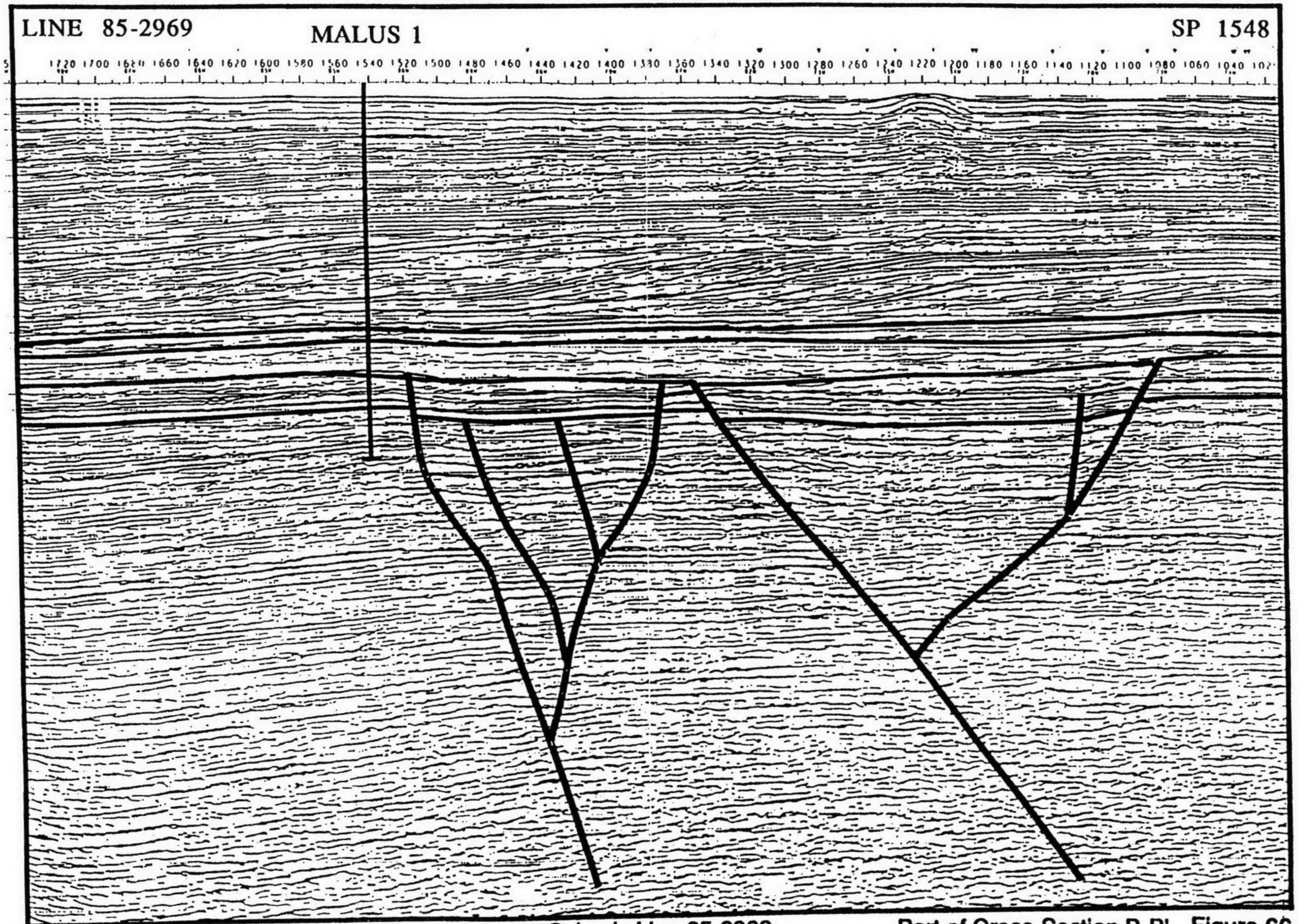
Seismic Line 86-3185 Part of Cross Section D-D' Figure [illegible]



Seismic Line 85-2953 (B) Part of Cross-Section E-E'. Figure 64



Seismic Line 83MPB-101 (B)   Part of Cross-Section E-E'   Figure 6E



Seismic Line 85-2969

Part of Cross-Section B-B'. Figure 66

Saturn 1:A glauconitic coarse grained sandstone at 3016-3022m (6m) occurs beneath Time Slice J10 and above Time Slice J2. The sand is undated and tentatively interpreted as being Time Slice J9 age. In fact it could be any age between Time Slice J2 (Barrow Group claystones) and Time Slice J9 (Dingo Claystone). The sand was untested but had a strong gas condensate show. (see Figure 68)

Malus 1: A coarse grained sand at 3089. 8 to 3099. 2m sub sea (9. 4m) dated as *W. spectabilis*, Time Slice J8 sits above Time Slice J1 or Time Slice T6 age and beneath Time Slice K1 claystone. (see Figure 66)

Gandara 1: A coarser grained sandy section at the top of a definite (*C. cooksoniae*) Time Slice J6 section of shale and claystones in the interval 2932 to 2965m sub sea (33m) the uppermost part of which is *C. dampieri* overlain by K1(see Figure 67).

These sands appear to be related to deposition or reworking of sediment associated with late Time Slice J6 early Time Slice J7 formation of the Lewis Trough and Main Unconformity surface. The sands have several possible modes of formation. They are found on the flank of the uplifted Rankin Trend and likely represent either material shed from the flanks or reworked by marine transgressive events. Whatever the depositional mechanism the sandstone has several factors that make it a prospective target across the area. This is because it is:

(i)probably deposited across the entire region.

(ii)always overlain by seal facies either upper Jurassic Time Slice J10 or lower Cretaceous Time Slice K1.

(iii) generally sealed below by claystone.

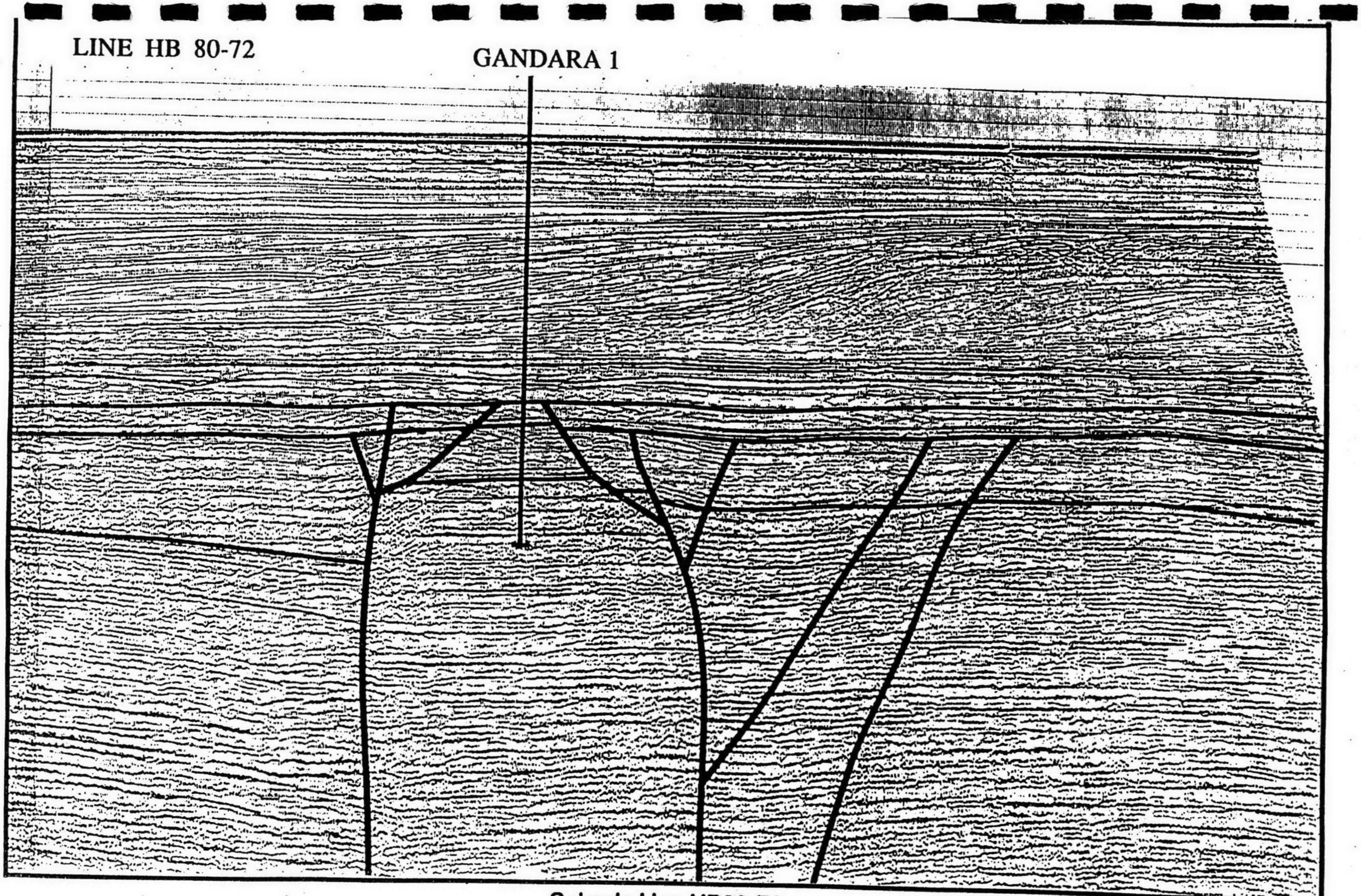
(iv)generally thin (10m) but up to 50m thick with good porosity.

(v) fault block and structural plays valid where fault or Triassic subcrop sourcing possible.

(vi)the equivalent of the Biggada Formation which has high pressure gas at Barrow Island.

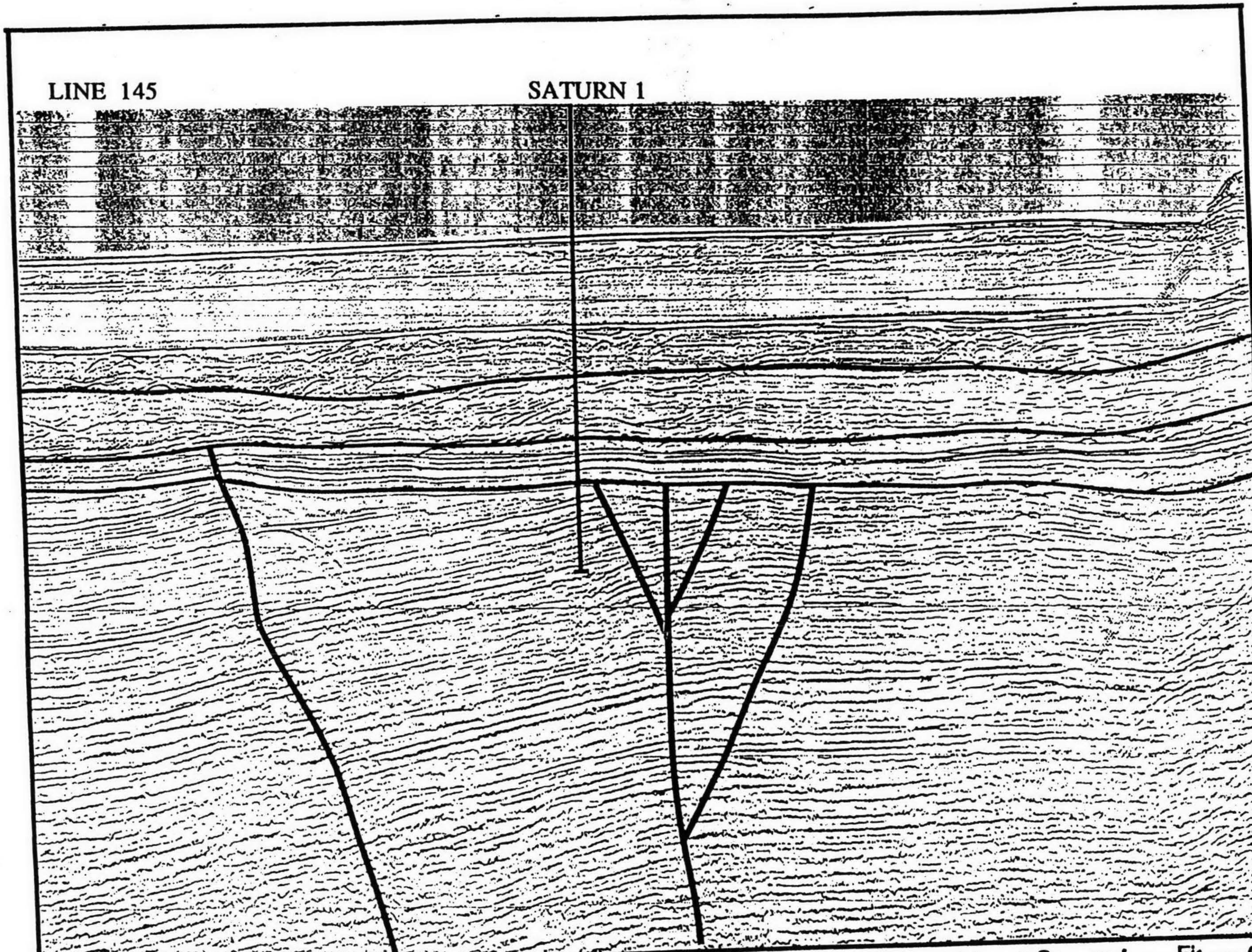
<u>(15) Poor Data Quality in Kendrew Terrace Area</u>

Potential traps on the Kendrew Terrace are difficult to define due to poor seismic quality. Figures 65 and 69 illustrate the poor seismic quality typical of this area.

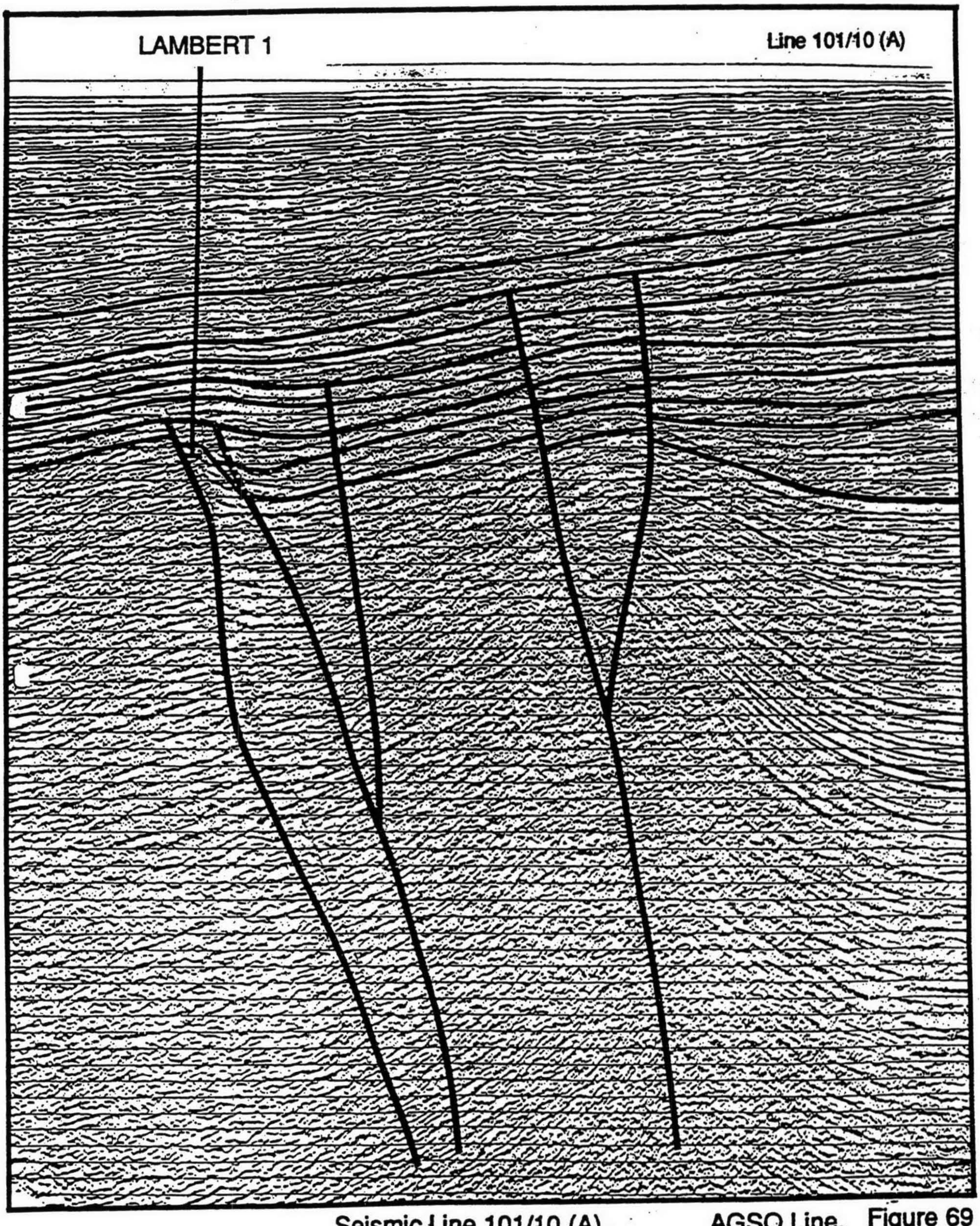


Seismic Line HB80-72

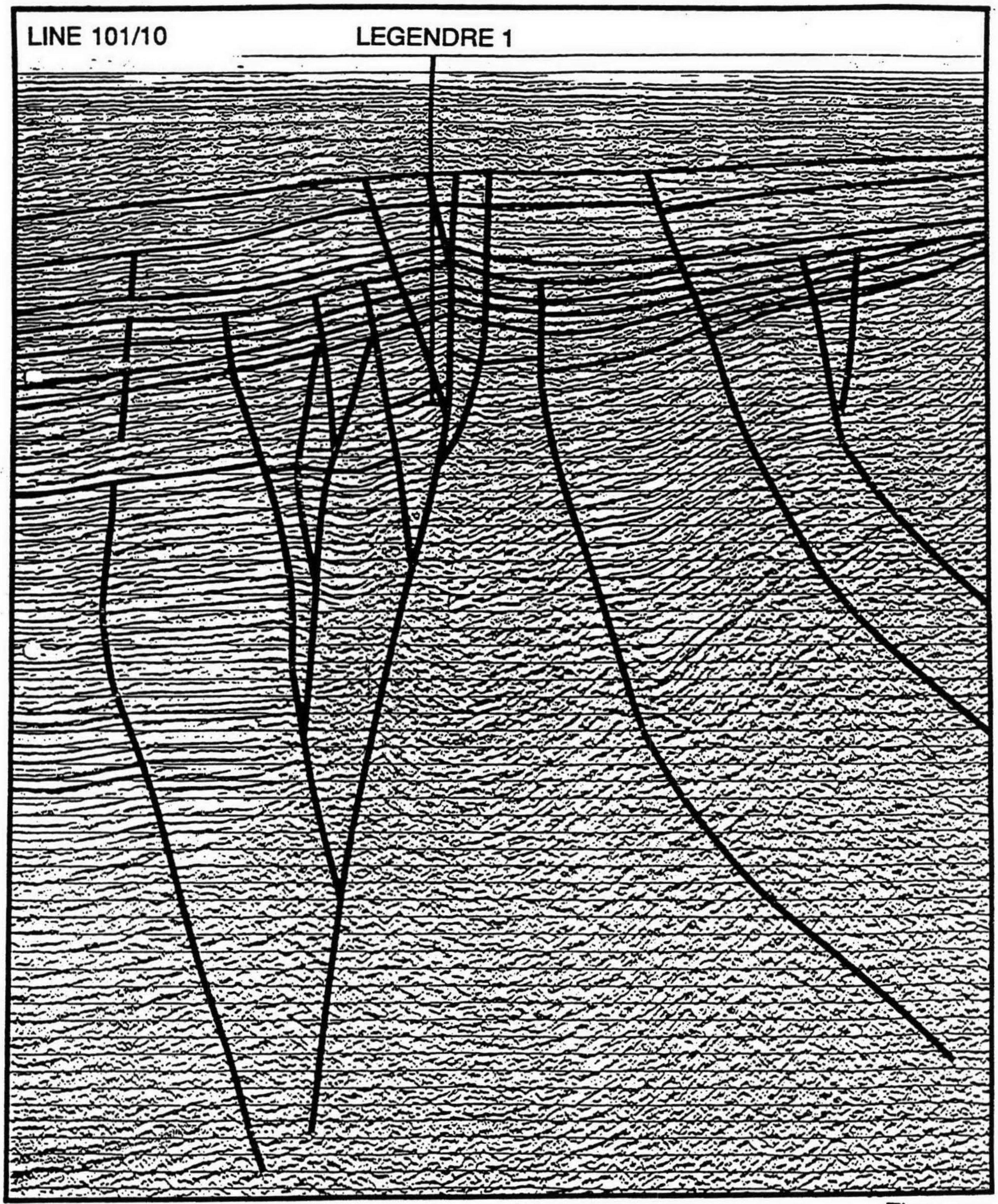
Part of Cross-Section D-D'. Figure 67



Seismic Line LINE [illegible] [illegible] of C[illegible]s-Section A [illegible] Figure 68



Seismic Line 101/10 (A) AGSO Line. Figure 69



Seismic Line 101/10 (B) AGSO Line. Figure 70

PALAEOGEOGRAPHY AND PETROLEUM SYSTEMS OVERVIEW

The Dampier Sub-basin is an amalgam of two petroleum super systems; the Gondwanan and the Westralian. These systems are separated by a major regional unconformity of middle Triassic age (Time Slice TR4). The relationships between the components of these systems, source rocks and reservoirs, together with the timing of trap formation and source maturation is shown in Figure 71.

Palaeogeography and Critical Features of the Gondwanan Petroleum System

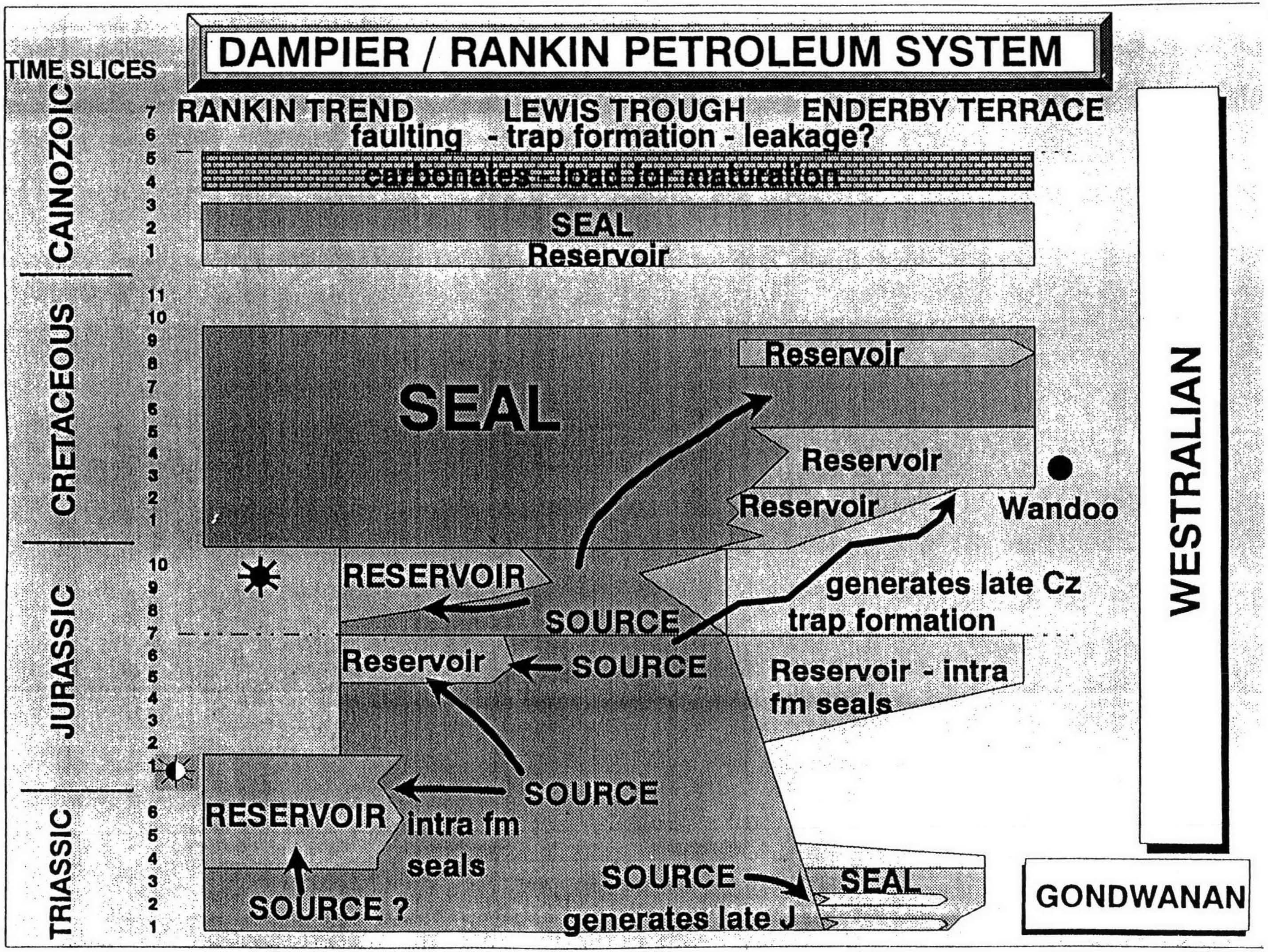
Earliest encountered sedimentation occurs in Time Slice TR1 or latest Permian and represents a major marine transgression onto Permian or older sediments of the Enderby Terrace. The transgression resulted in a basal reworked sandstone overlain by a restricted shallow marine shelf claystone. This claystone provides the first potential source and seal rock in the area. Oolitic shelf carbonates are interbedded with the shelf claystone and constitute potential reservoirs. A clastic source probably existed to the northeast and north. This transgression peaked at the end of Time Slice TR3, followed by a regression in Time Slice TR4. Deltaic and fluvial meander belt systems prograded from the north and north east across the area until a regional unconformity at Time Slice TR4 terminated the Gondwanan Petroleum System. To date there have been no discoveries in the Gondwanan Petroleum System in the Dampier Sub-basin but potential does exist for oil and gas condensate sourced from within this system to have accumulated within overlying and adjacent Westralian Petroleum System reservoirs.

Potential drillable reservoirs within this system are all on the Enderby Terrace and include basal transgressive sands and oolitic limestones (Time Slice TR1 to TR3) sealed by, and within, a potential source interval that matured in the late Cainozoic. Elsewhere in the area the Gondwanan System is deeply buried and would have matured during the middle to late Jurassic (Time Slices J7 to J10).

Palaeogeography and Critical Features of the Westralian Petroleum System:

To date, all of the successful plays in the Dampier Sub-basin have been within the Westralian System. The giant gas condensate fields of the Rankin Trend (Time Slices TR5 to J1) are reservoired in fluvio-deltaic and marginal marine sands that are probably sourced from associated finer grained facies (with a potential for input from the underlying Gondwanan System). The oil reserves of the Lewis Trough area occur at the top of mass flow depositional lobe sequences (Time Slices J9 to K1), the oil being sourced from associated organic rich basin shales(Time Slice J6 to J10). The adjacent Enderby Terrace is on a migration pathway for oil sourced from the Lewis Trough.

Deposition in the Westralian Petroleum System commenced in Time Slice TR5, with sediments still sourced from the southeast but with open marine circulation now established in the northwest. Deltaic lobes built out from the southeast, with marginal marine conditions in the central area and marine shallow shelf sediments in the southwest. During Time Slice TR6 the delta system built out into the Rankin area. The adjacent marine system appears to have been of moderate to high energy with significant tidal and wave influence. Tidal channel and beach deposits



Schematic Diagram of the Westralian Petroleum System in the Dampier Sub-basin

Figure 71

fringe the deltaic system. Point bars, fluvial and estuarine channel and offshore bars are present or predicted as major reservoirs. The best source rock quality is consistently associated with the lower delta plain facies. Time Slice TR6 is reservoir to the major gas condensate fields of the Rankin Trend, the better reservoirs are the marginal marine estuarine or beach sands.

Significant tectonic activity late in Time Slice J1 resulted in an area northwest and adjacent to the Enderby Terrace becoming a major depocentre. This event was associated with a major regression, a shift in source area to the northeast and an apparent reduction in marine energy. The regression probably exposed the Enderby Terrace resulting in incision of the terrace. Following on from this a late Time Slice J1 transgressive phase resulted in reworked transgressive sands on the Enderby Terrace. Overall the area was a low energy shallow marine shelf with deltaic lobes coming from the southeast with little indication of tidal or wave influence in the marginal marine zone that flanked the deltaic zones. The peak of the transgression occurred in Time Slice J2 with an offshore oolitic shoal being deposited in the Gandara area. The same pattern of a moderate to low energy shallow marine shelf continues until Time Slice J5, with a maximum transgression at Time Slice J3 when limestones where deposited in the Enderby Terrace area.

The major faulting that resulted in formation of the Lewis Trough commenced at the end of Time Slice J5. This event is also marked by a shift of dominant sediment source area from the east. Henceforth the Lewis Trough and the Rosemary Fault System (southeastern margin of the trough) are the dominant tectonic elements in the basins evolution. Deltas built out across the Enderby Terrace to the edge of the Lewis Trough and input sediment directly into the Trough. The Rankin Platform margin on the other side of the trough acted as a dam to sediment from this eastern source and does not appear to be a major source area. From Time Slice J5 to J7 the best source rock correlates with the prodelta facies of the shelf edge deltas. Poorer quality source rocks in the vicinity of Madeleine may reflect reworking from the Rankin Trend area. Some volcanism occurred in the hinterland and resulted in arkosic sandstones of poorer reservoir quality, due in part to diagenetic porosity reductions. The Enderby Terrace was episodically exposed and the Rankin Trend was either sub-aerially exposed or very shallow marine.

By Time Slice J8 the Lewis Trough was a marine embayment closed, or restricted, at its northern end. Sea level appears to be very high and mass flow deposition commenced in the Lewis Trough. The mass flows deposits are dominated by several depositional lobes that all appear to be fed from submarine canyons or channels which cross a marine shelf on the Enderby Terrace. The sand source is speculated to be a coastal zone in the hinterland which feeds the sand into the proximal end of the channels. These depositional lobe deposits continue throughout Time Slices J9 and J10. Major depositional lobes with discrete feeder channels occur in the vicinity of Montague, Angel, Legendre and Rosemary and the possibility exists for another lobe in the vicinity of Malus. The background sedimentation is marine clays with episodic indications of anoxia. These clays are the most oil prone source rocks encountered within the Westralian System of this basin. A pattern of better source rock quality towards the northeastern end of the

Lewis Trough is observed. The major oil accumulations of the Lewis Trough are all reservoired within the uppermost sands of these depositional lobes and sourced from the associated basin claystones. Oil from these source rocks has also migrated into the Rankin Trend reservoirs and onto the Enderby Terrace. The Lewis Trough was filled by the end of Time Slice J10.

A key to the Westralian Petrôleum Systems prospectivity is the outer shelf to basin claystones of Cretaceous Time Slices K2 to K7. These claystones were deposited during the margin sag phase when marine transgression reached a peak. These plastic claystones form an extremely effective regional seal facies on all of the major accumulations of the area.

The earliest Cretaceous marks a major change to sedimentation in the area. A continuing sea level rise establishes open oceanic circulation across the area and major sediment supply is abruptly terminated. Sediments of the earliest Time Slice K1 appear to be sourced from the southwest Barrow Sub-basin area. These distal prodelta deposits are good source rocks. The last vestiges of the mass flow deposits occur in the far northwest of the basin centred on the Talisman area. The Time Slice K2 transgression peaks as Greater India clears Australia and the area enters an early though not pronounced margin sag phase hinged on the Rosemary Fault System and characterised by extreme clastic starvation. Henceforth deposition is on an open marine shelf, shelf slope and base of slope environments.

The Rosemary Fault System defines an approximate shelf hinge line and the compacting Jurassic sediments of the adjacent Lewis Trough define a depocentre immediately northwest of this hingeline. Glauconitic sandstone deposition is characteristic of the outer and middle shelf deposition from Time Slice K1 onwards, with slope and basin siltstones and claystones having an increasing carbonate content offshore. The best organic preservation is associated with middle to outer shelf and shelf break in the vicinity of Withnell 1 and Rosemary 1. This area also appears to be a locus for minor clastic sediment input. The transgression associated with this early margin sag phase peaks in Time Slice K4 when the coast is probably far to the east. By this time the Rankin Trend, a positive submarine topographic feature has been finally onlapped and buried by a thin claystone sequence.

Major margin sag commences as India finally clears Australia in Time slice K5-K7. Radiolarites, marls and carbonates dominate deposition on an extremely clastic-starved shelf, and form the first substantial regional seal facies across the entire basin. Regional or global oceanic oxygen minima events occur in Time Slices K8 and K9. The best source rocks occur in upper slope deposits but lack maturity. A minor clastic source is still centred on the Rosemary area. This general pattern prevails throughout the remainder of the Cretaceous.

In earliest Time Slice Cz1 a major sea level fall occurred. A possible zone of glauconitic sandstone is predicted to have formed on the shelf margin at this time. The deposits are thought to form a band which parallels the palaeo-submarine topography , and this in turn is a probable reflection of underlying compaction in the

Lewis Trough and around the Rankin Trend. These glauconitic sandstones are of reservoir quality but require fault migration from underlying source as local source rocks are immature.

Post Time Slice Cz1 deposition is poorly constrained by palynological data and is not discussed here.

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