AGSO



# A PRELIMINARY PROPOSAL FOR ODP DRILLING:

## CARBONATE CLINOFORMS ON AUSTRALIA'S NORTH WEST SHELF – A KEY LINK IN GLOBAL NEOGENE SEA-LEVEL HISTORY

*by*

*M. Bradshaw, G. Karner, J. Kaldi,*
*S. Newman & L.B. Collins*



RECORD 1998/29



AGSO
AUSTRALIAN
GEOLOGICAL SURVEY
ORGANISATION

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Petroleum & Marine Division

AGSO Record 1998/29


# A PRELIMINARY PROPOSAL FOR ODP DRILLING:

## CARBONATE CLINOFORMS ON AUSTRALIA'S NORTH WEST SHELF - A KEY LINK IN GLOBAL NEOGENE SEA-LEVEL HISTORY

**Dr Marita Bradshaw**

Australian Geological Survey Organisation

GPO Box 378, Canberra ACT 2601 AUSTRALIA

**Dr Garry Karner**

Lamont-Doherty Earth Observatory, Columbia University

RT 9W / Palisades, NY 10964-8000 USA

**Professor John Kaldi**

National Centre for Petroleum Geology and Geophysics

Thebarton Campus, University of Adelaide, SA 5005 AUSTRALIA

**Stephen Newman**

Woodside Offshore Petroleum Pty Ltd

1 Adelaide Terrace, Perth WA 6000 AUSTRALIA

**Associate Professor Lindsay B Collins**

School of Applied Geology, Curtin University of Technology

GPO Box U 1987, Perth, Western Australia 6845

## DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister for Primary Industries and Energy: Hon. J. Anderson, M.P.
Minister for Resources and Energy: Senator the Hon. W.R. Parer
Secretary: Ken Matthews

## AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Executive Director: Neil Williams

ISSN: 1039-0073
ISBN: 0 642 27365 0

# A PRELIMINARY PROPOSAL FOR ODP DRILLING:

## CARBONATE CLINOFORMS ON AUSTRALIA'S NORTH WEST SHELF - A KEY LINK IN GLOBAL NEOGENE SEA-LEVEL HISTORY

### 1. Abstract

Documenting and understanding the timing, magnitudes, and causes of sea-level changes represents an important and challenging goal to the research community; and is one of key goals of ODP's Long Range Plan. The processes of sea-level change are poorly understood, both in regards to controls and mechanisms; yet, the impact of fluctuating sea-level on the stratal architecture and sediment facies on margins and basins is profound. We are presently at a cross-roads in the study of eustasy. The current paradigm is to study regions supposedly free of the effects of tectonics, as for example the New Jersey Margin. However, recent and continuing work is finding that "passive" margins, irrespective of age, are far from passive (e.g., Karner et al., 1992; Driscoll & Karner, 1998). In addition, the present paradigm is also concentrating on terrigeneous margins where the recovery and dating of sand-prone systems is particularly problematic. We are proposing to investigate the timing and amplitude of eustatic events on the northwest Australian margin through a transect of drill sites along well-defined Neogene carbonate progradational systems. Because of the carbonate composition, we believe that we will be able to increase recovery within both low-stand and high-stand systems in addition to dating the sequences. Perhaps much more importantly, rather than shying from the tectonic issue, we will integrate the tectonic studies of the northwest margin into our sequence stratigraphic framework of the region.

In the central Carnarvon Basin, seaward of the Rankin Platform, there are prograding Late Oligocene to Pliocene carbonate sequences. As on the New Jersey Margin, these can be drilled in a transect to precisely ascertain the ages of depositional sequences and their bounding surfaces, to develop better subsidence models, and to derive reliable paleobathymetric estimates.

High-resolution 3D seismic data are available from industry, who are partners in this proposal. The sequences are 0.3-0.4 seconds thick, and a full range of suitable clinoforms may be fully penetrated in holes less than 1000 m deep. We

believe that the tectonic effects that plague the development of global eustatic sea-level curves can be backed out from the sea-level history by using the existing data sets in this major petroleum province and the technique of Quantitative Basin Analysis (see section 7.1).

In the region of this proposal, seismic mapping of a number of horizons in the Tertiary has been done on 3D datasets and is available. Experienced company operatives can help in selecting safe sites. Well-documented biostratigraphic zonations for planktic foraminifera, nannofossils and palynomorphs, tied to international zonation, are available and being continually upgraded.

We propose 5-6 high-resolution drill sites, located on 3D data and tied back to recent exploration wells, to address the sea-level history of the entire prograding sequence. Water depths are generally 200-500 m.

**2. Scientific rationale: the key arguments**

*2.1 Sea-level Change* - One of ODP's long term goals is to drill a variety of passive margins to unravel the eustatic signal from local tectonic and depositional effects. The Neogene sequence of the North West Shelf is an excellent candidate to form part of this planned global array. As the same time interval studied on the New Jersey Margin (Leg 174A) will be intersected. It also offers the opportunity to drill paired sites either side of clinoform "roll-overs" to provide accurate estimates of water depth at time of deposition as done in the clastic section on Leg 174A (Mountain & Miller, 1997). The integration of data from the stratal geometry, sedimentary facies and fossil content will put constraints on the amplitudes and rates of sea-level change in the Neogene that can be compared with those derived for the baseline case of the New Jersey Margin.

On the North West Shelf there is a wealth of regional information on stratigraphy, tectonic history and biostratigraphy from inboard petroleum wells and onshore outcrop. The results from the outer shelf provided by ODP drilling can be placed in context, and will have direct relevance all along Australia's western margin and elsewhere in region (Indonesia) as well as globally.

*2.2 Climate Change* - Cored sections of the Neogene from the North West Shelf will also provide a record of proxies of climate change. Already, from the limited log and cuttings information, it is possible to recognise low frequency events on the order of ten or more million years, when increased clastic content within the

carbonates is the signal of a more humid period in the hinterland. There is one such episode in the Early Pliocene that correlates with the postulated Antarctic deglaciation (White, 1994). In the cores collected during ODP Leg 122 from the Exmouth Plateau a similar pattern is seen covering the interval from the Cenomanian to the Eocene (Golovchenko et al., 1992). Cores from this proposed drilling may extend this record into the Neogene and will probably reveal other higher frequency cycles.

*2.3 Diagenesis and interstitial water chemistry* - The proposed series of holes along a transect into prograding packages of varying ages also provides the potential for comparative studies of carbonate diagenesis, and other key processes related to sediments and pore fluids that may provide another record of sea-level and climate change. One of the unexpected results of Leg 174A was the relationship between sea-level fluctuations and interstitial water chemistry, as seen in salinity variations with depth consistent with alternate exposure of the shelf during the Pliocene-Pleistocene and then renewed flooding by seawater.

*2.4 Why is ODP drilling necessary?* - Although this region has been extensively examined by industry, both by seismic surveys and exploration drilling, until recently there has been little interest in the Cainozoic section. Consequently, very few *in situ* samples have been taken and the biostratigraphy depends on cuttings; and even these are lacking from the upper cased sections of many exploration wells. Thus, despite the superb high resolution seismic 3D data sets and the good log coverage, the Cainozoic, and especially the Neogene section, is very inadequately sampled. The detailed knowledge of sedimentary facies and ages required to fully interpret the seismic profiles and time maps is lacking. ODP drilling, with its continuous coring, will overcome the shortcomings of the existing data sets, and allow the sea-level history in this area to be elucidated. When the tectonics are backed out, via modelling of the seismic data using Quantitative Basin Analysis (Karner et al., 1997; Driscoll & Karner, 1998) global sea-level history can be addressed.

## 3. Geological setting

Neogene carbonate-rich sediments cover the entire North West Shelf including the Carnarvon Basin. The general setting of the basin on Australia's western margin is shown in Figure 1, and the main structural elements in Figure 2.

The primary area of interest is seaward of the Rankin Platform, the high block on the western edge of the Dampier Sub-basin annotated as 'RP' on Figure 2. The Neogene section of the Carnarvon Basin is the upper part of a marine passive margin sequence. Following sea-floor spreading in the Early Cretaceous, fine grained clastic sediments were deposited. From the Late Cretaceous onwards the sequence became increasingly dominated by carbonate sedimentation and prograding wedges are seen in the section at this level (Rasidi, 1995) but the clinoforms are most spectacularly developed in the Neogene (Figure 3).

**4. Summary of existing surveys, data sets and sedimentological knowledge**

A great deal of biostratigraphic information has been assembled as a result of company activity in the Carnarvon Basin over the last four decades. Regional biostratigraphic and paleogeographic studies that specifically address the Tertiary section of the Carnarvon Basin are available (Apthorpe, 1988; Langford et al., 1995). Hull et al. (1998) provide a sequence stratigraphic model developed from log motifs through the carbonate section, that could be evaluated from cores collected during the proposed ODP drilling. A standard stratigraphic column for the Barrow and Dampier Sub-basins with age control is shown in Figure 4 along with the sequence stratigraphic events documented by Hull et al. (1998).

There are more than twenty exploration wells in the area of interest (Figure 5) and hundreds of thousands of kilometres of seismic, including detailed 3D surveys as well as AGSO's high-resolution and deep seismic grids. A time slice on a Neogene reflector (Figure 6) indicates the quality of the resultant maps and shows a spectacularly channelled surface developed seaward of the Rankin Platform. Industry analysis has split the Late Cretaceous to Cainozoic sequence into dozens of seismic stratigraphic packages that can be used as a basis for ODP planning. Figure 7 from Hull et al. (1998) shows the level of detail that has been achieved for part of the Neogene section.

**5. Relevance to industry**

The proposed ODP coring provides an opportunity to obtain high quality lithological and biostratigraphic information from part of the section that has been rarely sampled, and in most wells lies behind casing. Despite hundreds of wells

having been drilled on the North West Shelf there are no cores in the Neogene section. However, knowledge of the lithological and age architecture of the Tertiary is crucial to exploration. This is especially so for seismic depth conversion in a poorly understood section with lateral and vertical varying facies and complex geometries. The Neogene also has a crucial role as the thermal load for maturation of the underlying Mesozoic section. The maturation history is, in part, controlled by the mosaic of clinoforms.

Predictive diagenetic models that may be developed will also have important application in petroleum engineering (drilling and production) on the North West Shelf. Investigation of re-injecting CO2 from one of the giant gas fields in the area is underway woth the aim of limiting emissions of greenhouse gas. Detailed knowledge of the lithology and pore fluid properties of the Tertiary section obtained from ODP coring would be a very valuable data set in these studies.

## 6. Safety Issues

The Carnarvon Basin is a major hydrocarbon province, but almost all oil and gas accumulations are trapped beneath the regional seal provided by Cretaceous shales. The one exception is the Maitland gas and condensate field, in which Paleocene sands are sealed by Eocene shale and marl (Sit et al , 1994). Maitland is located in the Barrow Sub-basin, well over 100 km inboard of the proposed drilling sites (Figure 2) and a DHI is clearly evident on the seismic over the gas accumulation. Similar hydrocarbon accumulations are considered unlikely in the Neogene section as reservoir sand, and shale seal, facies are not represented in the predominantly carbonate section, especially so in the outer shelf and slope location of the proposed sites.

It is our intention to work closely with the ODP Pollution Prevention and Safety Panel to ensure a safe and clean drilling operation. The detailed 3D seismic grid and close involvement of industry will enable sites to be selected that have no likelihood of intersecting hydrocarbons. The resolution of the information is more than sufficient to avoid sites with structural closure, anomalous velocities indicative of gas-filled porosity, and fault conduits for migration of hydrocarbons. The mature section lies at more than 2 km below the Neogene targets and is separated from them by a competent regional seal.

Weather conditions for drilling operations can be ideal on the North West Shelf. The intensive industry activity in the area has resulted in a good understanding of the weather behaviour.

## 7. Drilling objectives and analytical tools

*7.1 Paleoceanography, sediment history and tectonics* - The northward movement of Australia since the Eocene has greatly influenced global ocean circulation patterns and consequently global climate. The Neogene closure of the northern seaway, separating Australia from southeast Asia, changed global current patterns, with the equatorial current system between Pacific and Indian Ocean greatly reduced, and deep water progressively cut off. This had profound global climatic effects, affecting ice cap growth and hence sea-level and oceanic circulation. ODP drilling in the Carnarvon Basin would elucidate local changes in sediment history related to closing of the seaway (Oligocene end of chert formation, invasion of larger neritic foraminiferids in the Late Oligocene) and these could help better define global changes.

The northward movement of Australia has also resulted in a convergent plate boundary and pervasive tectonic effects, felt as far afield as the Carnarvon Basin. To back-out these tectonic effects from the eustatic signal they need to be quantified. Quantitative Basin Analysis (QBA) (Karner et al., 1997; Driscoll & Karner, 1998) combines quantitative kinematic and isostatic basin modelling with the principles of sequence stratigraphy to determine the tectonic significance of the major syn- and post-rift stratigraphic packages in a basin. By iterating between the modelled time-line basin stratigraphy and the observed stratal patterns, sedimentary facies, and estimated palaeoenvironments allows us to establish a quantitative relationship between the tectonic deformation of the lithosphere and the formation of stratigraphic sequences and their bounding unconformities. In particular, QBA helps to decipher the interaction between tectonic, erosional, and sedimentary processes and how they determine basin architecture, sedimentary facies, and the stratigraphic stacking patterns. Because tectonic events synchronously both create and destroy space - the formation of accommodation with concomitant footwall rebound - broad sediment deposition less than 100-200 m thick is the tell-tale signal of eustasy.

Although the Neogene development of the North West Shelf has been dominated by carbonate clastic systems generally infilling a sediment restricted

margin, the collision of Australia with Indonesia has led to the formation of onshore and offshore inversion structures. The Earth's lithosphere deforms when subjected to vertical and horizontal tectonic forces because it is not perfectly rigid. The deformation has both elastic (flexural; long-wavelength deformation) and inelastic (brittle; relatively short-wavelength deformation) components. Brittle deformation of the upper lithosphere is influenced by the distribution of existing faults and fractures in the crust and their orientation with respect to the applied tectonic force. AGSO's regional deep seismic grid and industry data provide excellent coverage of the North West Shelf's structural architecture (Stagg & Colwell, 1994). As discussed by Karner et al., (1992), the induced flexural deformation is governed by the pre-existing lithospheric deflection, the effective elastic thickness of the lithosphere when the force was applied, and the magnitude of the applied force. In general, the brittle deformation appears to be the most recognisable response of the lithosphere to in-plane force variations and tends to obscure the effects of any flexural deformation. The North West Shelf is no exception; inversion appears to best developed in the large accommodation zones along the margin where sub-basins terminate and the extensional deformation is offset in a right lateral manner (Driscoll & Karner, 1996). If these areas are avoided, we should be able to mitigate against severe inversion problems. The proposed study area, located seaward of the Rankin Platform, lies adjacent to the Dampier Sub-basin and removed from its junctions with the Barrow and Beagle sub-basins (Figure 2).

*7.2 Environmental and dating tools* - Planktonic and benthic foraminiferal biotic variations have all been thoroughly calibrated to global schemes, and benthic forams will provide key paleoenvironmental information. Nannofossils will also be excellent dating tools, and palynomorphs will provide paleoclimatic information for adjacent land areas. Trace elements, such as Mg and Sr measured in foraminiferal shells, can provide constraints on paleotemperatures, and are applicable further back in time than biotic approaches that require the presence of extant species or their known evolutionary ancestors.

The Neogene section should provide some stable isotope records that are not altered by dissolution or burial diagenesis, at least in the upper 400-500 metres of section (Miller et al., 1987). How useful they will be is an open question, but they are not regarded as critical to the success of the proposal. Oxygen isotopes will provide records of global ocean chemistry that mainly reflect continental ice volume. The use

of carbon isotopes as water-mass mixing tracers is widespread. In particular, planktonic-benthic carbon isotopic differences provide a record of the alteration of surface-water chemistry by biology and air-sea exchange, especially when combined with other nutrient tracers such a cadmium-calcium ratios.

Magnetostratigraphy proved to be a useful tool in the bathyal Neogene carbonates drilled on the central Exmouth Plateau on ODP Leg 122, to the west of this area, and it is expected that it will be valuable in this area also.

7.3 *Logging requirements* - The log program will aim to establish a high-resolution lithostratigraphy; to identify cyclical lithological responses to climatic variations; to provide inter-site correlation; to detect reversals in the paleomagnetic field; to allow the establishment of synthetic seismograms; and to correlate sediment properties to log data to resolve the undistorted depth of sedimentary layers from individual cores. The log combinations to be finally decided upon will include Triple Combination, FMS/Sonic and GHMT strings.

## 8. Drilling strategy

The sites are to be selected where the overburden is not too thick and where it is possible to drill most of the advancing succession of prograde. A typical regional profile showing the prograding Oligocene-Pliocene section is shown in Figure 3, as well as the generalised location of four sites that penetrate seven major prograding packages. The balance of sites will become a matter of judgement, because we are likely to be able to drill only perhaps 3000 m or a little more in the timeframe of a single two-month cruise. This means perhaps proposing 5 x 700 m sites, as a guide. Ideally we would not want to drill 1000 m sites, because that would mean more than one bit per site, and hence re-entry, and so more time. Also drilling rates decline with depth, however, one deeper hole will probably be required to meet the all objectives of the cruise. Work to define optimum sites, with the thinnest overburden is continuing on the 3D data set. We have the data set to avoid or target incised valley fills (Figure 6). An isopach from the sea bed to the top of the Middle Miocene (Figure 8) contoured from well data alone, indicates the thickening and thinning of the sediment packages across the region, and gives us confidence that the right mix of sites can be found.

## 9. Summary of proposed sites

The aim of the proposed ODP drilling leg would be to produce a general transect seaward from the Rankin Platform. With careful selection of sites a good balance can be struck between intersecting the maximum amount of stratigraphy and getting thick sections with potential for a high resolution record. Ideally, the program would intersect the entire Neogene, or the Quaternary to the Middle Miocene at least.


## Acknowledgments

The authors would like to thank Neville Exon, David Feary, Howard Stagg (AGSO) and Therese Van der Linden (Woodside) and for editorial advice; and Johnny Hull (NCPGG), David Rowland, Melissa Fellows, Rex Bates and Lindell Emerton (AGSO) for help with the figures and maps.


## References


APTHORPE, M.C., 1988 - Cainozoic depositional history of the North West Shelf. In P. & R. Purcell (editors) *Proceedings PESA North West Shelf Symposium*, Perth 1988.

DRISCOLL, N.W., & KARNER, G.D.,1996 - Tectonic and stratigraphic evolution of the Carnarvon basin, northwest Australia. Minerals and Energy Research Institute of Western Australia (MERIWA), Report no. 170.

DRISCOLL, N.W., & KARNER, G.D., 1998 - Lower crustal extension across the northern Carnarvon basin, Australia: Evidence for an eastward dipping detachment. J. Geophys. Res., 103, 4975-4992.

GOLOVCHENKO, X., BORELLA, P.E. & O'CONNELL, S., 1992 - Sedimentary cycles on the Exmouth Plateau. In von Rad, U., Haq, B.U., et al., Proceedings ODP Scientific Results, 122. College Station Tx (Ocean Drilling Program) 279-291.

HULL, J.N.F., SMITH, S.A. & YOUNG, H.C., 1998 - Sequence stratigraphic interpretation of carbonate wireline log motifs: an example from the North west Shelf of Australia. APPEA Journal 38 (1) 188-1198.

KARNER, G.D., DRISCOLL, N.W & WEISSEL, J.K., 1992 - Response of the lithosphere to in-plane force variations. Earth Planet. Sci. Letts., 114, 397-416.

KARNER, G.D., DRISCOLL, N.W. , MCGINNIS, J.P. , BRUMBAUGH, W.D. & CAMERON, N. , 1997 - Tectonic significance of syn-rift sedimentary packages across the Gabon-Cabinda continental margin. Marine and Petrol. Geol., 14, 973-1000.

LANGFORD, R.P., WILFORD, G.E., TRUSWELL, E.M. & ISERN, A.R., 1995 - Palaeogeographic Atlas of Australia. Volume 10 - Cainozoic. Australian Geological Survey Organisation.

MILLER, K.G., FAIRBANKS, R.G., & MOUNTAIN, G.S., 1987 - Tertiary oxygen isotope synthsis, sea-level history and continental margin erosion. Paleocenography, 2, 1-19.

MOUNTAIN, G.S. & MILLER, K.G., 1997 - The cause and effect of sea-level change - unravelling the stratigraphic yarn. JOIDES Journal 23 (1) 11-13.

RASIDI, J.S., 1995 - Depositional sequence of the Withnall formation, Dampier Sub-basin. APEA Journal 35 (1) 296-320.

SIT, K.H., HILLOCK, P.M., & MILLER, N.W.D., 1994 - The Maitland gas discovery - a geophysical/petrophyscial case history. In : Purcell P.G. & R.R. (eds) The Sedimentary Basins of western Australia. Proceedings, PESA Symposium, Perth 597-613.

STAGG, H.M.J. & COLWELL, J.B., 1994 - The structural foundations of the Northern Carnarvon Basin. In : Purcell P.G. & R.R. (eds) The Sedimentary Basins of western Australia. Proceedings, PESA Symposium, Perth 349-364.

WHITE, M.E., 1994 - After the Greening - the Browning of Australia. Kangaroo Press.

**Figures**

1. Regional setting of the North West Shelf showing bathometry and major sedimentary basins (from Stagg & Colwell, 1994).
2. Structural elements of the Carnarvon Basin (from Stagg & Colwell, 1994).
3. Seismic cross-section from Gandara-1 landward towards the Rankin Platform, AGSO Survey 136, part of line 12.
4. Stratigraphic column for the Barrow and Dampier Sub-basins with age control and sequence stratigraphic events (from Hull et al. ,1998).
5. Detailed location map of the Rankin Platform area showing exploration wells and bathymetry.

6. A time slice view on a Neogene reflector from a detailed 3D seismic grid located seaward of the Rankin Platform, showing a densely channelled surface.
7. Composite seismic section from the Dampier Sub-basin showing the relationship between wireline log and seismic response of the Oligocene-Miocene section (from Hull et al. 1998).
8. An isopach from the sea bed to the top of the Middle Miocene contoured from well information from AGSO's STRATDAT database.

**Proponents**

Dr Marita Bradshaw - (primary contact for correspondence)
Australian Geological Survey Organisation
GPO Box 378, Canberra ACT 2601 AUSTRALIA
mbradsha@agso.gov.au

Professor John Kaldi
National Centre for Petroleum Geology and Geophysics
Thebarton Campus, University of Adelaide, SA 5005 AUSTRALIA
jkaldi@ncpgg.adelaide.edu.au

Stephen Newman
Woodside Offshore Petroleum Pty Ltd
1 Adelaide Terrace, Perth WA 6000 AUSTRALIA
stephen.newman@woodside.com.au

Dr Garry Karner
Lamont-Doherty Earth Observatory, Columbia University
RT 9W / Palisades, NY 10964-8000 USA
garry@ldeo.columbia.edu

Associate Professor Lindsay B Collins
School of Applied Geology, Curtin University of Technology
GPO Box U 1987, Perth, Western Australia 6845
lindsay@lithos.curtin.edu.au

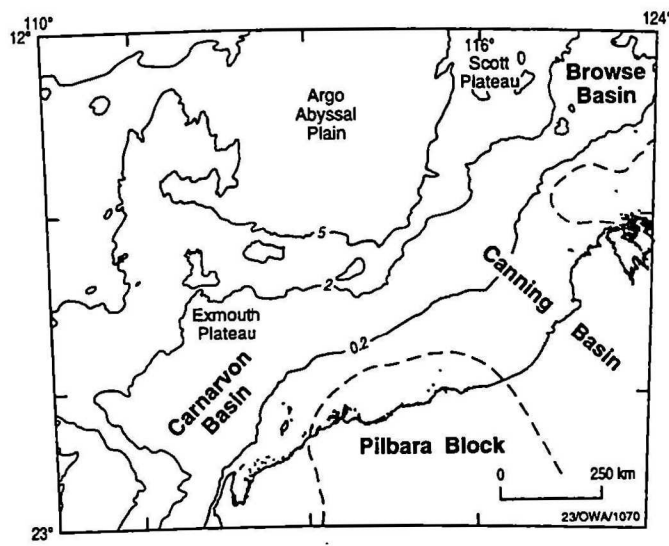
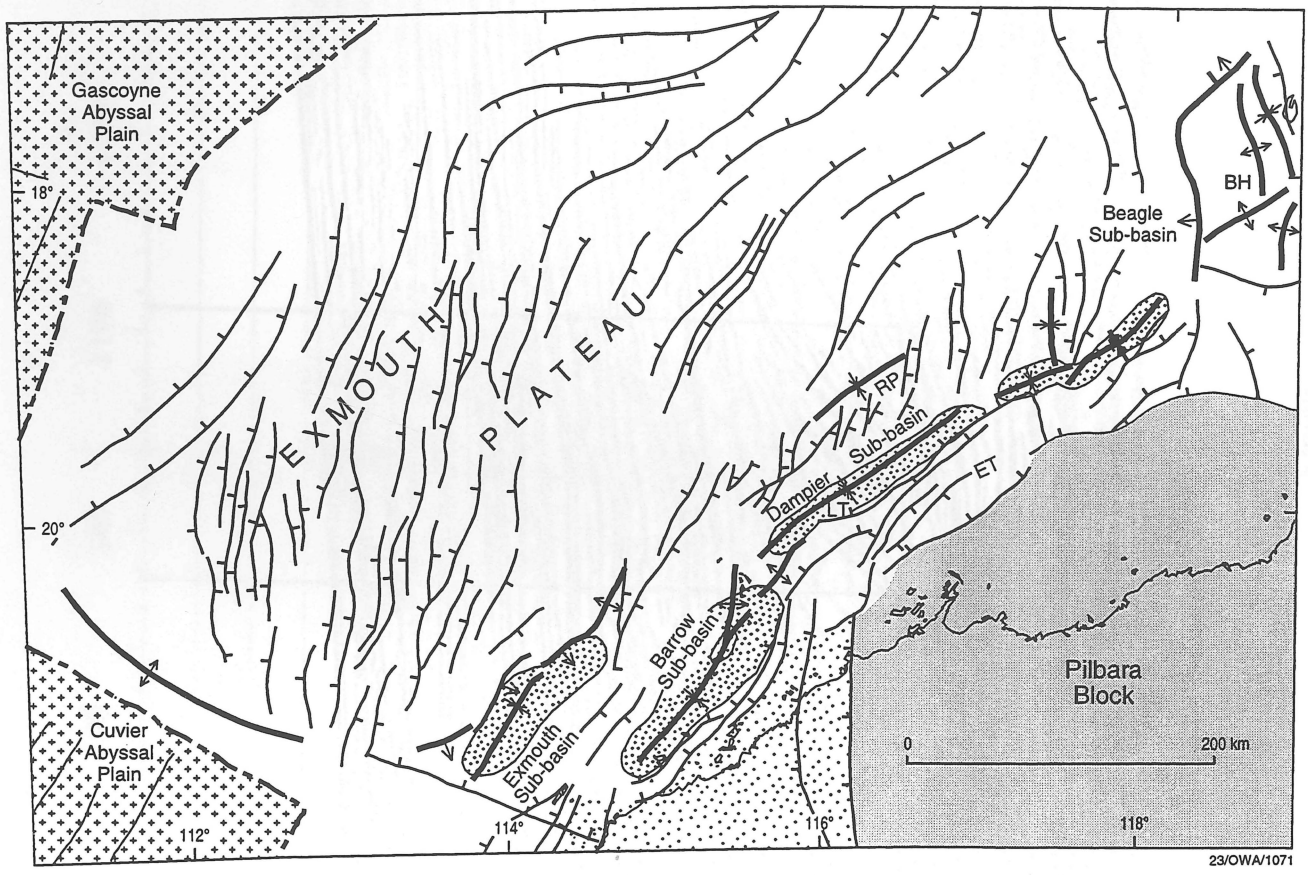

110°
124°
12°
116°
Scott
Plateau
Browse
Basin
Argo
Abyssal
Plain
5
2
Canning
Basin
Exmouth
Plateau
0.2
Carnarvon
Basin
Pilbara Block
0
250 km
23°
23/OWA/1070

**Figure 1**




*Oceanic crust*

*Shallow or exposed Precambrian rocks*

*Sedimentary basin of predominantly Palaeozoic age*

*Major late Mesozoic depocentre*

*Sedimentary basin of predominantly Mesozoic age underlain by indeterminate thickness of Palaeozoic strata*

B H Bedout High

E T Enderby Terrace

L T Lewis Trough

R P Rankin Platform

*Continent - Ocean boundary*

*Illustrated seismic line, with figure number*

**Figure 2**

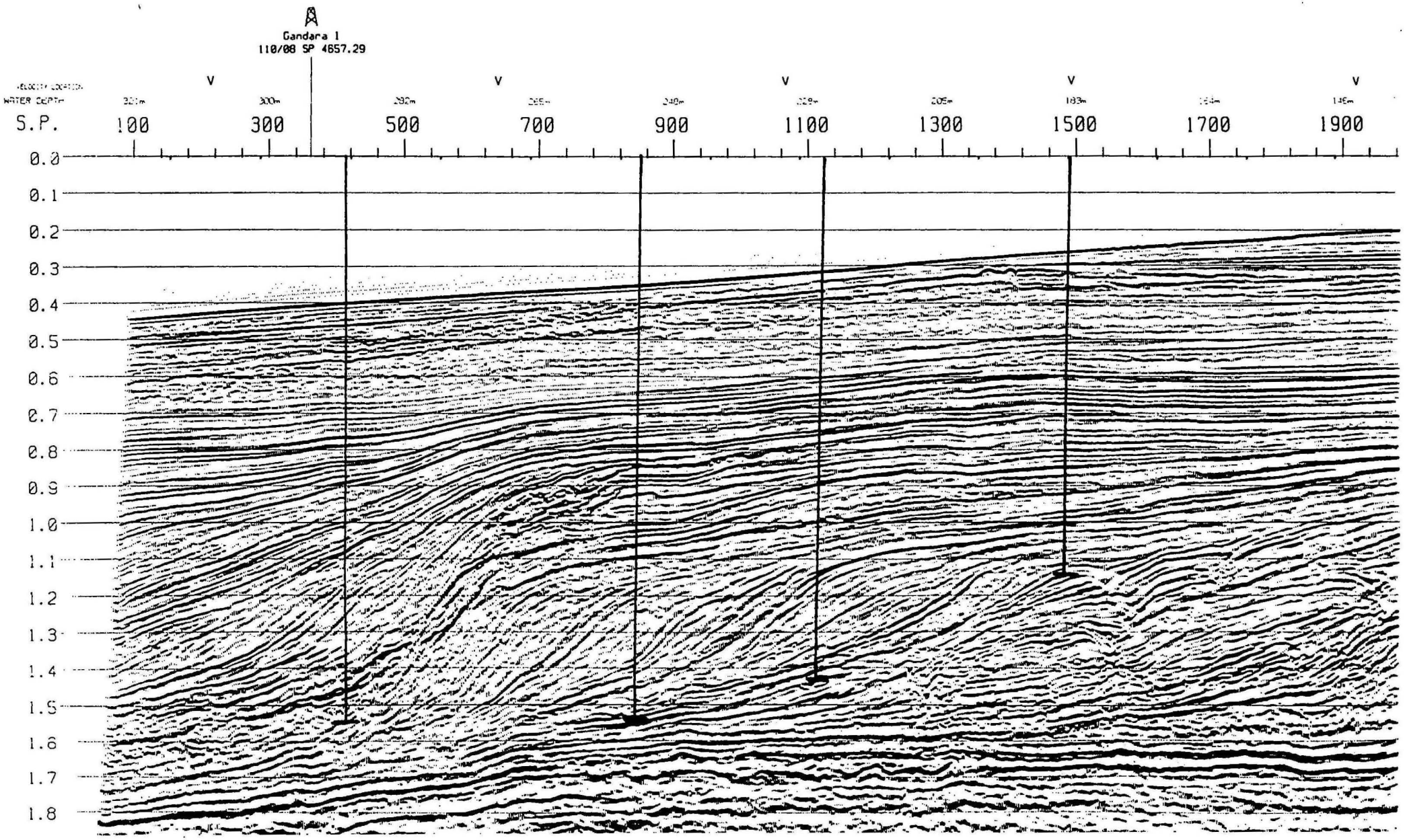

Gandara 1
110/08 SP 4657.29
S.P.
100
300
500
700
900
1100
1300
1500
1700
1900
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8

Figure 3

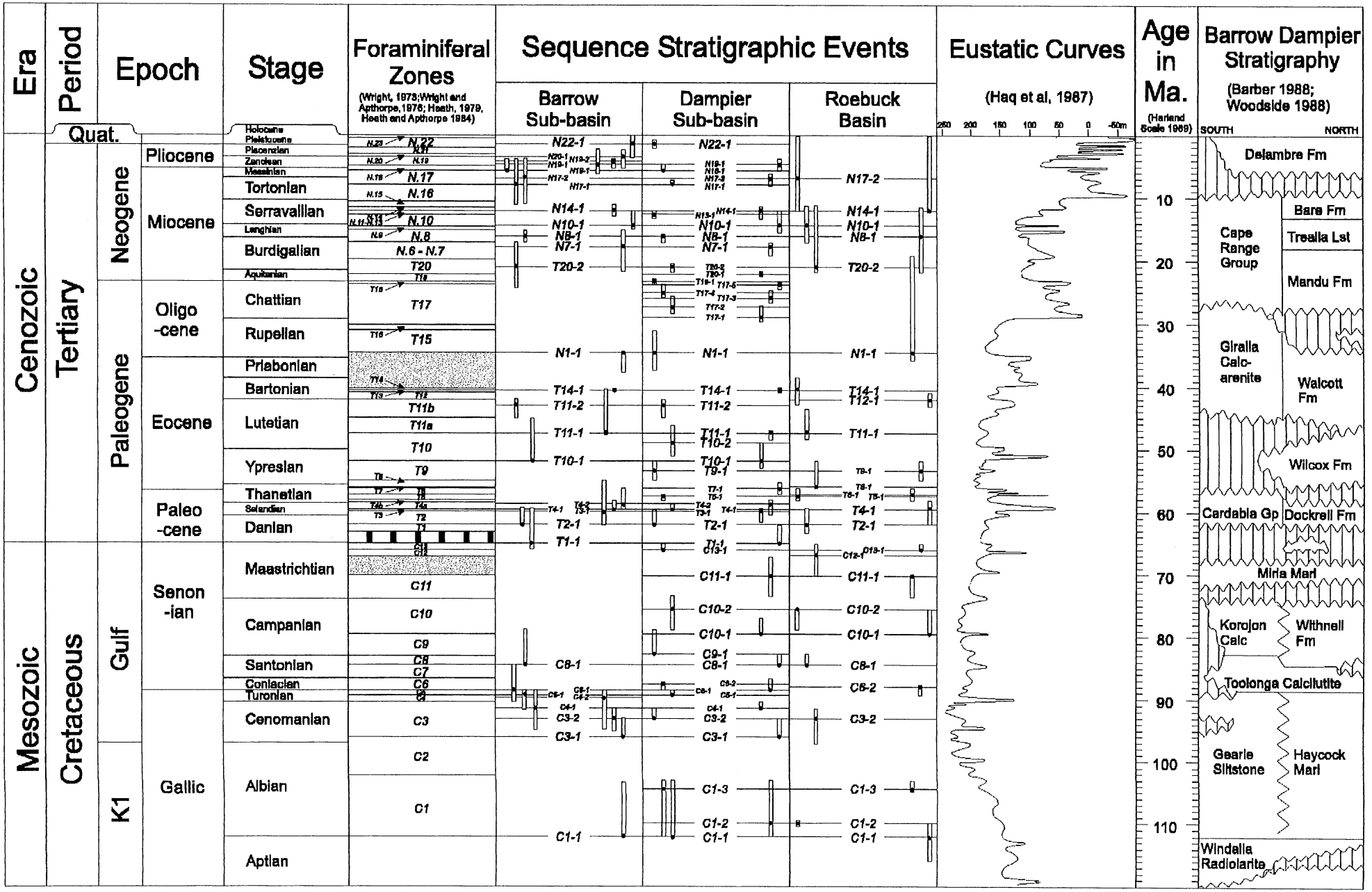

Era
Period
Epoch
Stage
Foraminiferal Zones
(Wright, 1978;Wright and Apthorpe,1976; Heath, 1979, Heath and Apthorpe 1984)
Sequence Stratigraphic Events
Barrow Sub-basin
Dampier Sub-basin
Roebuck Basin
Eustatic Curves
(Haq et al, 1987)
Age in Ma.
(Harland Scale 1989)
Barrow Dampier Stratigraphy
(Barber 1988; Woodside 1988)
SOUTH
NORTH
Cenozoic
Mesozoic
Quat.
Tertiary
Cretaceous
Neogene
Paleogene
K1
Gulf
Gallic
Pliocene
Miocene
Oligo -cene
Eocene
Paleo -cene
Senon -ian
Holocene
Pleistocene
Placenzian
Zanclean
Messinian
Tortonian
Serravallian
Langhian
Burdigalian
Aquitanian
Chattian
Rupelian
Priabonian
Bartonian
Lutetian
Ypresian
Thanetian
Selandian
Danian
Maastrichtian
Campanian
Santonian
Coniacian
Turonian
Cenomanian
Albian
Aptian
Delambre Fm
Bare Fm
Cape Range Group
Trealla Lst
Mandu Fm
Giralia Calc-arenite
Walcott Fm
Wilcox Fm
Cardabia Gp
Dockrell Fm
Miria Marl
Korojon Calc
Withnell Fm
Toolonga Calcilutite
Gearle Siltstone
Haycock Marl
Windalia Radiolarite

Figure 4

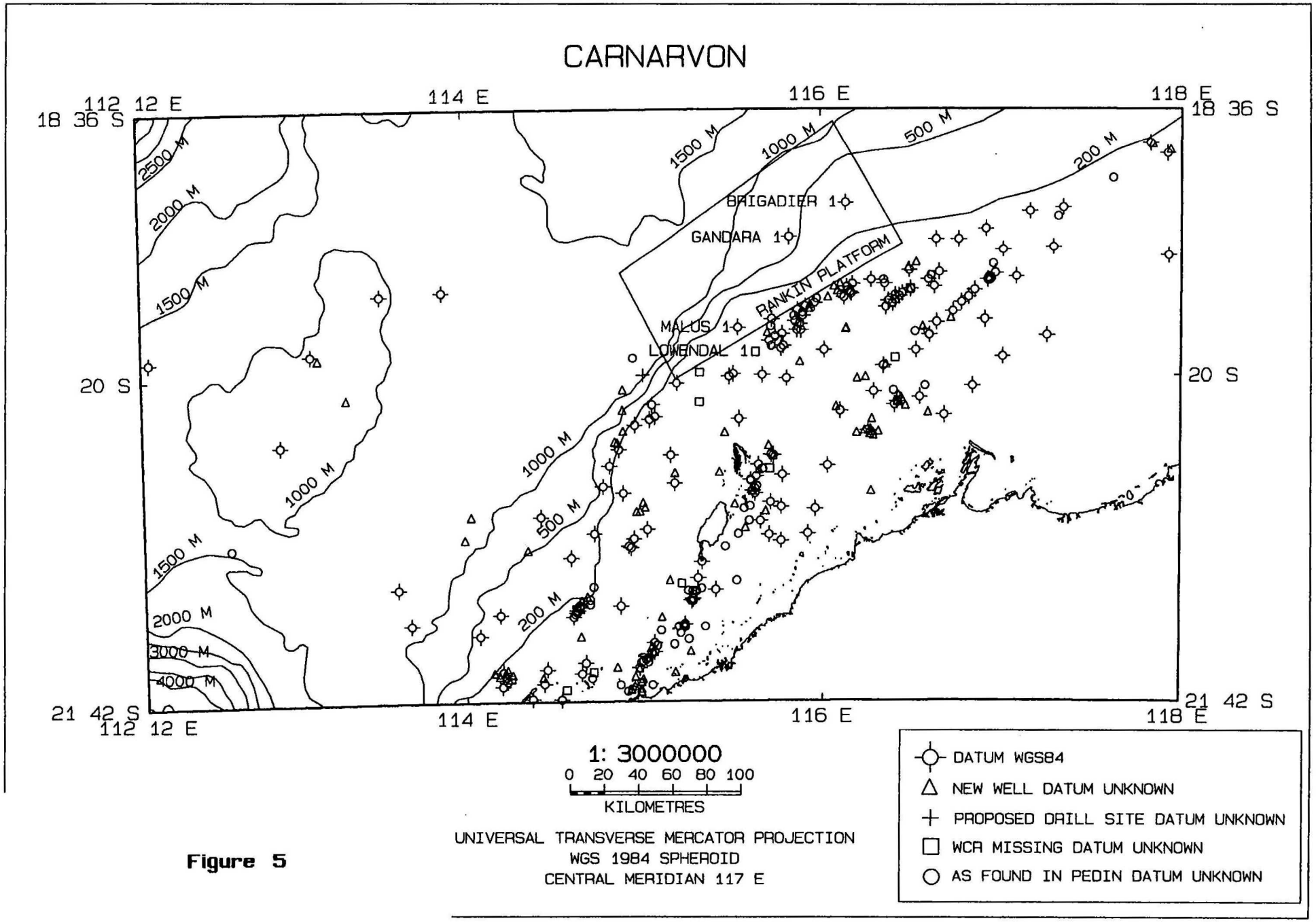
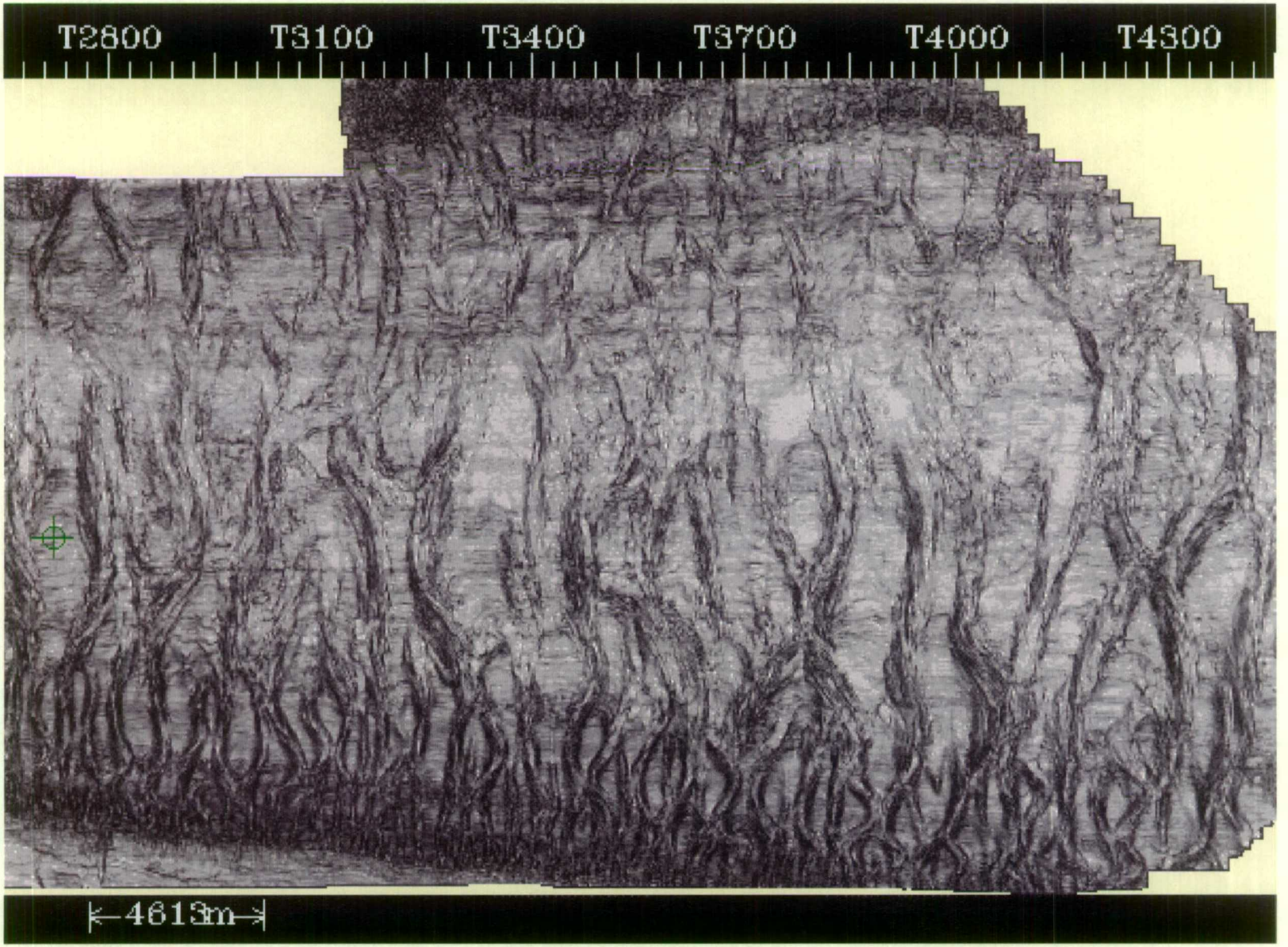
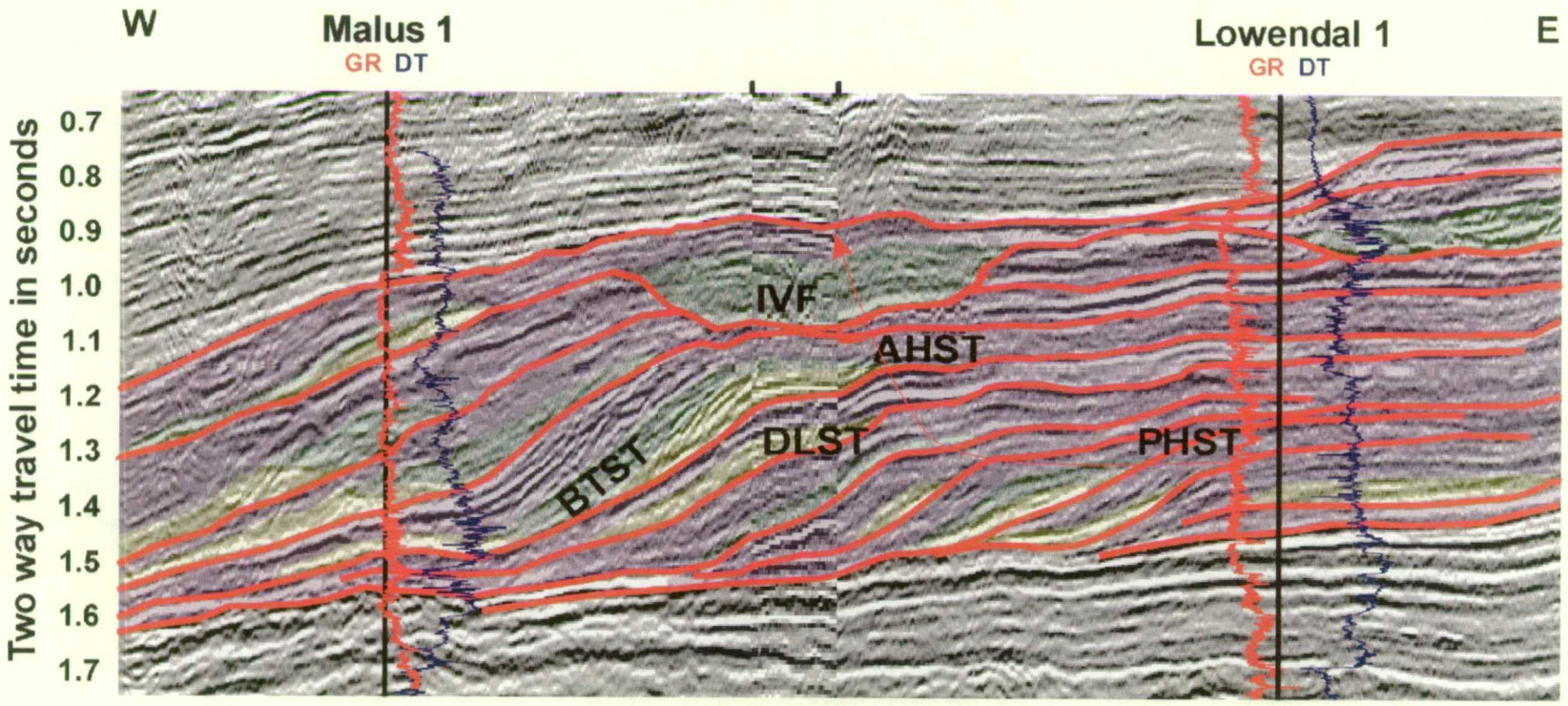

CARNARVON
112 12 E
114 E
116 E
118 E
18 36 S
20 S
21 42 S
2500 M
2000 M
1500 M
1000 M
500 M
200 M
3000 M
4000 M
BRIGADIER 1
GANDARA 1
RANKIN PLATFORM
MALUS 1
LOWENDAL 1
1: 3000000
0 20 40 60 80 100
KILOMETRES
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 117 E
DATUM WGS84
NEW WELL DATUM UNKNOWN
PROPOSED DRILL SITE DATUM UNKNOWN
WCR MISSING DATUM UNKNOWN
AS FOUND IN PEDIN DATUM UNKNOWN

**Figure 5**


T2800
T3100
T3400
T3700
T4000
T4300
4613m

# Wireline to seismic correlation




Highstand Systems Tract

Transgressive System Tract

Lowstand Systems Tract

AHST Aggradational HST

PHST Prograding HST

BTST Backstepping TST

DLST Downstepping LST

Locus of shelf break

Sequence Boundary

IVF Incised Valley Fill

Depth to Top Middle Miocene from sea floor (Offshore Carnarvon region).

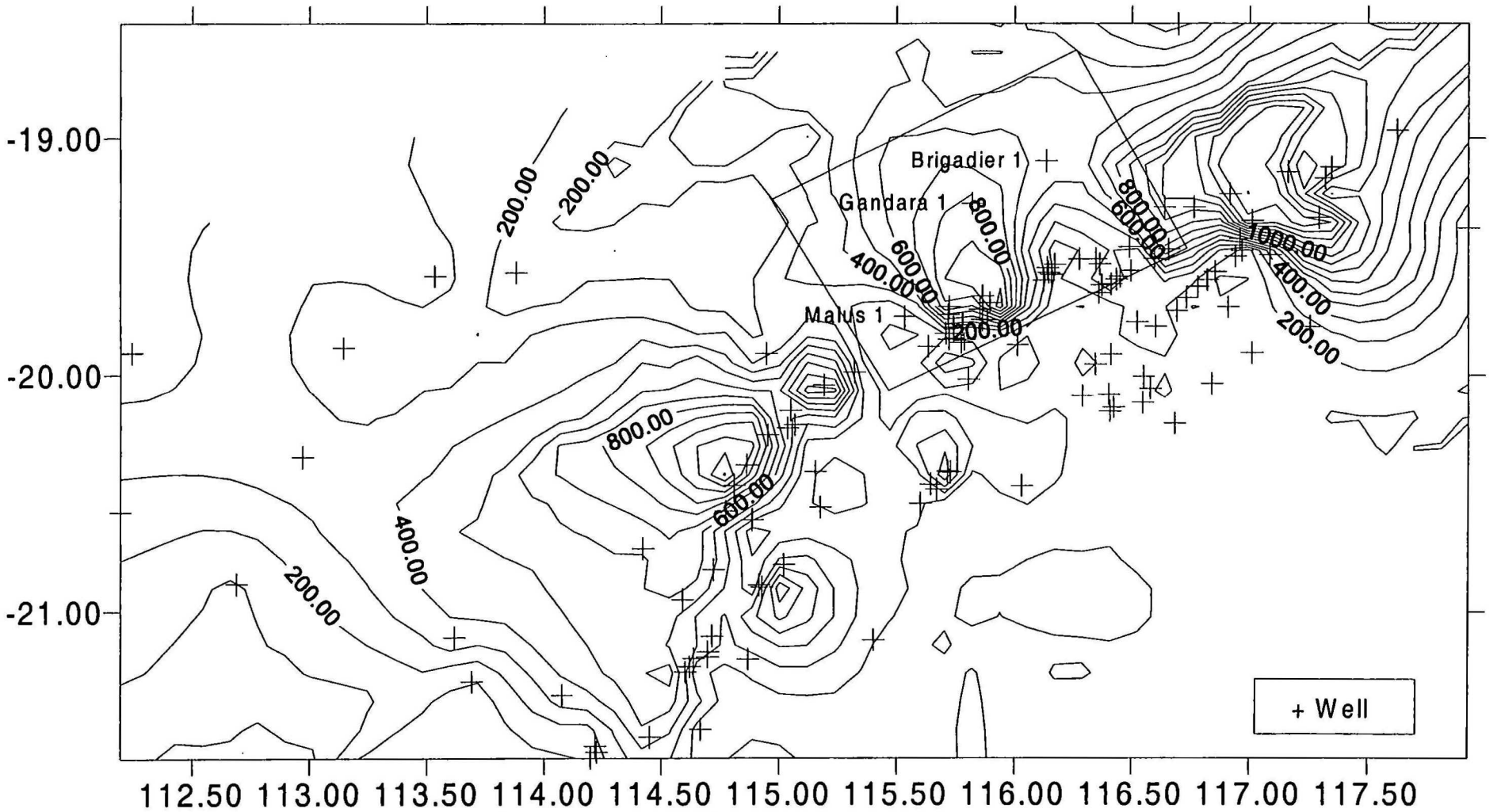



Figure 8