AGSO

NORTH WEST MARGIN TRANSECTS: SURVEY 128 POST-CRUISE REPORT

BY H I M STRUCKMEYER & SURVEY 128 SHIPBOARD PARTY

RECORD 1994/37

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Australian Geological Survey Organisation

Marine Geoscience and Petroleum Geology Program

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EXECUTIVE SUMMARY

The North West Margin Transects Cruise (Survey 128) forms part of a program being undertaken by AGSO to determine the structural architecture of the north-western margin of Australia and the influence of structuring on the location, migration and trapping of hydrocarbons in the region. An important aspect of this program is the acquisition of a series of full margin 'dip' transects extending from unrifted cratonic basement to beyond the continent-ocean boundary, and at least two 'strike' transects that will extend along the full length of the shelf from the eastern Timor Sea to North West Cape. The major objective of Survey 128 was to extend previous AGSO deep-seismic surveys across the Browse (Survey 119), offshore Canning (SNOWS-3/Survey 120) and northern Carnarvon basins (SNOWS-1/Survey 101, SNOWS-2/Survey 110) to complete these margin transects.

The survey vessel *Rig Seismic* left Port Hedland on 30 May 1994. A weather buoy was deployed for the Bureau of Meteorology at the beginning of the survey. Seismic acquisition commenced on 4 June 1994. The survey was completed on 25 June and finished in Fremantle on 30 June 1994. During the survey, 11 seismic lines were completed for a total of 3403.05 km at an average of 155 km per day (based on 22 days of acquisition). Transits between lines amounted to more than 800 km. The survey ties into the 1991 SNOWS-1 (101), 1992 SNOWS-2 (110), 1993 Browse Basin (119) and SNOWS-3 (120) deep-seismic surveys, and the 1990 standard record length Triassic Reef Survey (95).

The data were recorded from a 4800 m streamer, configured with 192 x 25 m active groups. Data were recorded with a 16 s record length and a 2 ms sample interval. The seismic source consisted of dual sleeve gun arrays with a total capacity of 50 litres, and was fired every 50 metres to give 48-fold CDP coverage. Navigation for the survey was provided by differential Global Positioning System (dGPS), using shore reference stations in Dampier, Broome, Perth and Darwin.

Both the seismic and non-seismic acquisition systems ran without major problems. Navigational data were of good quality, with differential GPS being available for more than 95% of the survey.

INTRODUCTION

In May to June 1994, the Australian Geological Survey Organisation (AGSO) conducted a deep crustal seismic survey (AGSO Survey 128) across the Scott Plateau, Argo Abyssal Plain and outer Exmouth Plateau. The survey was part of the acquisition phase of Projects 121.17 and 121.42. The research vessel *Rig Seismic* (Appendix 4) left Port Hedland on 30 May 1994 and began seismic acquisition on 3 June. The survey was completed on 25 June 1994 and finished in Fremantle on 30 June 1994. The shipboard personnel (Appendix 6) comprised 16 AGSO scientists and technicians and 13 Australian Maritime Safety Authority (AMSA) crew.

Specific objectives of the survey were to

- determine the regional structural framework of the Scott Plateau area and its relationship to adjacent features such as the Argo Abyssal Plain, the Browse Basin and the Rowley Sub-basin of the offshore Canning Basin;
- determine the regional structural framework of the Exmouth Plateau and its relationship to adjacent features such as the Barrow-Dampier Sub-basin, and the Argo and Gascoyne Abyssal plains;
- define the broad deep-crustal structure of the region and develop a model explaining the tectonic, subsidence and thermal histories of the Scott Plateau and the Exmouth Plateau in relation to the development of the continental margin and adjacent ocean basins; and
- assess the effects of the deep crustal structures and their reactivation phases on the development of known petroleum accumulations.

The cruise acquired 3403.05 km of data along 11 lines. The survey ties into AGSO's conventional 1990 Triassic Reef survey (95), and the 1991 SNOWS-1 (101), 1992 SNOWS-2 (110), 1993 Browse Basin (119) and 1993 SNOWS-3 (120) deep-seismic surveys and, together with these surveys, provides several complete margin transects from the inner Browse Basin across the Scott Plateau onto the Argo Abyssal Plain, and from the offshore Canning and the Carnarvon basins across the Exmouth Plateau onto the Argo and Gascoyne Abyssal plains. The data comprise 16s record-length, 48-fold seismic (shot using a 4800 m streamer and 50 litre airgun arrays), bathymetry, gravity and magnetics.

Background to project and seismic program

In 1990, AGSO's Marine Geoscience and Petroleum Geology Program (MGPGP) commenced a program of deep-seismic acquisition (up to 16 s records) over the north-western margin of Australia, with the objective of obtaining a full regional data set from the North West Cape in the south, to the western Arafura Sea in the north (Figure 1). This region was seen to be the most prospective part of Australia's margin outside of the Bass Strait basin system and likely to be the major source of Australia's future petroleum supplies as production from Bass Strait decreases. While portions of the North West Shelf have been quite intensively explored since the 1960's, there has been very little recent analysis of its regional structural framework incorporating modern extensional tectonic concepts for the formation of margins and their basins, collisional tectonic concepts, and the significant contribution of intraplate stress to reactivation of the primary basin-forming structures.

The MGPG program over the north-western Australian margin is designed to establish the gross architecture of the North West Shelf region by imaging the primary margin and basin-forming structures. This approach is improving our understanding of the relationship between plate tectonic setting, basin formation and reactivation, and can highlight critical regional factors controlling the petroleum systems within each basin element. It is also providing new insights into the linkages between the major structural elements and allowing revision of the gross structure of the region. Such information is vital to the development of new exploration strategies for the North West Shelf, and will aid future basin framework and resource studies.

The main objectives of the program are to:

- determine the broad regional structural framework by examining the relationships between the major structural elements;
- determine the deep crustal structure of the region and develop models explaining the tectonic, subsidence and thermal history of North West Shelf basins in relation to the development of the continental margin and adjacent ocean basins;
- assess the influence of deep structure on the development of the major hydrocarbon fields and plays in this relatively well-explored area and, in particular, the structural and depositional effects resulting from reactivation of these structures; and
- acquire a set of high-quality seismic tie lines linking exploration wells throughout the region to allow regional seismic correlations.

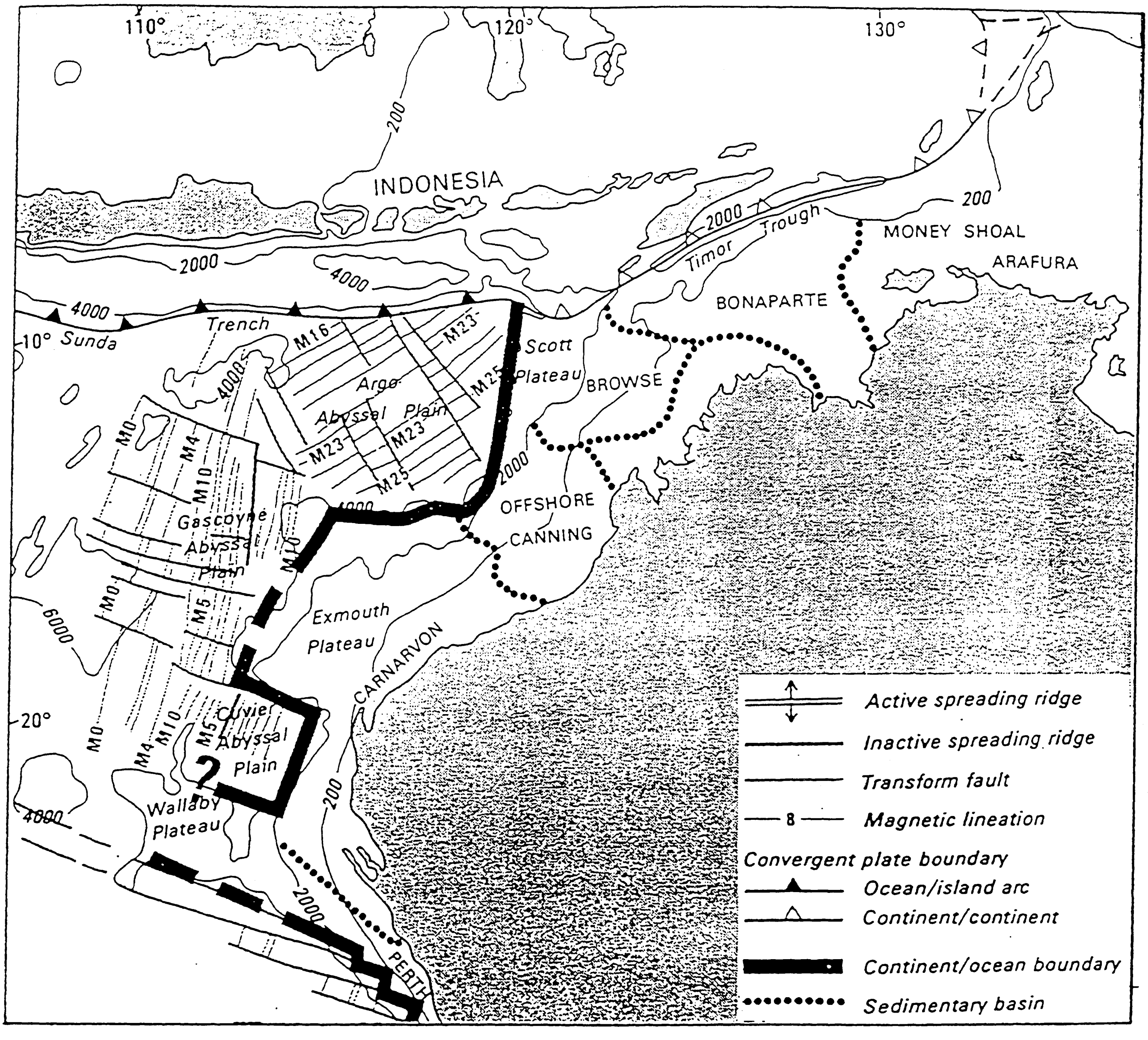

Figure 1: Regional tectonic and basin setting of northwestern Australia.

To address these objectives, devised a margin-wide program of deep-seismic acquisition was devised. An important aspect of this program is the acquisition of full-margin 'dip' transects (at least one in each major basinal element), extending, where possible, from unrifted cratonic basement near the coast across the margin to beyond the continent-ocean or plate boundary, and at least two 'strike' transects that will extend along the full length of the shelf. These transects are providing a new understanding of the development of the North West Shelf basin system, within the context of the development of the whole continental margin province. The transect lines shot for this survey were designed to obtain vital additional information on the following points in critical areas of the southern and central North West Shelf:

- Preliminary interpretation of AGSO's North West Shelf deep-seismic data indicates that the initial basin-forming extension occurred in the Early Palaeozoic, and was probably the only 'simple' extensional episode in the development of the region. The acquisition of deep-seismic margin transects in Palaeozoic dip and strike directions is therefore considered vital for a better understanding of the basin-forming processes and the thermal history of the region.

- Also, it appears that many of the structures that have been interpreted as primary features in conventional seismic data are really reactivation features that have been localised along older structures. These reactivation events are still poorly understood - in particular their relationship to the geometry of breakup in the adjacent ocean basins. A major change in spreading direction occurred in the Early Cretaceous, as spreading in the Argo Abyssal Plain ceased and spreading in the Gascoyne and Cuvier Abyssal plains started, but nothing is known about earlier spreading events in the area. Remnants of these earlier (Late Palaeozoic to Early Mesozoic) ocean basins could be preserved along the palaeo-tectonic boundary between the Argo and Gascoyne Abyssal plains now occupied by the Joey and Roo Rises. Acquisition of deep-seismic data across this major palaeo-tectonic boundary is critical to understanding the tectonic and thermal history and configuration of break-up in the ocean basins adjacent to the continental margin off north-western Australia.

To date, nine surveys in the North West Shelf region have been completed with a regional grid of deep-seismic data totalling 26624 km (Appendix 1). Survey 128 was part of the final stage of the deep-seismic program across the North West Shelf to obtain additional information in critical areas by extending previous AGSO deep-seismic lines and thus completing the outer margin transects.

EXPLORATION HISTORY

The nine margin transects were shot in water depths greater than 200 m and, generally, greater than 1000 m. Thus, little exploration for hydrocarbons has occurred in the survey area. During the 1970's, the central and southern Exmouth Plateau (south of the survey area) was a focus of petroleum exploration and 16 wells were drilled during this period, mainly targeting Triassic tilt-blocks and Neocomian deltaic sediments. With the exception of a major gas discovery at Scarborough, no hydrocarbon accumulations were found and all but one exploration permit were relinquished. No exploration drilling has been conducted on the Scott Plateau, which is located in greater water depths than the central Exmouth Plateau and is generally considered to have low prospectivity.

Regional reconnaissance seismic data have been collected over both the Scott and Exmouth Plateaus and the Argo Abyssal Plain, mainly by government organisations such as BMR, research institutes such as Lamont-Doherty Geological Observatory and Woods Hole Oceanographic Institution, and by the new ventures groups of oil companies such as Esso Australia, Gulf Research & Development, and Shell International Petroleum. The first surveys were carried out in 1967 and 1968 by BMR, and the most recent surveys were conducted in 1977 by the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR, Germany), and in 1986 and 1990 by AGSO (BMR). A summary of pre-1991 seismic surveys over the survey area is given in Appendix 2.

Some dredging and coring has been conducted over the margins of the Scott and Exmouth Plateaus during the 1977 BGR *Valdivia* (Hinz et al., 1978) and 1979 *Sonne* (von Stackelberg et al., 1980) surveys , and by BMR using *Rig Seismic* in 1990 (Surveys 95, 96). Much of the data from the two 1990 BMR surveys have been summarised in Colwell, Graham et al. (1990) and Exon & Ramsay (1990). During 1988, Legs 122 and 123 of the Ocean Drilling Program (ODP) drilled 8 sites on the north-western Australian continental margin and in adjacent ocean basins that are of relevance to this survey (Figure 2). The major objective of four sites drilled on the Wombat Plateau (759-61, 764) was an assessment of the synrift and postrift structural and palaeoenvironmental evolution of eastern Gondwanaland and the adjacent eastern Tethys ocean (Exon et al., 1992; von Rad et al., 1992). Site 765 on the Argo Abyssal Plain and Site 766 on the easternmost Gascoyne Abyssal Plain were drilled mainly to study the ages of the onset of seafloor spreading (Gradstein et al. 1990; Dumoulin & Brown, 1992; Ludden, 1992); they complement earlier data obtained at Deep Sea Drilling Project (DSDP) Sites 260 and 261 (Veevers, Heirtzler, et al., 1974).

STRUCTURAL ELEMENTS

Much of the following summary of the geology of the major tectonic/physiographic features crossed during the proposed survey is based on Stagg (1978), Stagg & Exon (1981), Colwell et al. (1990) and Symonds (1993) for the Scott Plateau area, and on Exon & Willcox (1980), Barber (1988), Exon et al. (1992) and von Rad et al. (1992) on the Exmouth Plateau area. Structural elements in the study area are shown in Figure 3 and generalised tectonic cross-sections across the Scott Plateau and the northern Exmouth Plateau are shown in Figure 4.

Scott Plateau

The Scott Plateau (including the adjacent Rowley Terrace) is a marginal plateau that occupies an area of approximately 80 000 km² in water depths ranging from 1000 to 3500 m (Figure 2). The plateau forms the subsided oceanward margin to the Browse Basin. On its western and north-western margins, which are incised by numerous canyons, it is well defined by the 3500 m isobath. The lower slope has an inclination of 2 to 7° towards the Argo Abyssal Plain. To the north and east, the Scott Plateau is defined by the 1000 m isobath, and in the south, is separated from the Exmouth Plateau by the Swan Canyon (Stagg & Exon, 1981). Interpretation of regional seismic data indicates that the plateau is probably underlain by relatively shallow Palaeozoic and basement rocks overlain by an average of 1000 m of Late Cretaceous and Cainozoic carbonates. Permian to Jurassic sediments of the Browse Basin appear to pinch out on the eastern flank of the Scott Plateau, although fault controlled lows could contain Triassic and Jurassic section (Powell, 1976), particularly just west of the Scott Reef Trend beneath the Scott Plateau Saddle (Stagg & Exon, 1981) (Figure 4). Throughout much of the period from the Carboniferous to Late Jurassic, when continental break-up occurred and seafloor spreading began, the Scott Plateau was probably above sea level and provided a source of clastic sediments for the developing Browse Basin and the offshore Canning Basin to the southwest (Stagg, 1978).

Rowley Sub-Basin

The Rowley Sub-basin of the offshore Canning Basin (Horstman & Purcell, 1988) is a NE-SW trending Mesozoic feature that cuts across the NW-SE trending structures of the Canning Basin (Figure 3). It is bounded by the Scott Plateau to the north, the Argo Abyssal Plain to the northwest, the Bedout High to the south and the Broome Platform to the southeast, but the basin boundaries to the northeast (Browse Basin) and southwest (Beagle Sub-basin) are poorly defined. The Rowley Sub-basin basin

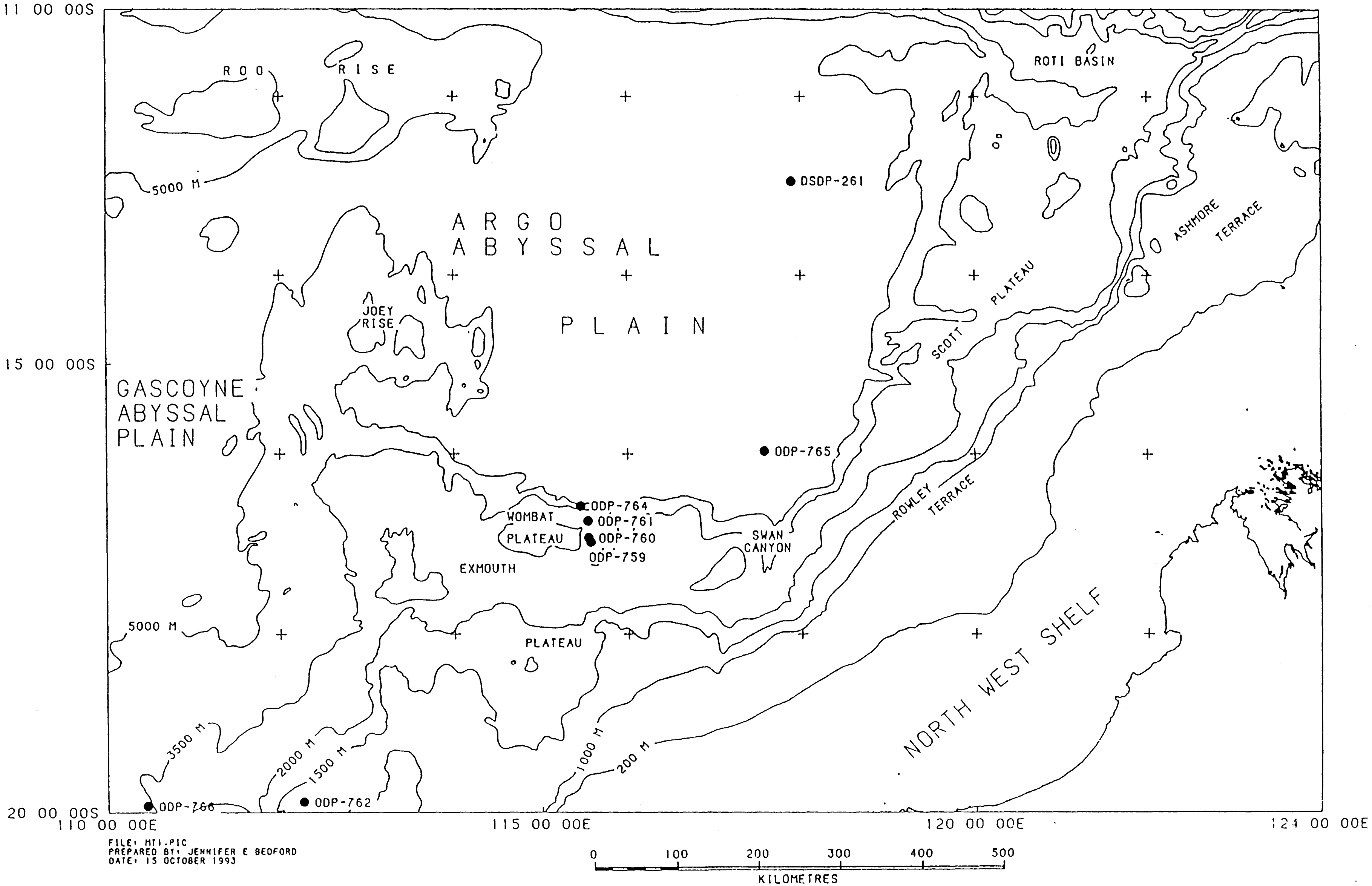

Figure 2: Physiography of the survey area and location of relevant ODP/DSDP sites.

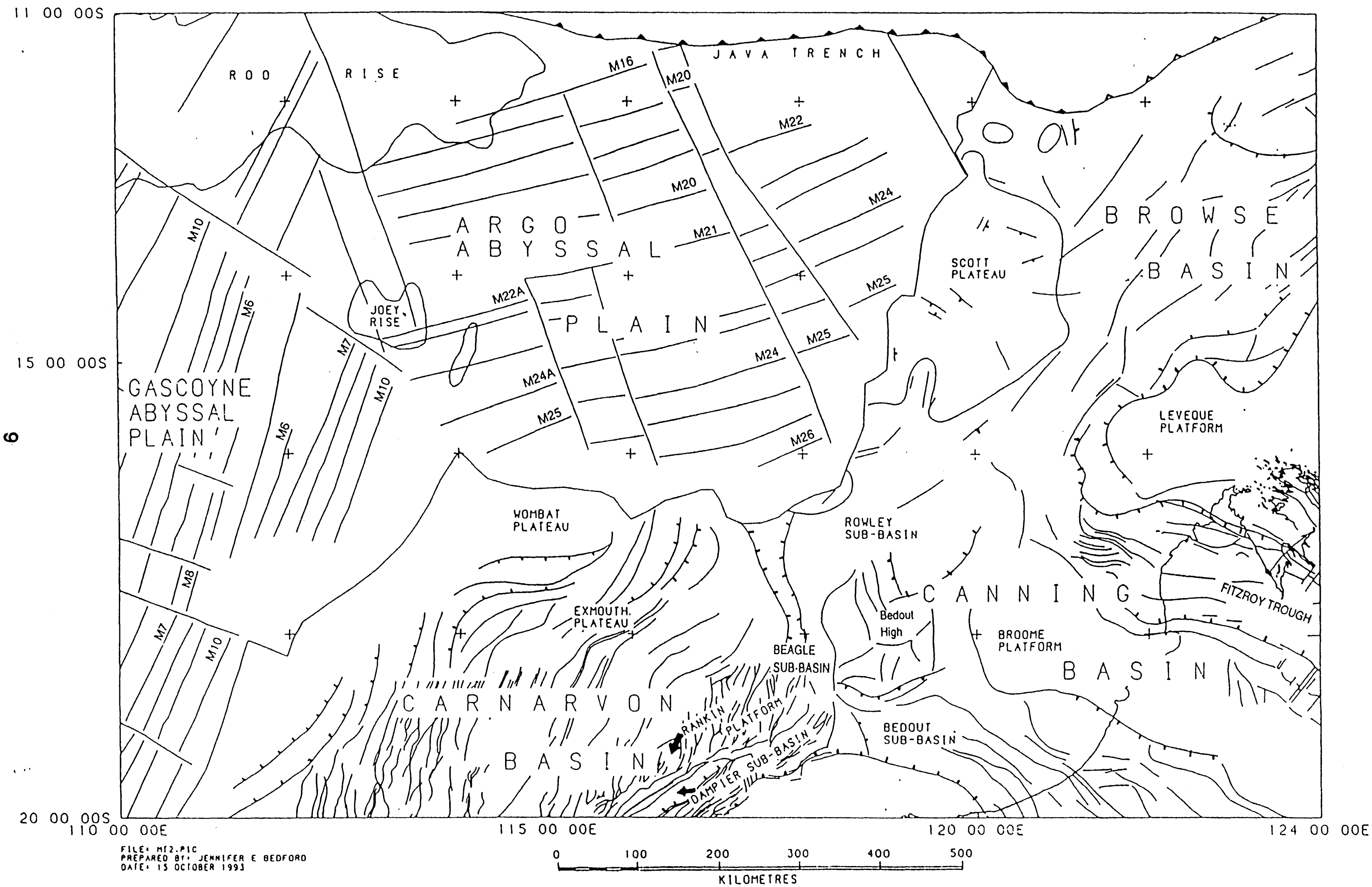

Figure 3: Structural elements map of the survey area (based on Stagg, 1993).

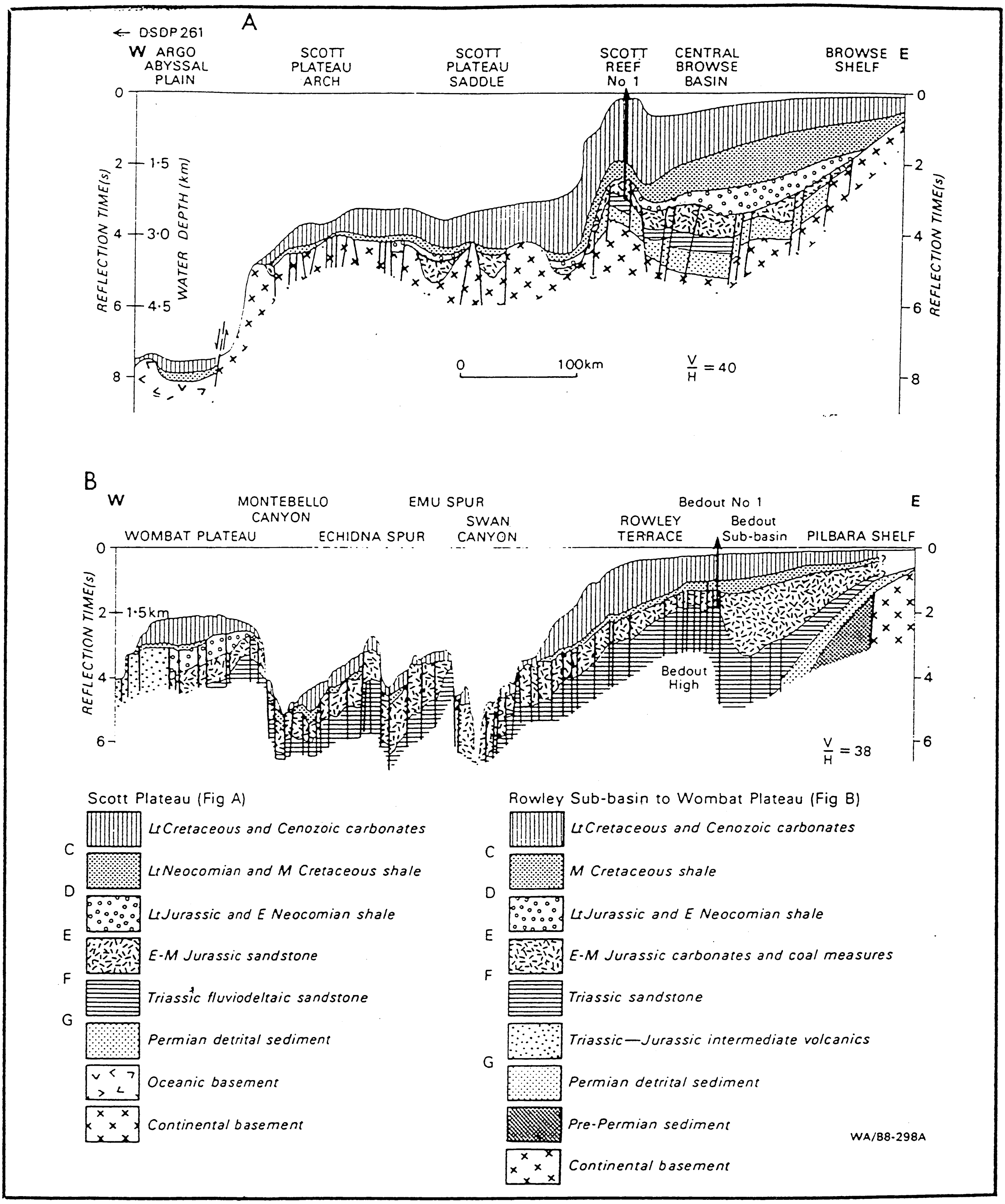

Figure 4: Schematic cross sections across A) the Browse Basin and Scott Plateau, and B) the Rowley Sub-basin and northern Exmouth Plateau (from von Rad & Exon, 1983).

contains a thick Mesozoic to Cainozoic sedimentary section and was a major depocentre in the post-Middle Jurassic; however, older sections may be present. Although modern high-quality seismic data are sparse, the data that are available suggest that the basin margins are extensively faulted and folded while the structure in the central basin is relatively subdued (Stagg et al., 1993).

Exmouth Plateau

The Exmouth Plateau lies at water depths of 800 to 4000 m (Figure 2). It is underlain by thinned continental crust and about 10 km of Phanerozoic sediments. The Exmouth Plateau is bounded by oceanic crust of the Argo, Gascoyne and Cuvier abyssal plains to the north, west and south respectively, and its sediments are contiguous with those of the northern Carnarvon and offshore Canning basins (e.g. Powell, 1976; Exon & Willcox, 1980; Exon et al., 1992). More than 3000 m of Triassic fluvial to deltaic clastics are overlain by latest Jurassic to Early Cretaceous deltaic to open marine sediments. Locally on the northern Exmouth Plateau, a succession of Early to Middle Jurassic shelf carbonates and coal measures are present as fill in large graben structures (Figure 4). Renewed subsidence of the plateau in the Middle to Late Cretaceous and a decrease of terrigenous sediment supply, shallow marine mid-Cretaceous sedimentation was gradually replaced by open ocean carbonate deposition in the Late Cretaceous to Tertiary (e.g. Exon et al., 1992).

Argo Abyssal Plain

The Argo Abyssal Plain is about 5700 m deep with a southeasterly gradient of about 0.02°. It is underlain by the oldest preserved oceanic crust of the Indian Ocean and is being subducted northwards at the Java Trench. The pattern of break-up in the Argo Abyssal Plain (Figures 1 & 3) off north-western Australia is important to the development of the Exmouth and Scott Plateaus as well as the sedimentary basins of the North West Shelf. Larson (1975) first identified the magnetic anomaly series, interpreting a 160 Ma break-up age (Late Oxfordian - 145 Ma on the time scale of Burger, 1990, and 155 Ma using Young & Claoue-Long, 1991), but recent drilling of the south-eastern Argo Abyssal Plain (Site 765) during Leg 123 of the Ocean Drilling Program (ODP) discovered much younger sediments overlying oceanic basement. A late Berriasian to earliest Valanginian age was initially suggested (Baumgartner & Marcoux, 1989; Gradstein et al., 1990). However, a recent K/Ar age on a basaltic hyloclastite directly overlying basaltic basement and underlying the oldest sediments

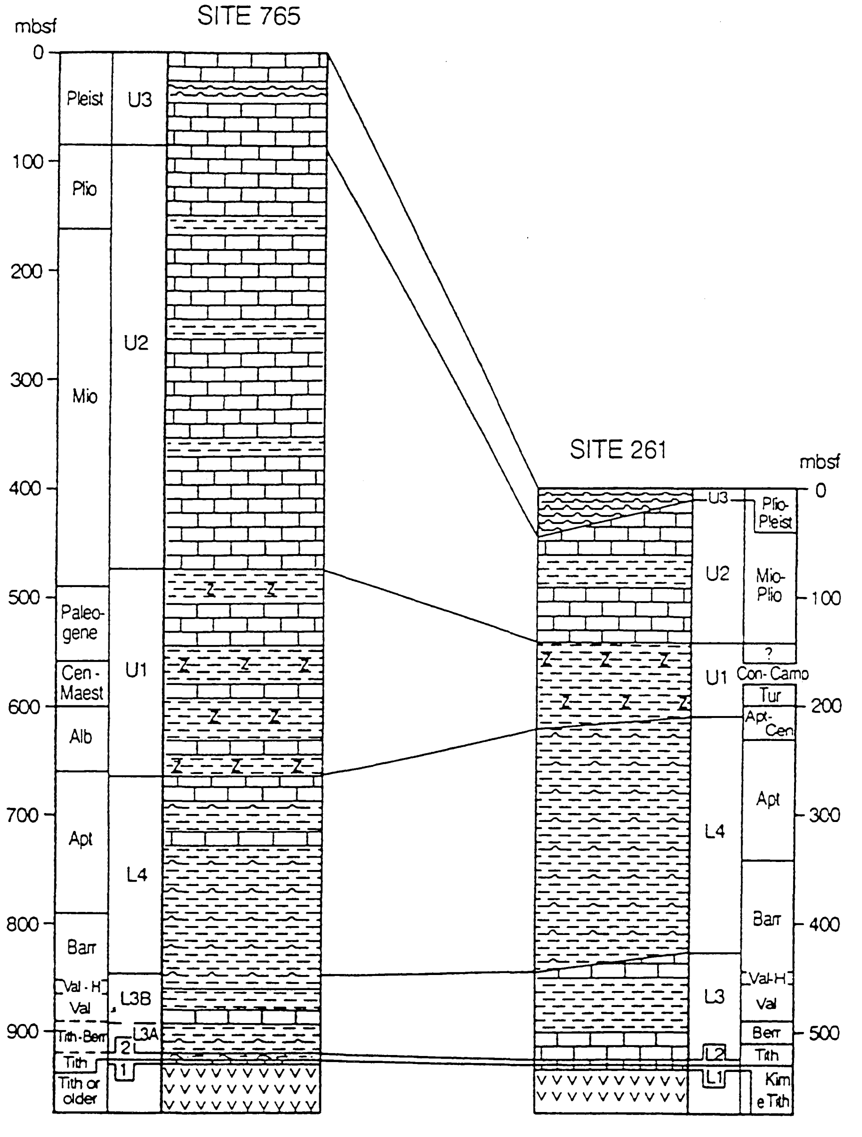

Figure 5: Lithostratigraphic and biostratigraphic correlation of ODP Site 765 and DSDP Site 261 (from Dumoulin & Brown, 1992).

gave an age of 155.3±3.4 Ma (Ludden, 1992) - that is, mid-Callovian using Burger (1990), or latest Oxfordian using Young & Claoue-Long (1991), which is based on calibration using the SHRIMP ion microprobe. Thus Site 765 (Figure 5) drilled on magnetic anomaly M26 (late Oxfordian stage; Burger, 1990) gives a minimum radiometrically derived break-up age of 155 Ma. This radiometric age is in agreement with the age calibration of the late Oxfordian stage using the Young & Claoue-Long (1991) timescale. Clearly this has significant implications for the timing of peak thermal conditions adjacent to much of the Northwest Shelf region.

Gascoyne Abyssal Plain

The Gascoyne Abyssal Plain lies at a water depth of greater than 5700 m, to the west and northwest of the Exmouth Plateau. It is separated from the Argo Abyssal Plain by the Joey and Roo Rises. Geophysical data are sparse for the Gascoyne Abyssal Plain. Break-up appears to have occurred at 125-130 Ma in the Hauterivian. (Larson, 1977; Veevers et al., 1985; Fullerton et al., 1989; Veevers & Li, 1991).

Joey Rise

The Joey Rise lies to the north of the Exmouth Plateau between the Argo and Gascoyne Abyssal plains (Figure 3), where the trend of magnetic lineations changes from N70°E in the Argo Abyssal Plain (Fullerton et al., 1989) to about N30°E in the Gascoyne Abyssal Plain. In a discussion of the origin of the Joey Rise, Cook et al. (1978) concluded that both the Joey and Roo Rises are likely to be of volcanic origin with a probable Cainozoic age, underlain by uplifted oceanic crust of Mesozoic age. This interpretation was based on the volcaniclastic and volcanic material recovered from core and dredge samples and interpretation of seismic reflection data.

TECTONOSTRATIGRAPHIC HISTORY

The tectonostratigraphic history of Australia's northwest margin in the context of Gondwanaland dispersal has been a subject of investigation by many authors. The following summary draws on work by Audley-Charles (1988), Bradshaw et al. (1988), Powell et al. (1988), Sengör et al. (1988), Veevers (1988), Metcalfe (1990), Veevers (1991), Exon et al. (1992), Von Rad et al. (1992), and preliminary results of AGSO's deep-seismic study of the northwest margin (O'Brien et al., 1993).

The tectonic history of the present-day north-western margin of Australia reflects a changing tectonic regime, from intracratonic rift basins, to passive margin, to collisional margin. There is general agreement among authors that, since at least the mid-Palaeozoic, the north-western margin of Australia has experienced repeated rifting events which led to the formation of ocean basins and the detachment of margin fragments as a result of the gradual fragmentation of eastern Gondwanaland during the mid-Palaeozoic to Mesozoic. Northward drift of these cratonic slivers and subduction of the newly formed ocean basins led to successive accretion of the slivers to the Asian continent.

The first extensional event occurred during the Devonian to Early Carboniferous when several continental slivers which now form part of China and Indochina ("Chinese Blocks") were detached from the margin (Figure 6). In the North West Shelf area this event resulted in the initiation of NW-SE trending intracratonic features such as the Petrel Sub-basin and the Fitzroy Trough, and the deposition of a thick, mostly shallow-marine sedimentary sequence of Late Devonian to Early Carboniferous age. The second extensional event, in the Late Carboniferous to Early Permian, resulted in the detachment of Sibumasu (Figure 6), a large continental block which now forms part of Malaysia and Burma, and the initiation of the Westralian Superbasin. The majority of the sedimentary basins of the North West Shelf and other major NE-SW structural features formed at this time and there was widespread deposition of thick glacio-marine to terrestrial clastics in the Early Permian. The Late Permian to Late Triassic was characterised by fluvio-deltaic to marine sag phase sedimentation. O'Brien et al. (1993) recognised a latest Triassic to Early Jurassic N-S to NNW-SSE directed compressional event in the northern North West Shelf region which resulted in the reactivation of the Permo-Carboniferous Westralian Superbasin fault systems.

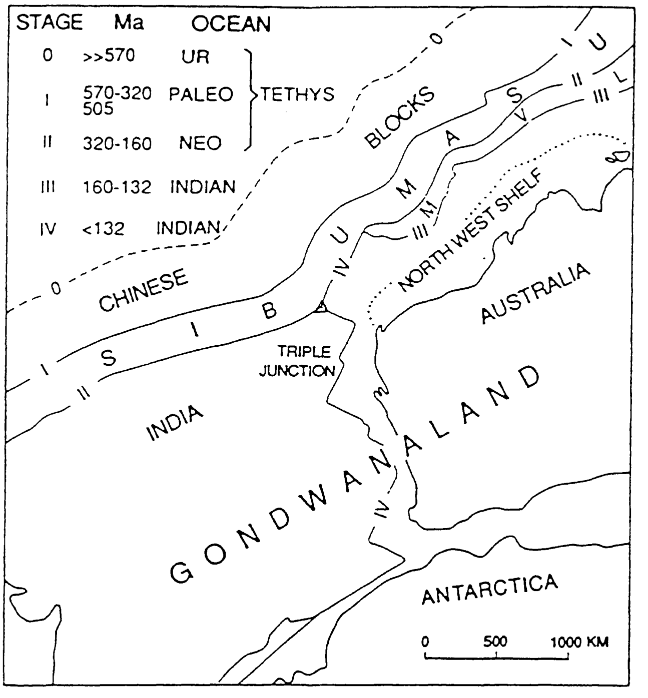

Figure 6: Tectonic setting of the northwest Australian margin prior to Early Carboniferous breakup (from Veevers, 1988).

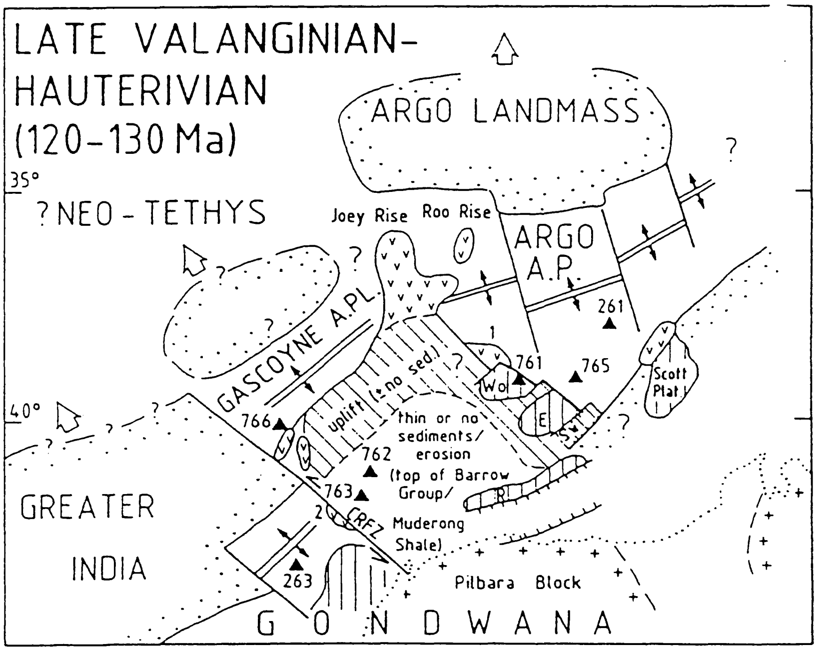

Figure 7: Early Cretaceous palaeogeographic and palaeotectonic reconstruction of the northwest Australian margin (from von Rad & others, 1992).

In the Late Jurassic, another sliver (Argoland or Mount Victoria Land) was removed from the craton margin (Figures 6 & 7) as a result of a latest Callovian to early Oxfordian NE-SW to NNE-SSW oriented extensional event which quickly led to continental break-up and seafloor spreading which formed the Argo Abyssal Plain. Argoland was probably a major sediment source for sedimentary basins of the North West Shelf during the Triassic. The Late Jurassic was characterised by widespread restricted marine deposition of fine clastics, which form a major source rock for many of the hydrocarbon accumulations of the North West Shelf.

Breakup between the south-western Exmouth Plateau margin and Greater India occurred in the Hauterivian to Valanginian and formed the Gascoyne and Cuvier Abyssal plains, thus initiating the formation of the modern Indian Ocean (Figure 7). A Late Jurassic to Early Cretaceous compressional reactivation event in the Timor Sea region north east of the survey area, recognised by O'Brien et al. (1993), may be related to this breakup. It is likely that the Joey and Roo Rises formed at this time along the newly formed plate boundary between the Argo and Gascoyne Abyssal plains, possibly as a result of leaking caused by mild extension related to the change in spreading lineation. During the earliest Cretaceous there was widespread deposition of mainly coarse-grained clastics, sourced from uplifted fault blocks formed during initial extension between greater India and Australia. Continuing subsidence coupled with a decrease in terrigenous sediment supply in the northern Carnarvon, offshore Canning and Browse basins during the Cretaceous, resulted in a transition to open marine environments and the deposition of calcareous claystones and limestones.

The Late Cretaceous to Cainozoic section on the North West Shelf is characterised by a monotonous sequence of calcareous mudstone and limestone deposited during several transgressive/regressive cycles. At ODP Site 765, an approximately 900 m thick section of fine-grained calcareous, mainly turbiditic sediments was penetrated (Figure 5). An increase in regional subsidence and sedimentation rates in the Pliocene may be linked to a Middle Miocene to Recent ENE-WSW oriented compressional reactivation event resulting from collision along the northern edge of the Australian craton.

OBJECTIVES OF THE STUDY

The Margin Transects Survey is part of a major AGSO regional research program, which involves at least eight other deep-seismic surveys designed to determine the broad structural framework of the north-western Australian margin. The major objective of Survey 128 was to extend previous AGSO deep-seismic surveys across the Browse, offshore Canning and northern Carnarvon basins to complete the margin transects in these areas. The study has the following specific objectives:

- Determine the regional structural framework of the Scott Plateau area and its relationship to adjacent features such as the Argo Abyssal Plain, the Browse Basin and the Rowley Sub-Basin of the offshore Canning Basin;

- Determine the regional structural framework of the Exmouth Plateau and its relationship to adjacent features such as the Barrow and Dampier sub-basins, and the Argo and Gascoyne Abyssal plains.

- Define the broad deep-crustal structure of the region and develop models explaining the tectonic, subsidence and thermal history of the Scott Plateau and the Exmouth Plateau in relation to the development of the continental margin and adjacent ocean basins.

- Assess the effects of the deep crustal structures and their reactivation phases on the development of known petroleum accumulations.

Specific questions examined by the collection of deep-seismic reflection data over the Scott and Exmouth Plateaus and the adjacent ocean basins are:

1. The applicability of recent models of rifted margin and basin development to the Scott and Exmouth Plateaus.

2. What is the structural relationship between the Scott Plateau and the adjacent Browse Basin and Rowley Sub-basin?

3. What is the structural relationship between the Exmouth Plateau and the offshore Canning Basin, in particular the Rowley Sub-basin?

4. What is the age, amount, and azimuth of the original extension that formed the Exmouth and Scott Plateaus and adjacent sedimentary basins?

5. Has structural reactivation had a major influence on the development of the Scott and Exmouth Plateaus and how does this reactivation relate to the timing and geometry of breakup in adjacent ocean basins?

6. What is the age, extent, and nature of any reactivation, and its relationship to the primary basin-forming structures and known hydrocarbon accumulations in adjacent sedimentary basins?

7. What is the geometry and nature of the boundary between the Argo and Gascoyne Abyssal plains?

8. What is the extent and significance of magmatism in the formation of the northwest Australian margin?

SURVEY PARAMETERS AND ACQUISITION DETAILS

Data acquired

Data collected on Survey 128 comprise

- deep-seismic reflection data, 48 fold, 16 second record length acquired with a 4800 m active length streamer and dual tuned airgun arrays (20 sleeve-guns of 50 litres total capacity);
- gravity data on all seismic and transit lines;
- magnetic data on approximately 95% of seismic lines and transit lines; and
- bathymetry on all lines.

Way-points used for navigation during Survey 128 are given in Appendix 9 and acquisition details are listed in Appendices 7 and 8. All seismic lines were collected to AGSO specifications.

Execution of seismic program

The seismic acquisition program was executed as planned (Struckmeyer, 1993), except for the addition of one deep-seismic line and an experimental partial re-shoot of line MT-H (128/0900).

Cruise Narrative

The Margin Transects cruise (AGSO Survey 128) commenced in Port Hedland on May 30 and finished in Fremantle on June 30. Cable deployment commenced on June 1 in the survey area and was completed on June 3. Seismic acquisition on line 128/0100 (MT-A) commenced on June 3. The following is a summary of the main events during Survey 128; dates indicated are local, i.e. Western Australian Time.

29 May:	cruise briefing and safety meeting.
30 May:	sailed from Port Hedland; deployed meteorological buoy for Bureau of Meteorology at Latitude 18°19.5'S and Longitude 118°32.4'E; start of survey tests.
31 May:	headed back towards Port Hedland to rendezvous with sea-plane at Clerke Reef to pick up sick crew member.
1 June:	commenced deployment of streamer.
2 June:	streamer deployed and balanced; testing guns.
3 June:	testing guns; SOL 128/0100; loss of DGPS differential corrections; commenced loop; EOL 128/0100.
4 June:	SOL 128/0101.
5 June:	EOL 128/0101; transit; SOL 128/0200.
7 June:	EOL 128/0200; transit; SOL 128/0300.
8 June:	EOL 128/0300; transit.
9 June:	SOL 128/0400.
11 June:	EOL 128/0400; gun maintenance loop; SOL 128/0401.
12 June:	EOL 128/0401; streamer on board; transit.
13 June:	Gun signature tests; streamer deployed; SOL 128/0500.
15 June:	EOL 128/0500; transit; SOL 128/0600.
16 June:	EOL 128/0600; transit.
17 June:	SOL 128/0700.
18 June:	EOL 128/0700; line aborted due to software problems; SOL 128/0701; EOL 128/0701; partial streamer retrieval for replacement of bird 5; transit; SOL 128/0800.
19 June:	EOL 128/0800; gun maintenance loop; tailbuoy not visible on radar during heavy swell;
20 June:	SOL 128/0801; EOL 128/0801; transit to re-shoot last 12 miles of line 128/0401; SOL 128/0402.
21 June:	EOL 128/0402; partial streamer retrieval for replacement of bird batteries 1 and 2; transit; SOL 128/0802;

22 June: EOL 128/0802; transit; SOL 128/0900;
23 June: EOL 128/0900; transit; SOL 128/1000;
24 June: EOL 128/1000; transit; SOL 128/1100;
25 June: EOL 128/1100; streamer retrieved; commenced transit to Fremantle.
30 June: Arrival at Fremantle; end of Survey.

Seismic Data Recorded

A total of 11 seismic lines were shot during Survey 128 (Figures 8 & 9); three of these were shot across the Scott Plateau, three across the Exmouth Plateau, two from the Rowley Sub-Basin to the Exmouth Plateau, and two across the Argo and Gascoyne Abyssal plains. Total seismic production was 3403.05 km. The survey ties into AGSO deep-seismic Surveys 101, 110, 119 and 120, and standard record length Survey 95 (Figure 10). Seismic line information is summarised in Appendix 10 and a list of tape numbers for each seismic line is given in Appendix 11.

<u>Line 128/100</u>: extends AGSO's Browse Basin line 119/6 from the outer Browse Basin across the northern Scott Plateau onto the easternmost Argo Abyssal Plain. The line also ties line 119/3. The line was shot in two segments.

<u>Line 128/200:</u> extends Browse Basin line 119/2 from the outer Browse Basin across the central Scott Plateau onto the Argo Abyssal Plain, crossing magnetic anomaly M24; it ties margin strike lines 119/3 and 119/12.

<u>Line 128/300:</u> extends from the south-western Browse Basin across the southern Scott Plateau (Rowley Terrace) onto the south-eastern Argo Abyssal Plain crossing magnetic anomaly M26. It ties AGSO's Browse Basin and SNOWS-4 lines 119/12 and 120/7, respectively, as well as the standard record-length Triassic Reef Survey line 95/6.

<u>Line 128/400:</u> is a NE-SW oriented strike line which extends AGSO's SNOWS-3 line 120/2 from ODP Site 765 on the southern Argo Abyssal Plain across the north-eastern and central Exmouth Plateau to SNOWS-2 line 110/13. It ties AGSO deep-seismic lines 110/9, 120/1, 120/14, and 95/14 and 19 (Triassic Reef Survey). The line was shot in three segments.

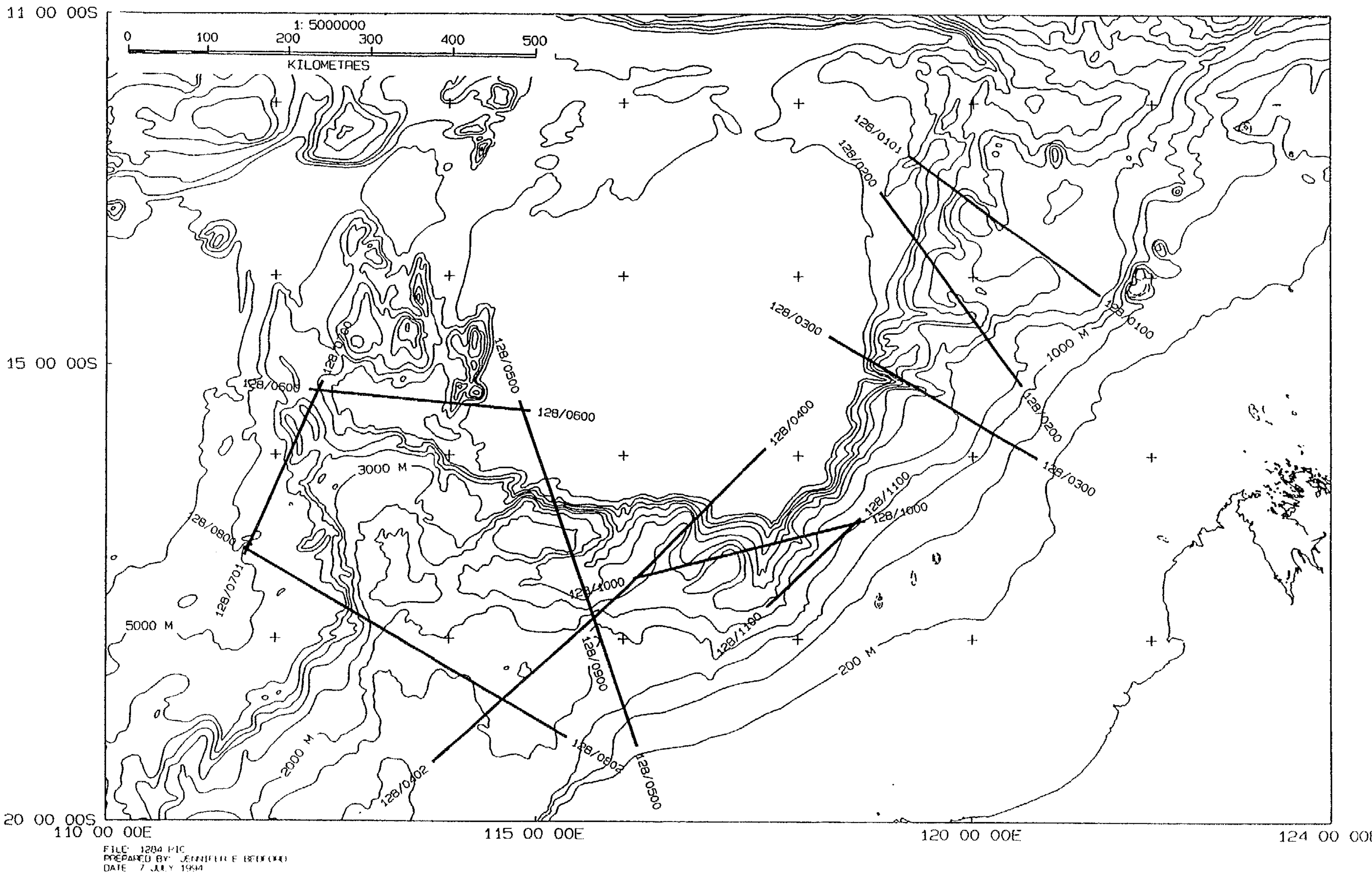

Figure 8: Location of seismic lines shot during Survey 128.

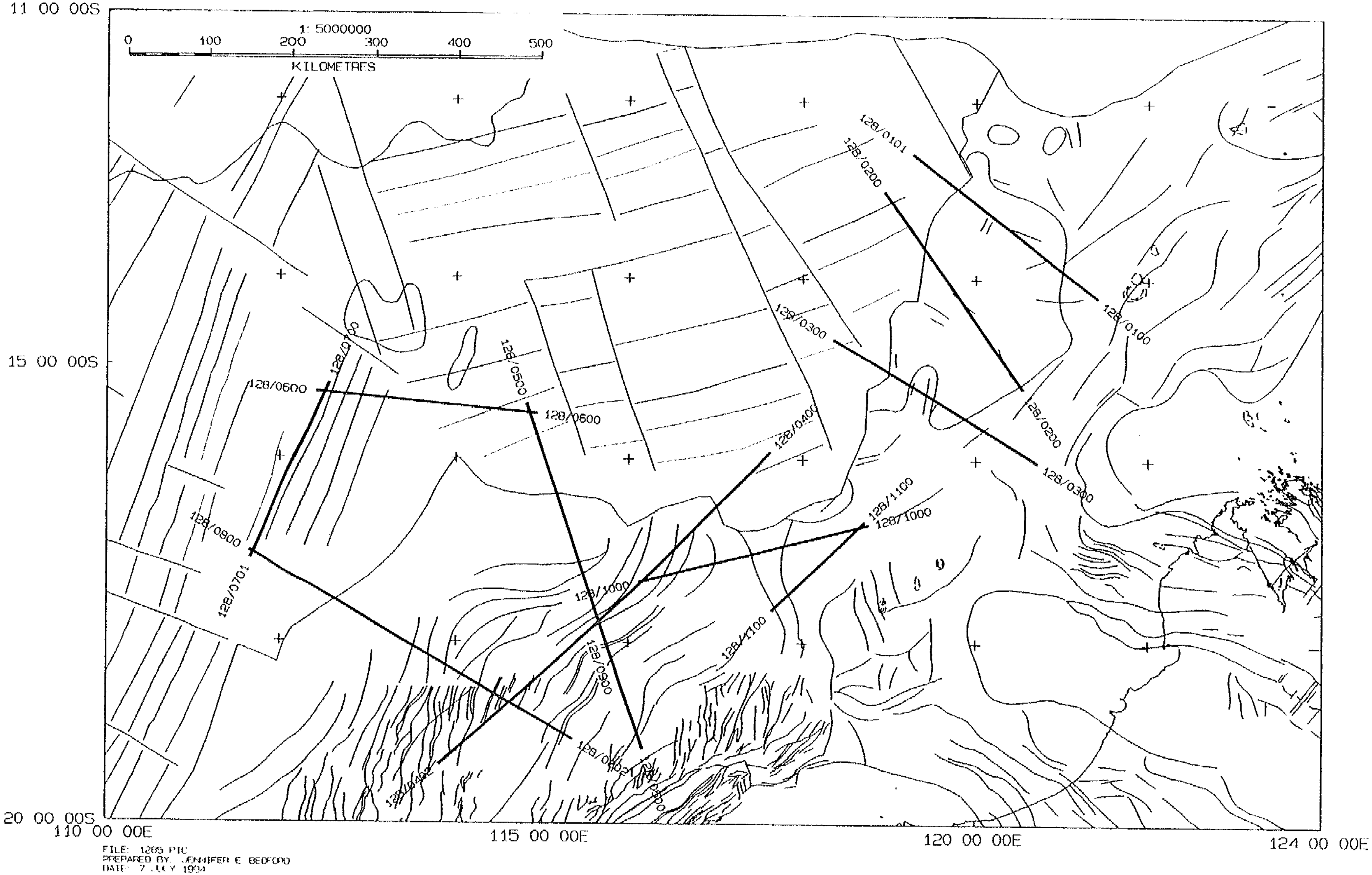

Figure 9: Location of seismic lines shot during Survey 128 with respect to major structural elements in the region.

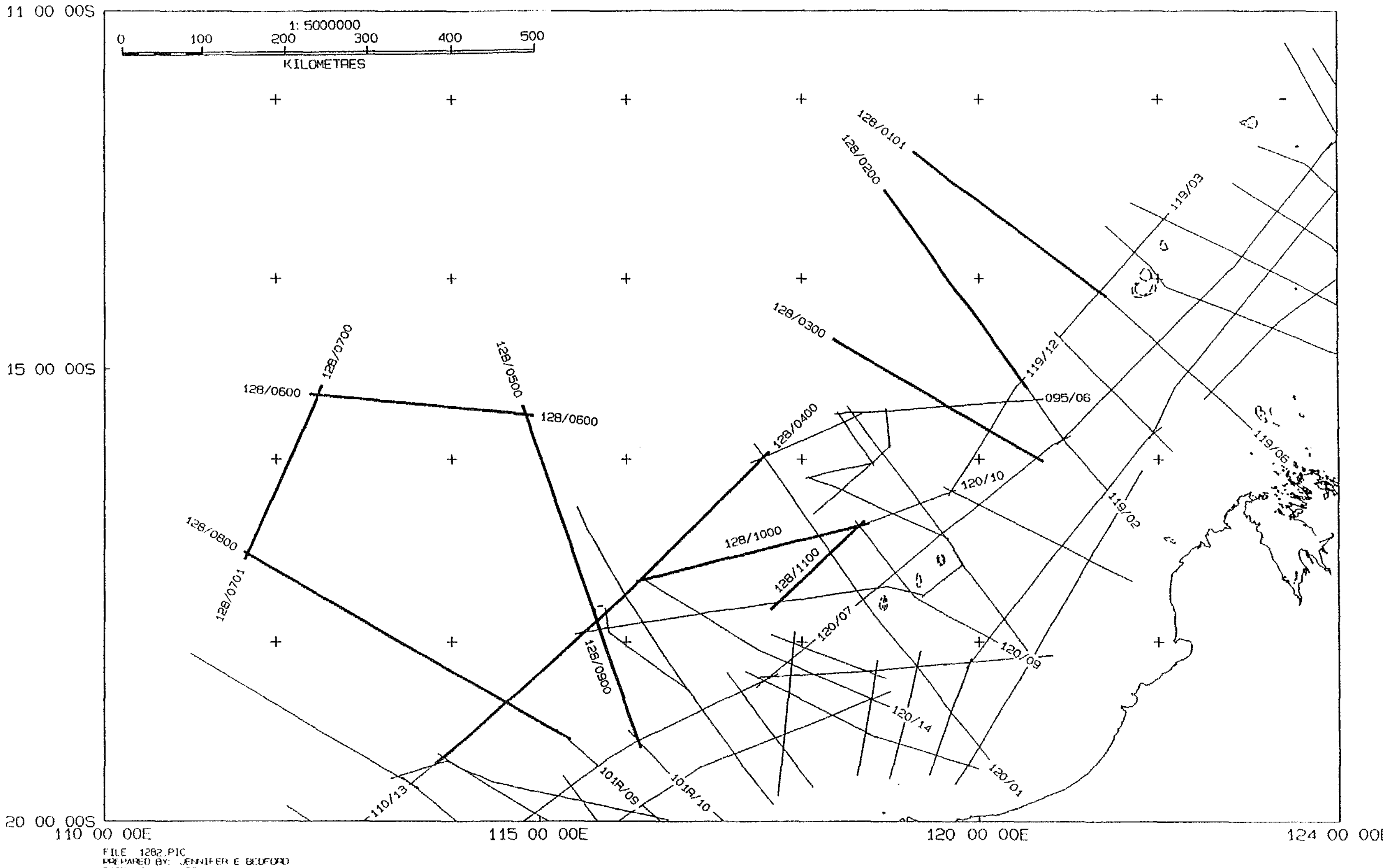

Figure 10: Location of seismic lines shot during Survey 128 in relation to other AGSO deep seismic surveys in the region.

Line 128/500: is a NNW-SSE oriented dip line with respect to the Argo Abyssal Plain and possible Palaeozoic extension direction. It extends from the northernmost Rankin Platform in the south, across the Wombat Plateau onto the Argo Abyssal Plain and ties AGSO's SNOWS-1 line 101/10 and SNOWS-2 line 110/8, and Triassic Reef Survey line 95/14. The line was shot with the guns at 6 m (±1.5 m) depth and was partly re-shot as line 128/900 with the guns at 10 m (±1.5 m) depth.

Line 128/600: extends across the boundary between the Argo and Gascoyne Abyssal plains south of the Joey Rise; it thus crosses a major palaeotectonic boundary which would have significantly influenced the breakup history of the continental margin. The line crosses magnetic anomalies M 6 to 10 on the Gascoyne and M 24A on the Argo Abyssal Plain.

Line 128/700: is a Gascoyne strike line between magnetic anomalies M6 and M7. The line was shot in two segments.

Line 128/800: is a NW-SE oriented dip line with respect to the Gascoyne Abyssal Plain and extends AGSO's SNOWS-1 line 101/9 from the Kangaroo Syncline across the western Exmouth Plateau onto the western Gascoyne Abyssal Plain. The line was shot in three segments.

Line 128/900: is an experimental re-shoot of parts of Line 128/0500 with the guns at 10 m (±1.5 m) depth;

Line 128/1000: extends SNOWS-3 line 120/10 to complete the outer margin transect from the northern Browse Basin across the Rowley Sub-basin and the Swan Canyon onto the Exmouth Plateau. It ties AGSO's SNOWS-4 lines 120/1, 120/11, and 120/14.

Line 128/1100: was designed to link line 128/1000 to well location Delambre-1 on the SE Exmouth Plateau. It ties with SNOWS-3 lines 120/09, 120/01 and Triassic Reef Survey line 95/14. The line was abandoned with 156.8 km shot to commence transit to Fremantle.

SUMMARY OF EQUIPMENT AND SYSTEMS REPORT

(condensed and edited version of AGSO internal reports by G. Cassim, M. Alcock, M. Callaway, R. Mleczko, W. Wierzbicki)

Navigation/Geophysical (non-seismic) Data Acquisition System (DAS)

Navigation

The navigation systems for Survey 128 consisted of two differential Global Positioning Systems, Multifix (primary) and DNAV (secondary), supplied by RACAL Survey Ltd. Each system comprises a Trimble 4000DS receiver, Racal demodulator and a Compaq 486/DX2 PC. Base stations at Darwin, Dampier, Broome and Perth were utilised and data were recorded on disk, backed up on DAT tapes and raw navigation data from DNAV were also recorded on optical disk. Differential GPS coverage was available throughout Survey 128 with the exception of one period from 154 15:28 to 154 16:38 (Julian date) when the Singapore earth station's UPS went down. As a result, line 128/100 was abandoned. Dead reckoning was used briefly when differential corrections were lost.

Magnetics

Apart from minor noise problems which were eliminated with regular fine tuning, the single channel magnetometer worked well.

Gravity

The gravity meter became increasingly noisy as the cruise progressed.

Bathymetry

Bathymetric data were collected during the entire survey without problems using 12 kHz and 3.5 kHz echo sounders. Water depths of less than 200 m to more than 5700 km were encountered.

Seismic Acquisition System

Amplifiers and Phoenix A-D Converter

The system performed well and remained within specification throughout the survey. The Phoenix A-D converter and IFP amplifiers used during the survey performed reliably. Start and end of line tests during the survey consisted of the usual amplifier, oscillator, high-cut and low-cut and impulse tests, and also dynamic range tests using normalised data. During the survey, channels 27 and 28 drifted high in the oscillator test. This problem is thought to originate either in the amplifier sub-rack or the MUX.

Tape drives

During the cruise occasional bad block errors were encountered, but these were kept to a minimum with the regular use of a tape cleaner. On two occasions tapes were ejected on start of line - the source of this problem has been tentatively traced to entering the start stop recording option in the menu.

Software

On two occasions large clock resets led to disruption of the shot spacing routine. The second time more than 10 shots were lost and a loop was required. The clock reset was then disabled in both systems requiring a large clock reset at the end of recording.

Seismic cable

The seismic streamer configuration is shown in Appendix 8. Twenty five remotely controlled cable leveller birds, each with a depth transducer, were deployed along the streamer. The cable was held at a depth of approximately 11 m to minimise swell noise. In addition to the depth controllers, 5 compass birds were deployed and an emergency satellite transmitter (ARGOS) was also mounted on the streamer as a security measure against cable loss. Parts of lines 128/500 and 128/1000 were affected by swell noise but remained within tolerances. Overall, the streamer performed well and was only retrieved twice, once because of reversed channels, the second time section 48 became noisy and sank to 16 m. On retrieval it was found to be full of water and was replaced. There were no major problems with birds or bird batteries.

Tail buoy

A non-active tailbuoy fitted with radar reflector, warning light and ARGOS transmitter was used during the survey and performed well. It became separated from the tow rope on 19 June and was lost.

Seismic source

The seismic source for Survey 128 was provided by two arrays of sleeve guns consisting of sixteen 150 cubic inch guns on each array. During seismic recording, 10 guns were fired from each array with the airguns grouped in clusters of 4, 3, 2 and 1 guns. The guns performed satisfactorily throughout the survey with only two loops required as a result of gun failure, one of which occurred after more than 48 hours of shooting.

Guns were deployed at 10 m for most of the survey. Line 128/500 was shot with guns at 6 m and partly reshot as line 128/900 with guns at 10 m for comparative reasons. The data on line 128/500 show no immediately apparent difference to the remaining survey data, but processing and assessment of both data sets and gun signature tests carried out for both depths is likely to clarify this issue.

There were problems with a large number of persistent false "no fires" being reported for some guns. Additionally, large variations in amplitudes and waveshapes between return signals resulted in timing errors of up to 3 milliseconds. Extensive tests on the gun-controller, shot-cards, signal input cards, wiring, sensor coils, solenoids, o-rings, seals, shuttle performance were carried out during the survey to find the cause for this problem. Some of the changes made to equipment as a result of these tests caused temporary or minor improvements to the problem. Tests indicate that the problem is likely to be caused by magnetic interference from iron rings used to clamp the top housing of each gun to the top-plate utilised to suspend the gun. It was recommended that the iron rings be replaced by stainless steel rings before the next survey.

Compressors

The compressors performed well throughout the survey.

PRELIMINARY RESULTS

The greater part of the survey area is located in deep water, with 97% of the survey shot in water depths exceeding 1000 m. Thus, some generalised characteristics of the upper part of the seismic sequences can be discussed. On the inner Scott Plateau, the top second of data is characterised by moderate- to high-frequency parallel to subparallel reflections probably representing a ?Late Mesozoic to Neogene sequence. More intense structuring is evident on the central to western Scott Plateau. A high-standing fault-block with a planed-off strongly angular unconformity (Figure 11) of possible Late Triassic or older age is a major feature on the northernmost line (128/100). Prominent faulting at ?Palaeozoic level can be observed on line 128/200 (Figure 12). On this line, a further pronounced erosional unconformity at the top of an almost transparent section is of possible Late Cretaceous age. A major feature observed on line 128/300 is a southeastward dipping half-graben with more than one s TWT sedimentary fill (Figure 13). This graben probably corresponds to the sedimentary embayment described by Stagg & Exon (1981) as a half-graben within probable Permo-Triassic and Palaeozoic rocks with Triassic to Jurassic fill. The graben fill on Line 128/300 is typically of low amplitude and near transparent. On the Exmouth Plateau transects, reflections on the monitor sections can be recognised down to the main Late Triassic unconformity which is cut by subtle to complex normal faults.

Oceanic basement was reached on all dip lines. The continent-ocean boundary appears to be volcanic on most lines with the exception of line 128/200, which appears to cross a faulted margin. On the Argo Abyssal Plain, basaltic basement typically lies at about 7.5 to 8.5 s TWT. Approximately 0.5 to 1.0 s TWT of sediment is draped over the basalt and occasional basement highs. Figure 14 shows a section of Line 128/600 which crosses the boundary between the Argo and Gascoyne Abyssal plains. No immediately apparent change in character or structure between the two ocean basins is evident from the monitor section. A number of basement highs were traversed on the line, and some are clearly younger than the sediments overlying the basaltic basement. Sediment thickness in the transition zone between the two ocean basins is approximately twice that of the eastern Argo Abyssal Plain, and basement typically occurs at about 6.5 to 7.5 s TWT and is thus present at shallower depths than on the Argo Abyssal Plain.

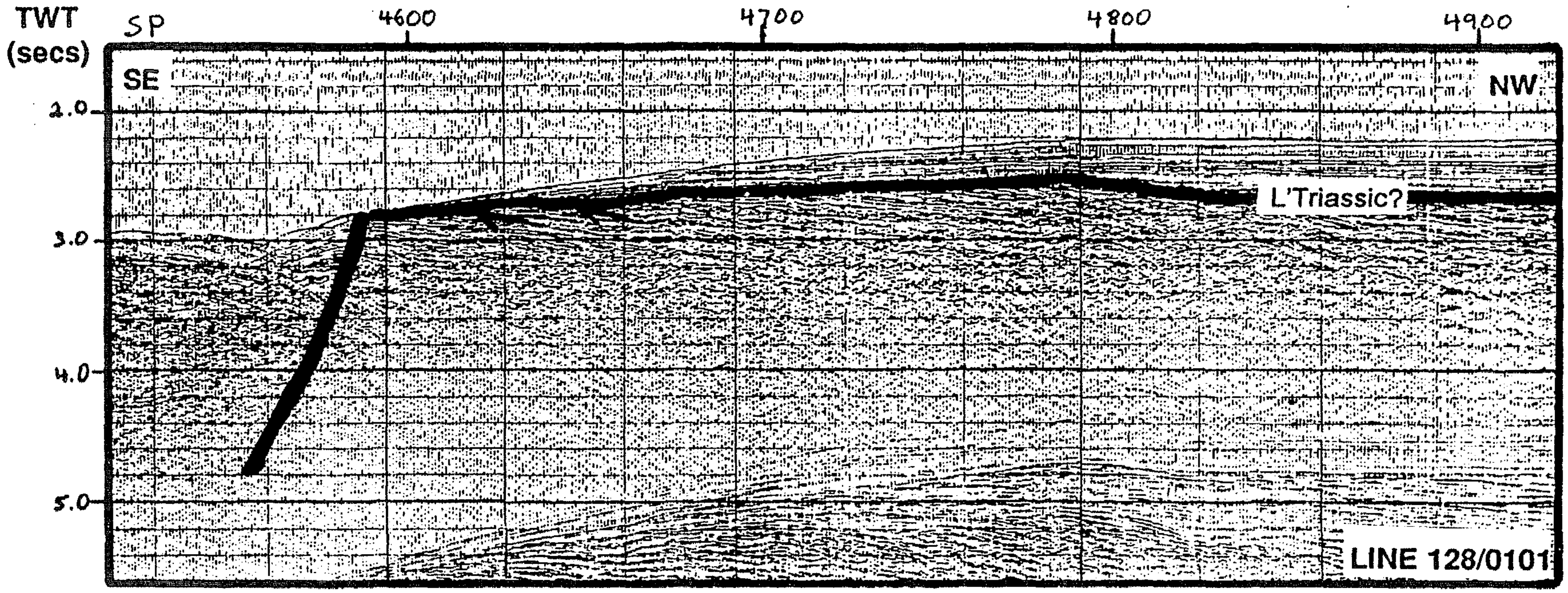

Figure 11: Seismic monitor section (line 128/0101) of the northwestern Scott Plateau.

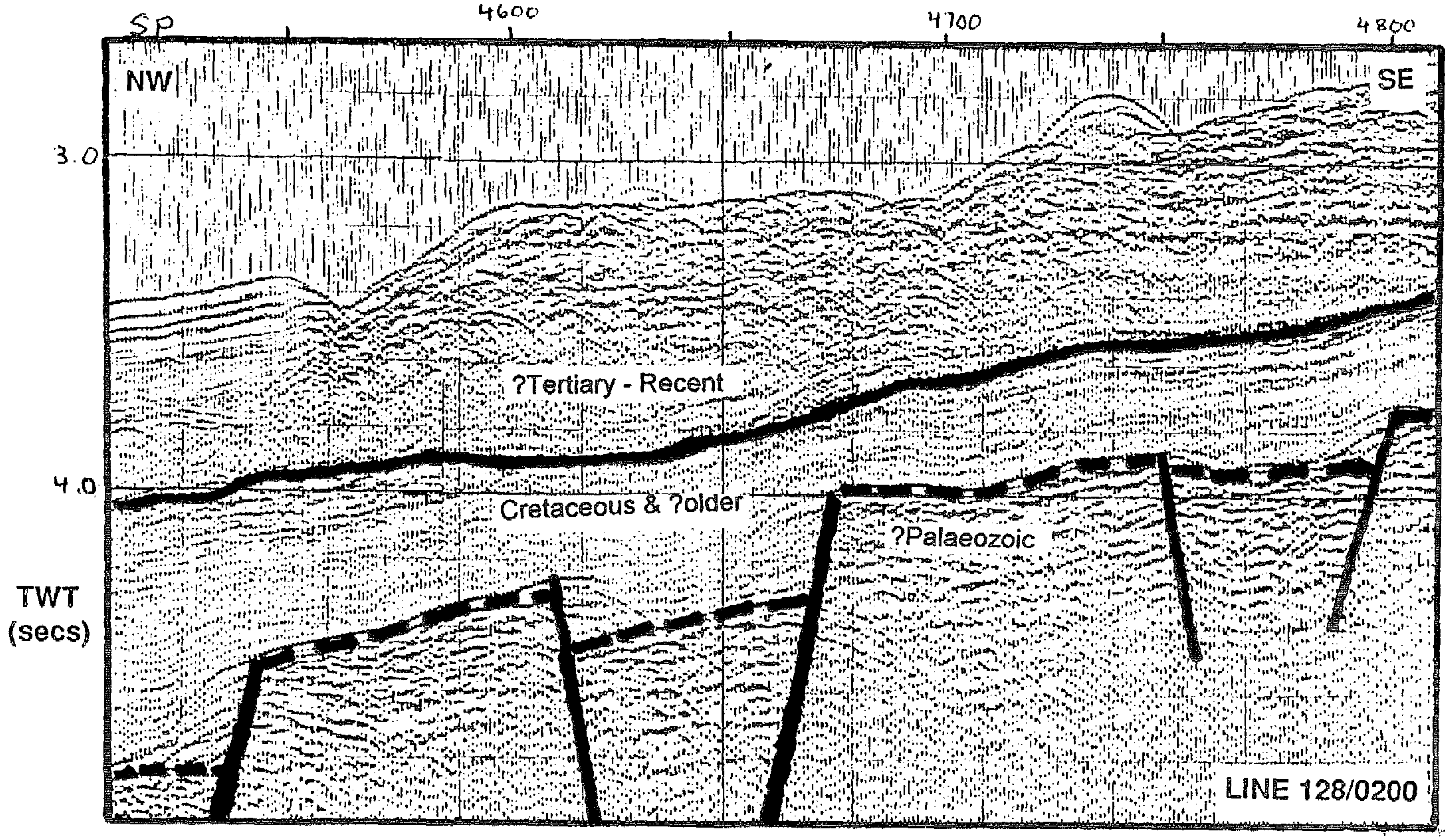

Figure 12: Seismic monitor section (line 128/0200) of the central Scott Plateau.

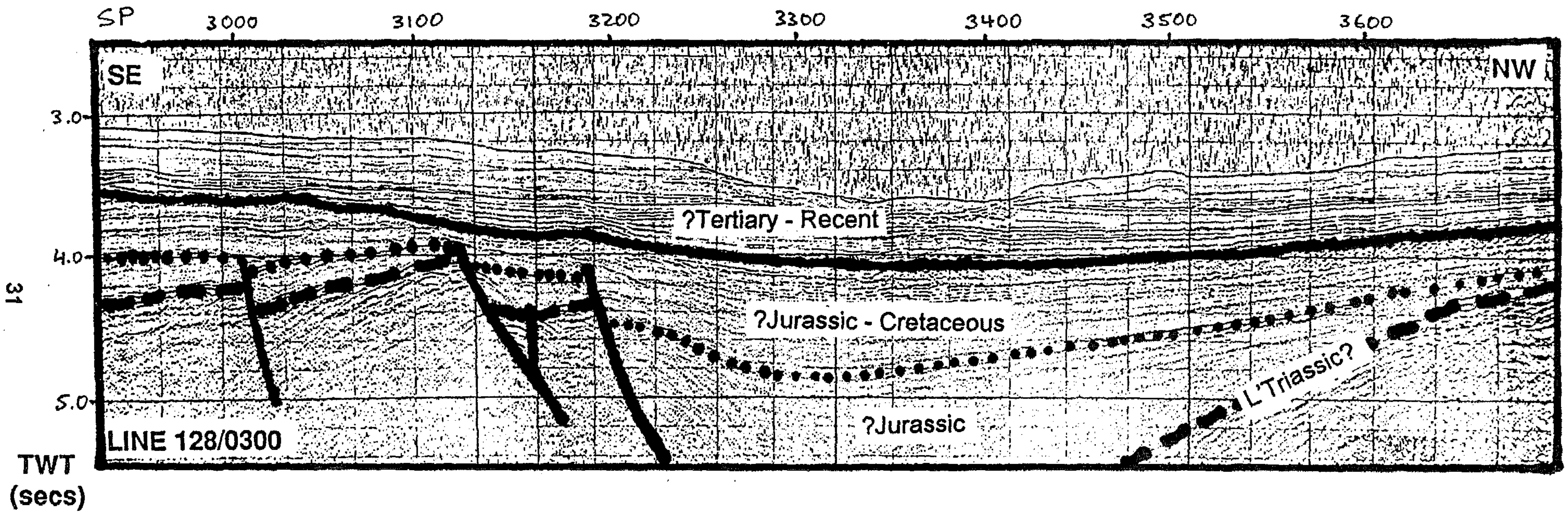

Figure 13: Seismic monitor section (line 128/0300) of the southern Scott Plateau.

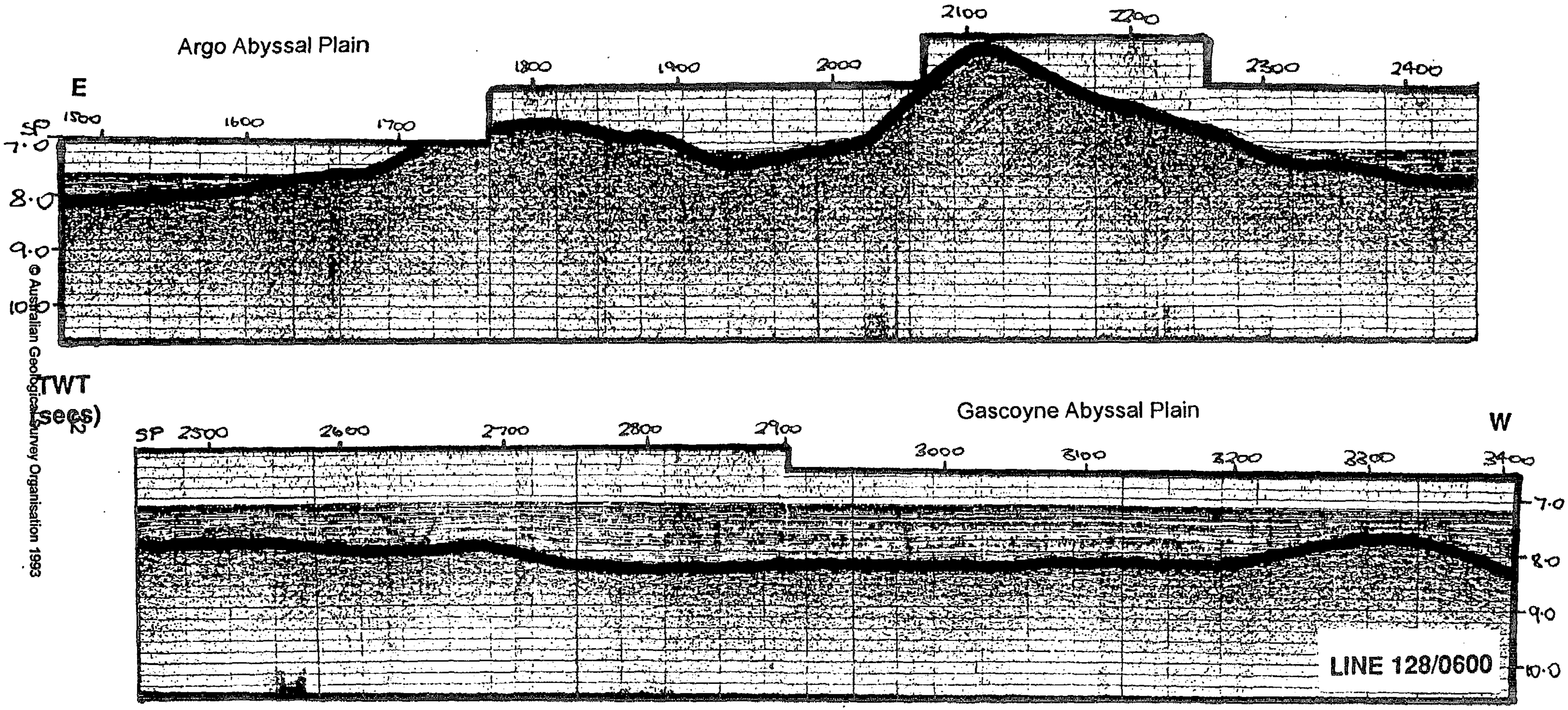

Figure 14: Seismic monitor section (line 128/0600) of the boundary between the Argo and Gascoyne Abyssal Plains.

ACKNOWLEDGEMENTS

The Master, Trevor Walters, and AMSA crew of the RV *Rig Seismic* are thanked for their help and close co-operation during the execution of Survey 128. Their expert skills and demonstrated professionalism made a vital contribution to the successful completion of the scientific program. I am grateful to Phil Symonds, Jim Colwell and Howard Stagg for the support they provided in the planning of this cruise during numerous valuable discussions. Howard Stagg and Jane Blevin are thanked for their reviews of the manuscript. Jenny Bedford prepared some of the illustrations for this report.

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APPENDIX 1: AGSO DEEP-SEISMIC SURVEYS IN THE NORTH WEST SHELF REGION

1. Vulcan Graben (Survey 98) - 1900 km of deep-seismic data - acquisition completed December 1990 (O'Brien and Williamson, 1990).

2. Petrel Sub-basin (Survey 100) - 2090 km of deep-seismic data - acquisition completed May 1991 (Willcox & Ramsay, 1991).

3. Northern Carnarvon Basin (SNOWS-1 - Survey 101) - 1654 km of km of deep-seismic data - acquisition completed June 1991 (Stagg et al., 1991).

4. Northern Carnarvon Basin (SNOWS-2 - Survey 110) - 2868 km of deep-seismic data - acquisition completed July 1992 (Stagg, 1992).

5. Australian - Indonesian Joint Development Zone and adjacent areas (Survey 116) - 3595 km of deep seismic data - acquisition completed March 1993 (Struckmeyer et al., 1993).

6. Malita Graben (Survey 118) - 3602 km of deep-seismic data - acquisition completed May 1993 (Hill et al., 1993).

7. Browse Basin (Survey 119) - 3460 km of deep-seismic data - acquisition completed July 1993 (Symonds et al., in prep.).

8. Offshore Canning (SNOWS-3 - Survey 120) - 4052 km of deep-seismic data - acquisition completed August 1993 (Stagg et al., 1993).

9. North West Margin Transects (Survey 128) - 3403 km of deep-seismic data - acquisition completed June 1994 (this survey).

10. Browse Basin Infill - approximately 3500 km proposed - acquisition proposed for July 1994.

APPENDIX 2: PRE-1991 SEISMIC SURVEYS OVER THE SURVEY AREA

Year	Organisation	Ship	Seismic Source	Recording
1967	BMR (Australia)	*Wyrallah*	21 kJ-sparker	Single channel analogue
1968	BMR (Australia)	*Robray 1*	21 kJ-sparker	Single channel analogue
1971	Shell International Petroleum Mij. (Netherlands)	*Petrel*	Airguns (6.4 1)	24-channel digital
1971	Lamont-Doherty Geological Observatory (USA)	*Vema*	Airgun (0.83 1)	Single channel analogue
1971/72	Esso Australia Ltd.		Maxipulse	24-channel digital
1972	Gulf Research and Development Co. (USA)	*Gulfrex*	Aquapulse	24-channel digital
1972	BMR (Australia)	*Hamme/ Lady Christine*	120 kJ-sparker	6-channel analogue
1972	JOIDES (USA)	*Glomar Challenger*	Airguns (0.5 1)	Single channel analogue
1976	Woods Hole Oceanographic Institution (USA)	*Atlantis II*	Airguns (2.0 1)	Single channel analogue
1977	BGR (Germany)	*Valdivia*	Airguns (18.0 1)	24-channel digital; single channel analogue
1986	BMR (Australia)	*Rig Seismic*	Airguns (8.2 1)	96-channel digital
1990	BMR (Australia)	*Rig Seismic*	Airguns (8.2 1) and Waterguns	96-channel digital

APPENDIX 3: COMPANIES CONSULTED DURING PREPARATION OF CRUISE PROPOSAL

During preparation of this cruise, the following exploration companies and organisations were contacted to provide input.

Amoco Production Co
Amoco Australia Ltd
Ampol Exploration Ltd
Ansbachall Pty Ltd
Apache International
BHP Petroleum Pty Ltd
BP Developments Aust. Ltd
Bridge Oil Ltd
Command Petroleum NL
Conoco Inc
Crusader Ltd
Cultus Petroleum (Australia) NL
Enterprise Oil Exploration
Esso Australia Ltd
Hadson Energy Ltd
Hardy Petroleum
Idemitsu Oil Development Co Ltd
Japan National Oil Company
KUFPEC Australia Pty Ltd
Lakes Oil Ltd
Marathon Petroleum Australia Ltd
MIM Petroleum Exploration Ltd
Mobil Exploration & Producing Australia Pty Ltd
NOPEC
Norcen International Ltd
OPIC Australia Pty Ltd
Petrofina Exploration Australia SA
Petroz Ltd
Phillips Australian Oil Co
Santos Ltd
SAGASCO Resources Ltd
Shell Development Australia Ltd
Stirling Resources NL
West Australian Petroleum Pty Ltd
Western Mining Corporation Ltd
Woodside Offshore Petroleum Pty Ltd
Department of Minerals & Energy, Western Australia
Bureau of Resource Sciences

APPENDIX 4: RESEARCH VESSEL *RIG SEISMIC*

R.V. *Rig Seismic* is a seismic research vessel with dynamic positioning capability, chartered and equipped by AGSO to carry out the Continental Margins Program. The ship was built in Norway in 1982 and arrived in Australia to be fitted out for geoscientific research in October 1984. It is registered in Newcastle, New South Wales, and is operated for AGSO by the Australian Maritime Safety Authority.

Gross Registered Tonnage:	1545 tonnes
Length, overall:	72.5 metres
Breadth:	13.8 metres
Draft:	6.0 metres

Engines:	Main: Norma KVMB-12	2640 H.P./825 r.p.m.
	Aux: 3 x Caterpillar	564 H.P./482 KVA
	1 x Mercedes	78 H.P./56 KVA
	Shaft generator:	AVK 1000 KVA; 440 V/60 Hz
	Side Thrusters:	2 forward, 1 aft, each 600 H.P.

Helicopter deck:	20 metres diameter
Accommodation:	39 single cabins and hospital

APPENDIX 5: SCIENTIFIC EQUIPMENT USED DURING SURVEY 128

- FJORD Instruments seismic receiving array: 25 m group length, 192 channels; 4800 metres active streamer length
- Syntron RCL-3 cable levellers; individual remote control and depth readout
- Haliburton Geophysical Service 32 x 150 cubic inch airguns in two 16 gun arrays; the normal operating array is 2 x 10 guns, giving a total of 3000 cubic inches normal operating array volume
- Air compressor system: 6 x A-300 Price compressors, each providing 300 scfm at 2000 psi (62 litres/min at 14 MPa)
- Digital seismic acquisition system designed and built by AGSO running on DEC µ VAX 4200:

  0.5msec-4msec sampling interval, 2sec-16sec record length
  Phoenix A/D converter and instantaneous floating point amplifier
  Data stored on Fujitsu 3480 cartridge tape drives
  Data in demultiplexed (modified) SEG-Y format.

- Raytheon echo sounders: 3.5 KHz (2 K.W.), 16 transducer sub bottom profiler and 12 KHz (2 K.W.)
- Geometrics G801/803 magnetometer
- Bodenseewerk Geosystem KSS-31 marine gravity meter

Navigation equipment

- RACAL SKYFIX differential GPS system

  MULTIFIX - primary; DNAV - secondary

- Magnavox MX 610D and Raytheon DSN 450 dual axis sonar dopplers
- Sperry gyro-compasses; plus Ben paddle log

APPENDIX 6: SURVEY 128 CREW LIST

Scientific Crew

G. Cassim	Vessel Manager/Cruise Leader
H. Struckmeyer	Survey Scientist
M. Fellows	Scientist
H. Miller	Systems Development/Quality Control
M. Alcock	Quality Control
R. Mleczko	Quality Control
C. Buchanan	Science Technician
D. Pryce	Science Technician
S. Ridgeway	Science Technician
J. Ryan	Science Technician
M. Callaway	Electronics Technician
W. Wierzbicki	Electronics Technician
A. Radley	Mechanical Technician
R. Bodger	Mechanical Technician
B. Dickinson	Mechanical Technician
S. Milnes	Mechanical Technician

AMSA Crew

T. Walters	Master
M. Gusterson	1st Mate
D. Watson	2nd Mate
R. Ayerst	1st Engineer
K. Jones	Electrician
R. Willis	Chief Integrated Rating
T. Dale	Integrated Rating
D. Fowler	Integrated Rating
J. Fraser	Integrated Rating
H. Dekker	Chief Steward/Cook
K. Beu	Cook
E. Strange	Catering/Attendant
S. Stavely	Catering/Attendant

APPENDIX 7: SEISMIC ACQUISITION PARAMETERS

Seismic Cable Configuration

standard	length	4800 m
	group length	25 m
	no. channels	192

Seismic Source

airgun array capacity	50 litres (3000 cu in)
airgun pressure	1800 psi (normal)
	1600 psi (minimum)
nominal shot interval	50 m

Fold

standard	4800 %

Recording Parameters

record length	16 s
sample interval	2 ms

APPENDIX 8: SEISMIC ACQUISITION GEOMETRY

Survey:	**North West Margin Transects**	**Survey No.**	**128**
Group Length: GL =	25 m	Date:	Jun-94
No. of Active Channels: N =	192	Gun Length: SCE =	13.5 m
Active Length: AL = (GLxN) =	4800 m	Gun Chain Length: GC =	30.7 m
Stretch Length: SL =	150 m	Antenna to Stern: NS =	51.2 m
Tow leader length (TLL) =	90 m	Tailbuoy rope =	140 m

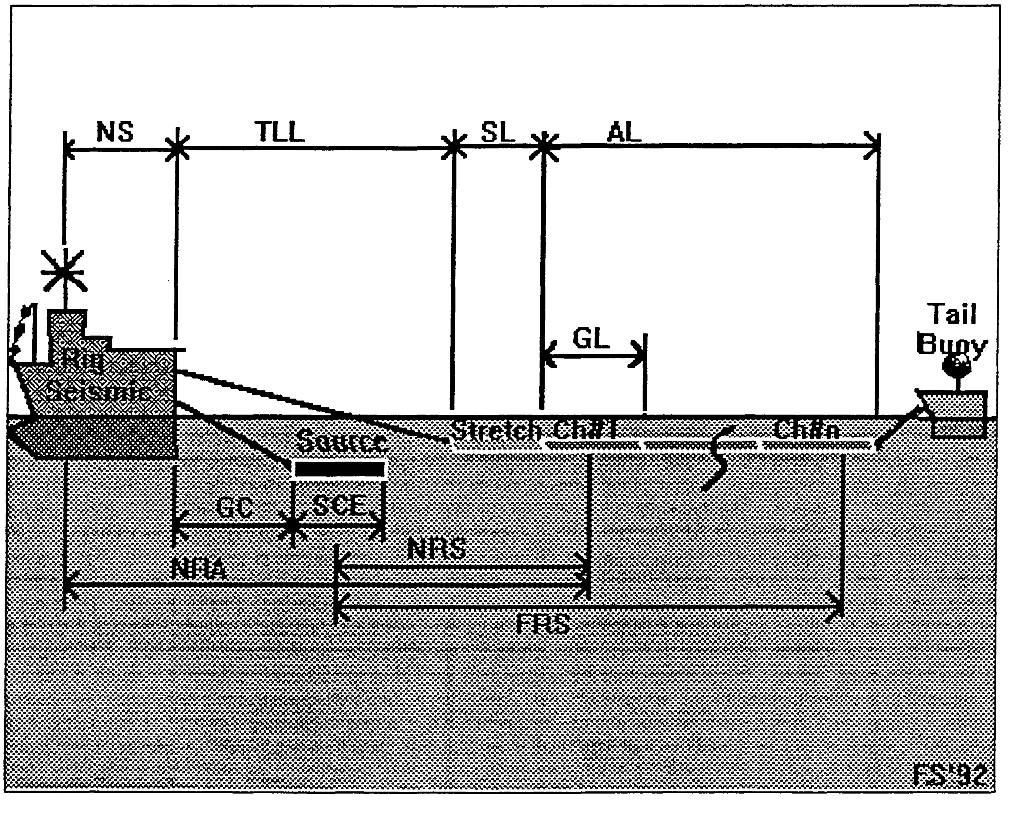
DT Birds located after Channels: 0,8,16,24,32,40,48,56,64,72,80,88,96,104,112
120,128,136,144,152,160,168,176,184,192

Compass Birds located after Channels: 29,69,109,149,189

Source Near Offset: NRS = TLL + SL + GL/2 - (GC + SCE/2) = 214 m

Source Far Offset: FRS = NRS + (N - 1)GL = 4989 m

Field Tape Format: BMR 16 BIT Floating Point SEG-Y, 3480 data cartridge



APPENDIX 9: WAY-POINTS USED FOR SURVEY 128

Line No.	Pre-Survey	Way Point		Latitude deg/min S	Longitude deg/min E
128/0100	MT-A	1	SOL	14 12.240	121 25.650
		2		14 08.887	121 21.252
		3	EOL	12 29.730	119 07.770
128/0200	MT-B	1	SOL	13 00.799	118 55.876
		2		15 04.093	120 26.052
		3	EOL	15 12.185	120 32.000
128/0300	MT-C	1	SOL	16 01.458	120 43.542
		2	EOL	14 41.112	118 22.170
128/0400	MT-D	1	SOL	18 47.538	117 38.096
		2	ODP765	15 58.477	117 34.440
		3		17 22.372	116 07.643
		4		19 12.617	113 59.398
		5	EOL	19 20.267	113 49.842
128/0500	MT-H	1	SOL	19 10.790	116 10.117
		2		19 06.060	116 08.393
		3	EOL	15 25.272	114 48.852
128/0600	MT-G	1	SOL	15 30.600	114 55.812
		2	EOL	15 17.083	112 24.642
128/0700	MT-F	1	SOL	15 10.980	112 32.142
		2	EOL	17 04.968	111 39.468
128/0800	MT-E	1	SOL	17 01.140	111 38.130
		1	EOL	19 03.768	115 19.897
128/0900	MT-H	1	SOL	18 22.537	115 52.585
		2	EOL	17 43.476	115 38.454
128/0900	MT-I	1	SOL	17 20.712	116 07.230
		2		16 44.280	118 38.982
		3	EOL	16 43.062	118 44.046
128/1100	MT-J	1	SOL	16 40.830	118 42.751
		2		16 44.280	118 38.982
		3	Delambre-1	18 31.000	116 41.883

APPENDIX 10: SURVEY 128 LINE SUMMARY

Line No.	Ref.-No. (pre-survey)	Date (Local at SOL)	Start Time Julian ddhhmmss	End Time Julian ddhhmmss	LOCATION Start Latitude deg/minS	LOCATION Start Longitude deg/minE	LOCATION Stop Latitude dg/minS	LOCATION Stop Longitude deg/minE	FSP	FCSP	LSP	LCSP	Length (km)	Total (km)
128/0100	MT-A	6/03/94	154130032	154152800	14 12.244	121 25.650	14 05.229	121 16.178	100	100	528	528	21.45	21.45
128/0101	MT-A	6/04/94	154192300	156013600	14 06.140	121 17.420	12 28.772	119 06.556	1468	1528	7413	7413	294.30	315.75
128/0200	MT-B	6/05/94	156085300	157170700	13 00.839	118 55.901	15 14.398	120 32.900	100	100	6122	6122	301.15	616.90
128/0300	MT-C	6/07/94	158032400	159101500	16 01.473	120 43.493	14 40.502	118 20.759	100	100	6020	6020	296.05	912.95
128/0400	MT-D	6/09/94	160030800	162034500	15 54.913	117 38.096	18 48.624	114 27.430	100	100	9420	9420	466.05	1379.00
128/0401	MT-D	6/11/94	162100911	162172825	18 47.538	114 28.694	16 09.983	117 45.435	10360	10420	11749	11749	66.50	1445.50
128/0402	MT-D	20/6/94	171144216	171175006	19 11.516	114 00.688	19 21.321	113 48.520	12684	12744	13239	13239	24.75	1470.25
128/0500	MT-H	13/6/94	164034200	166031900	19 10.790	116 10.117	15 23.800	114 48.326	100	100	8991	8991	444.60	1914.85
128/0600	MT-G	15/6/94	166103037	167153658	15 30.591	114 55.726	15 16.931	112 22.954	100	100	5582	5582	274.15	2189.00
128/0700	MT-F	17/6/94	167230523	168205538	15 10.974	112 32.140	16 51.365	111 45.783	100	100	4168	4168	203.45	2392.45
128/0701	MT-F	18/6/94	169002600	169041409	16 49.882	111 46.470	17 06.468	111 38.784	5108	5168	5780	5780	30.65	2423.10
128/0800	MT-E	18/6/94	169104950	170142451	17 01.142	111 38.130	18 06.468	113 35.945	100	100	4913	4913	240.70	2663.80
128/0801	MT-E	20/6/94	170195000	171053706	18 06.499	113 36.021	18 31.087	114 20.544	5853	5914	7725	7725	90.60	2754.40
128/0802	MT-E	21/6/94	172073334	172212738	18 30.254	114 19.022	19 04.464	115 21.335	8665	8726	11193	11193	123.40	2877.80
128/0900	MT-H	22/6/94	173084421	173170227	18 22.541	115 52.581	17 41.966	115 37.910	1990	1990	3579	3579	79.50	2957.30
128/1000	MT-I	23/6/94	174002700	175095223	17 20.719	116 07.230	16 42.656	118 45.707	100	100	5886	5886	289.35	3246.65
128/1100	MT-J	24/6/94	175141425	176055902	16 40.830	118 42.751	17 39.319	117 38.735	100	100	3235	3235	156.75	3403.40

FSP=First Shot Point FCSP=First Chargeable Shot Point LSP=Last Shot Point LCSP= Last Chargeable Shot Point

APPENDIX 11: SEISMIC TAPE LISTING

Line No.	FSP	FCSP	LSP	LCSP	First Tape	Last Tape
128/0100	100	100	528	528	128/001	128/008
128/0101	1468	1528	7413	7413	128/009	128/101
128/0200	100	100	6122	6122	128/102	128/195
128/0300	100	100	6020	6020	128/196	128/287
128/0400	100	100	9420	9420	128/288	128/432
128/0401	100	100	11749	11749	128/433	128/454
128/0402	12684	12744	13239	13239	128/868	128/877
128/0500	100	100	8991	8991	128/464	128/601
128/0600	100	100	5582	5582	128/602	128/686
128/0700	100	100	4168	4168	128/687	128/750
128/0701	5108	5168	5780	5780	128/751	128/761
128/0800	100	100	4913	4913	128/763	128/837
128/0801	5853	5914	7725	7725	128/838	128/867
128/0802	8665	8726	11193	11193	128/878	128/918
128/0900	1990	1990	3579	3579	128/919	128/944
128/1000	100	100	5886	5886	128/946	128/1035
128/1100	100	100	3235	3235	128/1037	128/1085