# NORTH WEST MARGIN TRANSECTS: CRUISE PROPOSAL



*by*
*H I M Struckmeyer*

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AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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# NORTH WEST MARGIN TRANSECTS: Cruise Proposal

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# EXECUTIVE SUMMARY

The North West Margin Transects Cruise is 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 the proposed cruise is to extend previous AGSO deep seismic surveys across the Browse (Survey 119), offshore Canning (SNOWS-3/Survey 120) and northern Carnarvon Basins (SNOWS-/Survey 101, SNOWS-2/Survey 110) to complete these margin transects. Specific objectives of the proposed survey are:

- 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 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.

To address these objectives it is proposed that RV *Rig Seismic* be used to acquire about 3276 km of deep crustal (16 second record length) multichannel seismic and other geophysical data along 9 transects across the outer margins of the Browse, offshore Canning and northern Carnarvon Basins. The survey will tie into the 1991 SNOWS-1 (101), 1992 SNOWS-2 (110), 1993 Browse Basin (119) and SNOWS-3 (120) surveys.

In line with the Marine Geoscience and Petroleum Geology Program's (MGPGP's) most recent deep seismic surveys over the North West Shelf, the Margin Transects Cruise will use a 4800 m streamer, configured with 192 x 25 m active groups. Data will be recorded with a 16 second record length and a 2 millisecond sample interval. The seismic source will be dual airgun arrays with a total capacity of 49 litres, and will be fired every 50 metres to give 48-fold CDP coverage. Using these parameters,

AGSO has consistently recorded reflections down to 8-12 seconds two-way-time (12-20 km depth), as well as obtaining good resolution in the upper 6 seconds of data. Navigation for the survey will be provided by differential Global Positioning System (dGPS), using shore reference stations in Western Australia. Full differential coverage should be achieved for the entire survey and it is estimated that positional accuracy should be better than ± 10 metres.

The proposed survey incorporates nine margin transects (MT) containing the following main elements:

1. **Scott Plateau transects**: Three NW-SE oriented dip lines (MT-A to C) totalling 933 km. The northern line (MT-A) extends AGSO's Browse Basin line 119/6 from the outer Browse Basin across the Scott Plateau onto the Argo Abyssal Plain. The southern lines (MT-B, C) tie 3 margin strike lines (AGSO survey lines 95/6, 119/12, 120/7) and one dip line (119/2), and extend from the Rowley Sub-basin across the central and southern Scott Plateau, and Rowley Terrace respectively, onto the Argo Abyssal Plain.

2. **Exmouth Plateau transects**: Two dip lines (MT-E, MT-H) and two strike lines (MT-D, MT-I) totalling 1823 km. Line E 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 Gascoyne Abyssal Plain. Line H is a NNW-SSE oriented dip line with respect to the Argo Abyssal Plain and possible Palaeozoic extension direction. It ties AGSO's SNOWS-1 line 101/10 and SNOWS-2 line 110/8, and extends from the Rankin Platform in the South, across the Wombat Plateau onto the Argo Abyssal Plain. Line D is a NE-SW oriented strike line which extends AGSO's SNOWS-3 line 120/2 from ODP Site 765 on the Argo Abyssal Plain across the central Exmouth Plateau to SNOWS-2 line 110/13. It ties lines 110/9, 120/14, and 95/14 and 19 (Triassic Reef Survey). Line I extends SNOWS-3 line 120/10 to complete the outer margin transect from the Rowley Sub-basin onto the Exmouth Plateau.

3. **Deep Water Transects**: Two lines totalling 520 km (MT-F, MT-G) across the Gascoyne and Argo Abyssal Plains linking the Exmouth Plateau dip lines (lines E and H) to characterise the nature of oceanic basement of different age. This is an important objective to ensuring that the margin dip transects cross the continent/ocean transition zone and thus examine the full width of the extensional terrane underpinning the margin. Line F is a Gascoyne strike line and line G extends across the boundary between the two abyssal plains to become a Argo strike line and thus crosses a major palaeotectonic boundary which would have significantly influenced the breakup history of the continental margin.

The program proposed here assumes a 28 day cruise. While the target of 3276 km of seismic data acquisition planned for this survey is very high, recent experience with similar surveys has shown that given reasonable weather conditions and high equipment reliability, the target is possible. The seismic lines have been prioritised in this report and all high priority lines will be shot on this survey.

# INTRODUCTION

In 1990, AGSO's Marine Geoscience and Petroleum Geology Program (MGPGP) commenced a program of deep seismic acquisition (up to 16 second 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 (Fig. 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 MGPGP 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 will improve understanding of the relationship between plate tectonic setting, basin formation and reactivation, and may highlight critical regional factors controlling the petroleum system within each basin element. It will also provide new insights into the linkages between the major structural elements and allow 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.

To address these objectives, MGPGP devised a margin-wide program of deep-seismic acquisition. It is expected that by mid-1994, there will be a regional grid of up

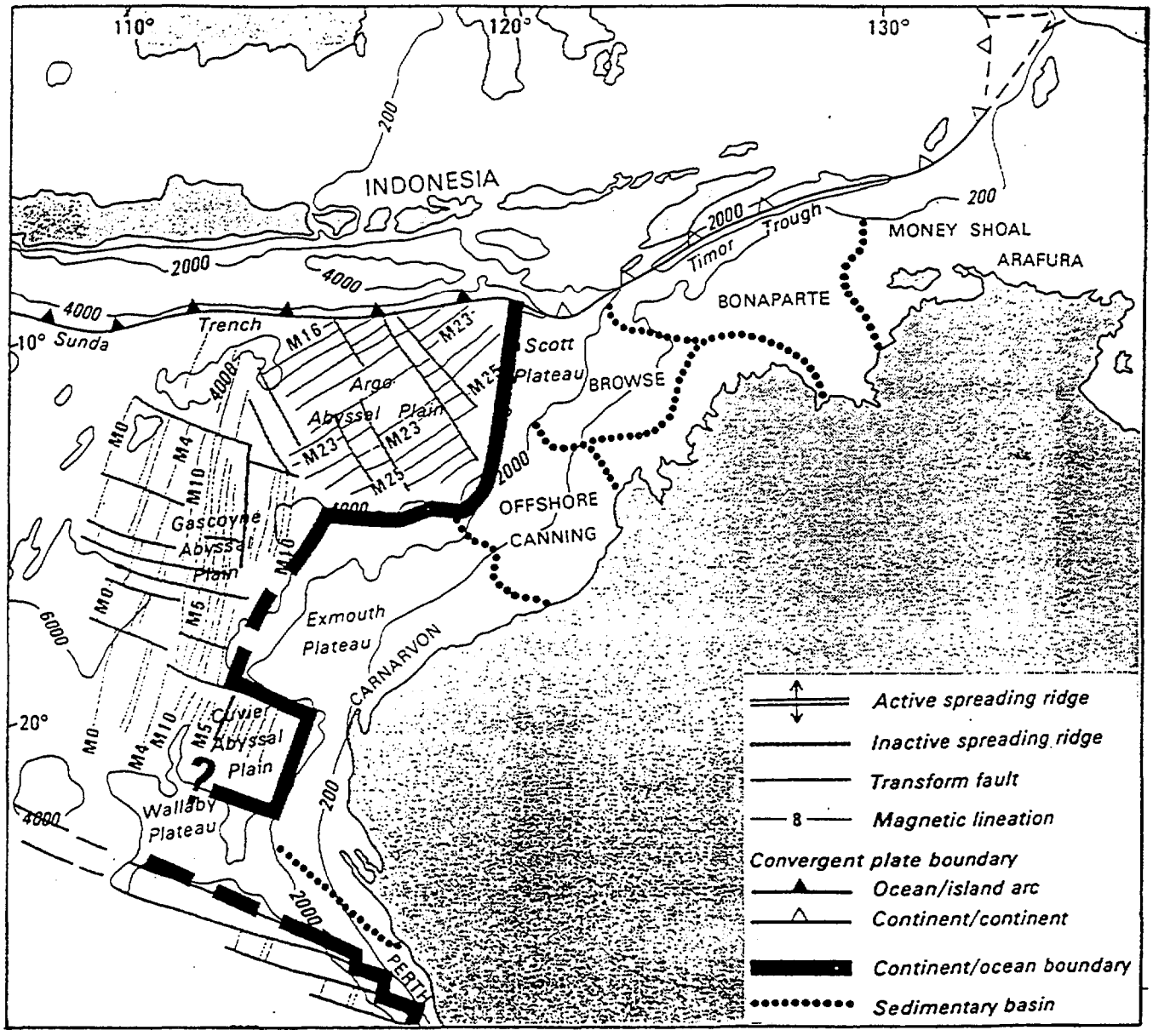


Figure 1: Regional tectonic and basin setting of northwestern Australia.

to 30000km of deep seismic data extending from North West Cape to the eastern Timor Sea. 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 should provide 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 margin transects proposed for this survey have been designed to obtain vital additional information in critical areas of the southern and central North West Shelf region:

- 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 the original basin forming dislocations. These reactivation events are still poorly understood - in particular their relationship to the geometry of breakup in the adjacent ocean basins. A change in spreading direction between the Argo and Gascoyne Abyssal Plains occurred in the Early Cretaceous, 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, eight surveys in the North West Shelf region have been completed with a regional grid of deep seismic data totalling 23221 km (Appendix 1). The proposed cruise is part of the final stage of the deep seismic program across the North West Shelf to obtain vital additional information in critical areas by extending previous AGSO deep seismic lines and thus completing the outer margin transects. Two further infill surveys may be carried out for the Roti Basin and Timor Trough areas.

# EXPLORATION HISTORY

The nine margin transects will be 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 proposed survey area) was the focus for some petroleum exploration and 16 wells were drilled during this period, mainly targeting Triassic tilt block plays sourced by Late Jurassic/Early Cretaceous shales of the Kangaroo Syncline. With the exception of a gas discovery at Scarborough, no major 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.

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 BMR. A summary of pre-1991 seismic surveys over the proposed 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 & others, 1978) and 1979 *Sonne* (von Stackelberg & others, 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 & others (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 the proposed survey (Fig. 2). The major objective of four sites drilled on the Wombat Plateau (759-61, 764) was an assessment of the syn-rift and post-rift structural and palaeoenvironmental evolution of eastern Gondwanaland and the adjacent eastern Tethys ocean. 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; they complement earlier data obtained at Deep Sea Drilling Project (DSDP) Sites 260 and 261.

# STRUCTURAL ELEMENTS

Much of the following summary of the geology of the major tectonic/physiographic features which will be crossed during the proposed survey is based on Stagg (1978), Stagg & Exon (1981), Colwell & others (1990) and Symonds (1993) for the Scott Plateau area, and on Exon & Willcox (1980), Barber (1988), Exon & others (1992) and von Rad & others (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 given 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 km$^2$ in water depths ranging from 1000 to 3500 m (Fig. 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) (Fig. 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 (Fig. 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 basin contains a thick

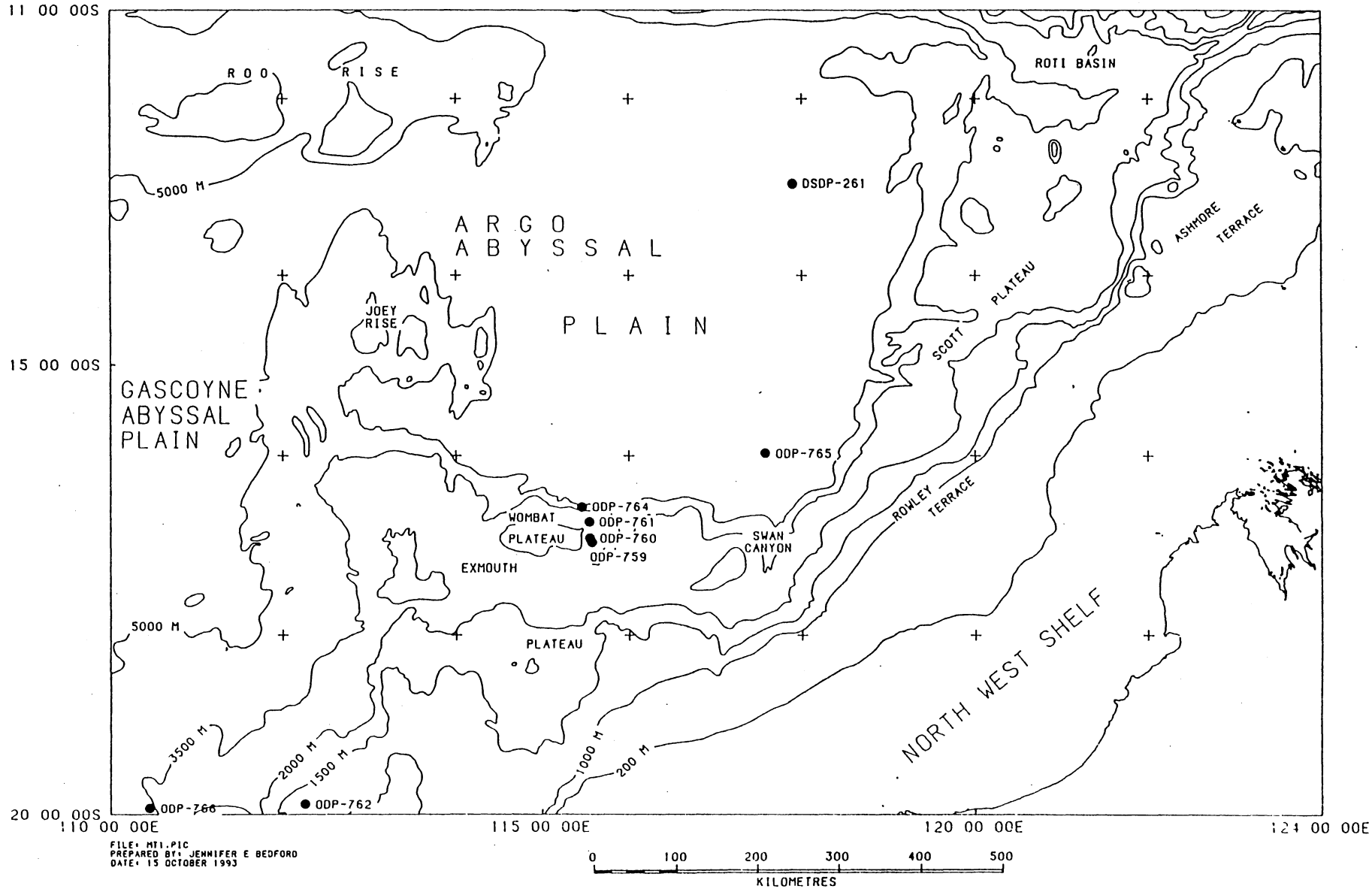


Figure 2: Physiography of the survey area and location of relevant ODP/DSDP sites.

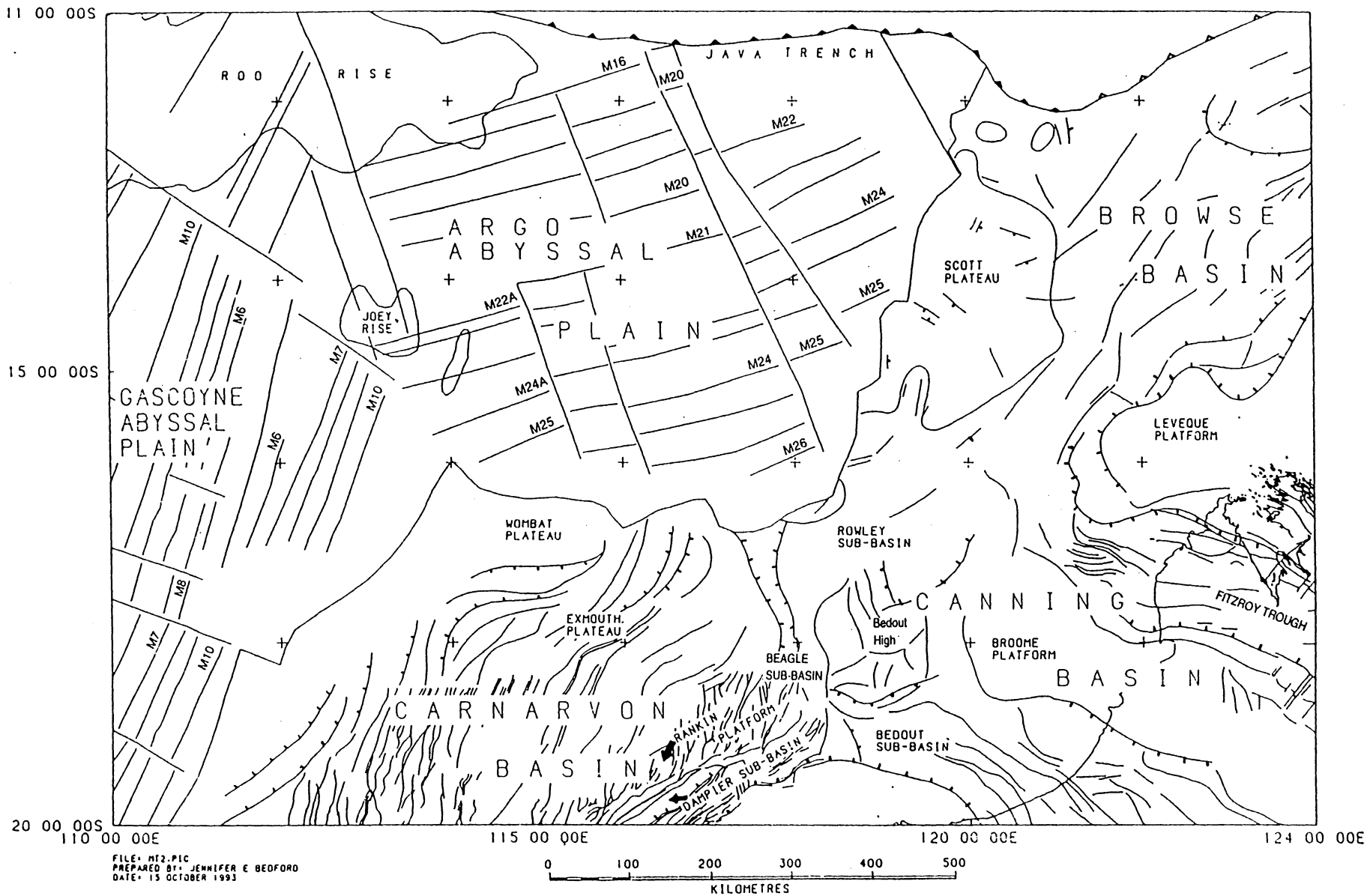


Figure 3: Structural elements map of the survey area (based on Stagg, 1993).

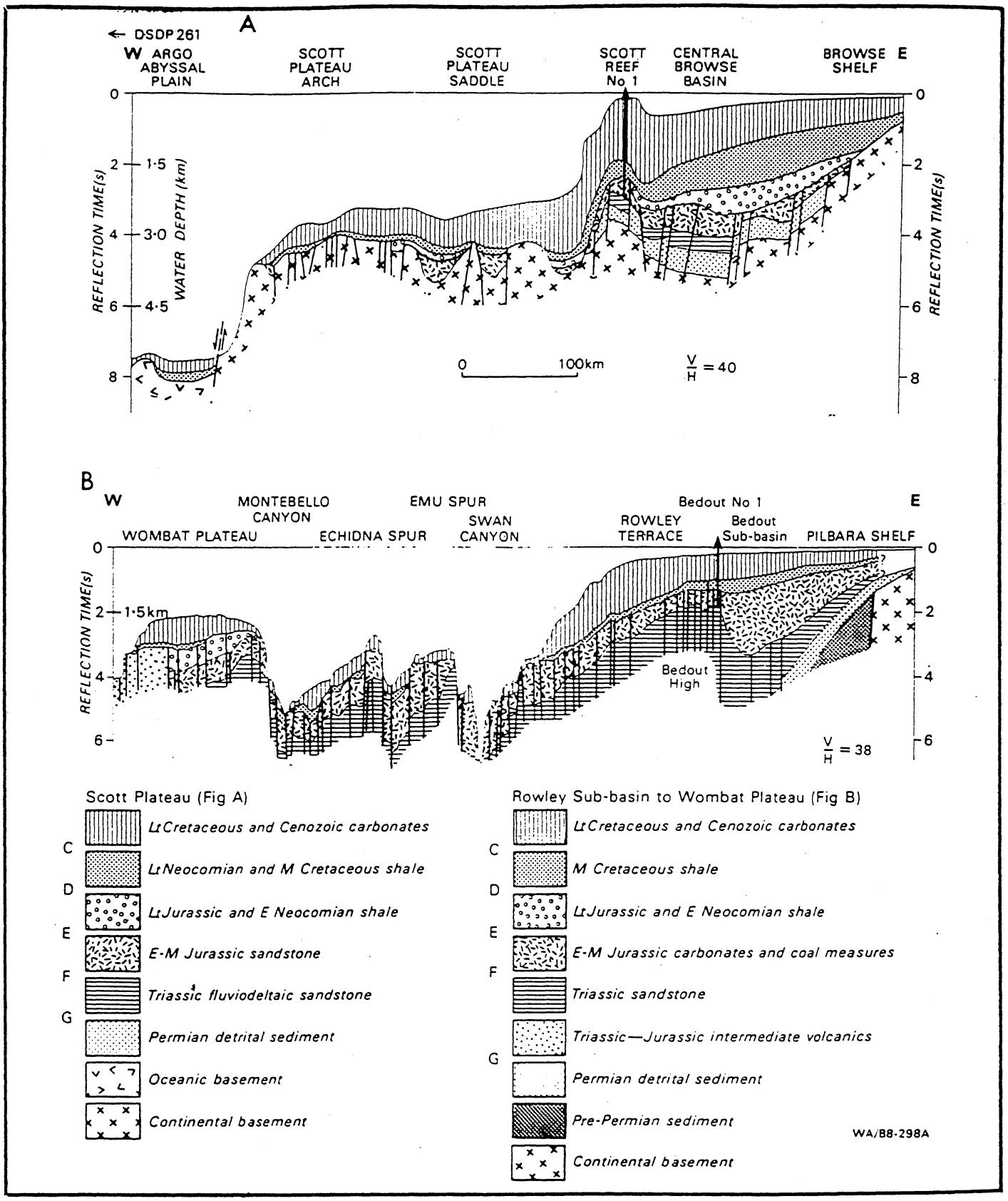


Figure 4: Schematic cross sections across A) the Browse Basin and Scott Plateau, and B) the Rowley Sub-basin and northern Exmouth Plateau (from von Rad & Exon, 1983).

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 structuring in the basin centre is relatively subdued (Stagg & others, 1993).

**Exmouth Plateau**

Similarly to the Scott Plateau, the Exmouth Plateau is a marginal plateau, and is located in water depths of 800 to 4000 m (Fig. 2). It is underlain by thinned continental crust which is overlain by up to 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 continuous with those of the adjoining northern Carnarvon and offshore Canning Basins (e.g. Powell, 1976; Exon & Willcox, 1980; Exon & others, 1992). In excess of 2000 m of Early to Middle Triassic fluvial to deltaic clastics are overlain by latest Jurassic to Early Cretaceous deltaic to open marine sediments. A thick succession of Early to Middle Jurassic shelf carbonates and coal measures are present locally as fill in large graben structures (Fig. 4). With initiation of subsidence of the plateau in the Middle to Late Cretaceous and a decrease of terrigenous sediment supply, shallow marine Middle Cretaceous sedimentation was gradually replaced by open ocean carbonate deposition in the Late Cretaceous to Tertiary (e.g. Exon & others, 1992).

**Argo Abyssal Plain**

The Argo Abyssal Plain is about 5700 m deep with a southeasterly slope 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 (Figs 1 and 3) off north-western Australia is important to the development of the Exmouth and Scott Plateaus as well as the sedimentary basins of the southern North West Shelf. Larson (1975) first identified the anomaly series, which gave the original 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 & others, 1990). However, a recent K/Ar age on a basaltic hyloclastite directly overlying basaltic basement and

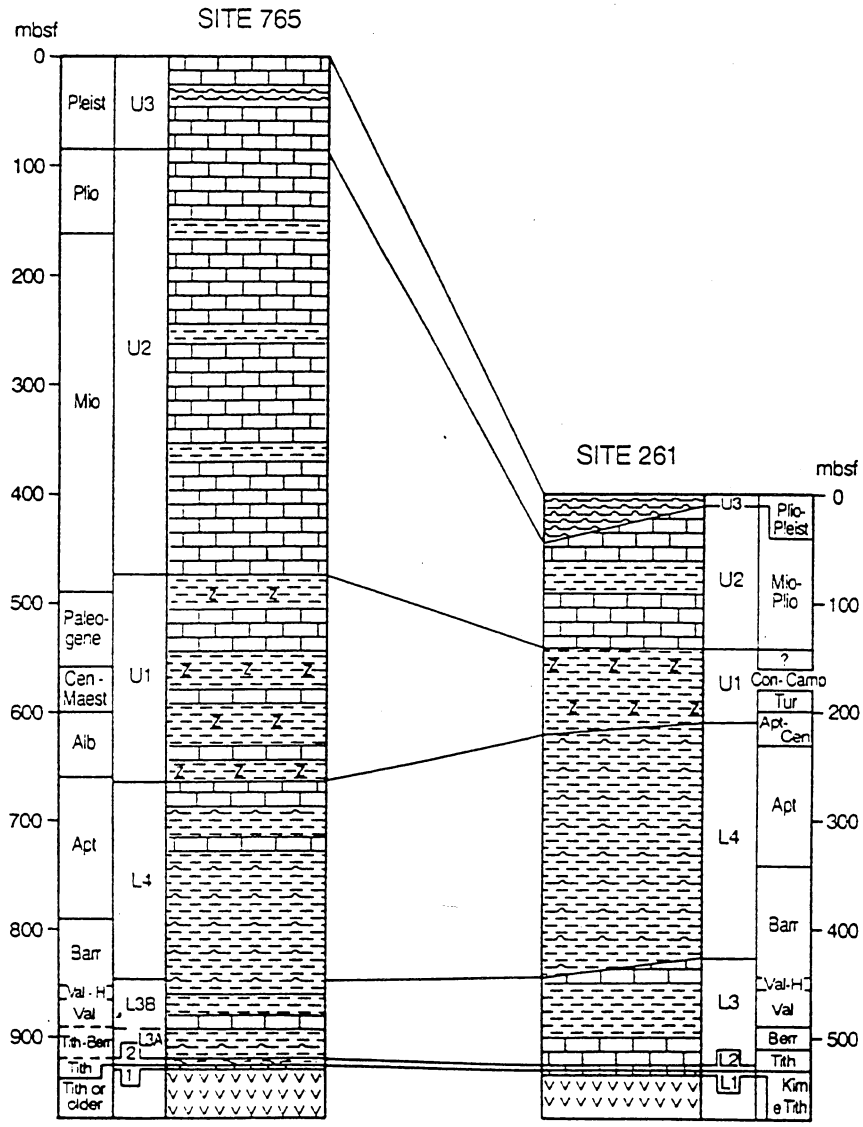


Figure 5: Lithostratigraphic and biostratigraphic correlation of ODP Site 765 and DSDP Site 261 (from Dumoulin & Brown, 1992).

underlying the oldest sediments gave 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 (Fig. 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 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. Little data are available for the Gascoyne Abyssal Plain. Break-up appears to have occurred at 125 to 130 Ma in the Hauterivian, but it remains relatively poorly defined (Larson, 1977; Veevers & others, 1985; Fullerton & others, 1989; Veevers & Li, 1991).

**Joey Rise**

The Joey Rise lies to the north of the Exmouth Plateau at the conjunction of the Argo and Gascoyne Abyssal Plains (Fig. 3), where the trend of magnetic lineations changes from N70°E in the Argo Abyssal Plain (Fullerton & others, 1989) to about N30°E in the Gascoyne Abyssal Plain. In a discussion on the origin of the Joey Rise, Cook & others (1978) concluded that both the Joey and Roo Rises are likely to be of volcanic origin with a probable Cainozoic age, and are 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 5 second seismic monitor sections.

# 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 & others (1988), Powell & others (1988), Sengör & others (1988), Veevers (1988), Metcalfe (1990), Veevers (1991), Exon & others (1992), Von Rad & others (1992), and preliminary results of AGSO's deep seismic study of the northwest margin (O'Brien & others, 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 (Fig. 6). In the North West Shelf area this event resulted in the initiation of NE-SW trending intracratonic features such as the Petrel Sub-basin and the Fitzroy Graben, 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 (Fig. 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 NW-SE 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 & others (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. At the same time volcanism occurred along the outer margins of the Exmouth and Scott Plateaus, probably related to initial extension along the Argo margin.

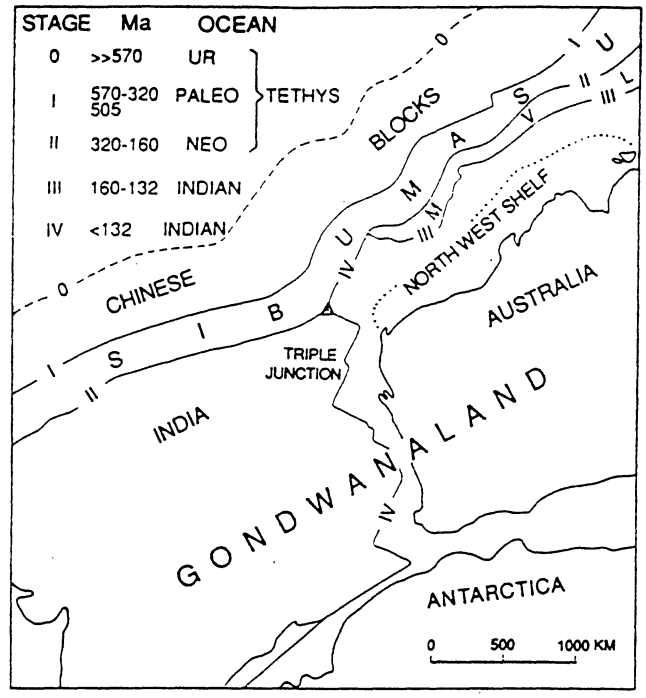


Figure 6: Tectonic setting of the northwest Australian margin prior to Early Carboniferous breakup (from Veevers, 1988).

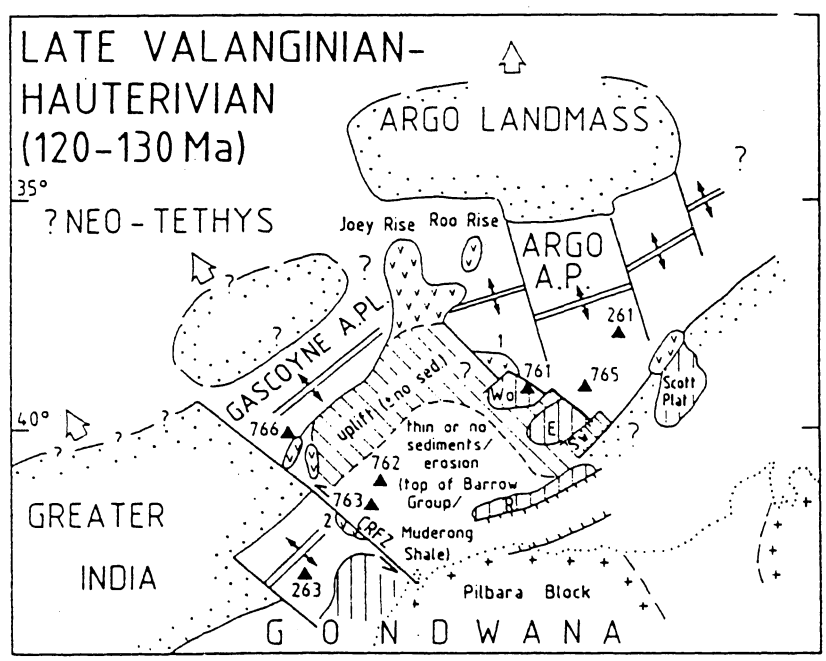


Figure 7: Early Cretaceous palaeogeographic and palaeotectonic reconstruction of the northwest Australian margin (from von Rad & others, 1992).

In the Late Jurassic, another sliver (Argoland or Mount Victoria Land) was removed from the craton margin (Figs 6, 7) as a result of a latest Callovian to early Oxfordian NE-SW to NNE-SSW directed extensional event which quickly led to continental break-up and the episode of 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.

Final breakup between the south-western Exmouth Plateau margin and greater India commenced in the Hauterivian to Valanginian and formed the Gascoyne and Cuvier Abyssal Plains, thus initiating the formation of the modern Indian Ocean (Fig. 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 & others (1993) may be related to this final breakup. It is likely, that the Joey and Roo Rises formed during this time along the newly formed plate boundary between the Argo and Gascoyne Abyssal Plains. During the earliest Cretaceous there was widespread deposition of mostly coarse grained clastics, sourced from uplifted fault blocks formed during initial extension between greater India and Australia. Increasing subsidence and decreasing terrigenous sediment supply in the northern Carnarvon, offshore Canning and Browse Basins during the Cretaceous resulted in increasingly open marine environments and the deposition of calcareous claystones and limestones. A mid-Cretaceous realignment of the spreading ridge between India and Australia contributed to the establishment of mature ocean carbonate deposition along Australia's north-western margin.

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 cycles of regression and transgression. At ODP Site 765, an approximately 900 m thick section of fine-grained calcareous, often turbiditic sediments was intersected (Fig. 5). An increase in regional subsidence and sedimentation rates in the Pliocene may be linked to a Middle Miocene to Recent ENE-WSW directed compressional reactivation event related to collision along the northern edge of the Australian craton.

# OBJECTIVES OF THE STUDY

The proposed 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 the proposed cruise is to extend previous AGSO deep seismic surveys across the Browse (Survey 119), offshore Canning (SNOWS-3) and northern Carnarvon Basins (SNOWS-1, SNOWS-2) 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-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 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 that will be 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 area.

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

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?

## PROPOSED PROGRAM

To address the questions outlined above, it is proposed that RV *Rig Seismic* be used to acquire about 3276 km of deep crustal multichannel seismic and other geophysical data along 9 lines across the Scott Plateau and the outer margins of the northern Carnarvon and offshore Canning Basins (Figs 8 and 9). The survey will tie into AGSO's 1990 Triassic Reef survey (95), 1991 SNOWS-1 (101), 1992 SNOWS-2 (110), 1993 Browse Basin (119) and SNOWS-3 (120) deep seismic surveys (Fig. 10). Major petroleum explorers in sedimentary basins adjacent to the proposed survey area have been consulted during the planning process (Appendix 3).

The 3276 km of seismic data acquisition planned for the Margin Transect Cruise is very high for a 28 day cruise, but recent experience with similar surveys has shown that given reasonable weather conditions and high equipment reliability, 3000 km of seismic data is certainly possible. The acquisition parameters and equipment that will be used on the Margin Transect Cruise (Appendices 5 and 6) are similar to most of MGPGP's other deep seismic surveys over the North West Shelf region. The seismic lines for the proposed survey have been prioritised into two categories as follows:

**Priority 1**: three dip transects across the Scott Plateau and Rowley Terrace (Lines MT-A, MT-B, MT-C), one dip transect across the Exmouth Plateau (Line MT-H), and one strike transect across the Exmouth Plateau ( Line MT-D) totalling 1976 km will be shot on this survey.

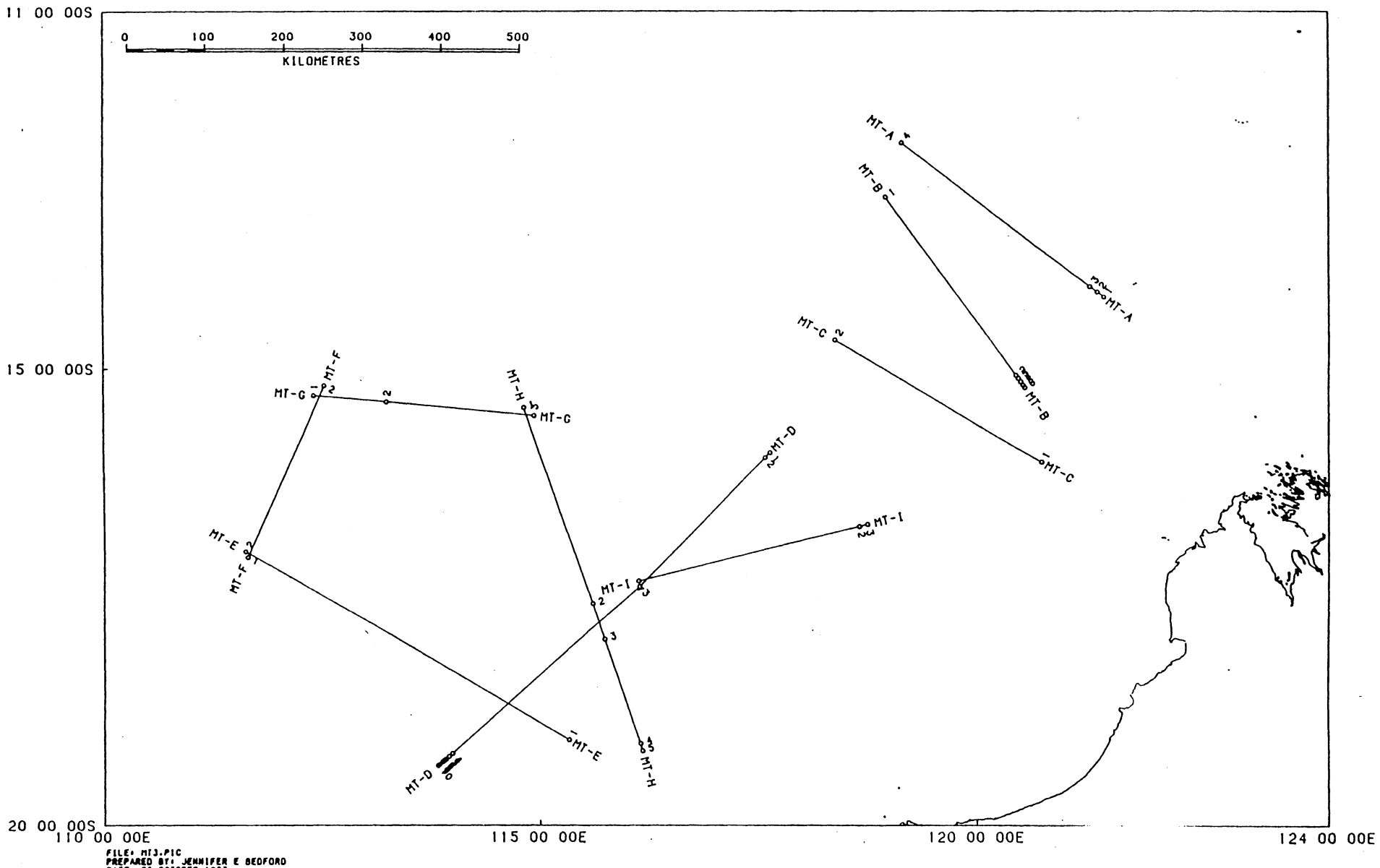


Figure 8: Proposed seismic lines for the survey.

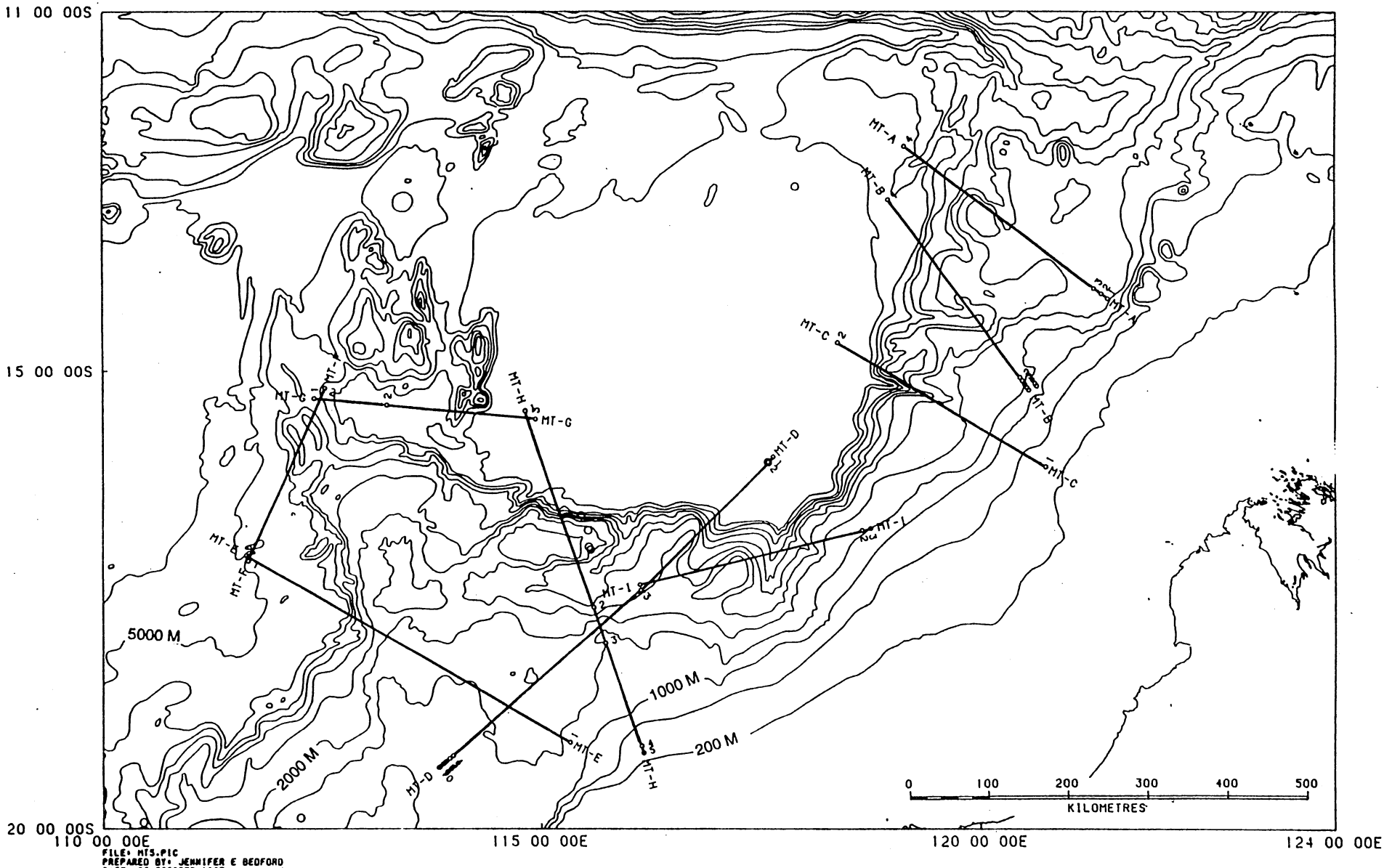


Figure 9: Proposed seismic lines for the survey and bathymetry in the region.

**Priority 2:** one strike transect from the Rowley Sub-basin onto the Exmouth Plateau (Line MT-I), one dip transect across the Exmouth Plateau (Line MT-E) and two deep water transects across the Gascoyne and Argo Abyssal Plains (Lines MT-F and MTG) totalling 1300 km will most probably be completed or at least partially completed on this survey.

A summary of each line and its objectives are listed below, and the way points for each line are given in Appendix 7. The proposed survey incorporates nine margin transects (MT) containing the following main elements:

## 1. Scott Plateau transects:

Three NW-SE oriented dip lines (MT-A to C) totalling 933 km have been designed to assess the regional structural framework, subsidence and thermal history 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 (Fig. 11). They will examine the outer part of the continental margin and attempt to image deep crustal features that underpin the Scott Plateau. They will also examine the nature of the continent-ocean boundary and the seismic characteristics of old continental crust.

**Line MT-A** (323 km) 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.

**Line MT-B** (298 km) 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.

**Line MT-C** (312 km) 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 may cross a major transfer zone controlling the western margin of the Scott Plateau. 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.

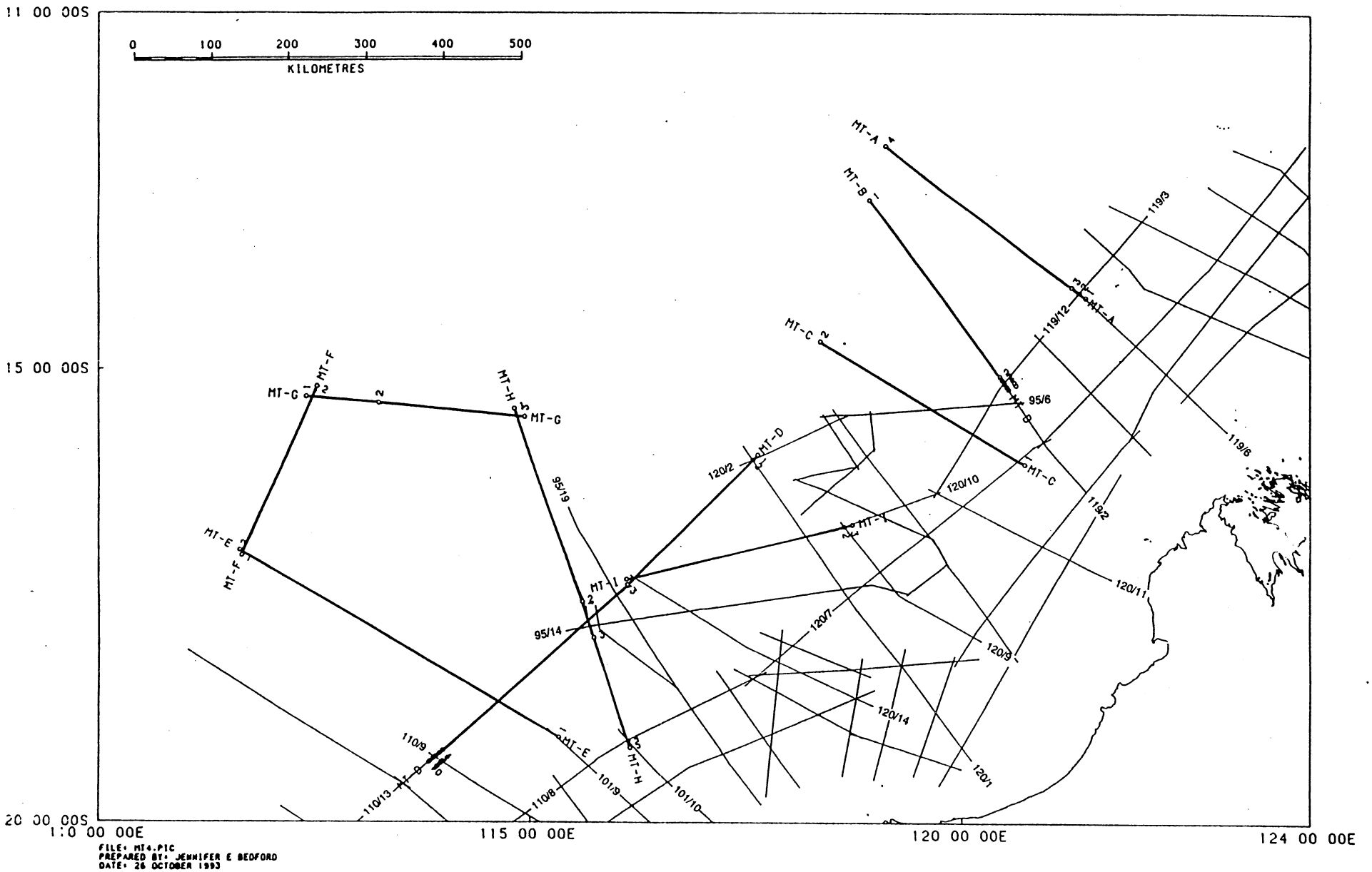


Figure 10: Proposed seismic lines for the survey and other AGSO seismic surveys in the region (surveys 95, 101, 110, 119, 120).

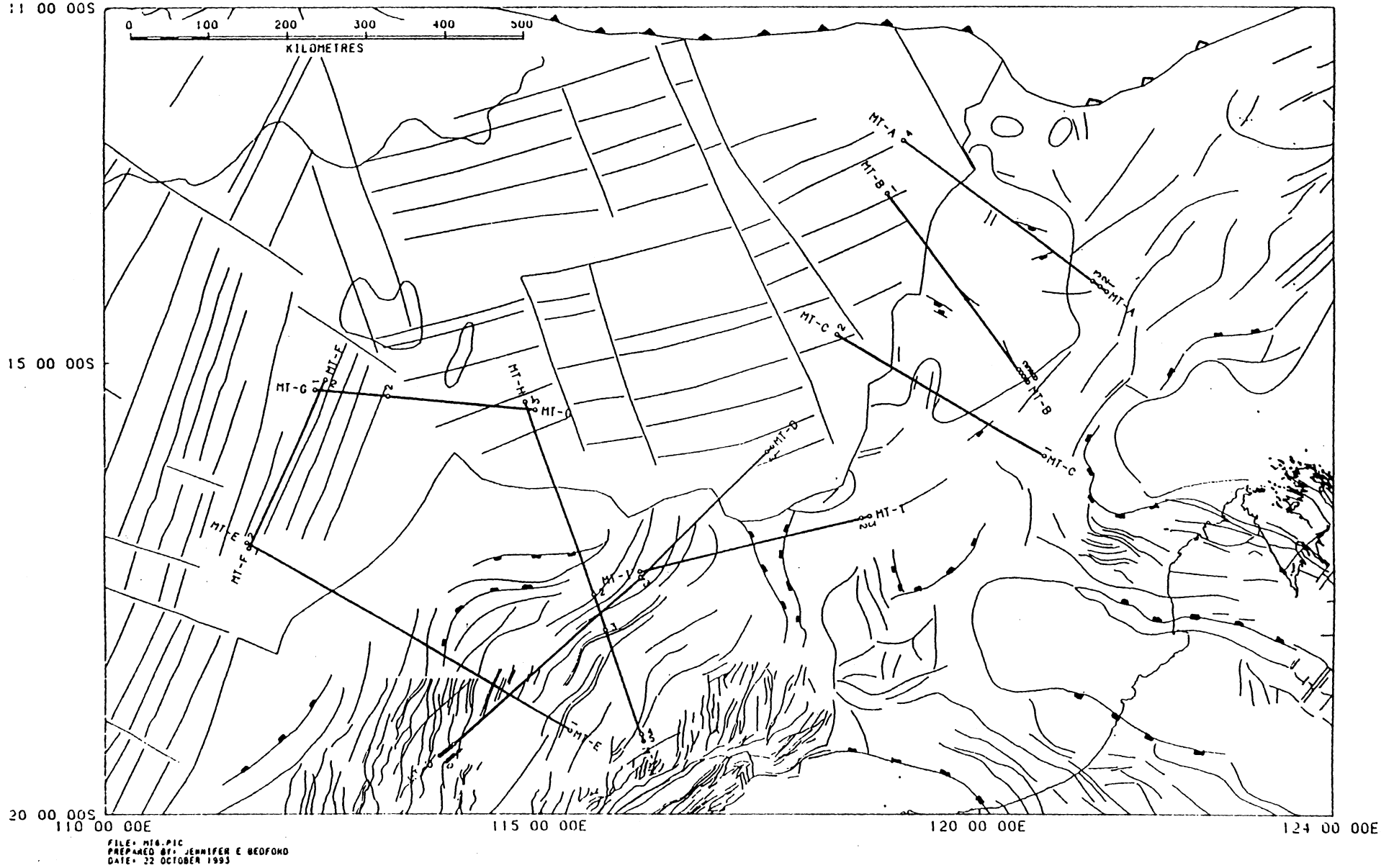


Figure 11: Proposed seismic lines with respect to major structural elements in the region.

## 2. Exmouth Plateau transects

Two NW-SE oriented dip lines (MT-E, MT-H) and two SE-NW and ESE-WNW oriented strike lines (MT-D, MT-I) totalling 1823 km have been designed to assess the regional structural framework, subsidence and thermal history of the Exmouth Plateau area and its relationship to adjacent features such as the Argo and Gascoyne Abyssal Plains, and the Rowley Sub-basin (Fig. 11). They will examine the outer part of the continental margin and attempt to image deep crustal features that underpin the Exmouth Plateau. They will also examine the nature of the continent-ocean boundary and the seismic characteristics of old continental crust.

**Line MT-E** (477 km) 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.

**Line MT-H** (460 km) 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.

**Line MT-D** (583 km) 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).

**Line MT-I** (303 km) 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.

## 3. Deep Water Transects:

Two lines totalling 520 km across the Gascoyne and Argo Abyssal Plains have been designed to link the Exmouth Plateau dip lines (lines E and H) and to characterise the nature of oceanic basement of different age in the region (Fig. 11). This is an important objective to ensuring that the margin dip transects cross the continent/ocean transition zone and thus examine the full width of the extensional terrane underpinning the margin.

**Line MT-F** (236 km) is a Gascoyne strike line between magnetic anomalies M 6 and M 7, and **Line MT-G** (284 km) extends across the boundary between the two 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.

## ACKNOWLEDGEMENTS

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. Jenny Bedford is thanked for preparing the maps for this cruise proposal. I also extend my appreciation to the organisations and exploration companies that took the time to provide advice and input during the planning of this survey. Finally, Phil Symonds and Howard Stagg are thanked for their editing and comments.

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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 & others, 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 & others, 1993).

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

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

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

9. North West Margin Transects - 3276 km (this proposal) - acquisition November/December 1993.

10. Timor Sea Infill - acquisition during mid 1994.

11. Roti Basin - west Timor Trough plate boundary - 2500 km proposed - acquisition during mid 1994.

12. Timor Sea/North-West Shelf refraction survey - acquisition during mid-late 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 proposal, 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
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 Mines
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 ON *RIG SEISMIC*

- FJORD Instruments seismic receiving array: 6.25 m, 12.5 m, 18.75 m and 25 m group lengths, up to 288 channels; up to 6000 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
- Seismic Systems S-15 and S-80 high resolution water gun array consisting of 5 x 80 cubic inch
- 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 3500:
- 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.
- Reftek and Yaesu sonobuoy receivers
- Raytheon echo sounders: 3.5 KHz (2 K.W.), 16 transducer sub bottom profiler and 12 KHz (2 K.W.)
- Geometrics G801/803 magnetometer/gradiometer
- Bodenseewerk Geosystem KSS-31 marine gravity meter
- EG & G model 990 sidescan sonar with 1000 m of cable
- Nichiyu Giken Kogyo model NTS-11AU heatflow probe
- Australian Winch and Haulage deepsea winch with 10 000 metres of 18 mm wire rope and hydrographic winch with 4000 m of 6 m wire rope
- Coring and rock dredging systems (various) and vibracorer
- Light hydrocarbon extractor and gas chromatographs for continuous DHD (direct hydrocarbon detection) in bottom water
- Hydrocarbon gas analyses in sediments
- Geochemical analysis equipment for environmental monitoring.
- 15 metre A frame with a 12.5 ton load capability, using a variety of winches, supporting towed arrays and future capability for large scale deep coring and drilling

**Navigation equipment**

- RACAL SKYFIX differential GPS system
- Magnavox T-Set Global Positioning System navigator
- Magnavox MX 1107RS and MX 1142 transit satellite receivers
- Magnavox MX 610D and Raytheon DSN 450 dual axis sonar dopplers
- Sperry, Arma Brown and Robertson gyro-compasses; plus Ben paddle log

# APPENDIX 6

## 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) |
| | shot interval | 19.4 sec @ 5 knots |
| | | 21.6 sec @ 4.5 knots |

### Fold

| | | |
|---|---|---|
| | standard | 4800 % |

### Recording Parameters

| | | |
|---|---|---|
| | record length | 16 s |
| | sample interval | 2 ms |

# APPENDIX 7

## WAY POINTS FOR NORTH WEST MARGIN TRANSECTS CRUISE

| Line No. | Way Point | | Latitude deg S | Longitude deg E | Latitude deg/min S | Longitude deg/min E |
|---|---|---|---|---|---|---|
| MT-A | 1 | SOL | 14.2040 | 121.4275 | 14 12.240 | 121 25.650 |
| | 2 | | 14.1481 | 121.3542 | 14 08.887 | 121 21.252 |
| | 3 | | 14.0875 | 121.2712 | 14 05.250 | 121 16.272 |
| | 4 | EOL | 12.4955 | 119.1295 | 12 29.730 | 119 07.770 |
| MT-B | 1 | SOL | 13.0968 | 118.9438 | 13 05.808 | 118 56.628 |
| | 2 | | 15.0682 | 120.4342 | 15 04.093 | 120 26.052 |
| | 3 | | 15.1040 | 120.4608 | 15 06.238 | 120 27.647 |
| | 4 | | 15.1407 | 120.4877 | 15 08.443 | 120 29.263 |
| | 5 | | 15.1773 | 120.5147 | 15 10.638 | 120 30.880 |
| | 6 | EOL | 15.2031 | 120.5334 | 15 12.185 | 120 32.000 |
| MT-C | 1 | SOL | 16.0243 | 120.7257 | 16 01.458 | 120 43.542 |
| | 2 | EOL | 14.6852 | 118.3695 | 14 41.112 | 118 22.170 |
| MT-D | 1 | SOL | 15.9180 | 117.6310 | 15 55.080 | 117 37.860 |
| | 2 | ODP765 | 15.9746 | 117.5740 | 15 58.477 | 117 34.440 |
| | 3 | | 17.4062 | 116.1274 | 17 22.372 | 116 07.643 |
| | 4 | | 19.2103 | 113.9900 | 19 12.617 | 113 59.398 |
| | 5 | | 19.2401 | 113.9530 | 19 14.407 | 113 57.182 |
| | 6 | | 19.2699 | 113.0166 | 19 16.192 | 113 54.995 |
| | 7 | | 19.2834 | 113.8999 | 19 17.003 | 113 53.993 |
| | 8 | | 19.2989 | 113.8808 | 19 17.933 | 113 52.847 |
| | 9 | | 19.3282 | 113.8450 | 19 19.693 | 113 50.698 |
| | 10 | EOL | 19.3394 | 113.8307 | 19 20.267 | 113 49.842 |
| MT-E | 1 | SOL | 19.0628 | 115.3316 | 19 03.768 | 115 19.897 |
| | 3 | EOL | 17.0190 | 111.6355 | 17 01.140 | 111 38.130 |
| MT-F | 1 | SOL | 17.0828 | 111.6578 | 17 04.968 | 111 39.468 |
| | 2 | EOL | 15.1830 | 112.5357 | 15 10.980 | 112 32.142 |
| MT-G | 1 | SOL | 15.2918 | 112.4107 | 15 17.083 | 112 24.642 |
| | 2 | | 15.3608 | 113.2453 | 15 21.648 | 113 14.718 |
| | 3 | EOL | 15.5100 | 114.9302 | 15 30.600 | 114 55.812 |
| MT-H | 1 | SOL | 15.4212 | 114.8142 | 15 25.272 | 114 48.852 |
| | 2 | | 17.5948 | 115.5972 | 17 35.688 | 115 35.832 |
| | 3 | | 17.9845 | 115.7308 | 17 59.070 | 115 43.848 |
| | 4 | | 19.1010 | 116.1399 | 19 06.060 | 116 08.393 |
| | 5 | EOL | 19.1790 | 116.1620 | 19 10.740 | 116 09.720 |
| MT-I | 1 | SOL | 17.3452 | 116.1205 | 17 20.712 | 116 07.230 |
| | 2 | | 16.7380 | 118.6497 | 16 44.280 | 118 38.982 |
| | 3 | EOL | 16.7160 | 118.7420 | 16 42.960 | 118 44.520 |