RC27-02

Rig Seismic
2nd ship

P. Buhl

RIG SEISMIC RESEARCH CRUISE

EXMOUTH PLATEAU:

DEEP SEISMIC STRUCTURE

March/April 1986

Chief Scientists: D.A. Falvey
P.E. Williamson

8 April 1986

Division of Marine Geoscience and Petroleum Geology

POST-CRUISE REPORT:

DEEP SEISMIC STRUCTURE OF THE EXMOUTH PLATEAU

Principal Investigators

D.A. Falvey and P.E. Williamson

Scientific Staff

F.M. Brassil, P. Buhl(*), J, Lock, C. Penney, S. Scherl, R. Whitworth

Technical Support Staff

J. Pittar, J. Bedford, R. Curtis-Nuthall, B. Maplestone, R. McMahon
M. O'Connor, I. Roach, K. Revill, G. Saunders, D. Simmington

9 April 1986

(*) Lamont-Doherty Geological Observatory, Palisades, N.Y., 10964, U.S.A.

This report is the preliminary shipboard record of the operations and results of the second phase of BMR - Marine Division's Exmouth Plateau research program. It is intended for use only within BMR and is not for general distribution The results presented are provisional and may not be quoted or cited in any form.

Contents

FIGURES

22. Seismic monitor and interpretation of line 55/02.

23. Seismic monitor and interpretation of line 55/04.

24. Seismic monitor and interpretation of line 55/07.

25. Seismic monitor and interpretation of line 55/09.

26. ODP site survey EP-2: track chart.

27. ODP site survey EP-2: bathymetry.

28. ODP site survey EP-2: depth to the Triassic unconformity.

29. ODP site survey EP-2: isopachs of sediment from seabed to Triassic unconformity.

30. ODP site survey EP-2: seismic monitors for lines 55/02 and 55/03E.

31. ODP site survey EP-2: well prognosis.

32. Seismic monitor and interpretation of sonobouy on line 55/09.

33. Summary deep structural cross section - Exmouth Plateau Transect.

Appendix B: Cable geometry.

CHAPTER 1: Introduction

This Report describes the preliminary results of the second phase of a three phase, Exmouth Plateau research program, undertaken by B.M.R.'s Division of Marine Geosciences and Petroleum Geology (B.M.R. Marine) during 1986. This phase consisted of a one month, two-ship seismic reflection and refraction study to define the deep basinal and crustal structure of the Exmouth Plateau. The ultimate objectives of this research program are a better understanding of passive continental margin subsidence and tectonic evolution and a redefinition of the regional petroleum potential of the Plateau.

The Exmouth Plateau is a submarine marginal plateau with an area of about 150,000 sq. km. situated off the N.W. Australian continental margin (Fig. 1). The Plateau consists of deeply rifted and subsided continental crust. It is separated from the N.W. Shelf by the Kangaroo Syncline and is bounded to the north, south and west by oceanic crust. At its crest, the Plateau is 800 m. below sealevel and sedimentary thicknesses, consisting of pre-breakup Paleozoic to early Mesozoic sediments, and post-breakup Mesozoic and Tertiary sediments, are up to 10 km.

The large areal closures in the post-breakup section, which drape the underlying fault controlled rift structures, encouraged petroleum exploration in the late 1970's and early 1980's. This led to the collection of more than 20,000 km. of multichannel seismic data over the central Plateau and the drilling of 14 exploration wells on five exploration permits. Exploration showed the Plateau to be mainly immature in the post-breakup section and predominantly terrigenous,gas prone and partly overmature in the prebreakup section with a possible increase in marine influence and possible oil sourcing potential to the west. The perceived gas prone nature of the area and the deep water over the Plateau has resulted in permit relinquishments through the early 1980's, with the exception of the area surrounding the Esso Scarborough gas discovery. Hydrocarbon exploration has ceased in recent years.

B.M.R. Marine Division planned this three phase research program to re-stimulate petroleum exploration over the Plateau. The first phase was a 6 day, heatflow program on the Plateau during January, 1986. This was designed to examine present day source rock maturation levels and is reported in B.M.R. Report XXX. The second phase, conducted in March/April, 1986, and reported here, involved a cooperative two-ship study in conjunction with Lamont-Doherty Geological Observatory, New York (LDGO). Broad structural analyses of the Plateau, its normal and transform faulted margins and adjacent oceanic features were carried out using multichannel seismic data both from two-ship Expanded Spread Profiles (ESP) and Wide Aperture C.D.P. Seismic Profiles. Data were collected from 18 ESP's arranged along three transects, with the centres of the individual ESP's tied with Wide Aperture C.D.P. seismic reflection profiles shot along the transects.

The study also addressed the nature of the continental to oceanic crustal transition. Suggested mechanisms for continental margin formation include lithospheric cooling, continental crustal streching, deep crustal metamorphism, subcrustal erosion and supracrustal erosion. This work provided a sound crustal data base on the different styles of ocean/continent boundaries associated with the Exmouth Plateau as evidenced by transform faulting in the south, rifting in the west and rifting and intrusion in the north. Thus, the Exmouth Plateau is an ideal location to study the transition from continental to oceanic crust. A full understanding of the formation of the Exmouth Plateau may be possible from this and other existing data sets. The project is therefore of worldwide scientific importance, as well as providing important insights into the origin and history of the Plateau, which might re-stimulate further petroleum exploration.

1.1 Crew of R/V Rig Seismic

Master	H. Foreman
Chief Officer	R. F. Hardinge
2nd Officer	J. Alexander
Chief Engineer	S. Johnson
2nd Engineer	P. Pittiglio
Electrical Officer	P. Jiear
EA/Seaman	K. Halliday
Chief Steward/Cook	W. Fowler
Cook	G. Conley
Steward	J. Caminiti
Steward/Seaman	M. Cumner
AB	N. Luscombe
AB	B. Marsh
AB	P. Holdsworth

1.2 Acknowledgements

The enthusiasm, skill, and cooperation of the master and crew of R/V Rig Seismic is gratefully acknowledged. They have made a major contribution to the success of both the cruise and the research program.

The contribution of NATMAP personnel in setting up and manning the onshore HIFIX radio navigation stations for the study is also gratefully acknowledged. This arduous effort in remote areas has resulted in effectively doubling the percentage of crucial high accuracy navigation during the study.

CHAPTER 2: Objectives

B.M.R.'s Exmouth Plateau program consists of three distinct research cruise projects. The broad objectives of this program are: to determine the history of basin subsidence; to define regional basin thermal history; to determine the structural and stratigraphic framework of the entire Exmouth sedimentary basin, as well as the structure of the deep crust underlying the basin; to relate the evolution of the crust and basin to the formation of the surrounding oceanic crust of the Argo, Gascoyne and Cuvier abyssal plains; and finally, to relate all these factors to the parameters governing regional petroleum potential.

This Report covers the second research cruise, whose principal objective was the determination of deep sedimentary basin and crustal structure by two-ship seismic reflection and refraction methods. The project was conducted in conjuction with the research vessel Robert D. Conrad, of Lamont-Doherty Geological Observatory, Columbia University, New York. In particular, the two ship seismic project was designed to address questions related to the nature of the continental crust underlying the Exmouth Plateau, the nature of the continent-ocean crustal transition, the mechanisms of deep crustal modifications associated with rifting and breakup, the relationships between these various mechanisms and the thermal history of the overlying sedimentary basin, as well as its structural fabric.

A great deal is already known about the Mesozoic-Tertiary sedimentary basin which underlies the southern, central and eastern Exmouth Plateau. This knowledge is derived from the large amount of good quality seismic data now on open file from industry sources, as well as some published results from exploration drilling. Little was known of the pre-Mesozoic sedimentary basin or the underlying crust. Gravity and magnetic data interpreted by Exon and Willcox (1980) suggest that basement is about 8-10 km. below seabed over much of the Plateau and that igneous bodies and crystalline basement are at shallow depths at its seaward margin. Regional crustal thickness was thought to be about 20 km. The deep seismic project focussed on the problems of basement depth, crustal thickness and structure in some detail.

The crustal structure of a rifted continental margin should be clearly related to the mechanism of basement subsidence: lithosphere cooling and contraction; continental stretching and crustal extension; deep crustal metamorphism; supra-crustal erosion; igneous injection and sub-crustal erosion - to name just a few proposed models. The determination of which mechanism applies, or the relative contributions of various mechanisms, can then be related to models which can be used to predict paleoheatflow and thus petroleum source rock maturation history. Understanding of the mechanisms also provides a means of predicting and modelling basin subsidence patterns.

A clearly long-term objective of deep crustal studies at passive continental margins is the development of a general model of the processes involved in continental margin formation in particular, and the processes involved in basin formation on continental crust in general.

CHAPTER 3: Cruise Plan

Two-ship multichannel seismic data were collected during this cruise with BMR Rig Seismic as principally the receiving ship and LDGO Robert D. Conrad as principally the shooting ship. The data were collected on 18 ESP's in three transects, together with Wide Aperture C.D.P. and other multichannel seismic data (Fig. 2). The basic technique for such ESP operations is for two ships to steam towards each other through and past a common midpoint, one ship firing an airgun array at a 60 second repetition rate, the other recording arrivals on a multichannel streamer (Fig. 3). The shooting ship may also collect vertical incidence multichannel seismic data at the same time on it's own streamer, thus obtaining structural information which is subsequently used in ESP data reduction. After a group of ESP's has been shot, the two ships then form up in-line and shoot a Wide Aperture C.D.P. seismic profile through the midpoints of all ESP locations, as described by Buhl and others (1982). ESP's can also be collected by the two ships steaming apart from a common midpoint. In this instance it is necessary for the shooting ship to rerun the ESP track to obtain the vertical incidence seismic data. At the end of the run the ships proceed to the midpoints of the next ESP line. The centers of these ESP's, shot from midpoint outwards, must also be subsequently tied by a regular reflection or wide aperture profile. Only the former of these methods of field acquisition was used during the co-operative BMR/LDGO survey program. A full description of both the ESP and WACDP methods and operations is contained in Chapter 5.

The ESP's were collected with a maximum offset of 100 km. Conrad had at that time the greater airgun capacity (6000 cu in at 2000 psi on a 60 sec repetition rate) and consequently was the shooting ship, with Rig Seismic being the receiving ship. Explosives were employed at longer ranges where seismic signal strength from the airguns was insufficient. LDGO is experienced in this technique and have acquired and processed around 100 ESP's to date: off the Voring Plateau, the East Greenland Margin, in the North Atlantic, on the East Pacific Rise, around the Hawaiian Swell and on the China Margin of the South China Sea.

The three transects collected during the Exmouth Plateau project are referred to as the *Exmouth, Cape Range* and *Cuvier* Transects and relate to the centre/western and southern margins of the Plateau, and the normal margin south of the Plateau. Each ESP took around 12 hours and the 18 ESP's and 3 WACDP profiles were collected in approximately 25 days of on-station time.

ESP data will be processed using the methods of Detrick and others, (1982); Mutter and others (1983); Diebold and Stoffa, (1981); and Wenzel and others (1982). This involves binning of the seismic data and analysis in the X-T and t-p domains to generate velocity/time information relating to the ESP midpoints (Fig 4). These data can then be converted to velocity/depth profiles by inversion.

CHAPTER 4: Background

The regional geological setting of the Exmouth Plateau is shown in Fig. 1. The Plateau is a continental block bounded on the north, west and south by oceanic crust forming the Argo, Gascoyne and Cuvier Abyssal Plains respectively. The Canning and Carnarvon Basin sediments which cover the Plateau extend to the east and abut the Pilbara Precambrian block. Prebreakup, rift phase deposition has been identified on the Plateau and beneath the shelf to the east (Fig. 5). The stratigraphic sequences in the region are shown in profile in Fig. 6a and b. These consist of Tertiary limestones overlying Cretaceous to Permian clastics overlying Precambrian basement. A more detailed description of the regional structural history and stratigraphy focusing on the Exmouth Plateau is given below.

4.1 Tectonic Framework

The geological development of the Exmouth Plateau has been discussed in some detail by Falvey (1972b), Falvey and Veevers (1974), Veevers and others (1974), Exon and others (1975, 1982), Hogan and Jacobson (1975), Veevers and Cotterill (1976), Powell (1976), Willcox and Exon (1976), Exon and Willcox (1978, 1980), Wright and Wheatly (1979), Larson and others (1979), von Stackelberg and others (1980), Falvey and Mutter (1981) and Willcox (1981).

The present structural configuration of the Exmouth Plateau region was initiated by rifting in Triassic to middle Jurassic prior to seafloor spreading. The western margin reflects a normal rifted structure and the southern margin reflects a transform dominated structure. The northern rifted margin may contain at least one crustal block of post breakup igneous origin.

The northern margin of the Plateau formed in the Callovian (approx. 150m.y. ago), when seafloor spreading commenced in the Argo Abyssal Plain (anomaly M-25 time). The northeast-trending seafloor spreading anomaly pattern was initially described by Falvey (1972a) and basin age was established by DSDP drilling (Veevers, Heirtzler and others, 1978). Throughout the Jurassic, prebreakup rift graben tectonics affected the entire western margin (Falvey and Mutter, 1981) (Figs 7 and 8). The initiation of rifting may be associated with the occurence of Triassic-Jurassic intermediate and acid volcanics (213-192 m.y. ago), which overlie a thick Triassic paralic sequence. Steady subsidence along the incipient northern margin, north of an east-west hinge line allowed several thousand metres of Lower and Middle Jurassic carbonates and coal measures to accumalate before breakup. Breakup occurred along a series of rifted and sheared margin segments, the tectonic setting being further complicated by northwest trending Callovian horsts and grabens. The horsts were planed off in late Jurassic and early Cretaceous times, and the whole northern margin was covered by a few hundred metres of Upper Cretaceous and Cainozoic pelagic carbonates as it subsided steadily to its present average depth of 2000-5000 m.

The northeast-trending western margin of the Plateau formed by breakup in the Neocomian as "Greater India" moved off to the northwest. At approximately 120 m.y. b.p. (early Cretaceous), seafloor spreading began in the Cuvier and Perth Basins (anomaly M-3 to M-10 time). Portions of the northeast trending seafloor spreading magnetic anomally pattern were initially described by Markl (1974) and Larson (1977), and have been integrated recently by Larson and others (1979). At a regional scale however, details of the spreading pattern around the southwest corner of Australia may be complex (Markl, 1978) and ~~are~~ yet to be fully described. Through the earliest Cretaceous, late stage rift graben tectonics affected the Australian southwest margin where it bordered India and Antarctica. Early Cretaceous rifting also affected Eastern Australia, the Gippsland Basin, Lord Howe Rise, and Queensland Plateau. The earliest phase of rifting also began on the southern margin adjacent to Antarctica (Falvey and Mutter, 1981). On the Western margin of the Exmouth Plateau, Callovian normal faults parallel the margin. A thick Triassic paralic sequence is unconformably overlain by a thin, post-breakup Upper Jurassic and later marine sequence indicating that the area was high in the early and middle Jurassic. Thin Upper Cretaceous and Cainozoic pelagic carbonates cover the western margin, which now lies more than 2000 m. below sealevel.

The northwest trending southern margin of the Plateau formed along an incipient transform in the Neocomian, at the same time as the western margin. It is cut by northeast trending normal faults, which formed in the late Triassic and Callovian, and is paralleled by Neocomian and later normal faults. A thick Jurassic paralic sequence is unconformably overlain by a thick Upper Jurassic and Neocomian delta. This suggests that the area was high in the early and middle Jurassic, but a depocentre before and afterwards. There was thermal uplift of more than 1000 m. during the Neocomian. Igneous intrusions butress the margin. Later normal faulting lowered the outermost margin, and turned the uplift into a marginal anticline trending northwest. The anticline had sunk beneath the sea by late in the Cretaceous, and thereafter this margin was covered by a thin sequence of pelacic carbonates, which now lie at a water depth of 1500 m. (Exon and others, 1982).

Von Stackelberg and others (1980) have reported 30 dredge hauls from the outer slopes of the Exmouth Plateau. More than half contained Jurassic and Triassic prebreakup shallow water sediments. Four dredges also contained intermediate to acid volcanics dated at about the time of rift onset. This suggests limited continental crustal anatexis very near to the incipient continent-ocean boundary. These data also indicate that it is not valid to interpret the occurrence of volcanics on a marginal plateau slope as definitive evidence of non-continental crustal structure, either in whole or in part (Falvey and Mutter, 1981).

4.2 Stratigraphy

The paleogeographic evolution of the Exmouth Plateau is sketched in Fig. 9 and the stratigraphy is outlined in Figs. 10a and b. Sediment starvation has led to a greatly reduced post breakup sequence on the continental margin. Thus, seismic profiling and drilling have been able to penetrate well into the prebreakup sequence and resolve early stages of margin evolution (von Rad and Exon, 1982). Fourteen petroleum wells have been drilled and results from Phillips Jupiter No. 1, Saturn No. 1 and Mercury No. 1 have been published (Fig. 11, Barber, 1982). Stratigraphic studies have been carried out by von Stackelberg and others (1980), Colwell and von Stackelberg (1981), and von Rad and Exon (1982). The extensive seismic control consists of 12,000 km. of BMR seismic reflection, magnetic and gravity data from the 1972 BMR continental margin survey, 9300 km. of GSI seismic data collected in 1976 and 1977 (Wright and Wheatley, 1979) and subsequent petroleum industry seismic data.

Interpretation of seismic profiles indicates that up to 5000 m. of Paleozoic strata and up to 5000 m. of younger strata overlie basement. The sediments have been gently folded, and the prebreakup section is affected by northeast trending faults.

The sediments beneath Exmouth Plateau are considered to have been deposited in an extension of the Carnarvon Basin. This formed a north-facing Tethyan embayment in Gondwanaland and received detrital sediments from the south until early Cretaceous time. In the central plateau region, at least 3000 m. of mainly paralic and shallow marine detrital sediments were deposited from Permian to middle Jurassic times. After the late Triassic rifting, about 1000 m. of shallow marine and deltaic detrital sediments derived from the south and east, covered the block faulted surface in late Jurassic and early Cretaceous times. About 200 m. of marine terrigenous sediment was deposited in the middle Cretaceous, and 500 to 1000 m. of carbonate sediment in the late Cretaceous and Cenozoic. In the Miocene, the rate of subsidence exceeded the rate of sedimentation and thereafter, the Exmouth Plateau arch and Kangaroo Syncline took their present form (Exon and Willcox, 1978 and 1980).

4.3 Petroleum Exploration

In the mid 1970's the Exmouth Plateau was regarded as the possible location of major petroleum reserves. Reconnaissance surveys shot in the mid-1970's (Fig. 12) revealed the presence of large fault bounded structures (Exon and Willcox, 1978; Wright and Wheatley, 1979) and, in spite of water depths greater than 800 m. , the close proximity of major hydrocarbon accumulations on the NW Shelf and at Barrow Island in the Carnarvon Basin encouraged optimism. Five exploration permits divided up the Plateau in 1977 and 14 exploration wells were drilled (Fig. 13). These included three wells by the Phillips Group (British Petroleum, Gulf, Mount Isa Mines, Mobil and Phillips) in Permit WA-84-P on the central Exmouth Plateau, which have been published (Barber, 1982). Several non-commercial gas shows were encountered as well as the Scarborough gas discovery that has been retained by Esso. However, no heavier hydrocarbons where encountered.

Early exploration concepts involved generation of oil from Upper Jurassic and Neocomian shales in the Kangaroo Syncline and subsequent migration into the Jurassic and Triassic tilted fault blocks on the Exmouh Plateau High. The lack of liquid hydrocarbons was attributed to unfavourable source rocks, unsuitable burial history and a low paleo-thermal gradient. For the three wells published (Phillips Saturn No. 1 , Jupiter No. 1 and Mercury No. 1) Upper Triasssic, Jurassic and Cretaceous sections were found to be immature and incapable of generating hydrocarbons. Most hydrocarbons so far encountered on the Exmouth Plateau are thought to have originated from deep (5 km. or more) overmature gas source rocks, probably Lower Triassic and Permian shales, by deep tapping of source beds along faults bounding the tilted block structures, enabling the gas to migrate upwards (Barber, 1982).

The lack of success in finding oil in the major Exmouth Plateau structures has resulted in dropping in all except part of one permit and cessation of petroleum exploration on the Plateau. The re-stimulation of further petroleum exploration interest would appear to depend on demonstrating a marine oil prone source at mature depths, either in Jurassic graben fill in the Kangaroo Syncline, in local grabens, or in Triassic and Permian prerift sediments on the western margin of the Plateau , along with suitably located trapping structures.

4.4 Evolution of the Continental Margins

The geological and structural evolution of a continental margin is a complex and protracted process. While this has been recognised to a greater or lesser extent ever since the concepts of continental drift were first enunciated, the majority of evolutionary schemes proposed have been largely qualitative and generally have not been based on studies of continental margins themselves (examples are Wagener,1929; Du Toit, 1937; Heezen, 1960; Dewey and Bird, 1970).

Falvey (1974) envisaged an evolutionary scheme for the Southern Australian margin which involved three distinct phases:

1. Initially, intracratonic basins and then rift basins developed as regions of major basement subsidence, generally in the vicinity of an incipient breakup axis. The rifting occurred some 50 m.y. before the initiation of a divergent plate boundary (the "rift valley" phase). Subsidence and deposition rates generally decreased towards breakup time.

2. During a 5-10 m. y. period near the time of breakup, the intensity of relative uplift and then subsidence increased

(the breakup phase).

3. After seafloor spreading had been active for a few million years, subsidence and deposition rates again generally decreased with sedimentation showing a marked decrease in marine influences (the post breakup phase).

These evolutionary phases appear to provide a generally satisfactory description of the development of most parts of Australia's rifted margins.

The mechanism of continental margin formation has been described in terms of models which usually relate cycles of uplift and subsidence to the thermal evolution of continental and oceanic lithosphere (Dewey and Bird, 1970; Sleep, 1971; Falvey, 1974; Mutter, 1978). However, such tectonic models differ markedly, and appear strongly dependent on the type of continental margin chosen by a particular author for analysis. Thus, the emergence of a general continental margin model has been hindered by apparent geological and structural complexity, and also by limited depth of penetration and resolution of relevant marine geophysical methods.

There are major advantages to the Exmouth Plateau as a study area for continental margin problems:

1. The progressive dispersal of Gondwanaland from around continental Australia has provided two parts of the western margin with different breakup times:
   a. Northwest- Late Jurassic (155 m.y. b.p.)
   b. Southwest- Early Cretaceous (120 m.y. b.p.)

2. The kinamatic evolution of the ocean basins adjacent to these margins is fairly well understood (Figs 7 and 8).

3. For various climatological and oceanographic reasons, post breakup deposition on these continental margins consists dominantly of thin carbonates. This alleviates many problems involving seismic resolution and depth of penetration.

4. Fairly extensive oil search coupled with government policy on open file and public release of information already provides a substantial set of shallow data on these margins.

CHAPTER 5: Geophysical Results

5.1 Expanded Spread Profiles (ESP)

5.1.1 Data Collection

An ESP is a highly specific two-ship seismic reflection/refraction experiment, that achieves a large spatial offset and a very high spatial density in a common reflection mid point geometry by use of a multichannel receiving array and repetitively fired high energy sound sources, as shown in Fig. 3 (Stoffa and Buhl, 1979).

An ESP involves collection of a set of source-receiver pairs, with one ship providing the source (airguns and/or explosives) and the other ship, the receiver (towed multichannel seismic streamer). Source-receiver separation was up to 100 km. on the Exmouth Plateau. The receiving system, provided by Rig Seismic, consisted of a 2.4 km., 48 channel Teledyne seismic streamer (Appendix B). The sources used during each ESP and shot from Robert D. Conrad, were of two types:

1. A dual source, consisting of 10 airguns in a 96 litre tunned array shot on one side of the ESP mid point; with explosive charges of 20 kg. shot on the other side. This combination of sources was used when deeper continental crust was anticipated.
2. The airgun array source alone was used on both sides of the ESP in regions of thinner continental, transitional or oceanic crust.

The shot repetition rate for the gun array was 60 second, which at 5 kts represented a shot interval of 150 m. or a shot-receiver separation of 300 m. This gives an 8-fold stack of traces from the 48 channels when summed in 50 m. bins. The shot repetition rate for the explosive sources was 7 minutes. This gives an effective single fold stack.

The shooting and receiving ships each sailed inwards from opposite ends of the selected ESP line (Fig. 14). A line was defined by its end points, which in turn defined a mid point. To maintain correct geometry the source ship began shooting at it's end of the line, underway at 5 kts with the centre of the source array over it's end point at the start time. The receiving ship sailed into it's end of the line at 5 kts with the centre of the receiving array over it's end point at the start time. With both ships maintaining a "collision" course at constant speed, the centre of the receiving array would then cross the centre of the source array at the mid point. The profile was then extended, as the source and receiving ships continued on course and passed out of opposite ends of the ESP profile simultaneously. Thus, two nominally identical ESP's were recorded during each full run. For a 100 km. line, this took 11 hours at 5 kts. In the case of ESP lines shot using only airguns as source, the source ship also towed its own streamer, thus obtaining a vertical incidence 8-fold CDP seismic profile. That profile is required for structural control during subsequent ESP processing. In the case of ESP lines shot with both airgun and explosive sources, the profile was begun with airguns and finished with explosives. At the end of an ESP, the two ships would then proceed along parallel tracks to the next ESP line (Fig. 15a).

The ESP shooting method described above results, as stated, in two ESP's: one on the inward track; and one on the outward track. A simpler method can be used which collects only a single ESP, as shown in Fig. 15b. Both ships turn, say to port, just after the mid point; one looping to avoid entangling streamers. The poceedure is reversed at the start of the next ESP. This method was used only once during the Exmouth Plateau project.

Clearly, an avoidance manouevre was required at the mid point (Fig. 14b). This was generally carried out by the source ship taking avoidance action. The side chosen was that opposite to the direction in which the streamer was feathering astern of the receiving ship; eg. if the streamer feathered to starboard, the ships passed port-to-port. Avoidance action commenced 2 km. ahead and concluded up to 4 km. astern of the receiving ship (ie. 20 minutes either side of the ESP line mid point). During Exmouth Plateau operations, Rig Seismic and Conrad passed between 200 and 1250 m. abeam, depending upon weather and the feathering angle of streamers on one or both ships.

Corrections were often required to account for different convergence rates. These were most easily and frequently carried out by the source ship through direct bridge-to-bridge communication. Unless the convergence rates remained constant, the mid point would shift towards the slower ship, disrupting the common mid point geometry.

These geometrical mid course corrections were based on precise navigational data. Waypoints were set in each ship's navigational computer corresponding to the ESP mid point and each ship's corresponding starting point. Each ship's bridge watch was responsible for minimizing computed cross course errors and differences in down line distance to and from the ESP mid point. Both ships were equiped with satellite navigation and Global Positioning System (GPS). The latter was available for only 10 to 11 hours each day during this survey, due to the small number of satellites in the constellation at present. Full coverage will not be available until 1989. During most of the survey, Rig Seismic used HIFIX, provided by NATMAP, as backup to GPS.

Precise processing requires knowledge of the relatively separation of source and receiver to an even greater precision. This was provided at short range by *miniranger* (less than 30 km.) and at longer ranges by RAYDIST. The actual lane number provided by RAYDIST was not necessarily reliable at the start of an ESP line. It was calibrated from *miniranger* later in the line and previous ships' separation recomputed. When taken in conjuction with the absolute HIFIX position for Rig Seismic, the relative range data also helped minimize errors in dead reckoning on Conrad.

The geometry on passing is also required to process the near range ESP data. Since neither *miniranger* nor RAYDIST provides information on bearing, these were provided from the bridge of each ship, at each shot instant, by optical or radar sights.

Finally, the shot instant had to be available to the receiving ship to an accuracy of about 1 millisecond. The recording cycle on the receiving ship was initiated by a master clock which also transmitted a calibration tone, at short ship-to-ship distances, to a slave clock on the source ship. The gun array was fired on the minute, and explosives timed for every 7 minutes.

ESP lines involving both airguns and explosives were shot as outlined above. The switch from airguns to explosives always took place after the source ship had passed the mid point and cleared the receiving ship's tail bouy (Fig. 14c). This would result in an approximately 30 to 50 minute, or 4 to 8 km. gap, 2 km. beyond the mid point while Conrad retrieved her gun array. This gap is covered by records made on converging ranges. Clearly, Conrad could not also tow a streamer during explosive lines and consequently, no vertical incidence CDP profile could be collected. Thus a separate multichannel seismic profile had to be subsequently collected by one or other ship, or the ESP laid out on a pre-existing seismic line. All mid course corrections were undertaken by the source ship, since she had no streamer astern.

ESP lines on the Exmouth Plateau were laid out in three transects: an *Exmouth Transect*, running WNW across the Plateau from the shelf north of Barrow Island to the Gascoyne Abyssal Plain, consisting of 9 ESP's; a *Cape Range Transect*, running SW from the centre of the Plateau to the Cuvier Abyssal Plain, consisting of 5 ESP's; and a *Cuvier Transect*, running ESE from the Cuvier Abyssal Plain to the shelf south of NW Cape, consisting of 5 ESP's. All 19 ESP's were laid out to avoid known structural complexity or along-line variation, to be representative of known structural or physiographic provinces, and to simplify operations and minimize transits. Where possible, ESP's on the *Exmouth Transect* were laid out along segments of the GSI 1976 "group shoot" multichannel seismic grid, as well as other commercial and B.M.R. data.

5.1.2 Data Interpretation

Seismic reflection and refraction data from all ESP's was recorded on Rig Seismic. In the case of the explosive segments of ESP lines, the various shot instants cannot be precisely known until navigation and seismic data from both Rig Seismic and Conrad are merged during post cruise processing. However, for the airgun portions of all ESP's, the relative shot instants were set by the slave clock on Conrad, which was calibrated to the master clock on Rig Seismic. The exact calibration will not be known until post cruise processing of navigation data, but since both clocks were initially reset to the transit satellite clock, the absolute shot instant is known to within one second.

Since the airgun segments of ESP's were shot 8-fold, displays of data panels consisting of all 48 channels from every 8th shot were "spliced" together to form a continuous, single fold "monitor" section of all such segments. A sample display section is shown in Fig. 16 (from ESP E-3). Minor tares in the data can be seen where the different panels join (eg. between panels 400 and 408, at 086.1703). Such tares arise when the relative speed of the ships varies from 10 kts. These minor discontinuities were ignored during preliminary interpretation and each panel was assumed to be 2.4 km. wide.

The upper right-hand corner of Fig. 16 clearly shows both a direct arrival through the water (the reflection hyperbola at about 0.2 sec. below the top time mark) and a suite of seabed reflections (at about 2 sec. below the top time-mark). Because of the avoidance manouver, the seabed reflection is not a true reflection hyperbola at near ranges. Zero on the x-axis of the display occurs at the roll-over on the direct reflection hyperbola.

Zero on the time axis may be estimated from the ship-to-ship separation abeam during the avoidance manoeuvre. These measurements were taken directly from radar ranges measured on Rig Seismic, or calculated indirectly from the angular separation of consecutive one or two minute ship-to-ship sightings (assuming a relative speed of 300 m./minute, with the ships on a parallel, but opposite course).

With the origin and scales of the record section thus defined, significant refraction events were picked and velocity and intercept time read off graphically. A simple flat-lying, multilayer case solution (with the water layer as layer 1) was obtained. These preliminary results are presented in the next section. To tie refraction and reflection solutions correctly at the seabed, an uppermost sediment layer with velocity 2.1 km./sec. on the shelf and 1.8 km./sec. off the shelf was assumed. The intercept time for this layer 2 was estimated so that the thickness of layer 1 was the same as the water depth.

5.1.3 Preliminary Results: Exmouth Plateau Transect

5.1.3.1 ESP E-1

No.	Velocity km/sec	Intercept sec	Thickness km	Depth km	Refl. Time sec
1	(1.50)	0.00	0.08	0.08	0.107
2	(2.10)	0.07	0.04	0.11	0.145
3	2.30	0.09	0.26	0.37	0.371
4	3.55	0.29	2.27	2.64	1.650
5	4.26	1.02	4.00	6.64	3.528
6	5.53	2.51			

Notes:
1. Velocity in brackets assumed.
2. Water depth measured from PDR.
3. Layer 2 intercept time adjusted to compute water depth.

5.1.3.2 ESP E-2

No.	Velocity km/sec	Intercept sec	Thickness km	Depth km	Refl. Time sec
1	(1.50)	0.00	0.08	0.08	0.107
2	(2.10)	0.07	1.23	1.30	1.278
3	3.24	0.98	0.76	2.07	1.747
4	4.02	1.37	3.83	5.89	3.653
5	4.76	2.51	0.75	6.64	3.968
6	6.40	3.30			

Notes:
1. As for ESP E-1.
2. Probable velocity inversion below layer 3.
3. Layer 6 uncertain.

5.1.3.3 ESP E-3

No.	Velocity km/sec	Intercept sec	Thickness km	Depth km	Refl. Time sec
1	(1.50)	0.00	1.44	1.44	1.920
2	(1.80)	1.06	0.68	2.12	2.676
3	2.45	2.03	0.87	2.99	3.386
4	2.91	2.62	0.30	3.28	3.592
5	3.45	2.98	1.35	4.64	4.375
6	4.37	3.71	2.31	6.95	5.432
7	6.40	4.86			

Notes:
1. As for ESP E-1.

5.1.3.4 ESP E-4

No.	Velocity km/sec	Intercept sec	Thickness km	Depth km	Refl. Time sec
1	(1.50)	0.00	1.10	1.10	1.467
2	(1.80)	0.81	0.45	1.55	1.967
3	2.05	1.24	0.47	2.02	2.425
4	2.33	1.66	1.12	3.14	3.387
5	3.74	2.92	0.97	4.12	3.905
6	4.36	3.32	3.38	7.50	5.456
7	6.25	4.76			

Notes:
1. As for ESP E-1.
2. Layer 7 uncertain.

5.1.3.5 ESP E-5

No.	Velocity km/sec	Intercept sec	Thickness km	Depth km	Refl. Time sec
1	(1.50)	0.00	0.96	0.96	1.280
2	(1.80)	0.71	0.38	1.34	1.702
3	2.31	1.24	0.72	2.07	2.326
4	2.56	1.61	1.05	3.12	3.146
5	4.27	2.77	2.70	5.82	4.411
6	5.44	3.71	2.10	7.93	5.183
7	6.08	4.22	1.53	9.46	5.686
8	7.26	4.84			

Notes:
1. As for ESP E-1.
2. Intercept times adjusted for variations in ships' speed.
3. Layers 7 and 8 uncertain.

5.1.3.6 ESP E-6

No.	Velocity km/sec	Intercept sec	Thickness km	Depth km	Refl. Time sec
1	(1.50)	0.00	1.53	1.53	2.040
2	(1.80)	1.13	0.02	1.56	2.062
3	2.49	1.65	0.70	2.26	2.624
4	3.36	2.23	2.36	4.61	4.029
5	4.29	3.27	1.51	6.12	4.733
6	5.30	3.98	4.20	10.32	6.318
7	6.23	5.05			

Notes:
1. As for ESP E-5, notes 1 & 2.
2. Layer 7 uncertain.

5.1.3.7 ESP E-7

No.	Velocity km/sec	Intercept sec	Thickness km	Depth km	Refl. Time sec
1	(1.50)	0.00	2.35	2.35	3.133
2	(1.80)	1.73	0.28	2.63	3.444
3	2.44	2.68	1.12	3.75	4.362
4	3.30	3.67	0.95	4.70	4.938
5	4.38	4.37	1.75	6.46	5.737
6	6.21	5.24	3.70	10.16	6.929
7	7.06	5.93			

Notes:
1. As for ESP E-6.

5.1.3.8 ESP E-8

No.	Velocity km/sec	Intercept sec	Thickness km	Depth km	Refl. Time sec
1	(1.50)	0.00	4.29	4.29	5.720
2	(1.80)	3.16	0.33	4.62	6.087
3	2.76	5.08	0.22	4.84	6.246
4	5.25	5.96	3.89	8.73	7.728
5	6.03	6.76			

Notes:
1. As for ESP E-1.

5.1.3.9 ESP E-9A

No.	Velocity km/sec	Intercept sec	Thickness km	Depth km	Refl. Time sec
1	(1.50)	0.00	4.74		
				4.74	6.320
2	(2.10)	4.42	0.82		
				5.56	7.101
3	5.51	6.80	2.48		
				8.03	8.001
4	6.95	7.46			

Notes:
1. As for ESP E-1.
2. E-9 reshot as E-9A because of large seabed relief.

5.1.3.10 Summary of Results

A compilation of the refraction results from the Exmouth Plateau Transect is given in Fig. 17. Only the upper 10 kms. of crustal structure may be resolved using the unprocessed, replayed monitor records. This data display does, however, give strong indications of other deeper events which will certainly emerge with post cruise processing. At this preliminary stage there are major qualifications concerning some results which must be emphasised:

1. Shelf ESP's E-1 and E-2 will be strongly affected by blind zones and velocity inversions. Velocity data from West Tryal Rocks No. 1 indicates an inversion of velocity below the 3.2 km./sec. layer.

2. Outer slope ESP E-7 may be strongly affected by steep dips and unseen structure.

3. Rise ESP's E-8 and E-9A may be strongly affected by navigation errors and seabed topography. Indeed, E-9 was reshot as E-9A because of a seamount.

The interpretation of the velocity layering has been aided by knowledge of the stratigraphy and upper velocity structure in NW Shelf and Plateau exploration wells, the interpretation of the WACDP profile through all ESP's on the transect (Section 5.2 and Fig. 20) and general knowledge of the significance of various crustal velocities. An immediately obvious conclusion is that the principal depocentre of the basin complex, consisting of the Exmouth Plateau, the NW Shelf continental margin and the northern Carnarvon Basin - prebreakup as well as post breakup elements - lies in the vicinity of the Kangaroo Syncline. The total sediment thickness above basement is about 7 kms.

1. Layers with velocities less than 3 km./sec. on the Plateau, its lower slope and rise can be associated with sediments of post Triassic rift onset unconformity age.

2. On the shelf, these sediments have velocities from 2.3 to 3.6 km./sec.

3. Layers with velocities in the range 3.3 to 4.8 km./sec. (mainly 4.0 to 4.4 km./sec.) can be associated with Triassic, probably Permian and possibly other Upper Paleozoic sediments. The structural relief of the Rankin Trend is apparent on either side of E-2. A lower set of velocities within the general range (3.5 to 3.7 km./sec.) occurs beneath the Kangaroo Syncline and may represent uppermost Triassic or lowermost Jurassic section which elsewhere has been removed by erosion. Other layers with lower velocities (3.3 to 3.4 km./sec.), also lying beneath the Triassic rift onset unconformity on the outer Plateau, but which are clearly strongly eroded (Fig. 20) and may indicate that this part of the section was never subjected to significant burial compared with that beneath the inner Plateau and shelf.

4. An intermediate crustal layer with a velocity range of 5.3 to 5.5 km./sec. (excepting E-7) lies beneath the Dampier Sub-basin (E-1) and also extends from beneath the Central Dome of the Plateau to the rise. It is interpreted as representing Lower Paleozoic sediments and metasediments.

5. Normal mid continental crustal velocities in the range 6.0 to 6.4 km./sec. (excepting E-7) are observed beneath the continental shelf, the Plateau and the rise.

6. Deep crustal velocities in the range 7.0 to (?)7.3 km./sec., typical of continental margins (Falvey and Middleton, 1981) occur beneath the outer rise and possibly beneath the Plateau itself. In this respect, the structure of the Exmouth Plateau and the Queensland Plateau are quite similar.

5.2 Wide Aperture CDP Profiles (WACDP)

5.2.1 Data Collection

A WACDP achieves the equivalent of a conventional multichannel seismic profile with an extra long receiving array. It is constructed from the streamers of two ships towed separately in line, each ship firing its own airgun array alternately into both streamers, as shown in Fig. 18 (Buhl et al, 1981). The benefit derived from use of a wide aperture, or long receiving array is that it provides a combined high CDP fold (48) with sufficient source-receiver offset that travel time separation of primary and multiple reflections can be achieved in relatively deep water. This is sufficient to enhance very deep reflection events and provide greater velocity discrimination at greater depths (Fig. 19). It is therefore ideally suited to deep crustal studies, in particular, in tying individual ESP lines together at their mid points. Centres of all the ESP's in the *Exmouth, Cape Range* and *Cuvier Transects* were tied with WACDP profiles.

In all three WACDP profiles, Rig Seismic was the lead ship and Conrad was the tail. Both ships towed a nominal 2400 m., 48 channel streamer. A 2450 m. gap (48 plus 1 channels) was left between the last channel on the lead streamer and the first channel on the trailing streamer. Rig Seismic fired its airgun pair on the minute and Conrad fired its airgun array on the half minute, both shots being recorded in both streamers, on both ships.

Timing of the shot cycle to 1 millisecond was achieved by using the same synchronized clocks on both ships, as used during ESP operations. Ship separation was maintained at better than 10 m., or less than a quarter of a group, by using *miniranger*. Thus a streamer of apparent nominal length 7200 m. was synthesized. In practice the much smaller airgun pair on Rig Seismic meant that the arrivals on the streamer from 4800 to 7200 m. were relatively weaker than those from 0 to 4800 m. and may therefore not always be useful.

5.2.2 Preliminary Results: Exmouth Plateau Transect

The Exmouth Plateau WACDP transect ties the midpoints of ESP's E1 through E9. Four of the range data sets were collected by the cable of the Rig Seismic and the remaining two by the cable of the Conrad. The Rig Seismic was the lead ship and thus recorded the 0 to 2400 m. and the 2400 to 4800 m. ranges.

The monitor records of the WACDP profile are single channel and so do not have the signal-to-noise enhancement obtained from stacking all 144 channels. Nonetheless, the monitor records do display the rift structure and define the main tectonic features investigated by the transect (Fig. 20).

The eastern end of the transect crosses the Rankin Trend, the location of current major gas production at North Rankin "A". The Rankin Trend diplays a dominantly horst and graben structure formed by normal rift faulting. Downfaulting west of the Rankin Trend forms the Kangaroo Syncline.

Further west of the Kangaroo Syncline, the reflector corresponding to the Triassic rift onset unconformity is progressively elevated along normal rift faults to form the Exmouth Plateau Central Dome and further west, downthrown to form the continental slope and rise of the Exmouth Plateau. The character of the seismic reflections below the rift onset unconformity surface over the Plateau and to the east is sedimentary, as will be further discussed in the context of lines 55/02 and 55/04 in the following section. On the deep margin of the Plateau (the "rise") the character of events below the rift onset unconformity suggests that volcanic flows have outpoured onto the rift surface, although these are not as extensive as the outpourings producing parallel reflectors on the Voring Plateau (Hinz,198*). The volcanic flows in this instance are interrupted seaward by a seamount towards the western end of the line. The seamount is downslope to the volcanic strata which were probably sourced from volcanic mounds near the base of the Exmouth Plateau lower slope.

Beneath these reflectors deeper weak seismic events dipping landward are identified. These events are down-faulted west of an uplifted zone at the rift unconformity and could represent either basement or deep crustal reflectors.

WACDP processing aims at enhancing deep arrivals. The shallow water arrivals of the 2400-4800 m. range data ~~set~~ also recorded on the Rig Seismic tend to be distorted because of the long travel path. Consequently, a deeper water example is presented (Fig. 21). Weak basement or deep crustal events appear to be present over the Plateau towards the deeper western Plateau margin, as on the monitor record of the close-in data set. Similar events are also present beneath the lower rise at the foot of the Plateau and are downfaulted further west. The monitor data also shows clearly that the area at the base of the Plateau is a large downthrown block with fault plain reflectors and the locations of the bounding faults shown by defractions evident at the Plateau edge and at the margin of the next westward block. On this data set the mounded volcanic features on the "rise" appear to be flat bottomed and to rest on the rift unconformity surface.

5.3 Multichannel Seismic Reflection

5.3.1 Data Collection

Acquisition of conventional 48 channel seismic reflection data and geological dredging to assist in petroleum resource studies, were planned as part of third phase of the Exmouth Plateau study. The late arrival of Robert D. Conrad for the second phase resulted in 1150 km. of multichannel seismic reflection data being collected during this cruise, prior to the start of ESP operations. These data included seven regional lines on the southwestern and western edge of the Exmouth Plateau and on the Platypus Spur, and an ODP site survey at proposed location EP-2 in 4000 m. water depth adjacent to the southwest of the Plateau. Of particular interest in the multichannel seismic study were any factors which could indicate the potential to source petroleum in areas of the Plateau rather than the thermal gas discovered in previous exploration of the Plateau crest; These factors included the possible presence of mature Jurassic graben source areas such as are associated with the Jabiru and other NW Shelf petroleum discoveries, and shallower burial which could reduce the thermally overmature condition of Lower Triassic and Permian source rocks on the Plateau crest.

5.3.2 Southwestern Exmouth Plateau

Line 55/02 (Fig. 22) ties Esso Vinck No. 1 petroleum exploration well and extends WNW to the base of the Plateau lower slope and the area of the ODP EP-2 site survey.

Horizons interpreted on line 55/02 are tied to Vinck No. 1, which encountered 677 m. of Jurassic deltaic sediments of the Barrow Group underlying 105 m. of the Albian/Aptian Gearle Siltstone and 56 m. of the Aptian/Neocomian Muderong Shale. The Barrow Group overlies a thin Upper Jurassic Dingo Claystone unit which rests unconformably on tilted fault blocks composed of Triassic sediments (rift onset unconformity).

Horst and graben rifted structures in the Triassic are overlain by post Triassic sediments, which progressively thin towards the Plateau margin. A relic shelf edge is preserved in an upper delta of the Barrow Group at the east of the line and seismic character is consistent with more distal facies west of this feature. A further change in seismic character from opaque to alternating reflectors argues for the facies of the Barrow Group again becoming more proximal further west around a Plateau edge high at the rift onset unconformity surface, which presumeably was emergent above sealevel during the period of deposition of the Barrow Group and was eroded to source the local Barrow Group sediments. The clearly sedimentary character of the strata below the rift onset unconformity changes westward until at the Plateau edge the seismic character is consistent with that of basement or igneous rock types.

Ponded sediments occur at the base of the outer slope of the Plateau on the western end of line 55/02 in the region of the proposed ODP location EP-2. Correlation of seismic character suggests that most of the 700 m. of ponded sediments overlying the rift onset unconformity in that region is composed of Lower Cretaceous and Jurassic time equivalents of the Barrow Group and Dingo Claystone.

Line 55/04 (Fig. 23) runs approximately east-west north of line 55/02. It ties the Eendracht No. 1 well to the EP-2 location. Eendracht No. 1 has a similar post rift sedimentary thickness to Vinck No. 1 but greatly reduced Lower Cretaceous and Jurassic sequences. The Lower Cretaceous /Upper Jurassic Barrow Group is 149 m. thick in Eendracht No. 1, compared to 677 m. at Vinck No. 1; the mid Cretaceous Gearle Siltstone is 25 m. thick, compared with more than 105 m. and the underlying Muderong Shale is 11 m. thick, compared with 56 m., respectively.

Basic features of line 55/04 are similar to those of line 55/02 except that the westward transition in the prerift reflection events from sedimentary to basement or igneous character is more clearly seen, and pronounced ponding of Lower Jurassic Dingo Claystone is observed landward of a Plateau edge high. A more proximal facies of these sediments occurs over an uplifted rifted feature suggesting lateral sourcing from an area of still higher relief.

5.3.3 Northwestern Plateau

The northwestern Plateau margin was traversed by line 55/07 (Fig. 24), which ties industry seismic data on the Plateau crest northwest onto the continental rise. Jurassic and Lower Cretaceous Barrow Group sediments are less well developed on the northwestern Plateau than in the south, compatible with the provenance of the Barrow Group deltas on the Plateau being mainly from south of the Plateau in prebreakup time.

Three seismic horizons were tied to the industry grid on the Plateau and grid data were in turn tied back to the Phillips Mercury No. 1 well. These horizons were base Tertiary unconformity, base Middle Cretaceous Gearle Siltstone (breakup unconformity for the central, western and southern Plateau) and the top Triassic rift onset unconformity. An horizon probably representing the top Barrow Group appears down-flank of the crest of the Plateau. On the Plateau crest it is replaced by the Muderong Shale. The reappearance of the Barrow Group towards the Plateau margin would relate to the erosion of uplifted areas prior to breakup on the western margin of the Plateau, producing a more proximal facies differing from the partly time equivalent Muderong Shale. The Triassic horst and graben topography under the rift onset unconformity progressively approaches the sea floor towards the Plateau edge and down the Plateau lower slope. This is accommodated largely by thinning of post Middle Cretaceous strata. The seismic character of the prerift lithology becomes chaotic towards the Plateau margin and it is likely that pre-Triassic sediments, basement or igneous material occur beneath the rift onset uncomformity on the edge of the Plateau, on the Plateau lower slope and rise. At the base of the escarpment they are covered by a zone of chaotic mounded sediments. This mounded zone is approximately 5 km. wide and 750 m. in thickness. An unconformity similar in seismic character to the mid Cretaceous base Gearle Siltstone is identified towards the top of these mounded sediments. West of the mounded zone a thinner (400 m.) representation of the same sediments is horizontally layered and an event interpreted on seismic character as equivalent to the top Barrow Group is recognised below the mid Cretaceous event. That event is not observed in the mounded region due to the chaotic nature of the sediments.

The thinning of overburden above pre-Jurassic source rocks towards the western Plateau margin in general could result in a zone west of the Central Dome where the Lower Triassic or Permian source rocks, thermally overmature at the crest could be less mature and produce oil rather than thermal gas.

5.3.4 Platypus Spur Region

The Platypus Spur is an extension of the northwestern Plateau. It is separated by a bathymetric low and has an area of 4000 sq. km. at the 2000 m. isobath. Lines 55/08 and 55/09 crossed this feature and investigate the nature of the Platypus

Spur and the possible presence of substantial particularly Jurassic source rocks in the graben feature separating the Exmouth Plateau from the Spur.

Line 55/09 is presented to show the characteristics of the northwestern Plateau, the Spur and the intervening graben (Fig. 25). A thickening of graben fill sediments in the reentrant between the Spur and the Plateau was observed but the maximum depth of Jurassic sediments is 2.0 km. which, at least on line 55/09, would not allow these sediments to be thermally mature for hydrocarbon generation even given the relatively high heatflow over the Plateau (approx. 80 mW/sq.m.).

Seismic horizons representing a base Tertiary unconformity, the mid Cretaceous Base Gearle Siltstone and the rift onset unconformity were tied from the Spur to the industry grid seismic on the Plateau. Thickening of sediments between the Spur and the Plateau were accommodated mainly in the thickening of pre-Tertiary strata. Triassic prerift strata exhibited rift graben topography with bedded Triassic sediments being evident on the Plateau itself.

Line 55/09 shows that the southern half of the Platypus Spur is composed of an uplifted Triassic sedimentary block covered by 300 m. of Tertiary and later sediments,and in its northern half by an accumulation of 2 km. of post Triassic sediments. The Spur is clearly continental and sedimentary in origin.

5.4 O.D.P. Site Survey: EP - 2

5.4.1 Background

In December, 1985 Australian and West German scientists presented a proposal to JOIDES for the drilling of a number of ODP holes on the margin of the Exmouth Plateau (collated by von Rad and Exon, 1985). Broadly, these drillholes aim to resolve questions concerning the early rifting history of passive continental margins. The ODP proposal was considered by the Indian Ocean Regional Panel and tentatively endorsed by the Planning Committee of ODP in January, 1986, subject initially to site survey considerations and Safety Panel assessment.

One of the proposed ODP sites was surveyed during this second phase of BMR's Exmouth Plateau project. The indicated site location is at 19 deg. 56'S, 110 deg. 25'E and designated EP-2 in the 1985 proposal. Specifically, site EP-2 is designed to test subsidence and stretching models for rift and subsequent continental margin evolution, leading to marginal plateau formation. The Exmouth Plateau is an old, sediment starved margin, beneath which pre-rift, rift phase and post breakup sedimentary sections are easily accessible by ODP-type drilling operations. Site EP-2 is one of a number of locations proposed for the Exmouth Plateau margin. It should be possible to integrate stratigraphic and paleontological data from these sites with similar data from open file commercial exploration wells on the summit of the Plateau and adjacent shelf , to establish a comprehensive picture of margin and plateau evolution.

5.4.2 Data Collection

The track layout for the EP-2 site survey is shown in Fig. 26. It consists of a 94 km. grid of multichannel seismic data, broadly covering an area 5 to 10 km. around the site and involving 10 line intersections. The lines into (line 55/02) and out of (line 55/03E) the area were shot with two 8 litre airguns and the intermediate detailed grid was shot with one 8 litre and one 1.6 litre airgun.

5.4.3 Data Interpretation

The onboard seismic data interpretation utilized the real-time, unprocessed monitor record sections of the near channel of the 48 channel streamer. The guns-near trace separation was 280 m. Seismic ties were made to Esso Vinck No. 1 along line 55/02 and to Esso Eendracht No. 1 along line 55/04. The following reflection events were carried into the site survey area and assigned the following tectonic and stratigraphic interpretation:

"Green" - top Barrow Gp.; top late rift phase or early post breakup phase deposition; top Neocomian overlain by Upper Cretaceous.

"Blue" - top Dingo Claystone equivalent; top early rift phase; intra Upper Jurassic overlain by Lower Cretaceous.

"Red" - top Triassic rift onset unconformity, as recognized on the Rankin Trend beneath the shelf; Upper Triassic overlain by late Lower to early Upper Jurassic or younger.

Interpretative contour maps of the bathymetry, Triassic unconformity depth and isopachs of sediment above the Triassic unconformity are given in Figs. 27, 28 and 29. The site area lies at the foot of the main outer slope of the SW corner of the Exmouth Plateau. Triassic and older sediments, volcanics and/or basement outcrop east and west of the site area (see Fig. 22, showing the regional interpretation of line 55/02). The water depth lies between 3950 m. and 4100 m., sloping gently from NNE to SSW. The seabed is gently terraced (Fig. 30), each step downwards representing progressive erosion of Tertiary and the Cretaceous sediments. This is probably caused by boundary currents along the base of the plateau slope. Over the SW quarter of the survey area, post Neocomian sediments are absent (Fig. 29).

The Triassic unconformity surface forms a broad syncline, plunging gently to the south and generally trending parallel to the foot of the Plateau slope. A basement block or volcanic intrusion outcrops in the SW corner of the survey area. Early rift phase Jurassic sediments are thickest over the synclinal axis in the Triassic unconformity surface and thin out on both flanks. The Jurassic section is absent over the western half of the survey area and to the east below the Plateau slope (Fig. 28). The thickest overall section above the Triassic unconformity lies along a north-south axis between the foot of the slope and the axis of the Triassic syncline (Fig. 29).

5.4.4 Site Proposal

The above interpretation suggests a provisional ODP drill site location at the intersection of lines 55/02 and 55/03E, at 19 deg. 56'S, 110 deg. 27'E (Fig. 30). A well at this site should sample both post breakup and prebreakup sections in a structurally low position. A provisional well prognosis is given in Fig. 31. Total drill depth is 750 m. subbottom.

It is anticipated that four units would be encountered in EP-2, which would adequately define prebreakup margin subsidence seaward of the lower Plateau slope. The seismic stratigraphic interpretation and correlations with Vinck No. 1 and Eendracht No. 1 suggest that Triassic non marine sediments, similar to the Mungaroo Beds, but possibly including volcanics, should be encountered at 630 m. subbottom. The overlying 530 m. of prebreakup, rift phase sediments might be expected to show progressive upward marine influence. However, most of the 4000 m. of submarine subsidence probably occured post breakup (120 m. y. b.p.).

It is anticipated that data on paleowater depths and environments of deposition should allow construction of a definitive subsidence curve, which will test various models of passive margin evolution.

5.5 Sonobouy Data

One REFTEK sonobuoy was deployed while recording reflection data on line 55/09. As in previous research cruises, the seismic data were treated as an additional channel (49) and recorded using the same parameters as for the seismic reflection data. Six seconds of record were displayed on the special, "self-serve" monitor, using the record skip to give maximum display of refracted arrivals at the largest offsets.

The sonobuoy was recorded for 2 hours 50 minutes, over a distance of 27 km. The hydrophone was set to delay for about 20 minutes before extending fully to 20 m but from the character of the monitor record it appears that this occurred on deployment (Fig. 32).

As a single sonobuoy gives a one way record, no information on structure or dip of refractors could be included in the modelling of depths and thicknesses derived from apparent velocities and zero time intercepts calculated from identified refractors. The simple flat layer model given here is a preliminary model which will be refined by further modelling which takes into account the structure seen on the coincident reflection record (line 55/09).

No direct wave (D wave) was recorded, so the water velocity was taken to be 1.5 km/sec with an intercept of zero on the time axis (see below). A refractor from the seafloor was also not recorded, so sediment velocity of 1.8 km./sec was assumed for the first layer and the intercept adjusted iteratively until the depth of the water column corresponded with that recorded in the bathymetry (1.71 km). The ship's speed was assumed to average 5 kt.

Two refractors were identified at larger offsets. The first of which has apparent velocity of 5.13 km/sec, however true velocity will be greater as as recording is down-dip. The second refractor has an apparent velocity of 7.23 km/sec which is consistent with arrivals refracted in the crust. These refraction branches deviate little from a straight line, despite the complexity of the upper sequences of the Plateau.

No.	Velocity km/sec	Intercept sec	Thickness km	Depth km	Refl. Time sec
1	(1.50)	0.00	1.71		
				1.71	2.280
2	(1.80)	1.26	0.54		
				2.25	2.880
3	2.44	2.20	0.24		
				2.49	3.077
4	2.96	2.55	2.15		
				4.64	4.529
5	5.13	4.10	5.31		
				9.95	6.600
6	7.23	5.78			

Notes:
1. Velocity in brackets assumed.
2. Water depth measured from PDR.
3. Layer 2 intercept time adjusted to compute water depth.

5.6 Magnetics

Magnetics were recorded during ESP's, WACDP, conventional multichannel seismic reflection profiling and in transit using 2 Gradiometrics G801/803 proton procession magnetometers. Where Gradiometer data were not collected due to equipment servicing or complexity of manouevres, single channel magnetometer data were recorded. Diurnal effects during the study were monitored by an onshore magnetic station maintained by NATMAP personnel. Details of magnetic data collected are given in Appendix A and are plotted along with seismic profiles on Figs 20 and 22-25.

Total field magnetic anomalies recorded over the Plateau are of long wavelength and low amplitude reflecting a substantial thickness of non-magnetic sediments. Towards the Plateau edge and on the slope and rise the shallower basement and the presence of igneous rocktypes at the rift unconformity produces higher amplitude shorter wavelength anomalies.

5.7 Gravity

Gravity data were recorded during ESP's, WACDP, conventional mutichannel seismic reflection and in transit using a Bodenseewerk Geosystem KSS-31 Marine Gravity Meter. Locations of traverses are given in Appendix A and gravity data corrected for Etvos effects but not latitude are displayed along with seismic data on Figs 20 and 22-25.

The raw gravity data largely reflect changes in water depth. However, regional variations are observed which are due to local changes in crustal rocktypes and densities. Processing of the gravity data and modelling in conjunction with the results of the ESP, WACDP and multichannel seismic reflection results will allow a more refined definition of the structure and crustal composition of the Plateau.

CHAPTER 6: Systems Results

6.1 Data Acquisition System

6.1.1 General

The load on the shipboard acquisition and processing system (DAS) continues to rise as the demand for more facilities continues. The Exmouth Plateau cruise presented a considerable challenge in providing high accuracy navigation in deep water. This was needed to both adequately control the ESP and WACDP profiles, and to define ODP well site locations for future occupation. A major effort has been mounted by the Division of National Mapping (NATMAP) to provide a HIFIX radio navigation system in a difficult and remote environment.

User access to the DAS computer as a general purpose computing facility has risen sharply with the need to provide a post-processing function. The restricted user disc space of 10 Mbytes has proven to be a major limitation in this role, which should be largely overcome when two 50 Mbyte drives are installed in June/July this year. Meanwhile playback of selected parts of the ESP profiles was managed using an Epson RX100 printer in an identical fashion to that used in the seismic acquisition system.

6.1.2 Navigation

Positioning of the ship is derived from a hierachy of three largely independent systems. Considerable skill is required to choose the best system as each exhibits limitations from time to time.

6.1.3 Global Positioning System

A Magnavox T-Set gives continuous absolute positioning within about 20 metres r.m.s. under optimum conditions. However the system is in the experimental stage with only 7 of the proposed 24 satellites in orbit. Positioning is possible for some 8 hours a day but this can be extended to 12 hours in the two-satellite mode by using an atomic frequency standard. Success depends entirely upon an acceptable frequency bias between the satellite transmissions and the standard being determined during the previous period of three to four satellite visibility.

The period from 2000 through to 0300 GMT generally gave consistently good results with three or more satellites above the horizon for about five hours. A further period from 1100 to 1900 GMT could also be used for navigation but for roughly half the time there were only two satellites visible. Effective use of periods of only two satellites was found to have considerable uncertainty. With the incomplete satellite constellation, the quality of fixes as the third satellite disappeared from view was often poor, and the resultant frequency bias inaccurate. Positions in error by as much as two or three miles were found to occur, so continued monitoring of the bias values and exclusion of unacceptable periods was necessary.

Experience in evaluating the effects of frequency bias and dilution of position caused by satellite geometry continues to build up, but it will be some time before we adequately understand the processes involved.

6.1.4 Radio Navigation System

The HIFIX system is typically used for position fixing over distances of 100-200 kms where shore transmitters can be located to provide acceptable accuracy in hyperbolic range mode. The Exmouth Plateau exercise required operation in the range 300-500 kms while the the shape of the coastline meant a restrictive shore station geometry. As a result, only two transmitters were likely to be received at any one time.

From previous experiments on the Queensland Plateau, we had shown that HIFIX data could be satisfactorily received over ranges in excess of 500 kms, though noise levels were in excess of 20 centi-lanes (about 30 metres) at night. If the geometry problem could be solved along with operation using only two transmitters, we had a viable navigation system.

The requirement has been met by installing an atomic standard at the master station onshore to stabilise all shore transmissions. In addition another atomic standard was used on the ship to provide pseudo-range observations, obtained by comparing the observed signal with the standard rather than another of the channels as in hyperbolic mode. In theory the only error is the drift between the two standards.

Shore stations have been set up at Karratha, Onslow, Exmouth and later at Ningaloo and Gnaraloo. Only three transmissions can be received at any one time. The prime transmitter was at Onslow for the northern chain and Ningaloo for the southern chain, with Exmouth as a common slave station. Operation of the transmitters has been an arduous task both because of the remote locality, and temperatures frequently in the order of 40 degrees C.

HIFIX reception on the ship has proven successful most of the time despite the long range. Onslow and Exmouth have been picked up 24 hours per day with a tendency to lose lane lock between dusk and midnight local time when over the western side of the Plateau. Less success has been obtained with Karratha and similarly with Ningaloo when night time reception was almost nonexistent.

Despite these problems, adequate real-time navigation (25-50 metres) has been achieved over much of the Plateau for some 18 hours a day. There are times when the velocity control can be most inadequate, though positional control can still be acceptable. It is expected that post-processing will allow recovery of accurate positions for upwards of 20 hours a day.

6.1.5 Dead Reckoning System

Two independent systems incorporating gyro compass, dual-axis sonar doppler log and satnav receiver provide basic dead reckoning for periods where the other systems prove inadequate. Such a system was the main method for positioning a research ship until the advent of GPS, or the rare occasions when a high resolution system such as HIFIX was available.

The primary dead reckoning system of Arma-Brown gyro, Magnavox MX610D sonar doppler and MX1107RS satnav receiver provides the best available positioning of this type. A lower grade system of Robertson gyro, Raytheon DSN450 sonar doppler and MX1142 satnav receiver is the backup.

Both systems have problems in rough weather or when heading into the sea due to air being trapped under the hull and blanking the transmission of all sonar systems. A small paddle wheel log is still under test as a way of validating the information coming from the sonar dopplers. It should allow identification and rejection of suspect data at such times.

Interference by the 3.5 kHz echo sounder in the operation of the MX610D sonar doppler has not occurred on this cruise. The numbers of transducers in use and cabling have been changed which has helped reduce the pickup in the doppler system.

6.1.6 Ship-to-Ship Ranging and Synchronisation

Determining the relative positions of the Conrad and Rig Seismic was achieved using radar observations and two independent electronic distance measuring systems, the Miniranger III and the Raydist. The prime station for both EDM systems was on the Conrad, and no information could be obtained or recorded from the transponders on the Rig Seismic.

Direct observation of range and bearing were made out to around 5 kms as the two ships passed, using radar and gyro compass. These best define the common centre of the the ESP lines.

At medium range, the Miniranger was used to give accurate distances directly in metres. Two transponders were needed on the Rig Seismic, one looking forward and one looking aft to give all round coverage out to about 20 kms. However, no bearings could be obtained and these must be derived from best fit of the observations to ships' position. The Mini-Ranger was also used to maintain vessel separation during WACDP work. system similar to HIFIX giving only a relative distance. Lane count and

For ranges up to 100 kms the Raydist was used. This is a phase comparison phase must be calibrated against the Mini-Ranger to give distance. Again information on bearings is not available.

A VHF radio was installed in the instrument room for communication between the Rig Seismic and Conrad laboratories. Range was about 40 km. Clock synchronisation was checked by transmitting an alarm signal which was sounded on the minute by the Rig Seismic's gun firing system, via the VHF radio to the Conrad.

6.1.7 Bathymetry

Development of both the 3.5 kHz and 12 kHz echo sounder system is continuing. The 3.5 kHz system has been separated into two groups of transducers, one in a special coffer dam and the other in Centre Tank 6 to allow evaluation of the noise levels and bubble entrapment at different hull locations. Testing has yet to be undertaken.

Another step forward has been to develop slave recorders that are intended for both the bridge and winch labs, with automated time marks and labelling. These are driven by an M-series computer which provides independent asynchronous operation. Evaluation is continuing. Eventually, these will operate with the 12 kHz echo sounder to give more reliable depth information around the ship, when coring or in restricted waters.

The 12 kHz system has been converted to operate with the CESP-I signal correlator. This provides an improvement in signal-to-noise ratio of 20 dB which should allow effective operation at abyssal plain depths and on the steep slopes of the continental margin. Performance is similarly marred by aeration under the hull resulting in total loss of signal. An unfortunate by-product is the parallel loss of digital depth data until the digitiser can be reset to the correct depth level.

6.1.8 Magnetics

Deploying a magnetometer sensor from Rig Seismic continues to be a relatively difficult operation because of the need to deploy the sensor over the side of the vessel midships with the limited winch space available aft.

A gradiometer with two sensors 200 metres apart was used for most of the survey because of the considerable distance from shore. Synchronisation of the two standard magnetometers used has proved difficult to achieve because of a drift in the timing cycle triggering polarisation and measurement. Considering the depth of water and wavelength of the magnetic anomalies, the noise levels are quite acceptable though further improvement is necessary to detect the nuances at the surface caused by faulted basement under great thicknesses of sediment found over the Exmouth Plateau.

A magnetic shore station was set up at the airport in Onslow. Diurnal variation data are not available for much of the period following failure of the cassette tape recorder.

6.1.9 Gravity

Essentially no problems were experienced with the Bodenseewerke KSS-31 marine gravity meter. One instance of automatic caging of the sensor occurred when the 5 Volt power supply level dipped. Malfunction of the auto-pilot to gyrocompass interface resulted in use of the magnetic compass for all the cruise. During heavy rolling seas, the ship's heading varied by up to 10 degrees which in turn produced increased noise levels in the gravity data, at times reaching around 5 mgals. Post-processing should allow reduction of this to a more acceptable level.

6.2 Seismic Acquisition Systems

The differing operational techniques used in CDP, ESP and WAPCDP, have necessitated the software generation of three separate Seismic Acquisition Operating Systems. Basic differences exist in record length and shot firing control. The CDP system is similar to that used on previous B.M.R. cruises, while the other two operating systems have grown as hybrids of this.

6.2.1 Conventional CDP Data Acquisition

To enable the modification of a general system to cope with the variations required for ESP and WAPCDP profiles, changes were needed to the basic philosophy of the system timing. Previously, shot interval, acquisition delay and acquisition rate timings were intermingled providing an opportunity for illegal interrupts to corrupt the system and bring it to a halt.

The clock interrupt program in which the 0.1 sec clock interrupt is serviced, now handles the shot firing and the acquisition delay. The current shot rate is converted into a negative counter which is incremented until it reachs zero. Control on the interface card responsible for the pulse to the firing box is set and the guns fire. The shot interval is then reset and the process repeated.

After the shot is fired a secondary counter which handles the acquisition delay is set and incremented on each interrupt. When this counter has reached zero, the Time Base Generator interface card, which is used to control the acquisition rate, is set to give a 1/2, 1, 2 or 4 millisec pulse depending on the recording interval required. This pulse is used to start acquisition of the seismic data. A further counter is kept in synchronization with the T.B.G. and reset on each firing of the air-guns, allowing a check on the shot interval to better than 1 millisec accuracy.

The control of the shot firing is therefore separate from the aquisition process and can be modified without affecting that process.

On previous cruises, trouble has been encountered with the writing of data to magnetic tape, especially immediately after tape changes. The tape drive units have been checked by the manufacturer and found to be within specifications. To ensure that faults do not occur with the tape writing process, the dynamic status of the tape drives is checked before any attempt is made to write or move the tape. This allows for such error conditions as tape drive off-line and no write-ring to be detected and an appropiate error message to be posted. No data will attempt to be written to the tape until this condition has been rectified.

A colour display of the seismic streamer's depth has been fully incorporated and has been used successfully to aid in the control of the streamer's depth.

6.2.2 ESP Data Acquisition

The ESP operating system is similar to that used for the CDP profiles except that the shot rate is constant and cannot be altered. To assist in the synchronizing of firing upon R.V. Robert D. Conrad and acquisition of seismic data upon R.V. Rig Seismic, the shot was fired on the minute, using transit satellite time. System clocks upon the two ships were checked regularly; R.V. Rig Seismic's Seismic Acquisition System transmitted a tone over a VHF radio to Conrad at Rig Seismic's one minute mark.

Instead of the shot interval being converted into a counter and incremented as it is in the CDP operating system, the system clock is read on the 0.1 sec interrupt to determine when there is a new minute. If it is a new minute, acquisition will be scheduled but no guns fired as the firing lines are not connected.

A record length of 32,000 was chosen to make full use of the Hewllett Packard computer's 16 bit logic and enable observation of later seismic returns.

Due to the slow sampling rate and the lack of visible information, the displays upon the ship-board monitors have been spread out and a raster limit set to better emphasize the seismic return. Two of the monitors were preset so that one displays the record length 0 - 12 secs + delay and the other 12 - 24 secs + delay.

As it was not possible to see most of the raw data, it was decided to use the following rules to decide on the acquisition delay.

Distance from Centre of ESP Line (n.miles)			Delay (secs)
0	-	10	0
10	-	16	5
16	-	20	8
	> 20		10

6.2.3 WAPCDP Data Acquisition

The WAPCDP operating system is the most diverse from the standard CDP in its concept of alternate shot firing. Similar to the ESP operating system, the system clock is checked to determine whether acquisition should occur. If it is a new minute then control is set, a pulse sent to the firing box and acquisition occurs after the specified delay has elapsed. On the half minute, acquisition is restarted but no control is set to fire the guns, thus producing a non-shot acquisition cycle.

The acquisition which occured when there was no shot fired by Rig Seismic's Seismic Acquisition System, was that for the shot fired on-board Conrad, where firing occurred on the half minute.

Using the shot instant time which is recorded in the SEG-Y header to determine which shot has just been fired, the on-board seismic monitors were modified so that the Cycling, Slow and Fast monitors displayed the seismic returns from Rig Seismic's shots and the Special monitor became a Fast monitor displaying Conrad's shots. Data enhancement techniques used in the ESP operating system have been incorporated in this system. Special attention was required to ensure correct annotation on all outputs. During the WAPCDP profiles, acquisition delays were determined by the observed seismic returns from Rig Seismic's shots.

6.2.4 Airguns

Two 8 litre Bolt 1500c airguns were operated successfully throughout the cruise, with no difficulty encountered in maintaining both in operation during lines when Rig Seismic was shooting as well as receiving. All guns and gun bundles had been fully overhauled before operations started. Air pressure was maintained at 2050 psi during the WACDP line and at 1850 psi during lines 55/02 to 55/09. This variation was due to the number of compressors which needed to be kept on-line to maintain the different firing rates. One 1.6 litre Bolt gun, plus one 8 litre gun, was used during the ODP site survey (lines 55/03A to 55/03D).

CHAPTER 7: Conclusions

The preliminary results of phase two of the Exmouth Plateau research program indicate that the ESP, WACDP and multichannel seismic reflection data collected so far should better define the crustal structure and stratigraphy of the Exmouth Plateau region. This will enable particularly a reassessment of the possible distribution of potentially oil-prone Lower Triassic and Permian source rocks beneath the Plateau by calibrating seismic reflection data with ESP velocity results which identify gross stratigraphy and structure.

Thirteen ESP's were collected, nine on the Exmouth Plateau transect and four on the Cape Range transect. Six of the ESP's were collected with explosives and airguns, and seven with airguns alone. The WACDP tie to the Exmouth transect collected 700 km. of two-ship multichannel seismic reflection data. Conventional 48 channel seismic reflection data (1150 km.) and gravity and magnetics data were also collected over the western and northwestern Plateau. The remainder of the proposed 19 ESP's, an additional 1100 km. of multichannel seismic reflection data and geological dredge samples will be collected in phase three of the project.

The principal conclusion from the ESP and WACDP Transect of the Exmouth Plateau is that the northern Carnarvon Basin and the continental margin basins beneath the NW Shelf and the Exmouth Plateau form a single, continuous Permian to Recent sedimentary basin, up to 800 kms. wide and 7 kms. thick, as illustrated in Fig. 33. This extensive basin was formed prior to the rifting which preceeded breakup and seafloor spreading, firstly along the boundary of the Argo Abyssal Plain and the along the boundaries of the Gascoyne and Cuvier Abyssal Plains. Rift faulting and formation of horsts and grabens occurred at the end of the Triassic. Post breakup thermal subsidence commenced on the western, central and southern Plateau about 120 m.y. ago.

One of the sites of deepest Triassic rifting and post Triassic subsidence was along the axis of the present Kangaroo Syncline. This also appears to be an axis of arching at mid crustal levels. Basement beneath the central and western Exmouth Plateau and beneath the Dampier Sub-basin on the shelf may be an old sub-basin consisting of up to 4 kms. of Lower Paleozoic sediments/metasediments. This layer is absent beneath the Kangaroo Syncline. The post Triassic rift axis and basin depocentre may therfore correspond to an axis of previous uplift and crustal thinning by erosion.

The process of pre-breakup rifting and associated uplift has clearly thinned the pre-rift Permo-Triassic sequences towards the edge of the Plateau by erosion. This thinning becomes even more pronounced over the 100 kms. of rise, which appears to be underlain by thinned, intruded and deeply metamorphosed continental crust. The patterns of deepest Plateau subsidence and their driving mechanisms could be examined by ODP drilling at site EP-2.

The preliminary results of the multichannel seismic reflection study indicate the presence of suitable fault bounded trapping structures for hydrocarbon accumulations. No substantial graben-fill marine Jurassic source rocks at mature depth were indicated on the western and northwestern Plateau. However, the shallowing of probable Lower Triassic and Permian strata towards the western Plateau margin suggest that these strata may pass from being thermally overmature under the central Plateau dome to being mature for oil generation to the west if suitable source rocks are present. Source rock properties of these strata are to be investigated by geological dredging in phase three of this research program.

Integration of the results from all phases of the program will take place over the next 2 years.

References

ALLEN, G.A., PEARCE, L.G.G., & GARDNER, W.E. 1978 - A regional interpretation of the Browse Basin. *The APEA Journal*, 18(1), 23-33.

AVEDIK, F., & HOWARD, D., 1979 - Preliminary results of a seismic refraction study in the Meriadzek-Trevelyan area, Bay of Biscay. *In* MONTADERT, L., ROBERTS, D.G., & others, *Initial Reports of the Deep Sea Drilling Project*, 48, 1015-23.

BARBER, P.M., 1982 - Paleotectonic evolution and hydrocarbon genesis of the central Exmouth Plateau. *APEA Journal*, 22(1), 131-144.

BMR, 1976 - Gravitry map of Australia, 1:5,000,000. *Bureau of Mineral Resources, Australia, Canberra.*

BOTT, M.P.H., 1971 - Evolution of young continental margins and formation of shelf basins. *Tectonophysics*, 11, 319-27.

BUHL, P., DIEBOLD, J.B., and STOFFA, P.L. 1982 - Array length magnification through the use of multiple sources and receiving arrays. *Geophysics*, 47(3), 311-315.

COLWELL, J.B. & von STACKELBURG, U., 1981 - Sedimentological studies of Cainozoic sediments from the Exmouth and Wallaby Plateaus, off northwest Australia, *BMR Journal of Australian Geology and Geophysics*, 6, 43-50.

CROSTELLA, A. 1976 - Browse Basin. *In* LESLIE, R.B., EVANS, H.J. & KNIGHT, C.L. (editors), Economic Geology of Australia and Papua New Guinea, 3 - Petroleum. *Australian Institute of Mining and Metallurgy Monograph*, 7, 194-199.

CROSTELLA, A., & CHANEY, M.A., 1978 - The petroleum geology of the outer Dampier Sub-basin. *The APEA Journal*, 18(1), 13-22.

DAVIDSON, A., MOORE, J.M., DAVIES, J.C., SHIFERAW, A., TEFERRA, M., DEGEFFU, A., WOLDE RUFAUL, A., GELATTA M., & HINTSA N., 1976 - Preliminary report on the geology and geochemistry of parts of Gemu Gofa, Kefa and Illubador Provinces Ethiopia. *Ethiopian Ministry of Mines and Power, Omo River Project, Report 2.*

DEIGHTON, I., FALVEY, D.A., & TAYLOR, D.J., 1976 - Depositional environments and geotectonic framework: southern Australia continental margin. *The APEA Journal* 16(1), 25-36.

DETRICK, R., PHILLIPS, J., BUHL, P., MUTTER, J.C., STOFFA, P., DIEBOLD, J., & HINZ, K., 1982 - North Atlantic Transect: Expanding Spread Profiles. EOS, 63, 1031 (abstract).

DUTOIT, A.L., 1937 - Our wandering Continents: an hypothesis of continental drifting. Oliver & Boyd, London.

DIEBOLD, J.B. & STOFFA, P.L., 1981 - The traveltime equation, tau-p mapping and inversion of common mid-point data. Geophysics, 46(3), 238-254.

DEWEY, J.F. & BIRD, J.M., 1970 - Mountain belts and the new global tectonics. Journal of Geophysical Research, 75, 2625-47.

EXON, N.F., WILLCOX, J.B., & PETKOVIC, P., 1975 - A preliminary report of the regional geology of the Exmouth Plateau. Bureau of Mineral Resources, Australia. Record 1975/158 (unpublished).

EXON, N.F. & Others, 1982 - The geological development of the margins of the Exmouth Plateau off northwest Australia. Marine Geology, 47, 131-152.

EXON, N.F., & WILLCOX, J.B., 1978 - Geology and petroleum potential of the Exmouth Plateau area off Western Australia. AAPG Bulletin, 62(1), 40-72.

EXON, N.F., & WILLCOX, J.B., 1980 - The Exmouth Plateau: Stratigraphy, Structure and Petroleum Potential. Bureau of Mineral Resources, Australia Bulletin, 199, 52p.

FALVEY, D.A., 1972a - Sea-floor spreading in the Wharton basin (northeast Indian Ocean) and the breakup of eastern Gondwanaland. The APEA Journal, 12(2), 86-8.

FALVEY, D.A., 1972b - The nature and origin of marginal plateaux andadjacent ocean basins off northern Australia. Ph.D. Thesis University of New South Wales (unpublished).

FALVEY, D.A., 1974 - The development of continental margins in plate tectonic theory. The APEA Journal, 14(1), 95-106.

FALVEY, D.A., & VEEVERS, J.J., 1974 - Physiography of the Exmouth and Scott Plateaux, Western Australia, and adjacent northeast Wharton Basin. Marine Geology, 17, 21-59.

FALVEY, D.A., & MIDDLETON, M.F., 1981 - Passive continental margins: evidence for a prebreakup deep crustal metamorphic subsidence mechanism. Oceanologica Acta, 4(2), in press.

FALVEY, D.A., & MUTTER, J.C., 1981 - Regional plate tectonics and the evolution of Australia's continental margins. BMR Journal of Australian Geology and Geophysics, 6, 1-29.

HALSE, J.W., 1976 - Beagle Sub-Basin. In LESLIE, R.B., EVANS, H.J.,& KNIGHT, C.L. (editors), Economic Geology of Australia and Papua New Guinea, 3 - Petroleum. Australian Institute of Mining and Metallurgy Monograph.

HEEZEN, B.C., 1960 - The rift in the ocean floor. Scientific American, 203, 98-110.

HEIRTZLER, J.R., CAMERON, P., COOK, P.J., POWELL, T., ROSESE, H.A., SHKARDI, S., & VEEVERS, J.J., 1978 - The Argo abyssal plain. Earth and Planetry Science Letters, 41, 21-31.

HOGAN, A.P., & JACOBSEN, E.P., 1975 - Geophysical results from the northwest continental margin of Australia. Bureau of Mineral Resources, Australia, Record, 1975/101 (unpublished).

JARVIS, G.T., & McKENZIE, D.P., 1980 - Sedimentary basin formation with finite extension rates. Earth and Planetry Science Letters, 48, 42-52.

JOHNSTONE, M.H., LOWRY, D.C. & QUILTY, P.G., 1973 - The geology of southwest Australia - a review. Journal of the Royal Society of Western Australia, 40, 25-32.

McKENZIE, D.P., 1978 - Some remarks on the development of sedimentary basins. Earth and Planetry Science Letters, 40, 25-32.

LARSON, R.L., 1975 - Late Jurassic sea-floor spreading in the eastern Indian Ocean. Geology, 3, 69-71.

LARSON, R.L., 1977 - Early Cretaceous breakup of Gondwanaland off Western Australia. Geology, 5, 57-60.

LARSON, R.L., MUTTER, J.C., DIEBOLD, J.B., CARPENTER G.B., & SYMONDS P., 1979 - Cuvier Basin: A product of ocean crust formation by Early Cretaceous rifting off western Australia. Earth and Planetry Science Letters, 45, 105-114.

McCALL, G.J.H., 1967 - Geology of the Nakuru - Thompson's Falls - Lake Hannington area. Geological survey of Kenya, Report, 78.

MAGUIRE, P.K.H., & LONG, R.E., 1976 - Structure on the western flank of the Gregory Rift (Kenya), Part I. The Crust. Geophysical Journal of the Royal Astronomical Society, 44, 661-675.

MARKL, R.G., 1974 - Evidence for the breakup of eastern Gondwanaland by the early Cretaceous. Nature, 251, 196-200.

MARKL, R.G., 1978 - Basement morphology and rift geometry near the former junction of India, Australia and Antarctica. Earth and Planetry Science Letters, 39, 211-225.

MIDDLETON, M., 1978 - Genesis of the Cooper and Eromange Basins. Ph.D. Thesis, University of Sydney, (unpublished).

MIDDLETON, M., 1980 - A model of intracratonic basin formation, entailing deep crustal metamorphism. Geophysical Journal of the Royal Astronomical Society, 61, 1-14.

MONTADERT, L., ROBERTS, D.G., DECHARPAL, O., & GUENNOC, P., 1979 - Rifting and subsidence of the northern continental margin of the Bay of Biscay. In - MONTADERT, L., ROBERTS. D.G., & others, Initial reports of the Deep Sea Drilling Project, 48, 1025-1060.

MUTTER, J.C., 1978 - An analysis of the Mesozoic - early Cenozoic rifting history of Australia and Antarctica. M.Sc. Thesis, University of Sydney, (unpublished).

MUTTER, J.C., TALWANI, M., and STOFFA, P., 1983 - Structure of the oceanic crust adjacent to the Norwegian Margin. Journal of Geophysical Research, in press.

POWELL, D.E., 1976 - The geological evolution of the continental margin off northwest Australia. The APEA Journal, 16(1), 13-23.

SHAW, R.D., 1978 - Seafloor spreading in the Tasman Sea: A Lord Howe Rise - eastern Australia reconstruction. Bulletin of the Australian Society of Exploration Geophysicists, 9(3) , 75-81.

SLEEP, N.H., 1971 - The thermal effects of formation of Atlantic Continental margins by continental breakup. Geophysical Journal of the Royal Astronomical Society, 24, 325-350.

STAGG, H.M.J., 1978 - The geology and evolution of the Scott Plateau. The APEA Journal, 18(1), 34-43.

SYMONDS, P.A., & CAMERON, P., 1977 - The sturcture and stratigraphy of the Carnarvon Terrace and Wallaby Plateau. The APEA Journal, 17(1), 13-20.

TAYLOR, L.W.H., & FALVEY, D.A., 1977 - Queensland Plateau and Coral Sea Basin: stratigtaphy, structure and tectonics. The APEA Journal, 17(1), 13-29.

THOMAS, B.M., & SMITH, D.A., 1976 - Carnarvon Basin. In - LESLIE, R.B., EVANS, H.J., & KNIGHT, C.L., (editors), Economic Geology of Australia and Papua New Guinea, 3 - Petroleum. Australasian Institute of Mining and Metallurgy Monograph 7, 126-155.

TALWANI, M., MUTTER, J.C., HOUTZ, R., & KONIG M., 1979 - The

crustal structure and evolution of the area underlying the magnetic quiet zone on the margin south of Australia. In WATKINS, J.S., MONTADVERT, L., & DICKERSON,-P.W., (editors), Geological and Geophysical investigations of continental margins.
American Association of Petroleum Geologists Memoir, 29, 151-175.

VEEVERS, J.J., HEIRTZLER, J.R., 1974 - Tectonic and paleogeographic systhesis of leg 27. In VEEVERS, J.J., HEITZLER, J.R,. & others, Initial reports of the Deep Sea Drilling Project, 27, 1049-1054.

VEEVERS, J.J., HEITZLER, J.P., & others, 1974 - Initial Reports of the deep sea drilling project, 27.

VEEVERS, J.J., & COTTERILL, D., 1976 - Western margin of Australia: a Mesozoic analogue of the East Africa rift system. Geology, 4, 713-717.

APPENDIX A: Geophysical Data Set

LINE	TIME START (GMT)	TIME FINISH (GMT)		WAY-POINT LATITUDE DEG S	WAY-POINT LONGITUDE DEG E	TAPES	LINE LENGTH	DATA COLLECTED	
1	System/cable tests					55/001-012			
2	73.1957	74.2132	SOL	20 49.80	112 51.10	55/013-075	239	S G N B	
			EOL	20 35.07	112 11.57				
3	74.2144	75.0913				55/076-102	107	S01 G M N B	
3A			SOL	19 53.60	110 21.00				
			EOL	19 54.00	110 27.00				
3B			SOL	19 55.00	110 28.00				
			EOL	19 58.00	110 28.00				
3C			SOL	19 58.00	110 25.50				
			EOL	19 52.00	110 25.50				
3D			SOL	19 52.00	110 23.00				
			EOL	19 58.00	110 23.00				
3E			SOL	19 56.00	110 21.00				
			EOL	19 56.00	110 30.00				
4	75.0913	76.0515	SOL	19 56.00	110 30.00	55/103-149	187	S G M N B	
			EOL	19 54.50	110 14.60				
5	76.0515	76.1720	SOL	19 54.50	111 14.60	55/150-177	113	S G M N B	
			EOL	19 02.00	111 52.00				
6	76.1720	76.1141	SOL	19 02.00	111 52.00	55/178-219	171	S G M N B	
			EOL	18 25.00	113 19.00				
7	77.1141	78.0121	SOL	18 25.00	113 19.00	55/220-251	128	S G M N B	
			EOL	17 51.00	112 21.00				
8	78.0122	78.1720	SOL	17 51.00	112 21.00	55/252-289	149	S G M N B	
			EOL	17 15.00	113 37.00				
9	78.1935	79.0700	SOL	17 15.00	113 37.00	55/290-321	128	S G M N B	
			EOL	18 20.00	114 00.00				
R1	79.0239	79.0529				55/311-318	27		BROOME
12	84.1926	85.0708	SOL	19 05.00	113 32.20	55/322-338	109	EX5 G M N B	
			MP	19 30.75	113 20.20				
14	85.1846	86.0623	SOL	19 49.00	113 47.20	55/339-356	107	EX4 G M N B	
			MP	19 23.25	114 00.40				
16	86.1155	86.2248	SOL	19 09.80	114 31.80	55/357-373	102	EX3 G M N B	
			MP	19 36.65	114 34.80				
18	ABORTED					55/374-379			
18	88.0540	88.1632	SOL	20 03.20	115 12.00	55/380-395	101	E2 G M N B	
			MP	19 47.60	115 33.65				
20	89.0050	89.1202	SOL	19 40.00	116 31.00	55/396-412	105	E1 G M N B	
			MP	19 55.00	116 07.50				
21	90.0306	92.0234	SOL	19 19.50	113 56.00	55/413-495	239	W1 G M N B	
22	92.0247	93.0132		19 43.00	112 41.00	55/497-535	203		
			EOL	18 10.00	110 52.50				
24	93.1038	93.1528	SOL	18 39.10	110 51.00	55/536-543	45	E9 G M N B	
			MP	18 21.35	111 05.00				
26	93.1755	93.2358	SOL	18 28.00	111 13.00	55/544-552	56	E9A G M N B	

			MP	18 10.00	111 27.00			
28	94.0541	94.1509	SOL	18 30.30	111 51.80	55/553-566	88	E8 G M N B
			MP	18 47.90	111 35.80			
30	94.2309	94.1014	SOL	19 31.10	111 44.00	55/567-583	103	EX7 G M N B
			MP	19 11.70	112 03.50			
32	95.1634	96.0338	SOL	19 10.00	112 39.40	55/584-600	103	EX6 G M N B
			MP	19 32.20	112 31.60			
34	96.1735	97.0536	SOL	20 27.50	112 26.00	55/601-618	112	CX3 G M N B
			MP	20 47.50	111 47.00			
36	97.1035	97.2150	SOL	21 05.00	112 14.00	55/619-635	105	C2A G M N B
			MP	20 40.50	112 02.50			
38	98.0227	98.1350	SOL	21 01.00	112 21.00	55/636-652	106	C2 G M N B
			MP	20 33.50	112 17.00			
40			SOL	20 45.40	112 50.60	55/653-		C1 G M N B
			MP	20 20.20	112 40.05			

S 48 channel seismic reflection
SOn ODP deep ocean drilling program seismic reflection site survey
Rn sonobuoy
En ESP expanded spread profile using airguns
EXn ESP expanded spread profile using airguns to the midpoint and explosives for the remainder of the line.
Cn CR Cape Range ESP
CXn CR Cape Range as for EXn
Wn WACDP wide aperture constant depth profile
*n n is the line number
SOL start of line
MP midpoint of line
EOL end of line
G gravity data
M magnetic data
N navigation data
B bathymetry

APPENDIX B: Equipment List

B.1 Geophysical

B.1.1 Primary Seismic Systems

2400 m Teledyne hydrophone streamer cable; minimum group length of 12.5 m; maximum 96 channels.

Syntron RCL-2 idividually addressable cable levelers.

3 BOLT 1500C airguns, each of 500 cu in (8.2 l) capacity, with wave-shape kits; one or two guns, fired simultaneously, would normally be used.

Teledyne gun signature phones and gundepth sensors, and Input/Ouput SS-8 shot-instant transducers (1 each per gun).

3 Price A-300 compressors, 300 scfm each; output pressure 2000 psi.

1 Price AGM W2 compressor, 200 scfm; output pressure 2000 psi.

B.1.2 Secondary Seismic Systems

2 Teledyne 28420 single-channel hydrophone streamers.

1 BOLT 1500C airgun of 100 cu in (1.6 l) capacity, with wave-shape kit.

Reftek 6 sonobuoy receiver.

Teledyne 28990 acoustic beacon cable location system.

B.1.3 Bathymetric Systems

Raytheon deep-sea echo sounder; 2 kW maximum output at 3.5 kHz.

Raytheon deep-sea echo sounder; 2 kW maximum output at 12 kHz.

B.1.4 Magnetic System

2 Geometrics G801/803 proton precession magnetometers; may be used as standard single-sensor cable or in horizontal gradiometer configuration.

B.1.5 Gravity meter System

1 Bodenseewerk Geosystem KSS-31 Marine Gravity Meter.

B.2 Navigation

B.2.1 *Prime Systems*

(1). Magnavox G.P.S. T-Set

(2). Decca Hi-Fix

(3). Magnavox MX1107RS dual channel satellite receiver.
Magnavox MX610D sonar doppler speed log.
Arma-Browm SGB1000 gyro-compass.

B.2.2 *Secondary System*

Magnavox MX1142 single channel satellite receiver.

Raytheon DSN450 sonar doppler speed log.

Robertson gyro-compass.

B.3 Computer Equipment

B.3.1 *Non-Seismic Acquisition System (DAS)*

Hewlett-Packard 2113 F-Series 16-bit minicomputer with 512 kw of memory.

2 x Hewlett-Packard 7905 15 Mb, moving-head disc and multi-access disc controller.

2 x Hewlett-Packard 7970E 1600 bpi, 9-track magnetic tape drives.

Facit cassette recorder.

Hewlett-Packard 12979 I/O extender.

Hewlett-Packard 2748A paper tape reader.

BMR-designed and built 16-channel digital multiplexer (up to 3).

BMR-designed and built 16-bit gyro/speed log interface.

Phoenix 6915 15-bit analogue-to-digital multiplexer.

GED, NCE, or CHRONOLOG digital clocks (x2).

KSR-43 teletypes, TELEVIDEO TVI-910 VDU's, and EPSON RX-80 line printers (various combinations).

KAGA RGB colour monitors (up to 7) driven through RCA microcomputers.

W & W 6-pen strip-chart recorders (x3).

CALCOMP 1044 8-pen high-speed 36-inch drum plotter.

B.3.2 *Seismic Acquisition System (MUSIC)*

Hewlett-Packard 2113 E-Series 16-bit minicomputer with 1 Mega word of memory (acquisition system).

Hewlett-Packard 2117 F-Series 16-bit minicomputer with 256 kw of memory (development system).

Hewlett-Packard 7905 15 Mb moving-head disc drive and multi-access disc/cpu controller.

3 x Hewlett-Packard 7970E 1600 bpi, 9-track magnetic tape drives.

Phoenix 6915 15-bit analogue-to-digital multiplexer.

BMR-designed 48-channel SMF-1 computer-controlled preamp/filters.

KSR-43 teletype and TELEVIDEO TVI 910 VDU.

EPSON MX-100 dot-matrix line printers (x4).

EPSON MX-100 shot logger.

Tektronix 611 X-Y storage CRO.

BWD 804 single-channel CRO.

BWD 845 dual-channel storage CRO.

CHRONOLOG digital clock.

BMR-designed and built NTM-1 marine timing unit.

B.3.3 *Hi-Fix Acquisition System (Hi-Fix)*

Hewlett-Packard 2108 M-Series 16-bit minicomputer

BMR-designed and built 16-channel digital multiplexer

TELEVIDEO TVI-910 VDU

B.3.4 *Raydist/Miniranger Acquisition System*

Forward looking Miniranger III transponder

Backward looking Miniranger III transponder

Raydist transponder

VHF radio

B.3.5 *Sub-bottom Profiler Acquisition System*

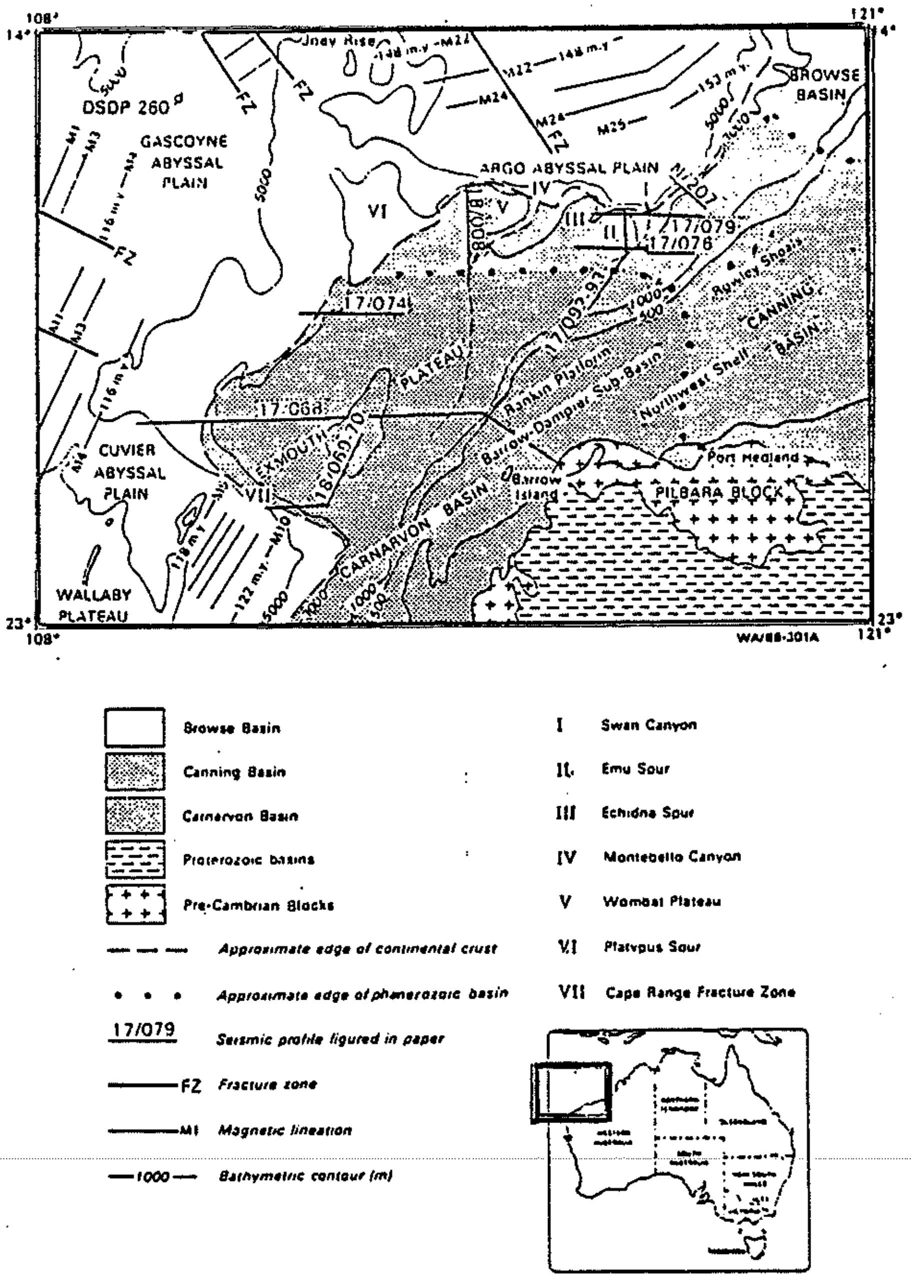
Hewlett-Packard 2108 M-Series 16-bit minicomputer.

Facit Cassette recorder.

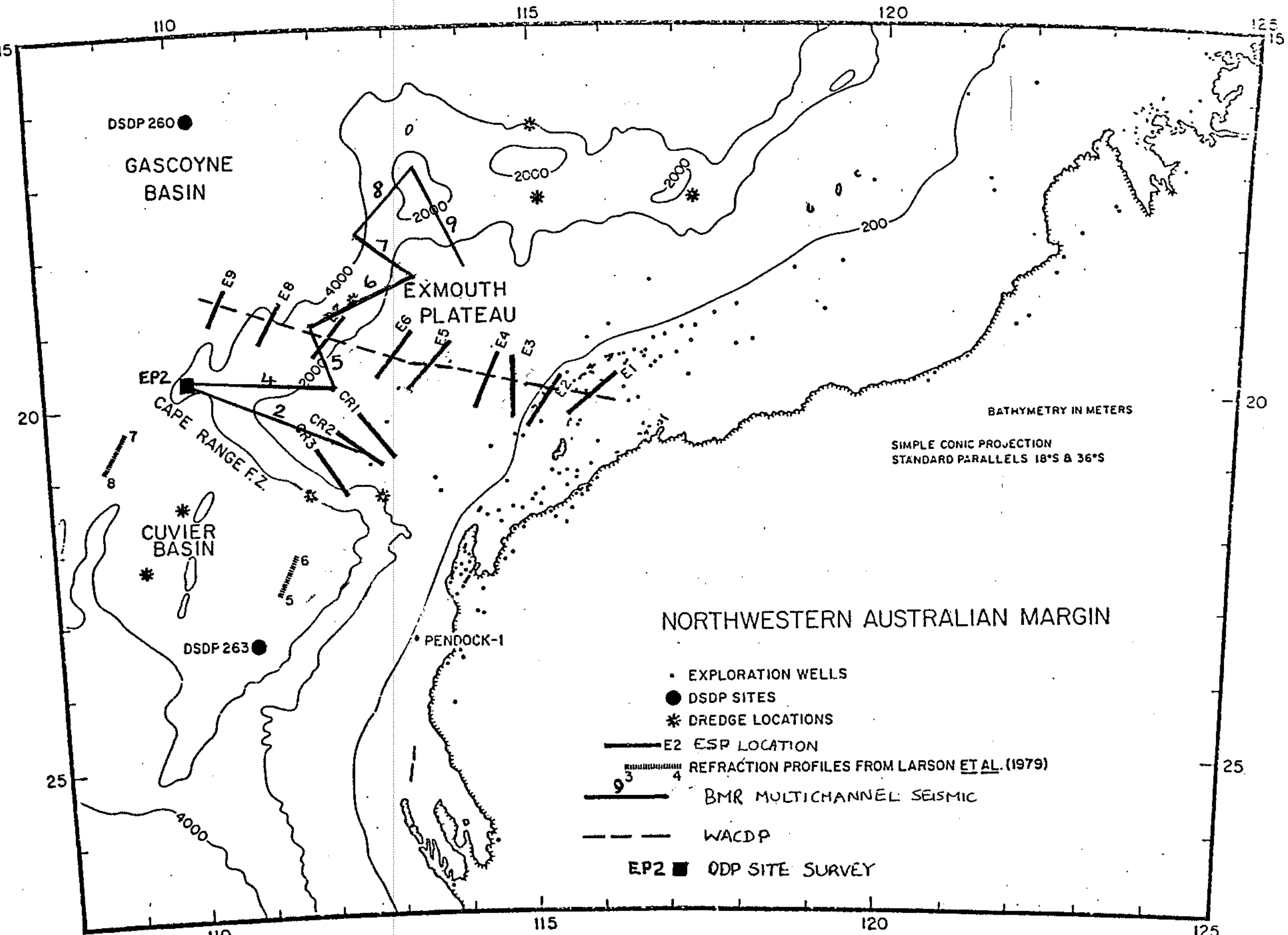
Phoenix 6915 15-bit analogue to digital multiplexer.

TELEVIDEO TVI-910 VDU

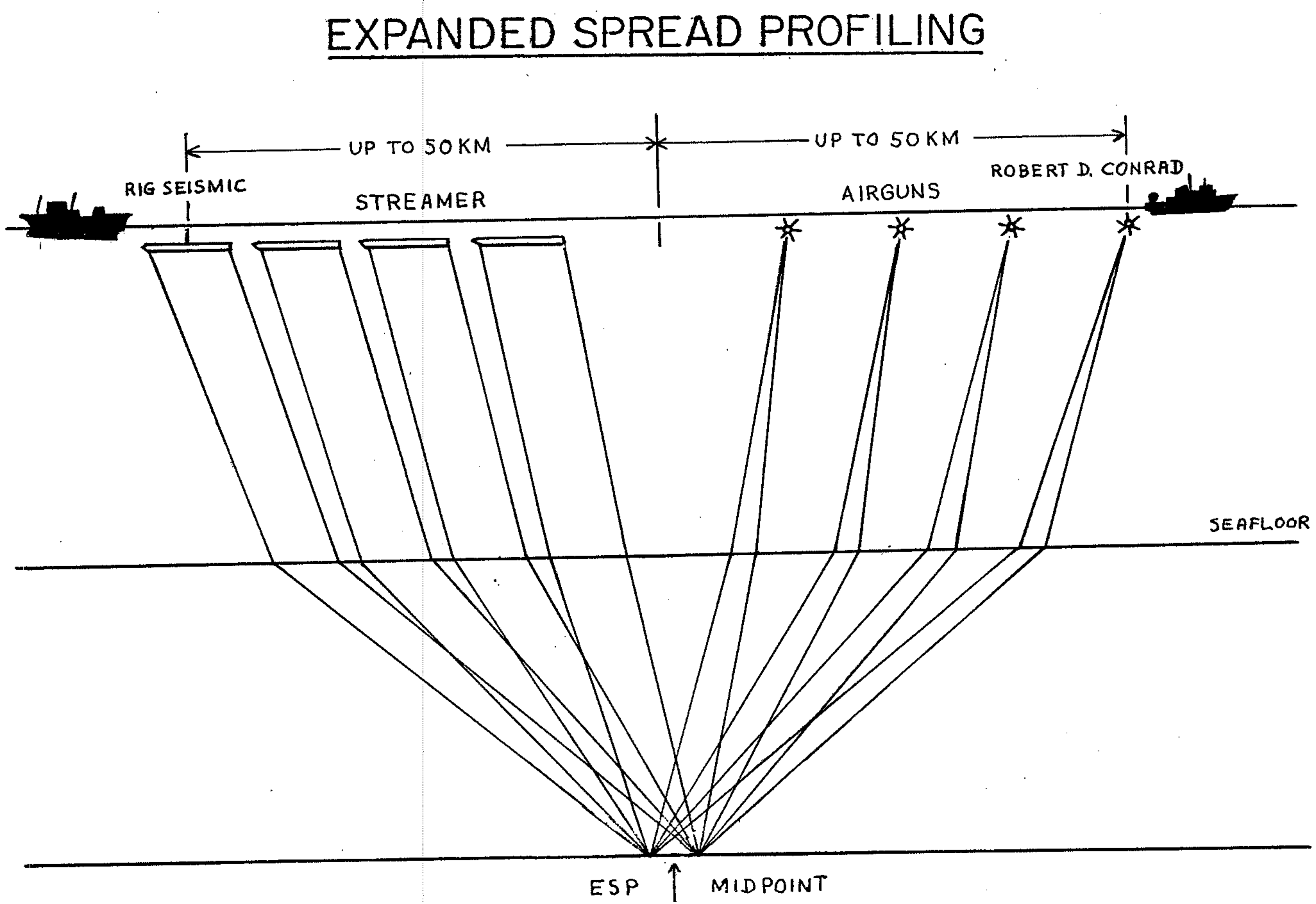
EPC Graphic Recorders (up to 4) rx80 expcrd::30



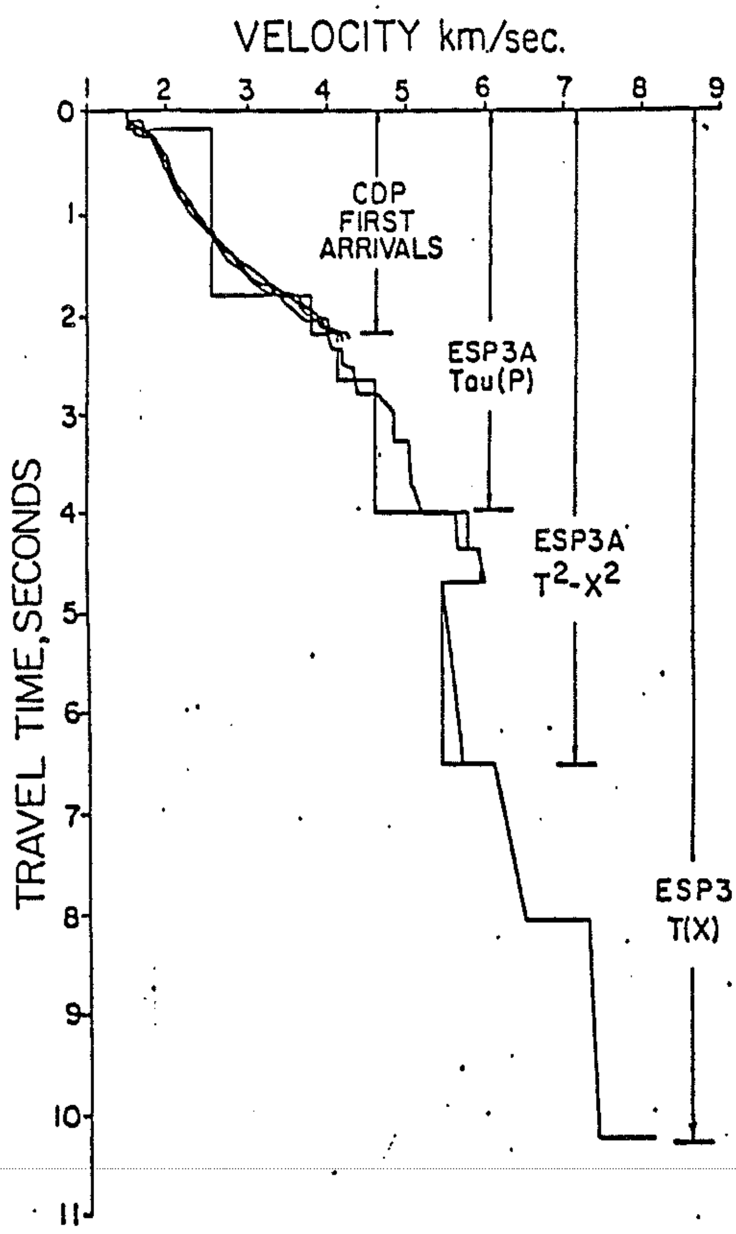
1. Regional and tectonic setting of the Exmouth Plateau.



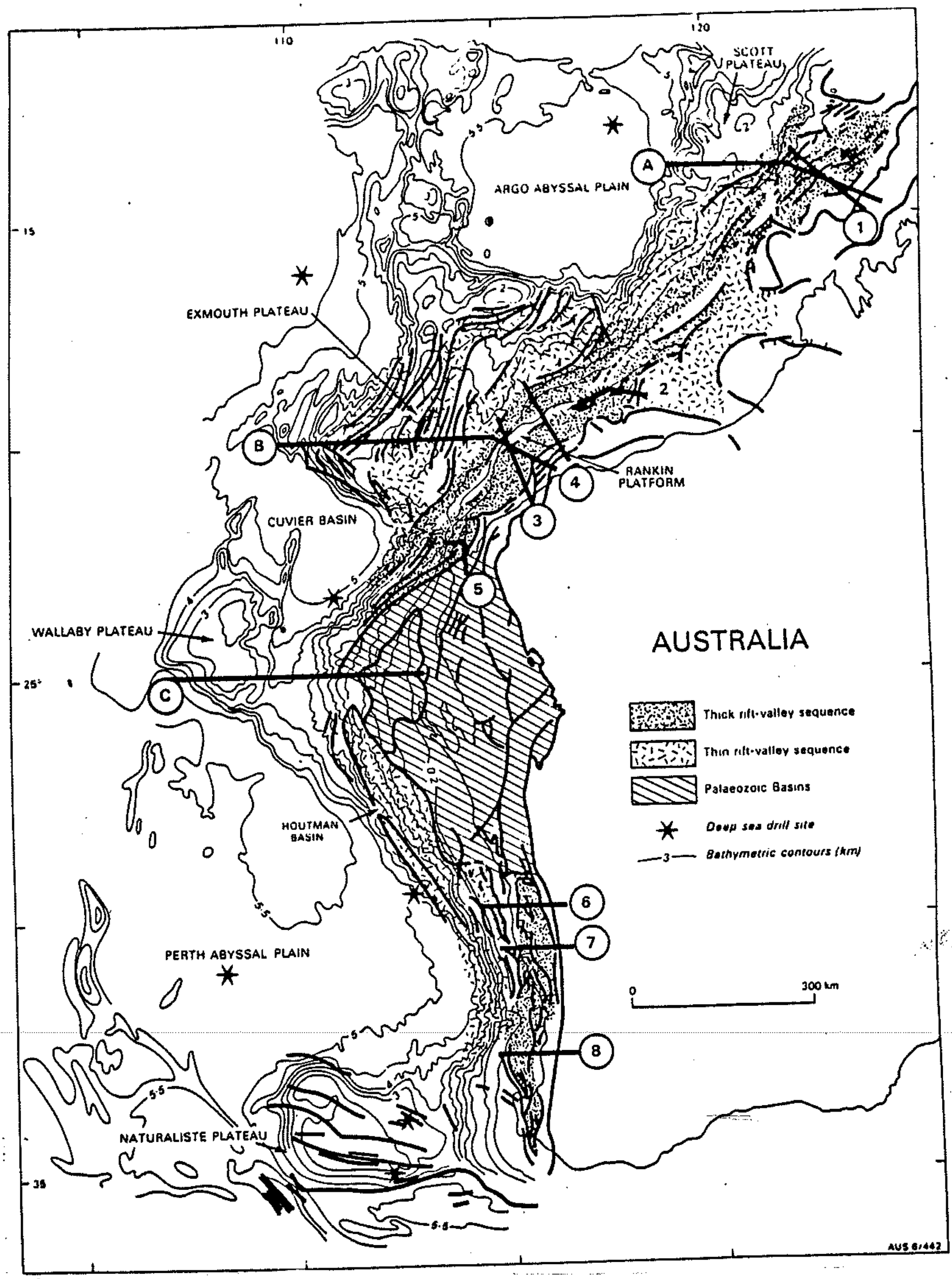
2. Location of conventional CDP, ESP and WACDP seismic lines shot during Exmouth-1.



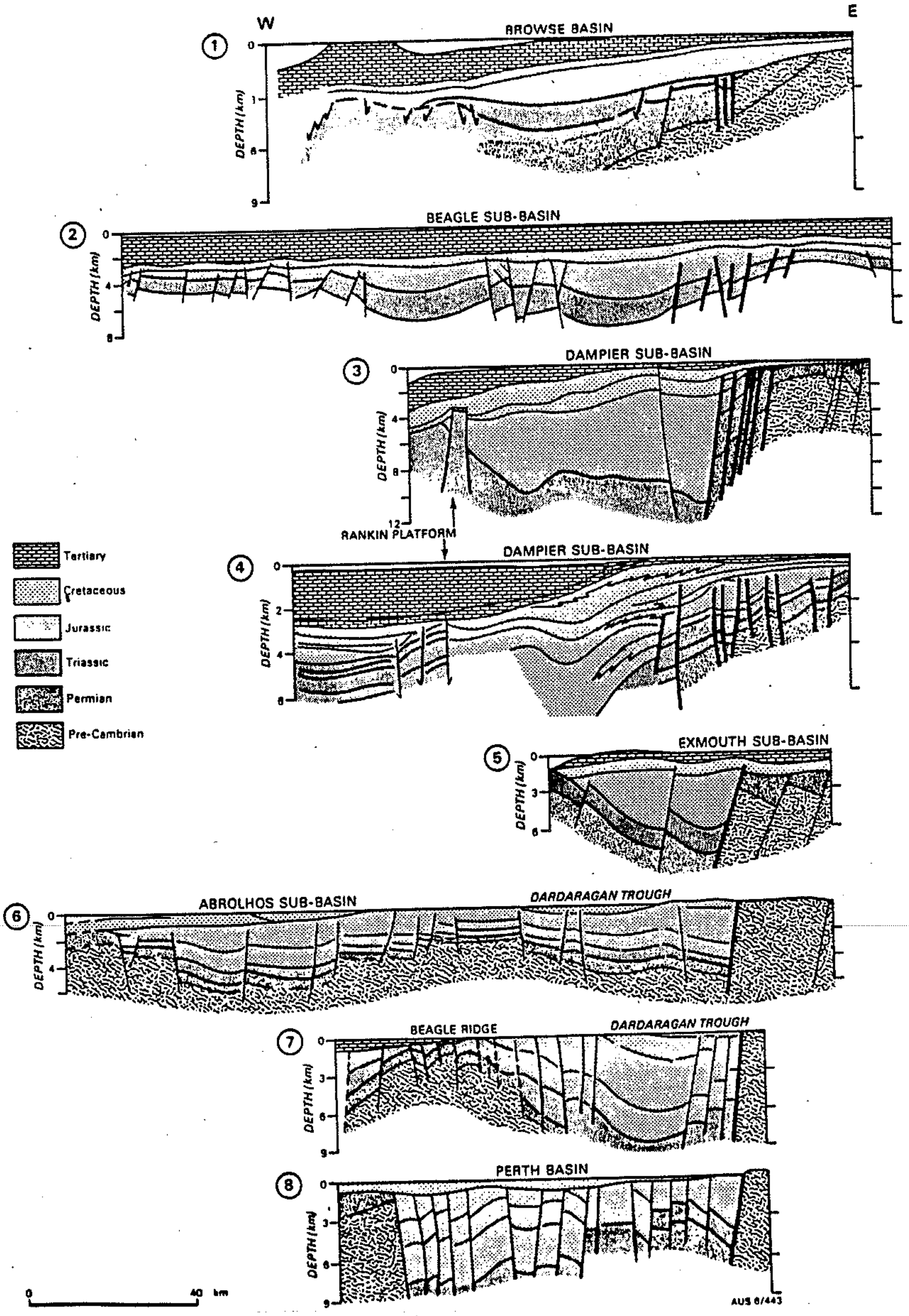
3. Schematic of an Expanded Spread Profile (ESP).



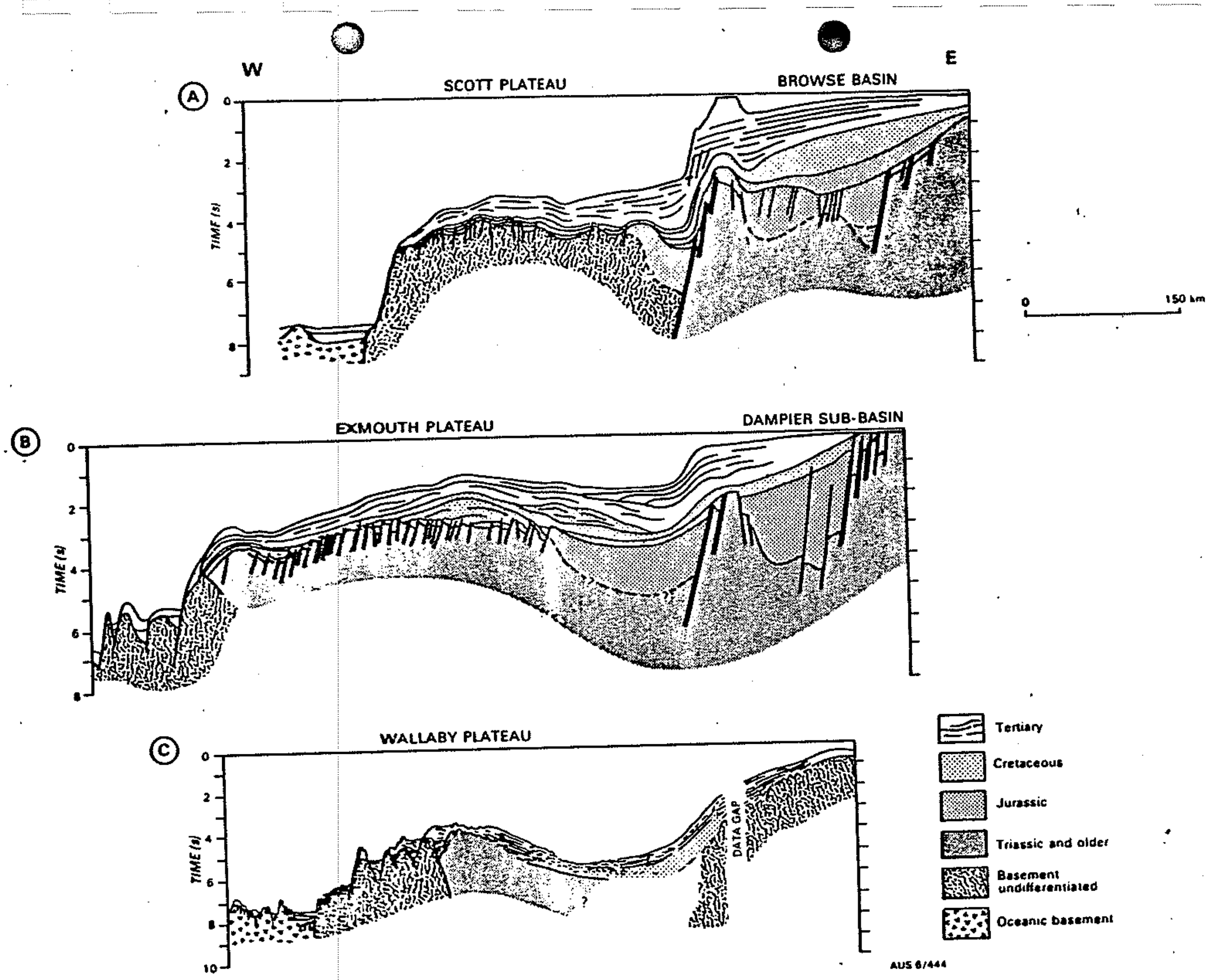
4. Example of an ESP velocity-time inversion.



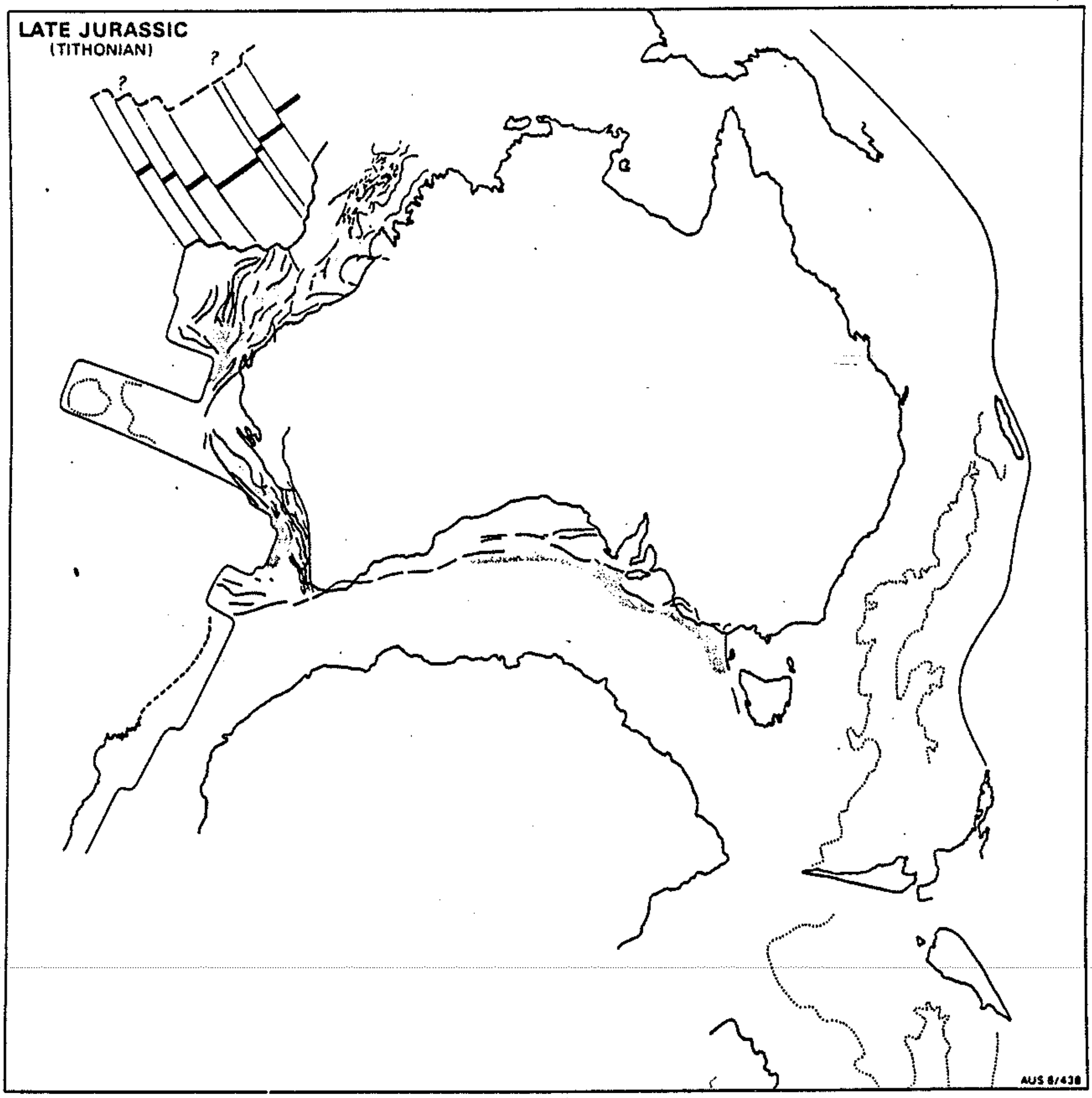
5. Major structural trends on the Western Australian continental margin.



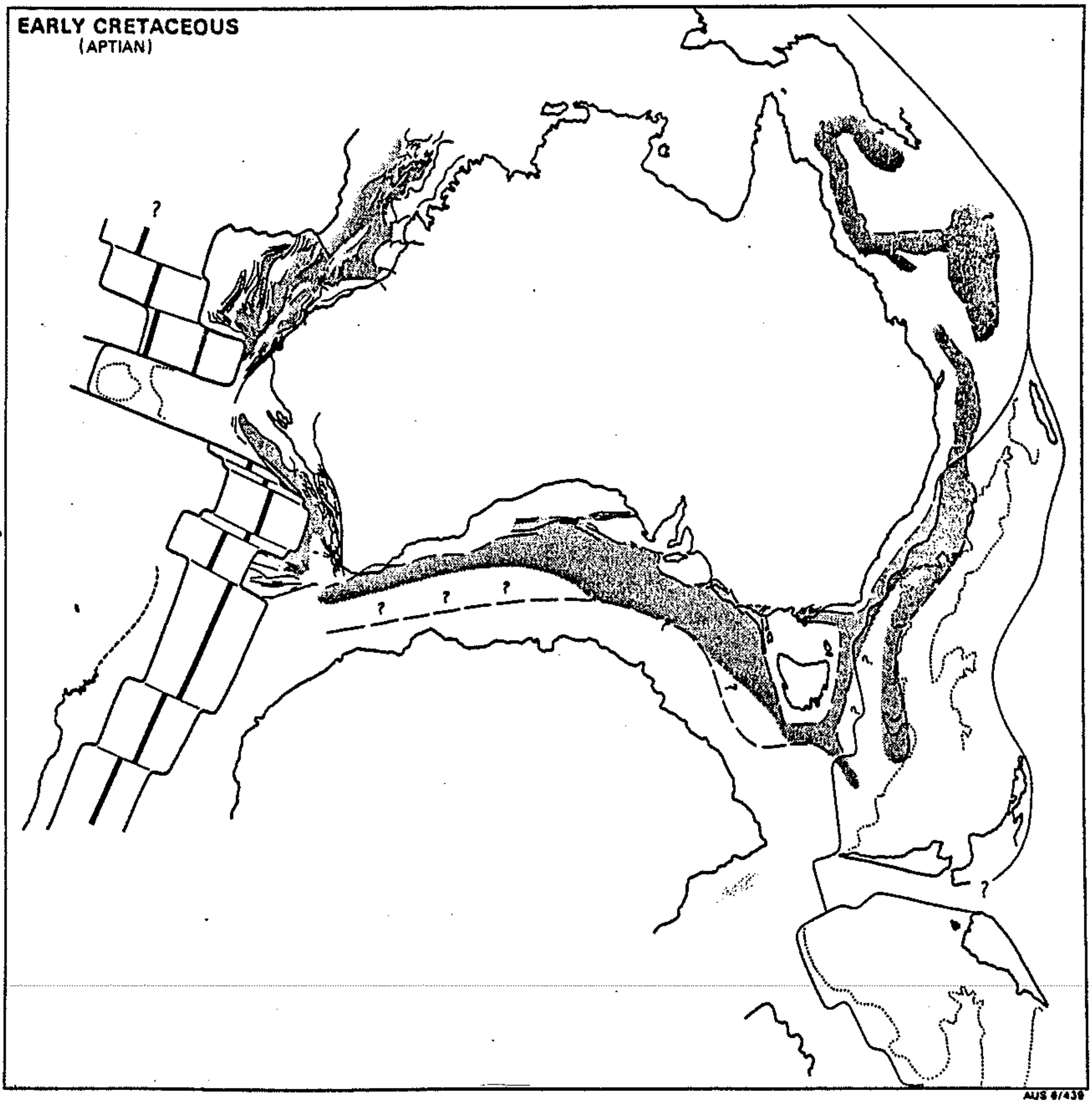
6. (a) Structural and stratigraphic cross sections 1-8, Fig. 5.



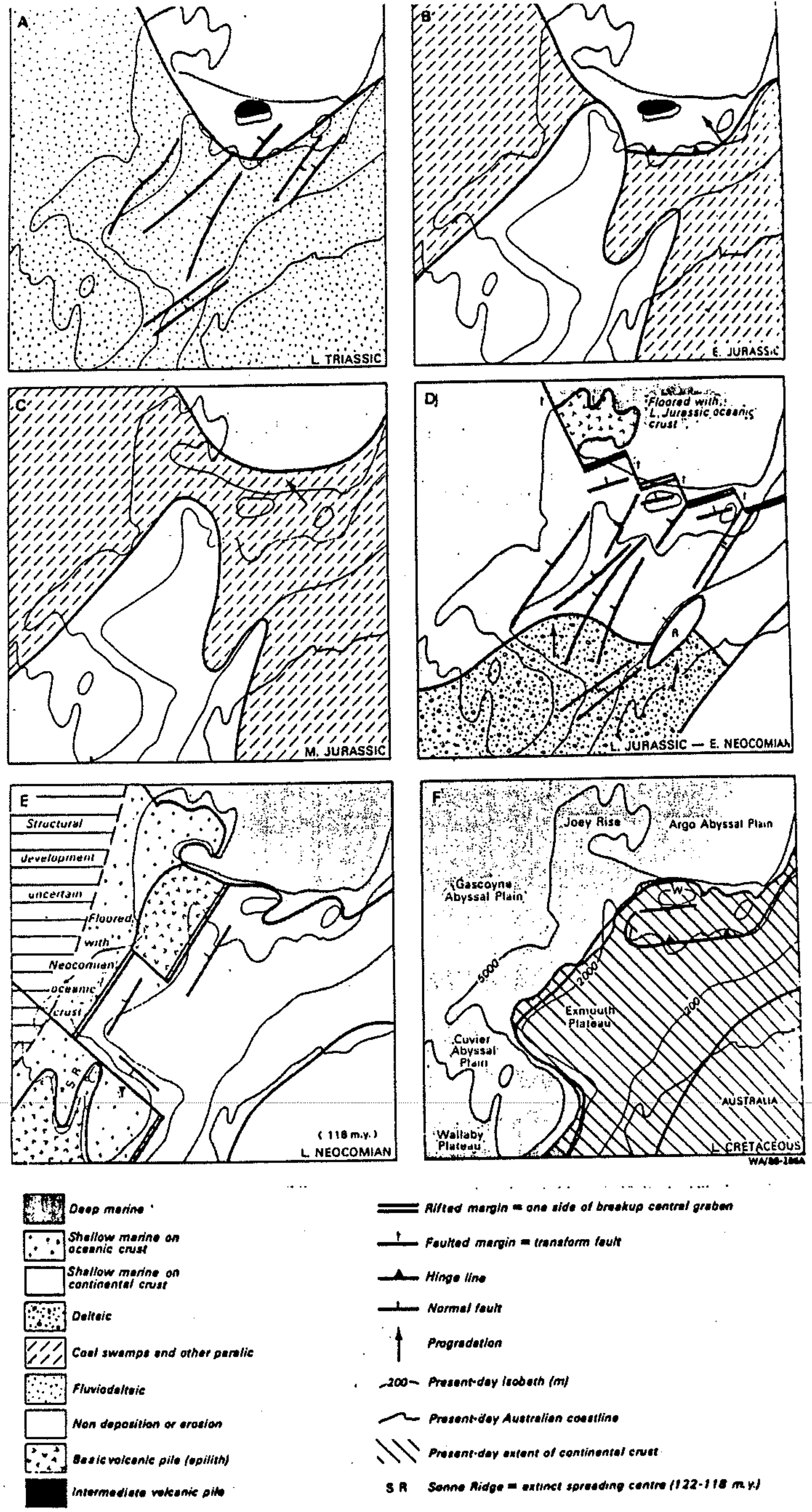
(b) Structural and stratigraphic cross sections A–C, Fig. 5.



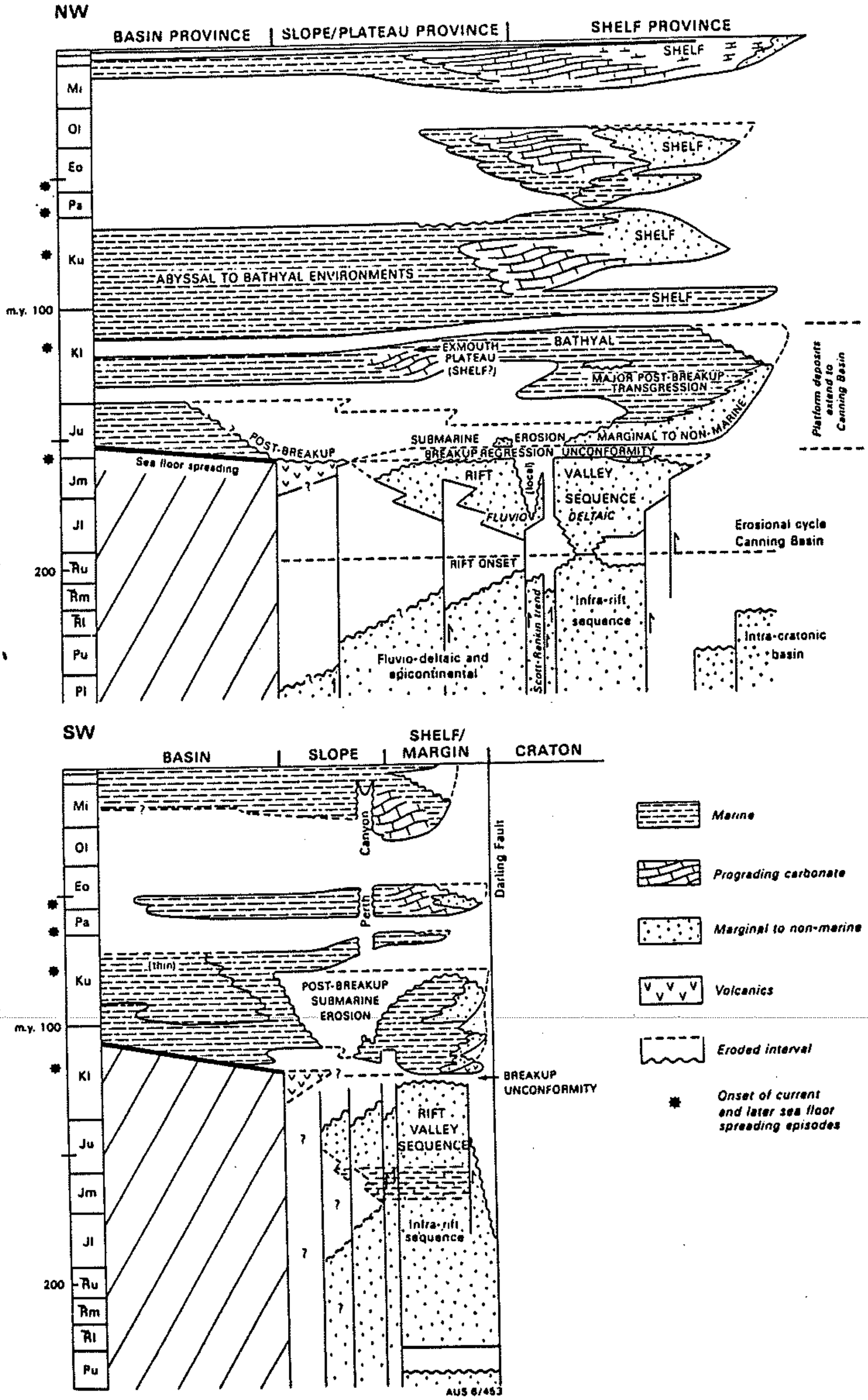
7. Late Jurassic reconstruction of Australia, India and Antarctica.



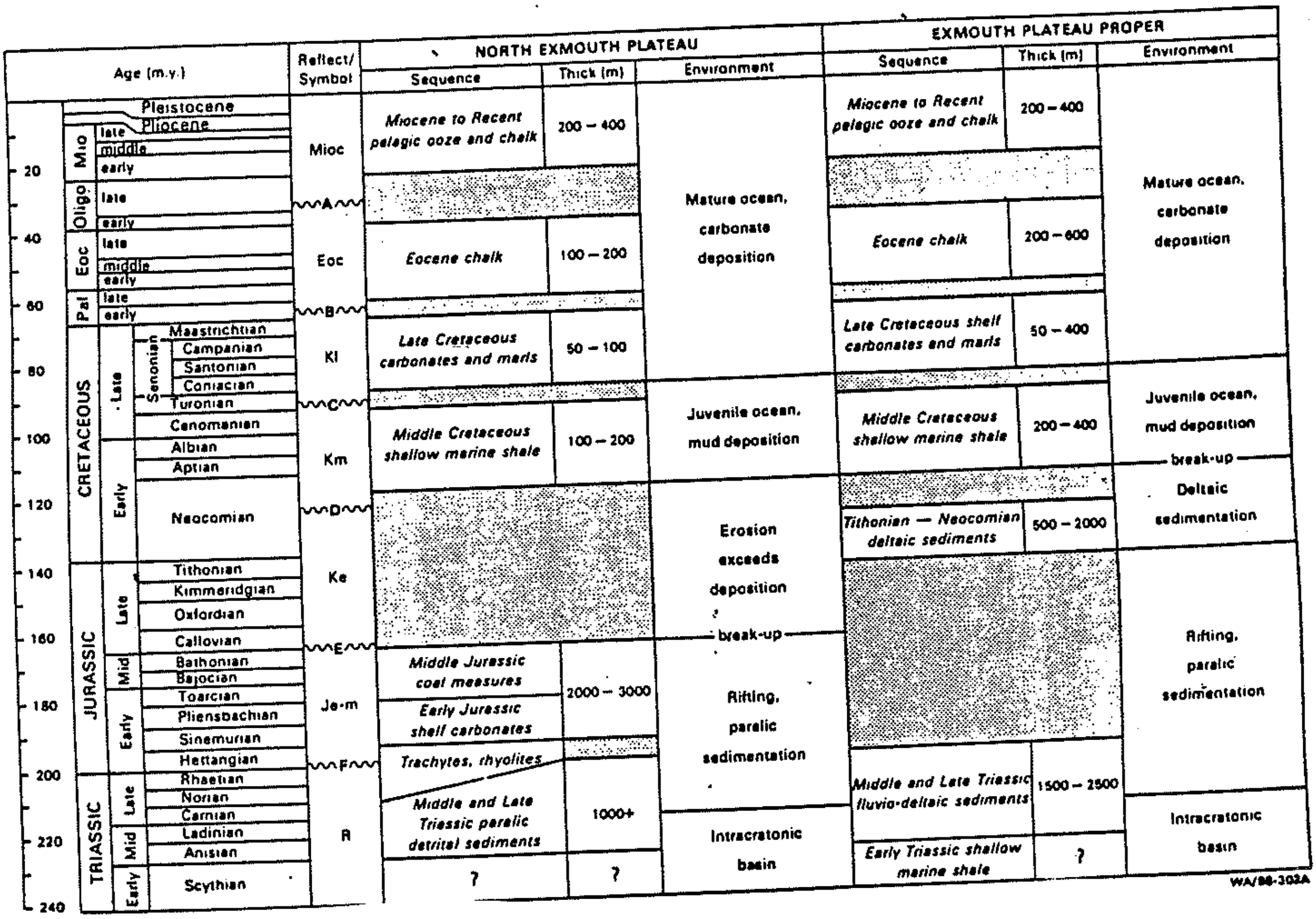
8. Early Cretaceous reconstruction and seafloor spreading.



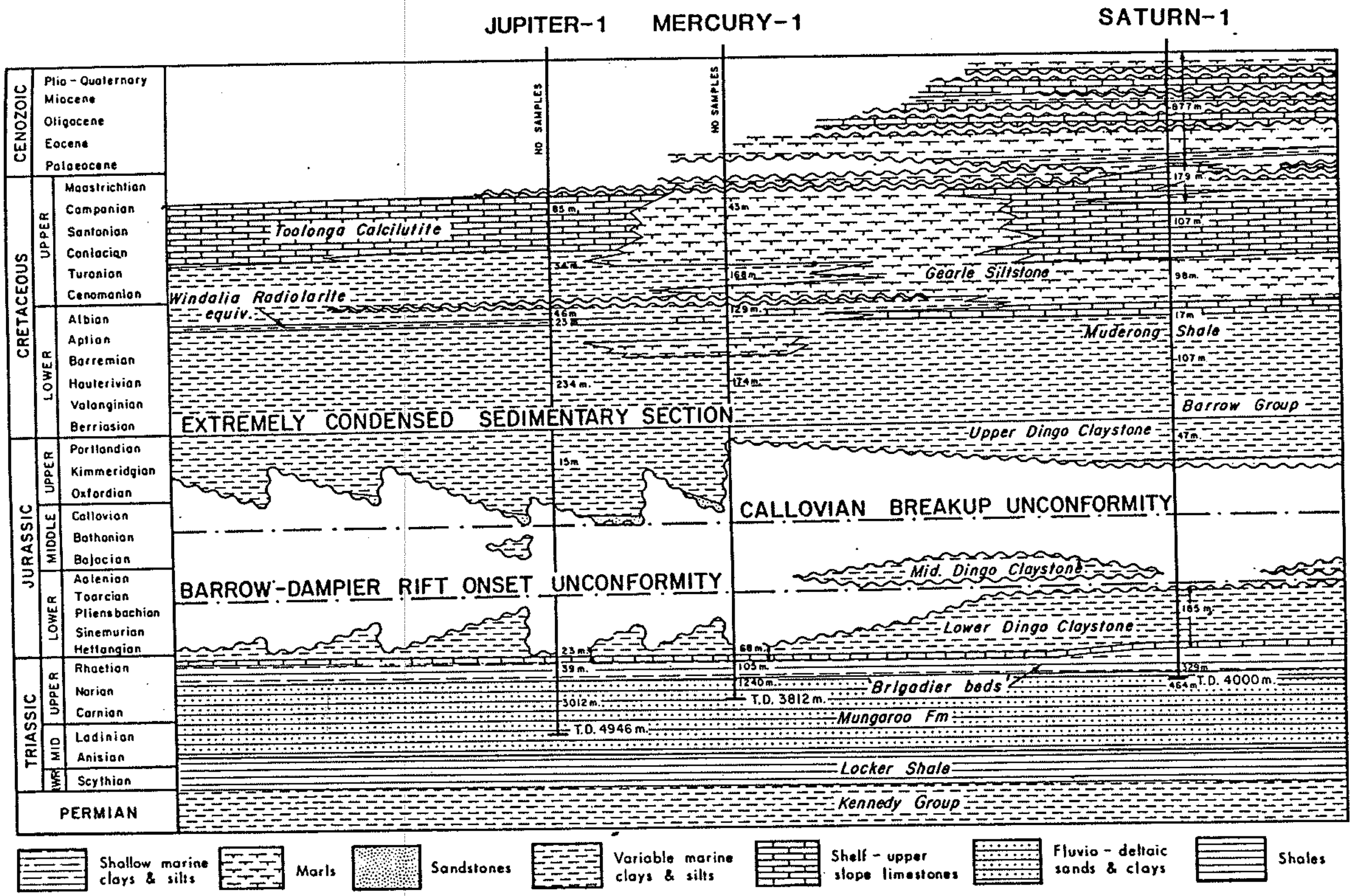
9. Paleogeography of the Exmouth Plateau region.



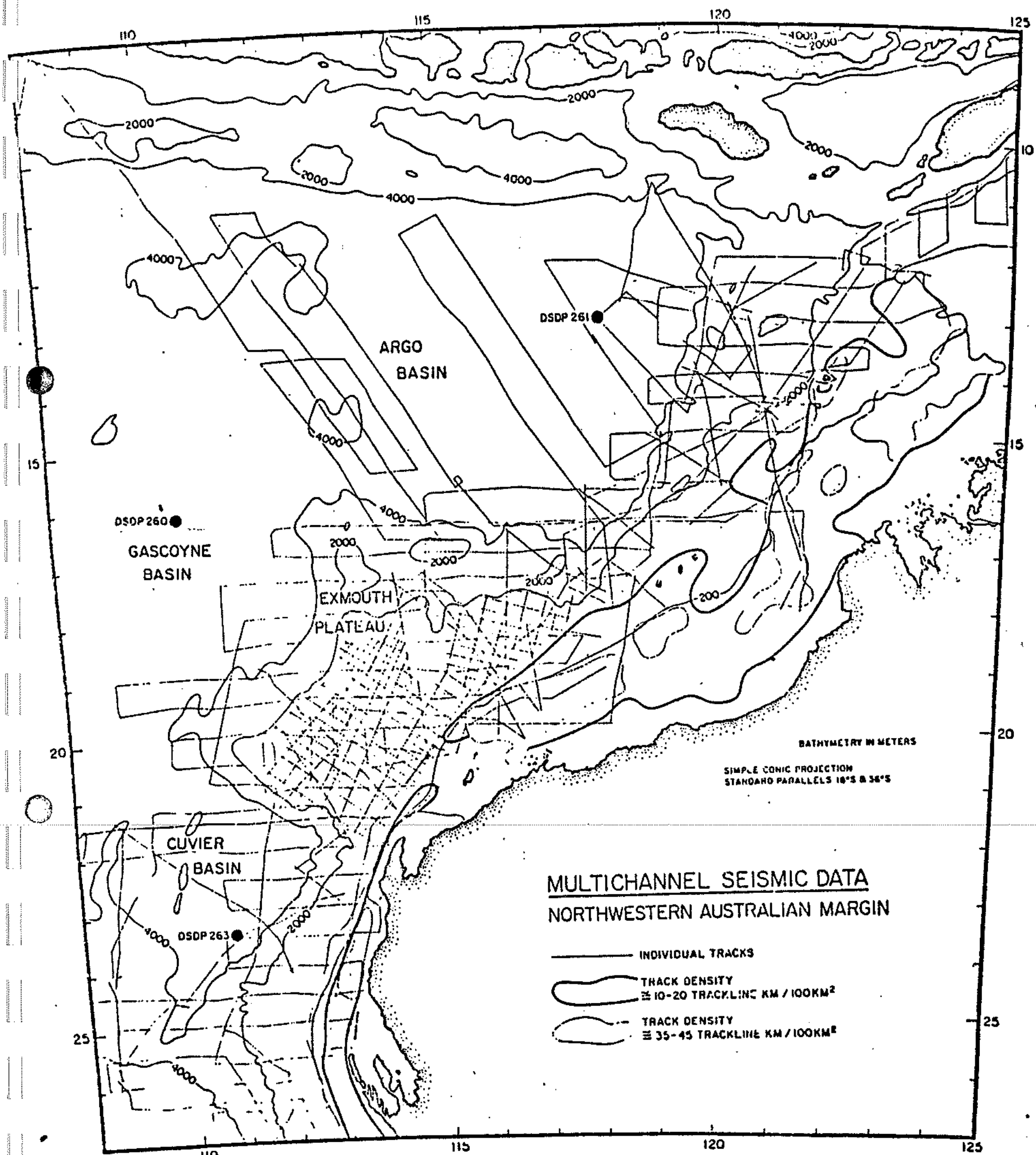
10. (a) Generalized time stratigraphy: Western Australian margin.



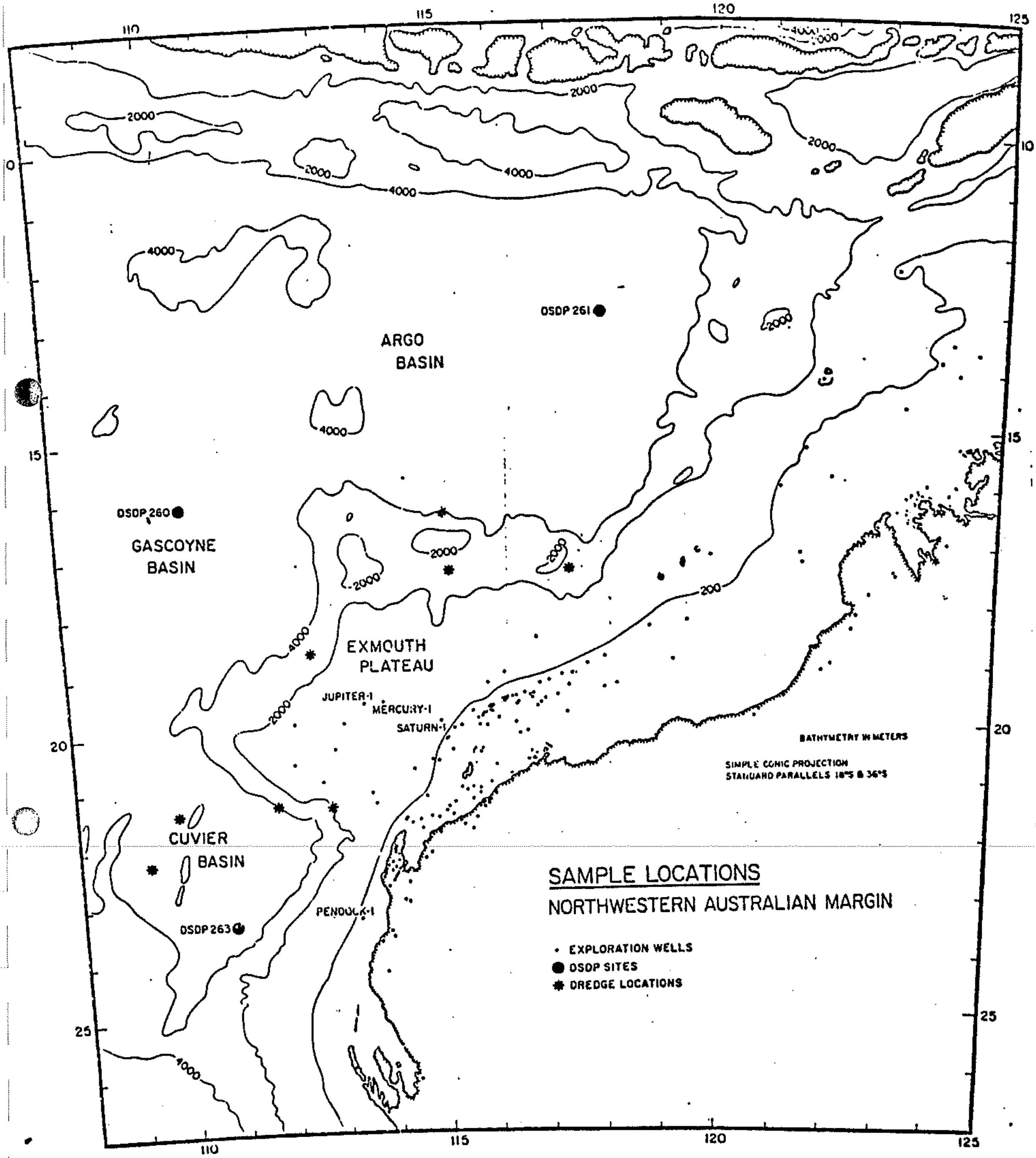
(b) Simplified stratigraphy of the Exmouth Plateau region.



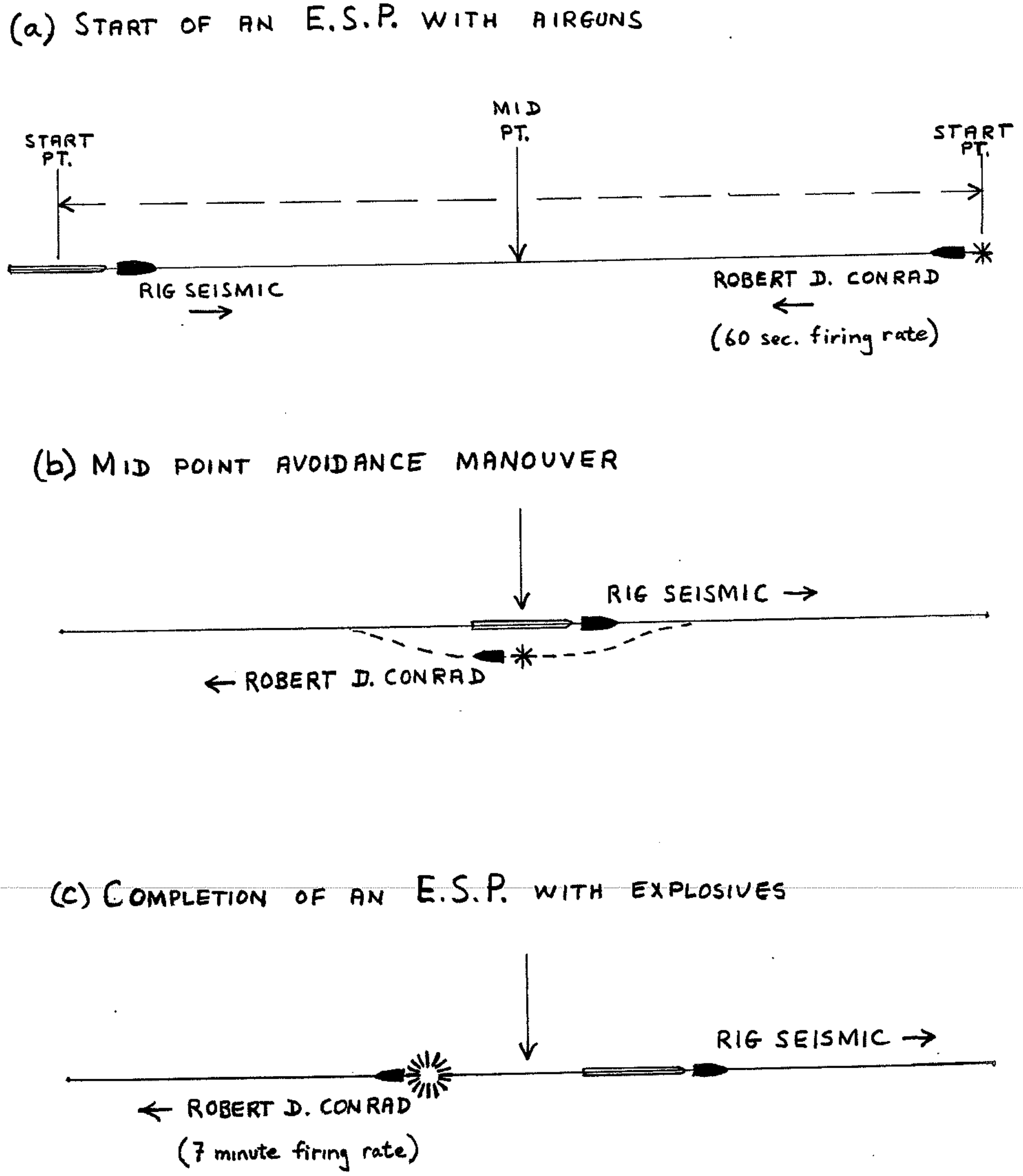
11. Detailed time stratigraphy of the Exmouth Plateau.



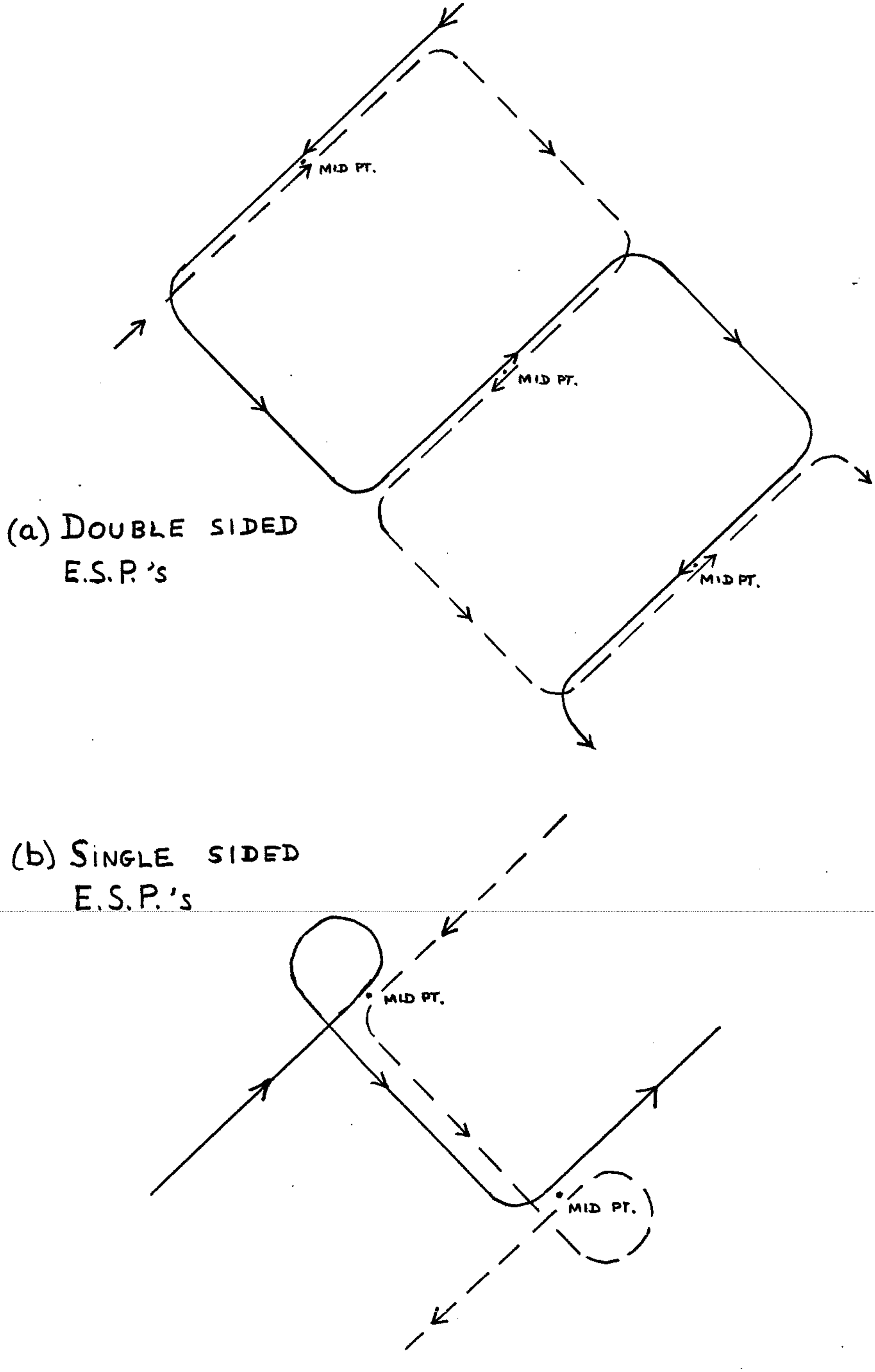
12. Multichannel seismic coverage the Exmouth Plateau region.



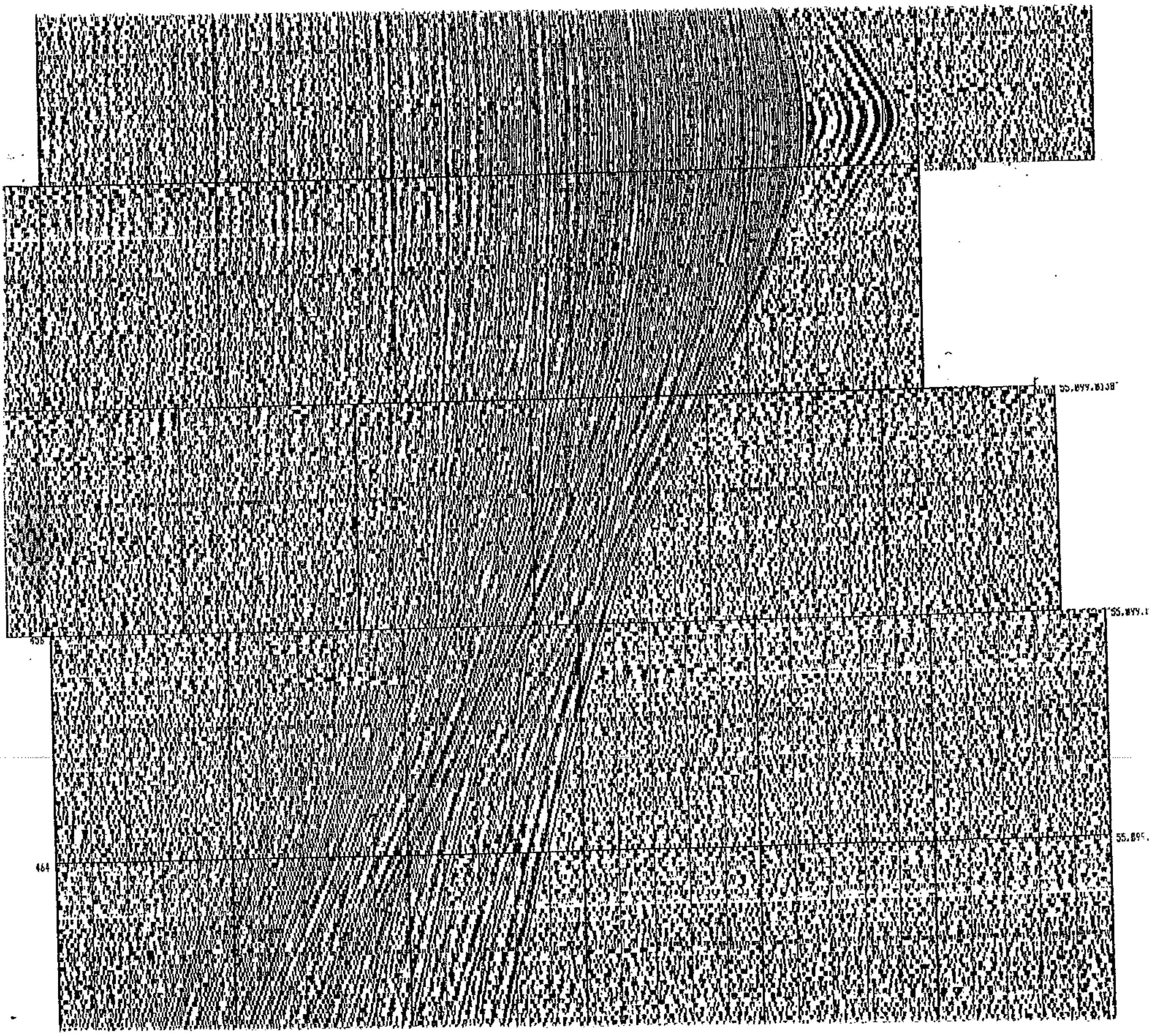
13. Exploration well and dredge locations - Exmouth Plateau and NW Shelf.

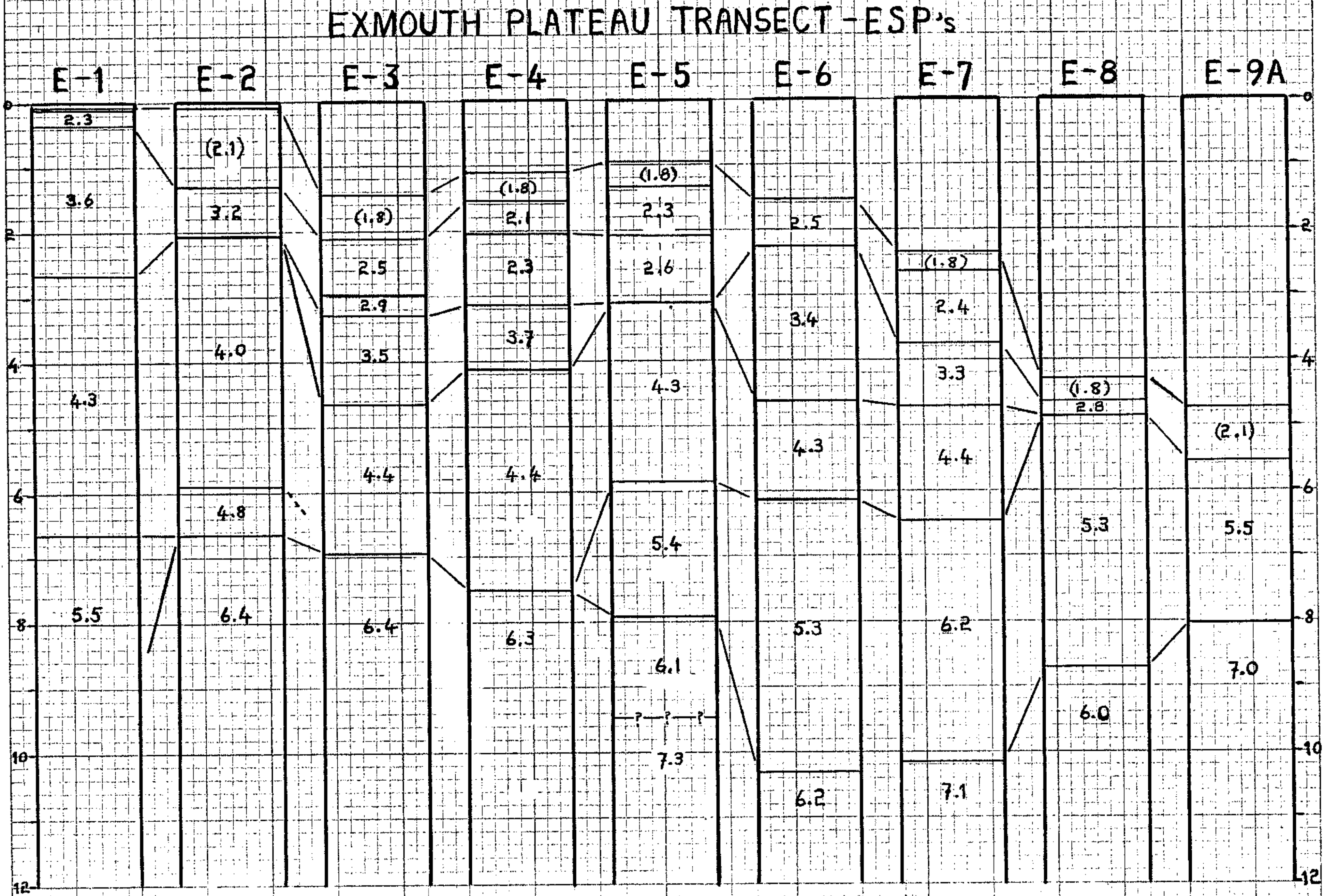


14. Ship manoeuvres for an ESP.



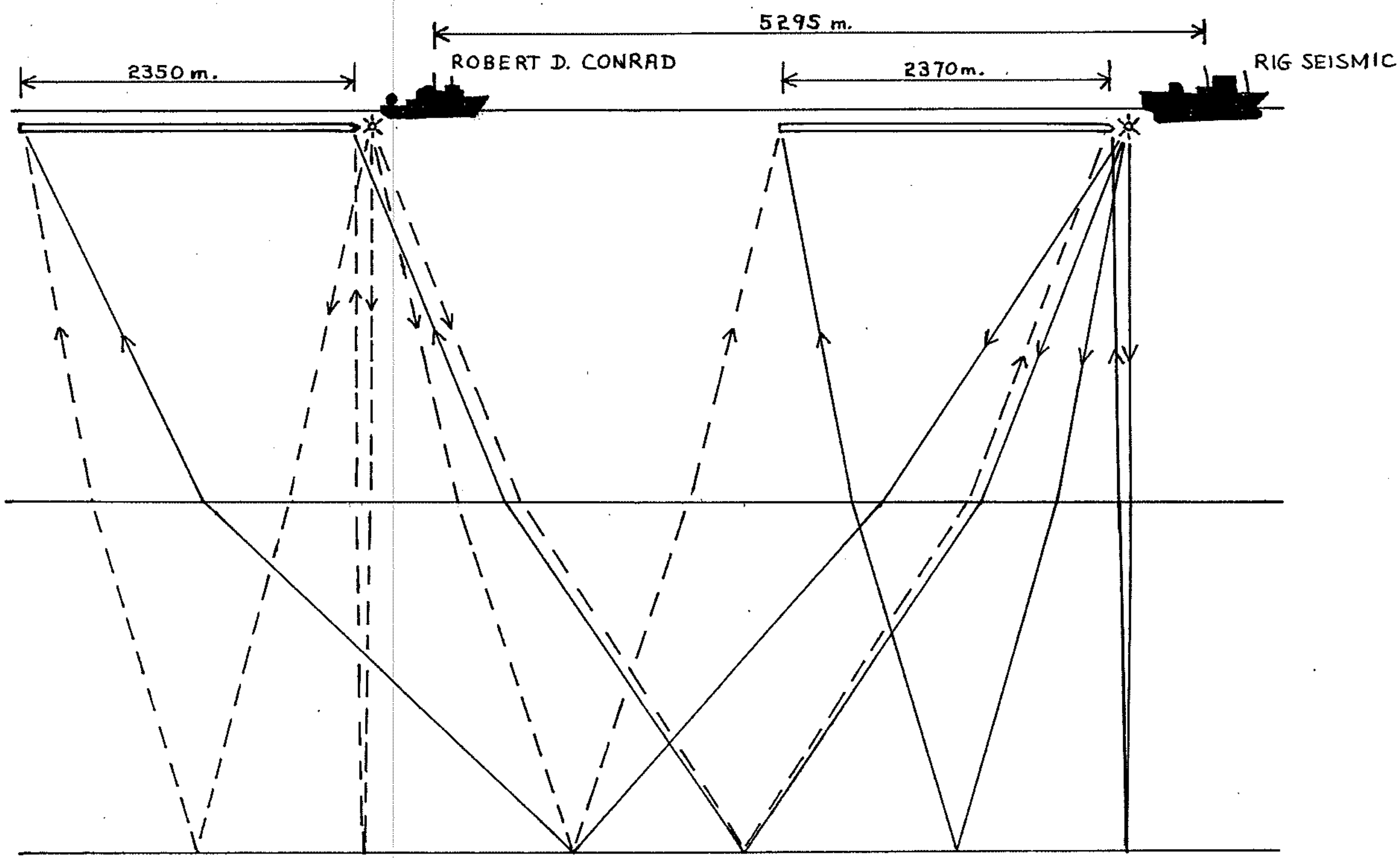
15. Ship manoeuvres for multiple ESP's.


464

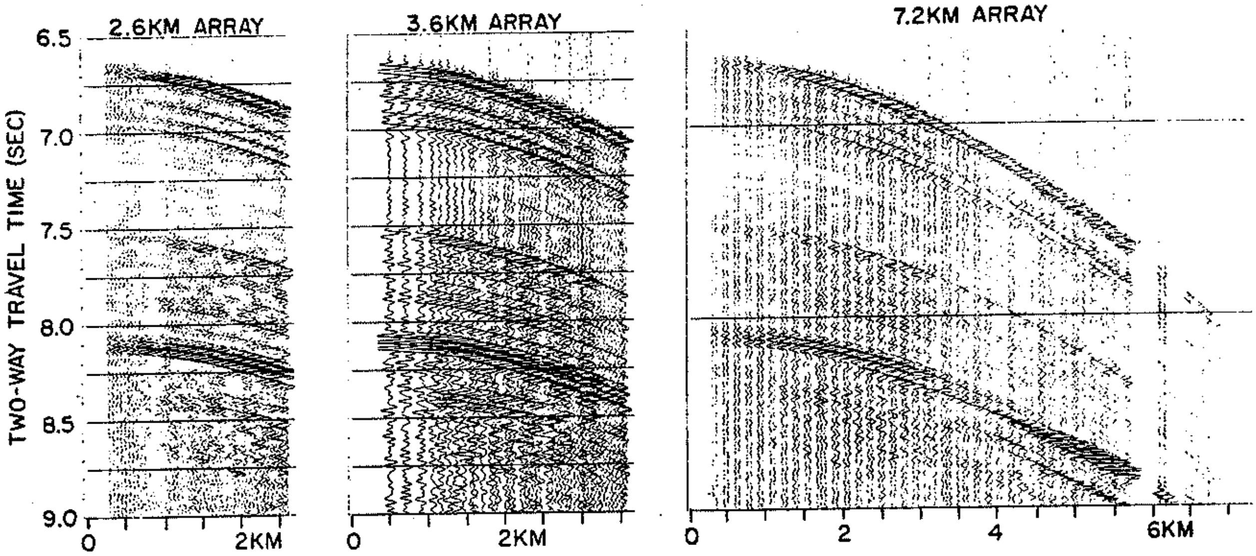


17. Summary crustal velocity columns - Exmouth Plateau Transect.

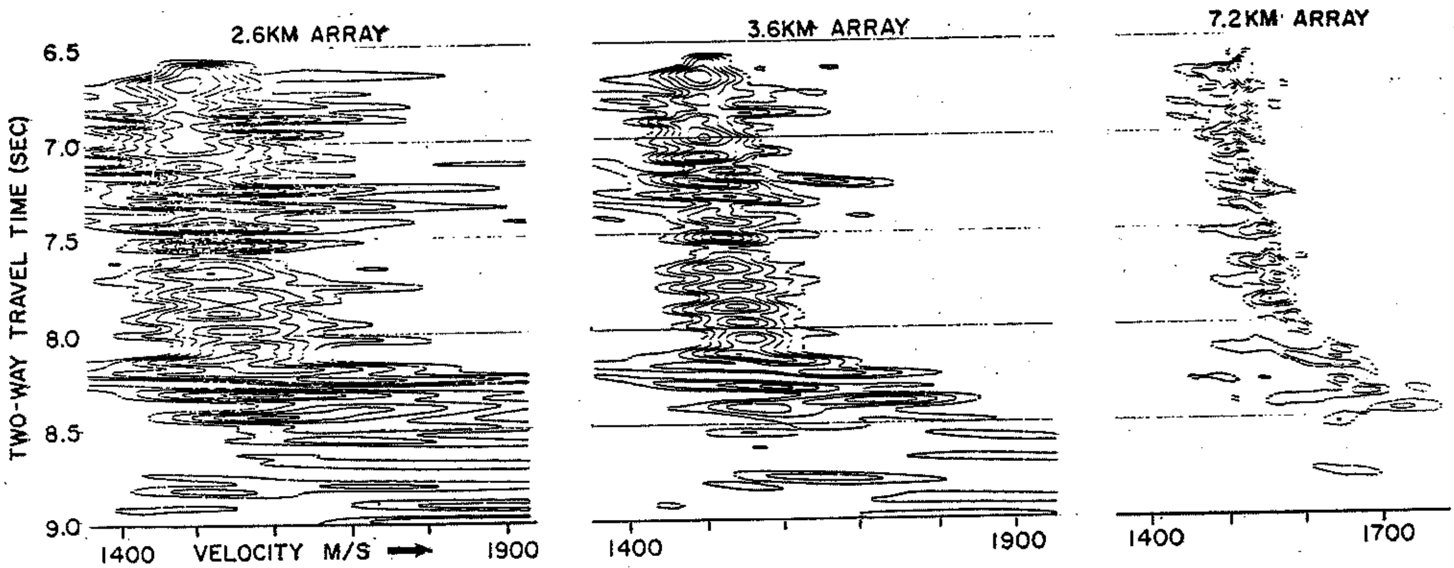
WIDE APERTURE C.D.P. PROFILING



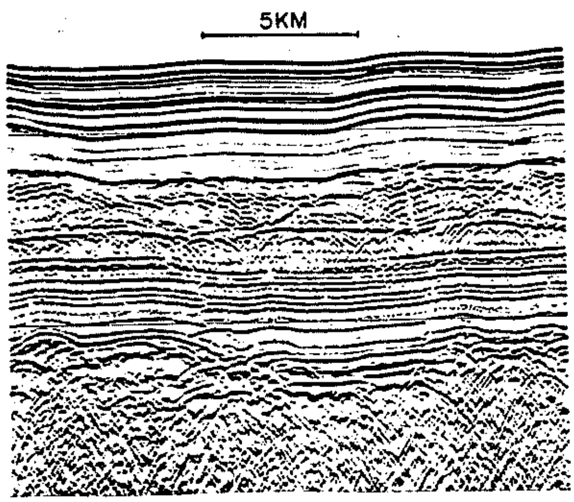
18. Schematic of a Wide Aperture CDP profile (WACDP).



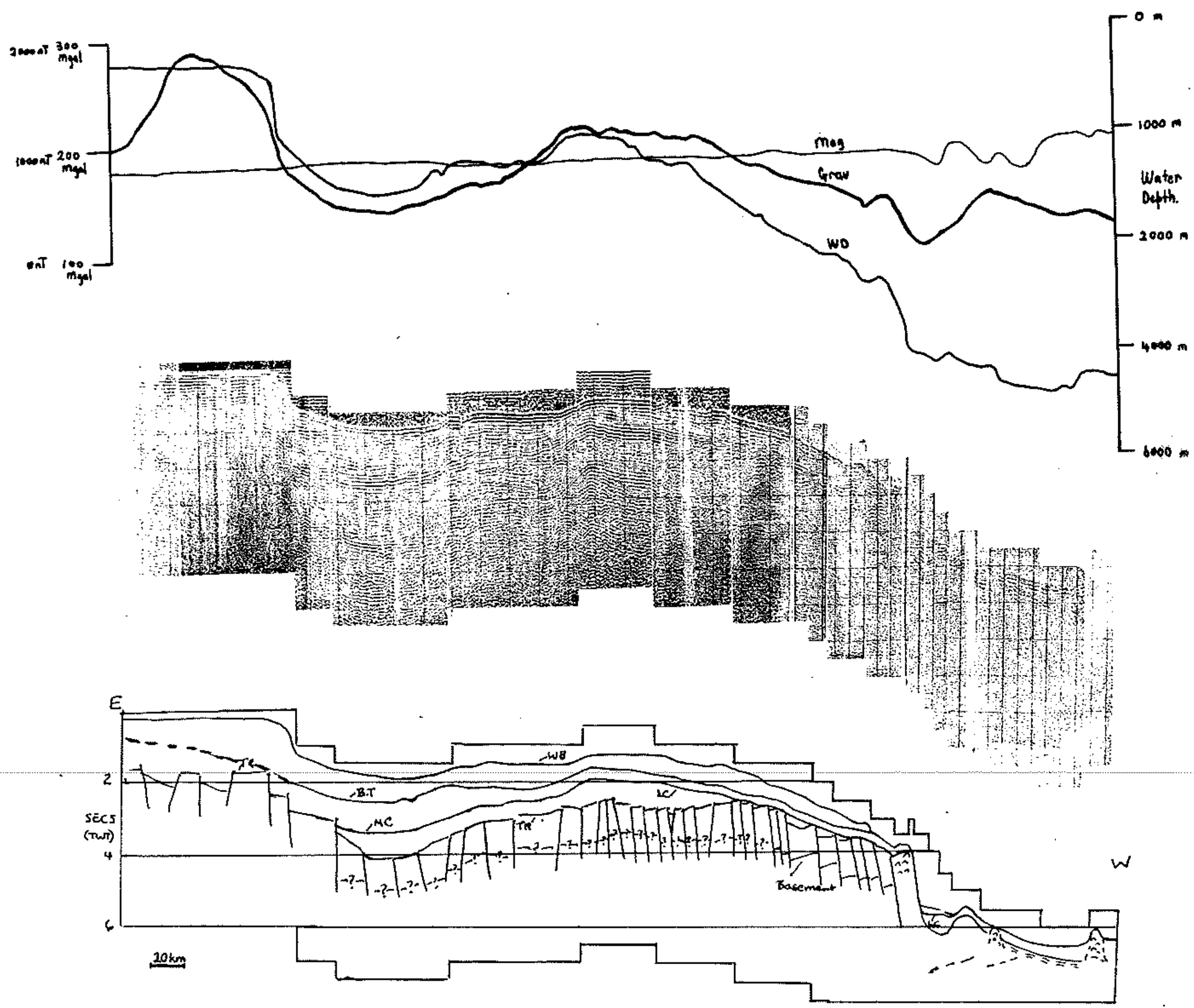
CDP velocity analysis: *CDP record, and a corresponding set of gathers from arrays of three different lengths. As the array length increases there will be information from a greater portion of the time-distance curves of reflections from various geologic horizons. As the amount of the time-distance curve available for analysis is increased, it is possible to determine the velocity of sound in the geology above a horizon with ever greater accuracy.*



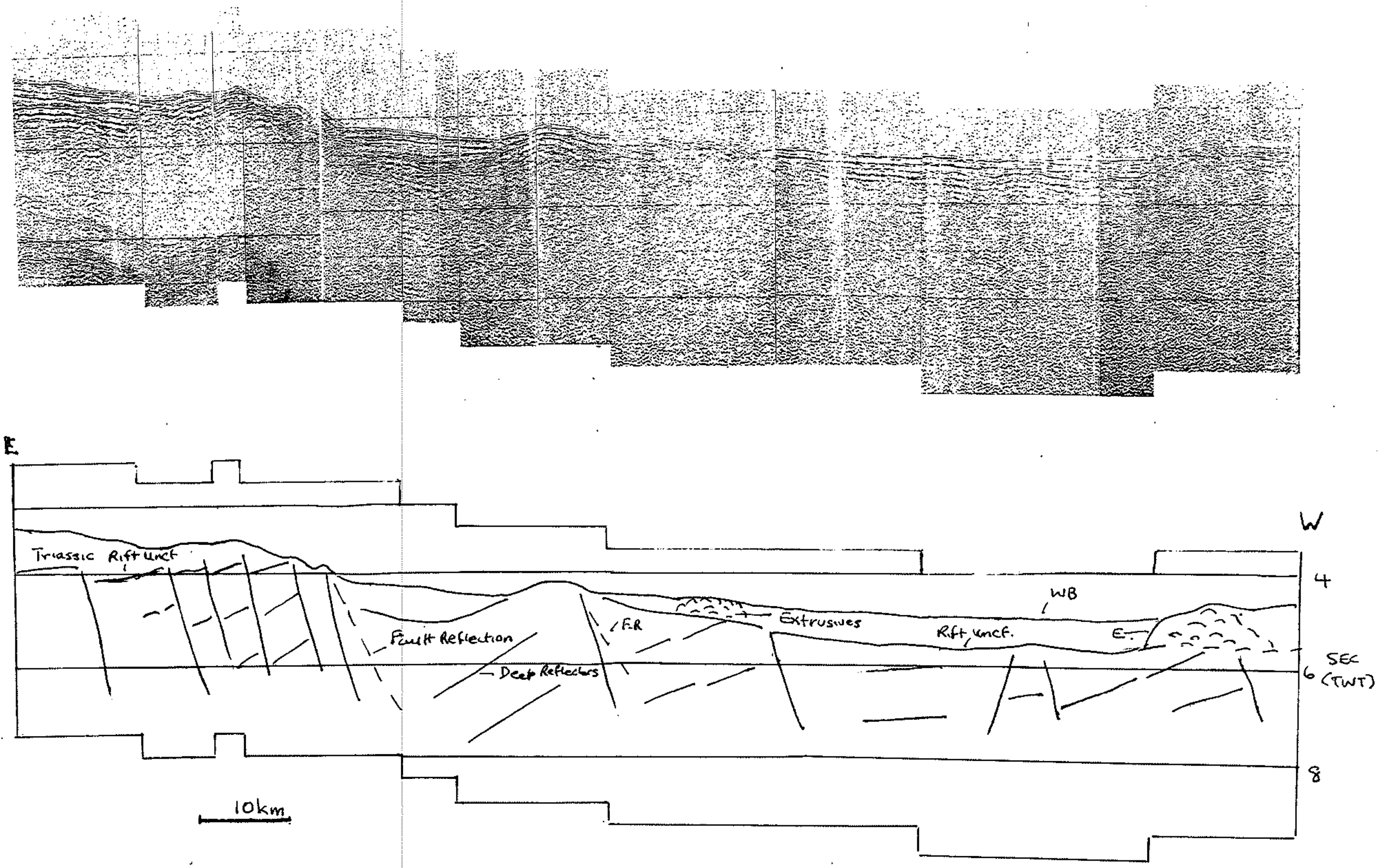
Semblance velocity calculation: *An example of hyperbolic semblance velocity calculations for the data displayed in the CDP gathers above. The center of the contoured bullseye indicates the best stacking velocity for the data at the two-way traveltime of the bullseye center. The width of the contours around the bullseye is related to the precision of the velocity estimate. With longer array length, tighter contours are obtained around the center of the bullseye.*



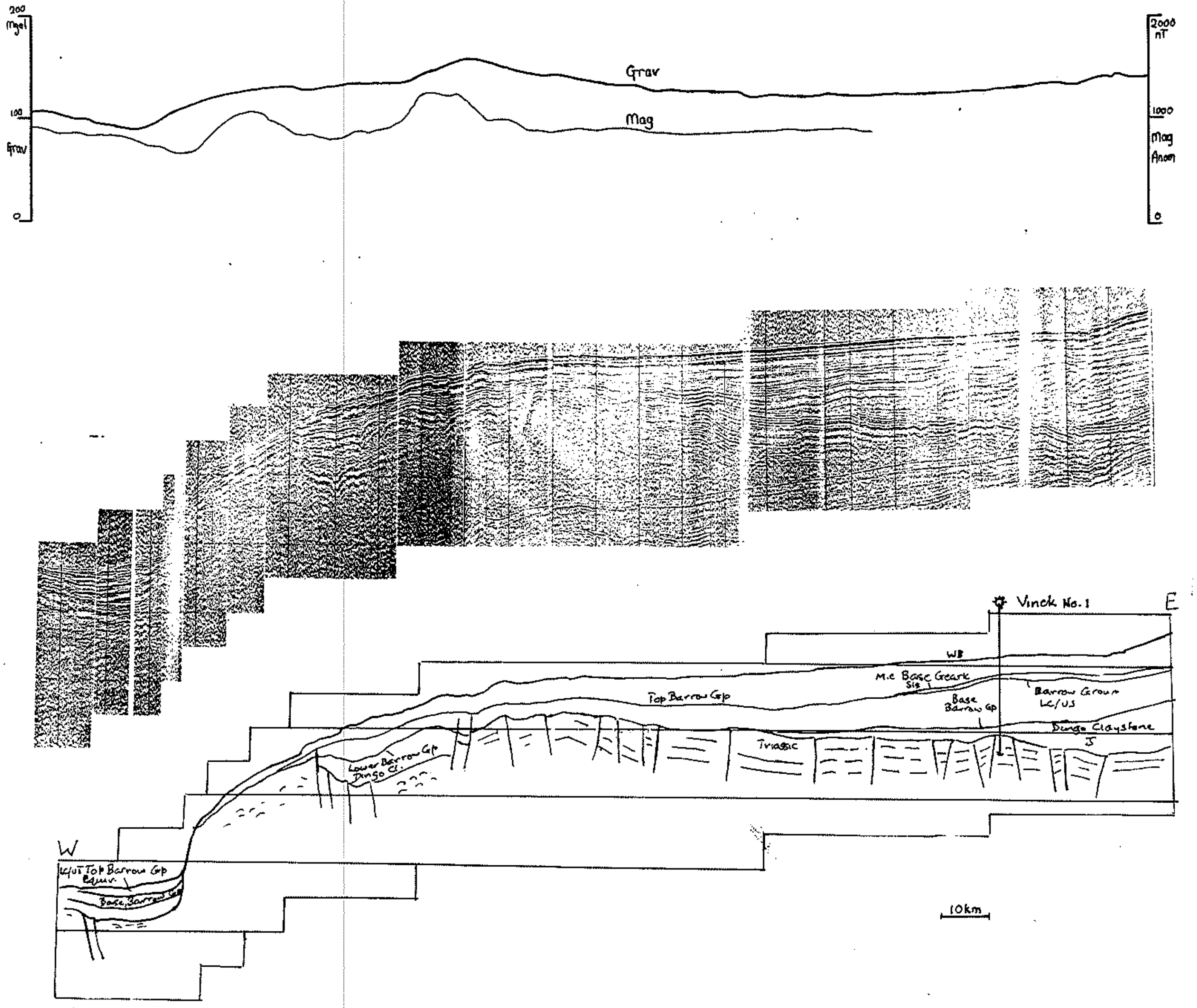
19. Example of improved velocity dicrimination obtained from long array lengths.



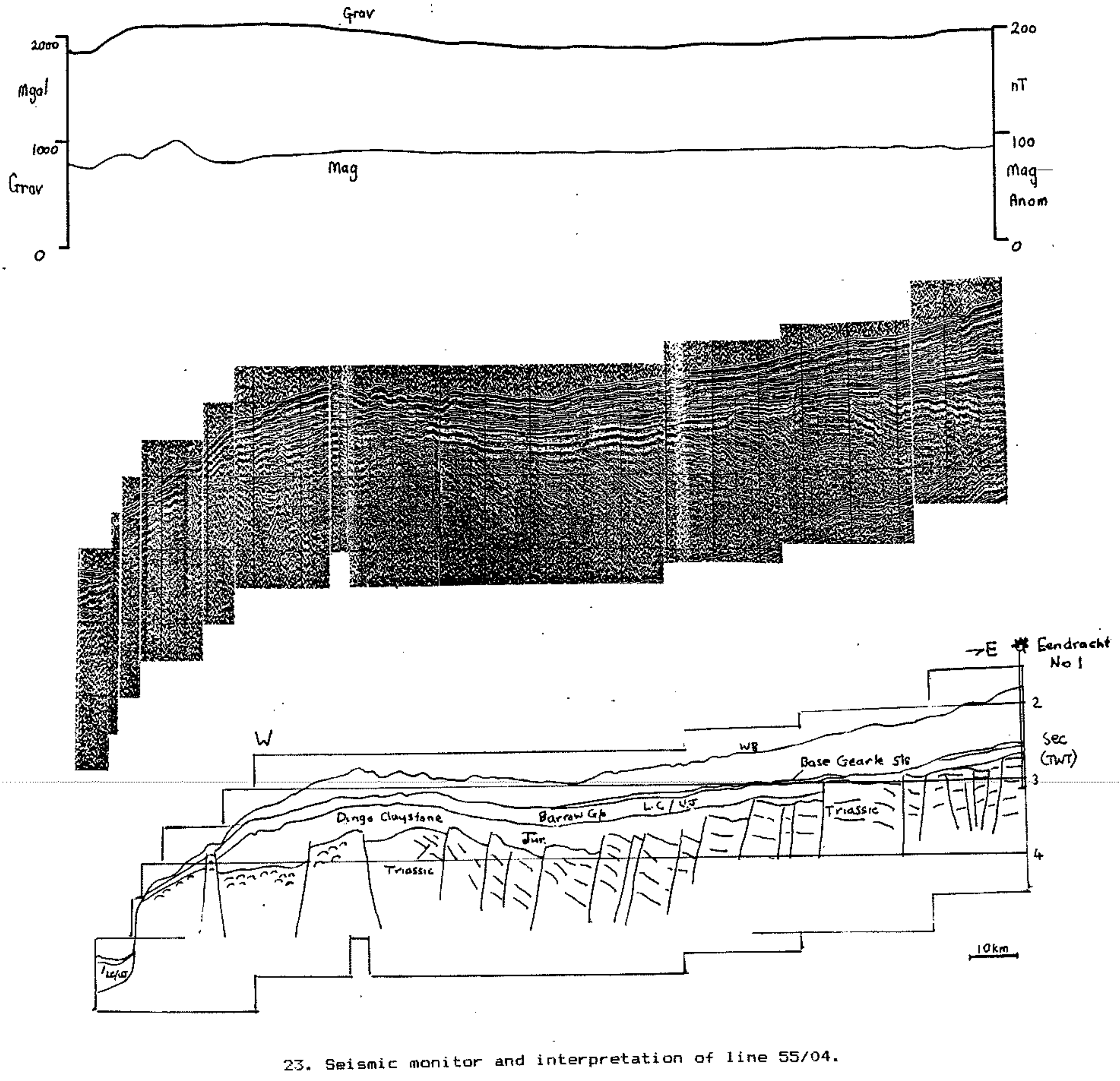
20. Seismic monitor section and interpretation - Exmouth Plateau WACDP profile (Rig Seismic's near trace from Rig Seismic's guns; lines 55/21 & 55/22).



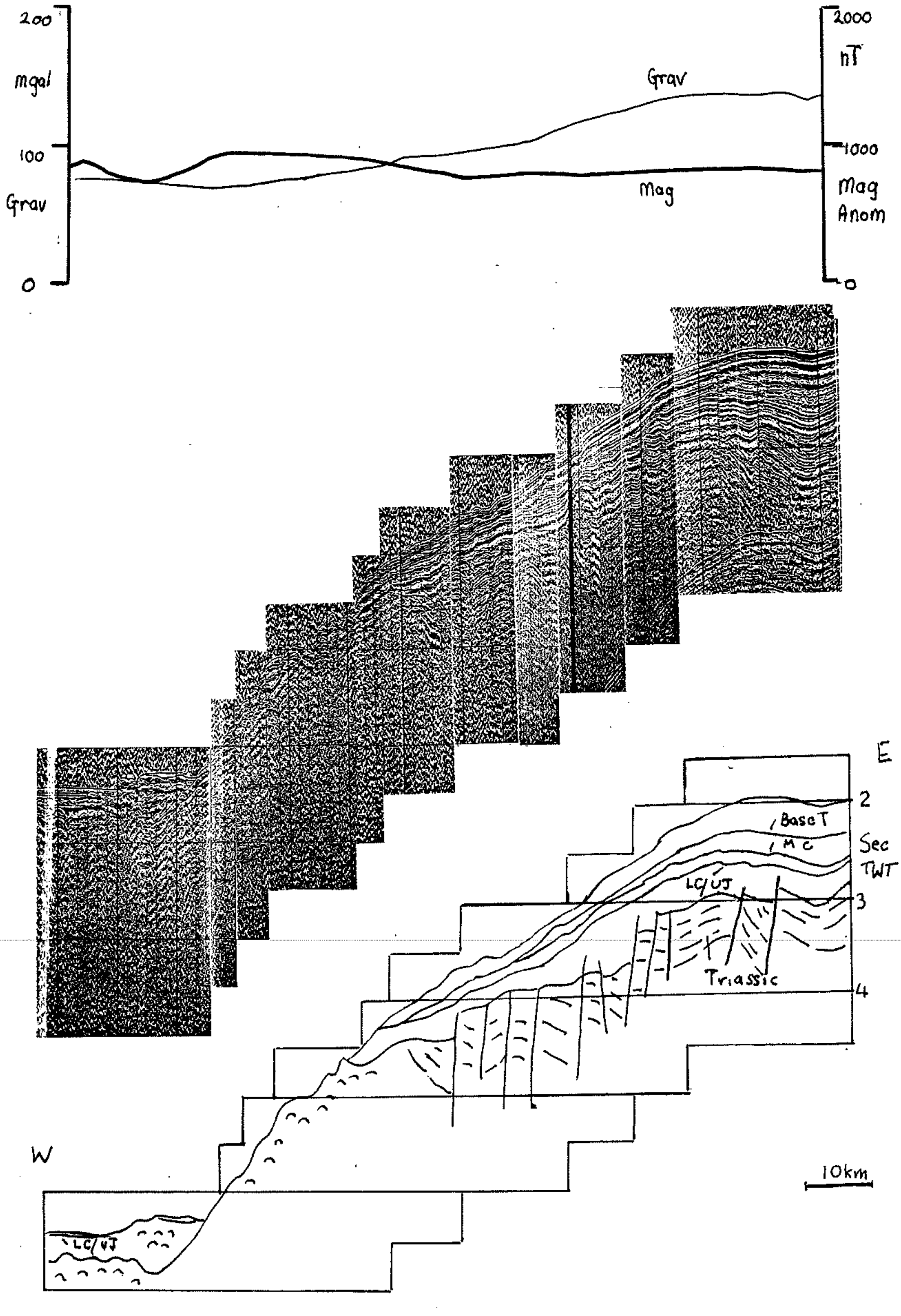
21. Seismic monitor section and interpretation - Exmouth Plateau WACDP profile (Rig Seismic's far trace shot from Conrad's guns; line 55/22).



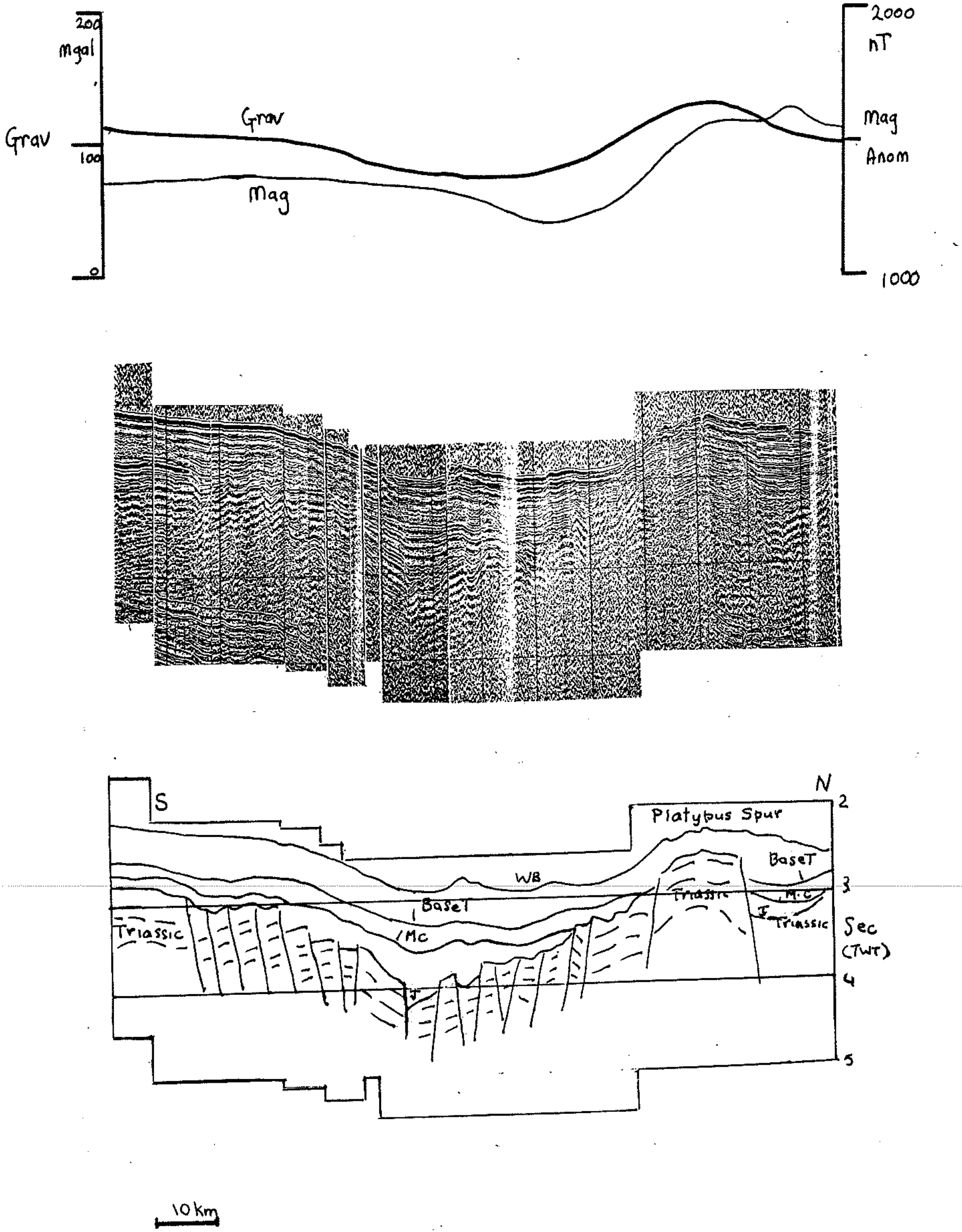
22. Seismic monitor and interpretation of line 55/02.



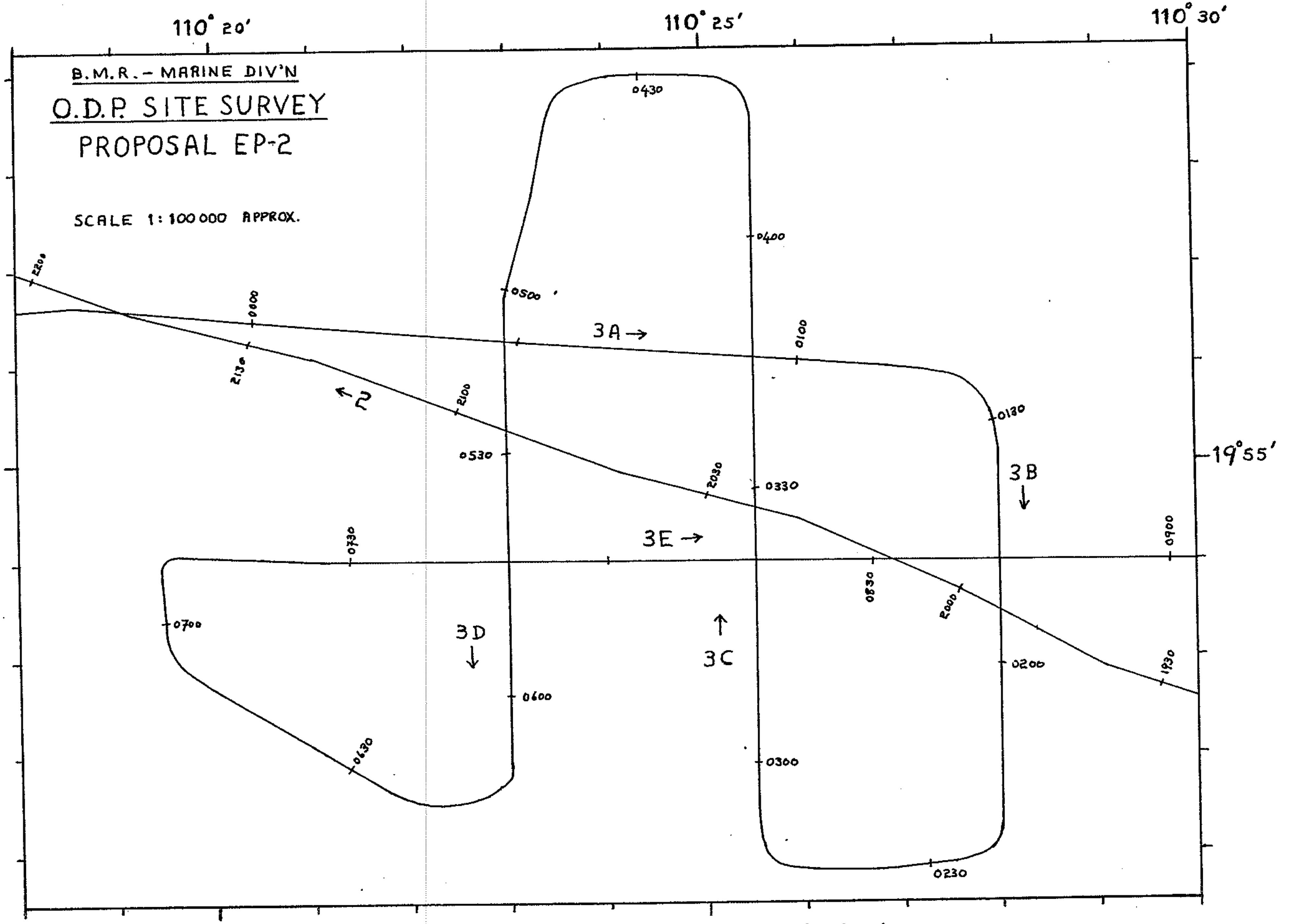
23. Seismic monitor and interpretation of line 55/04.



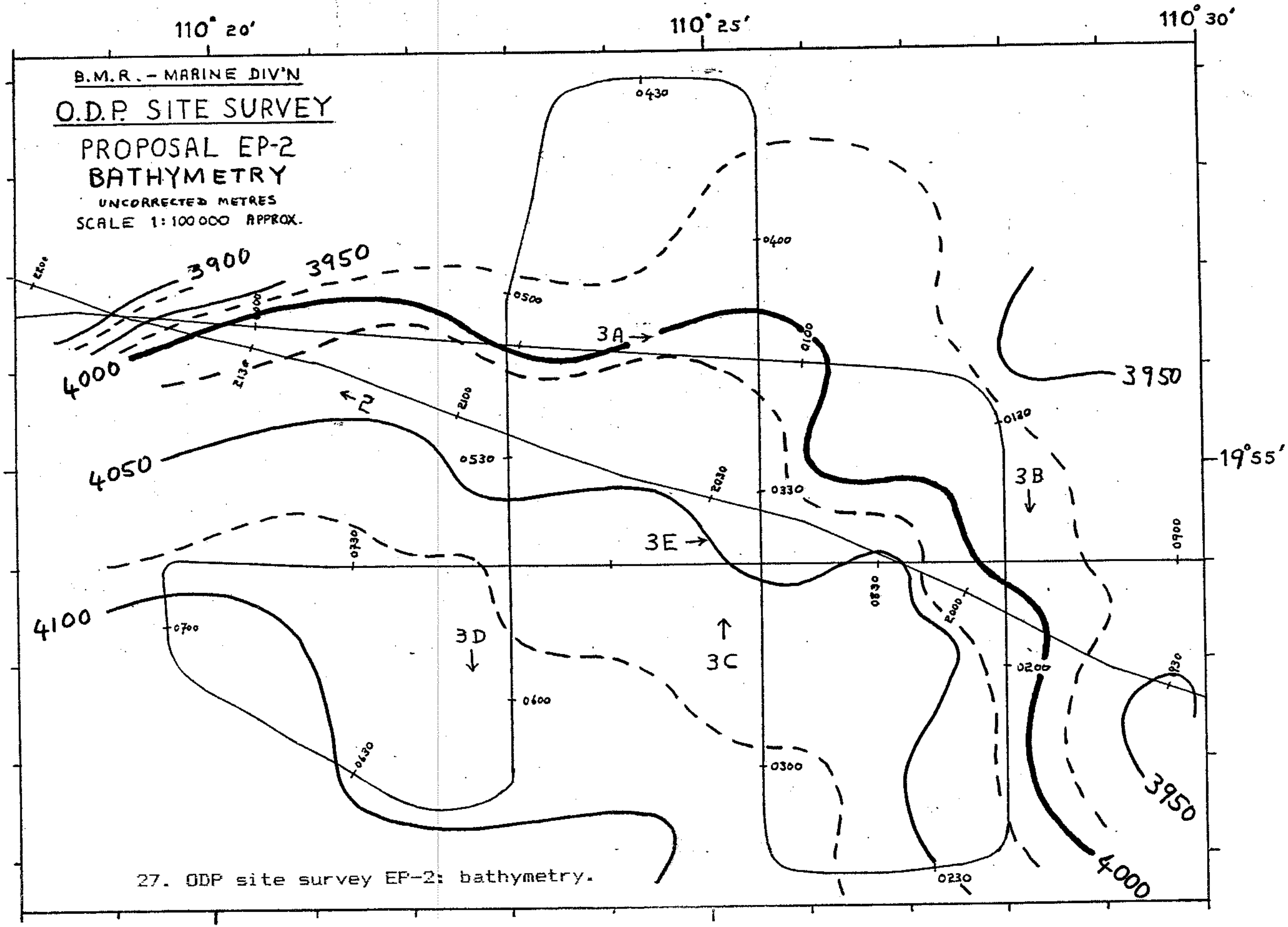
24. Seismic monitor and interpretation of line 55/07.



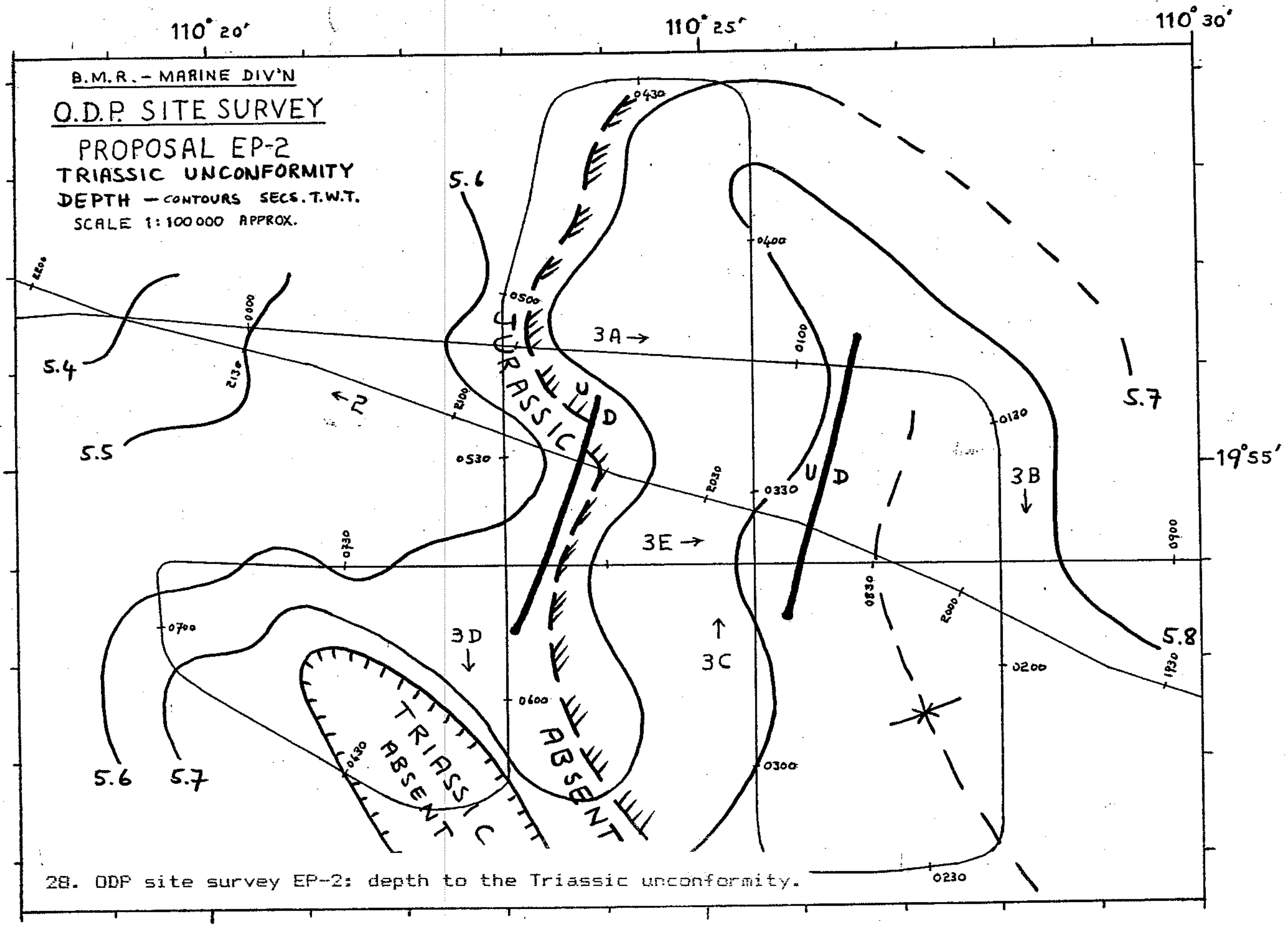
25. Seismic monitor and interpretation of line 55/09.



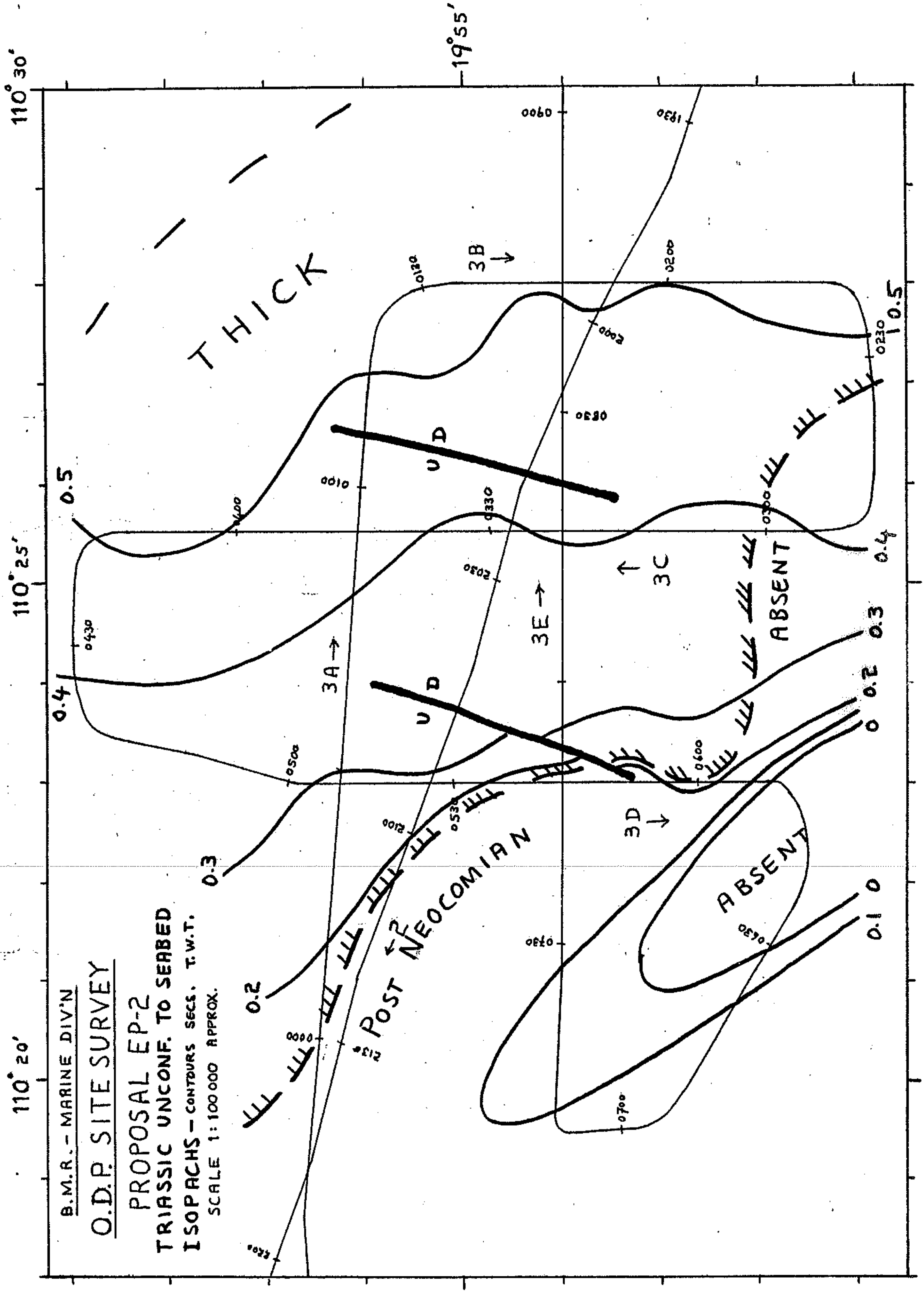
26. ODP site survey EP-2: track chart.



27. ODP site survey EP-2: bathymetry.

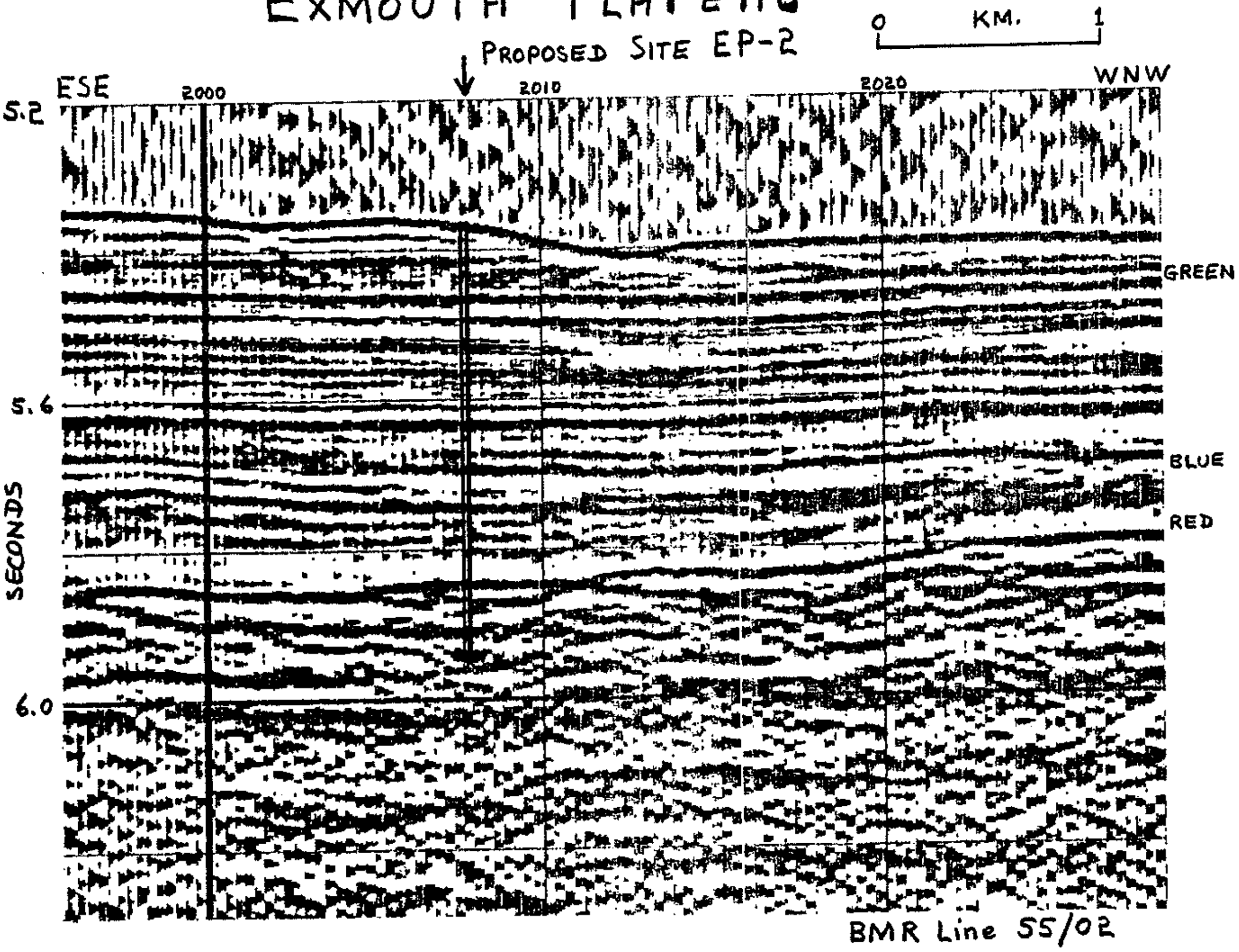


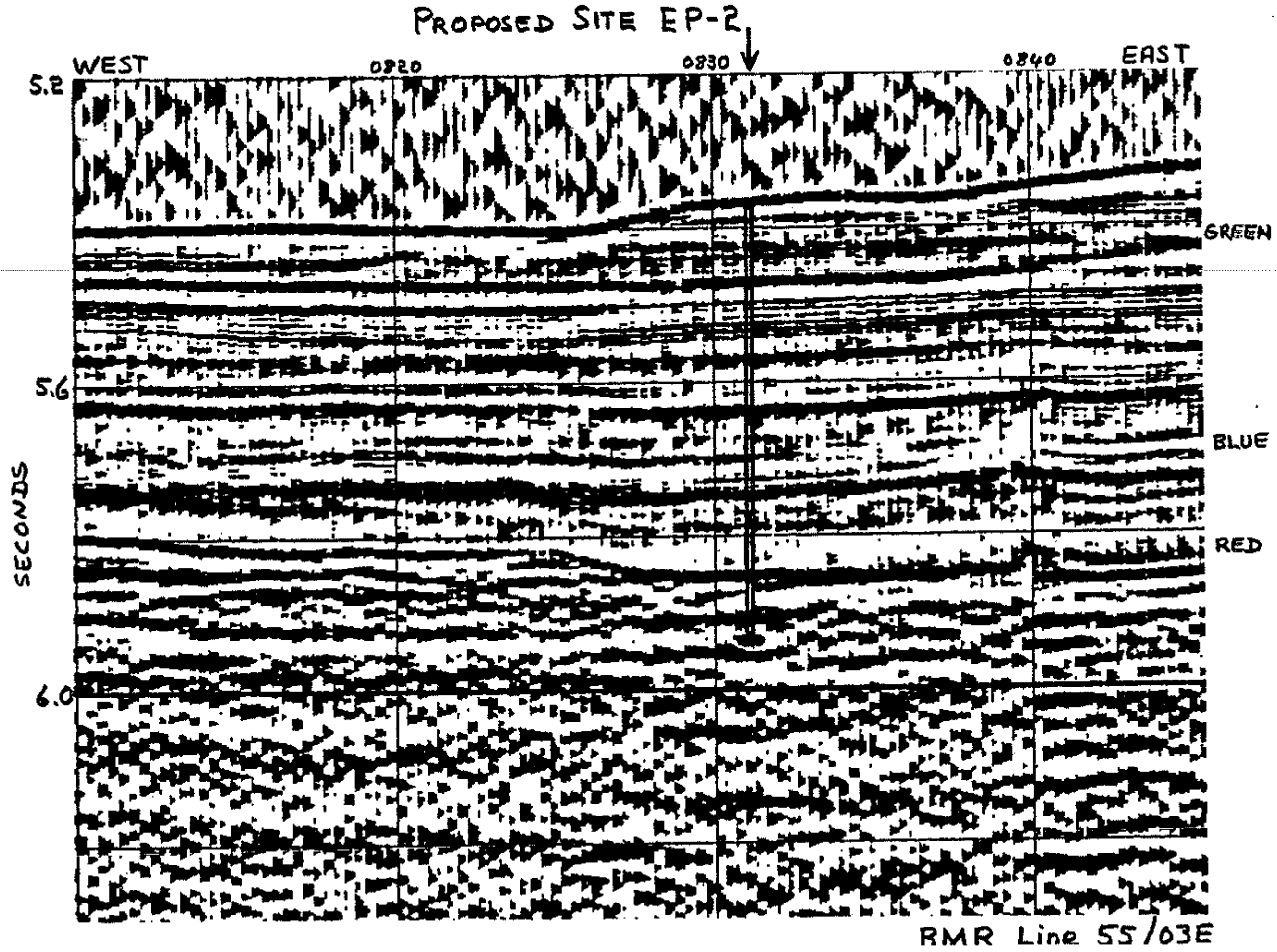
28. ODP site survey EP-2: depth to the Triassic unconformity.



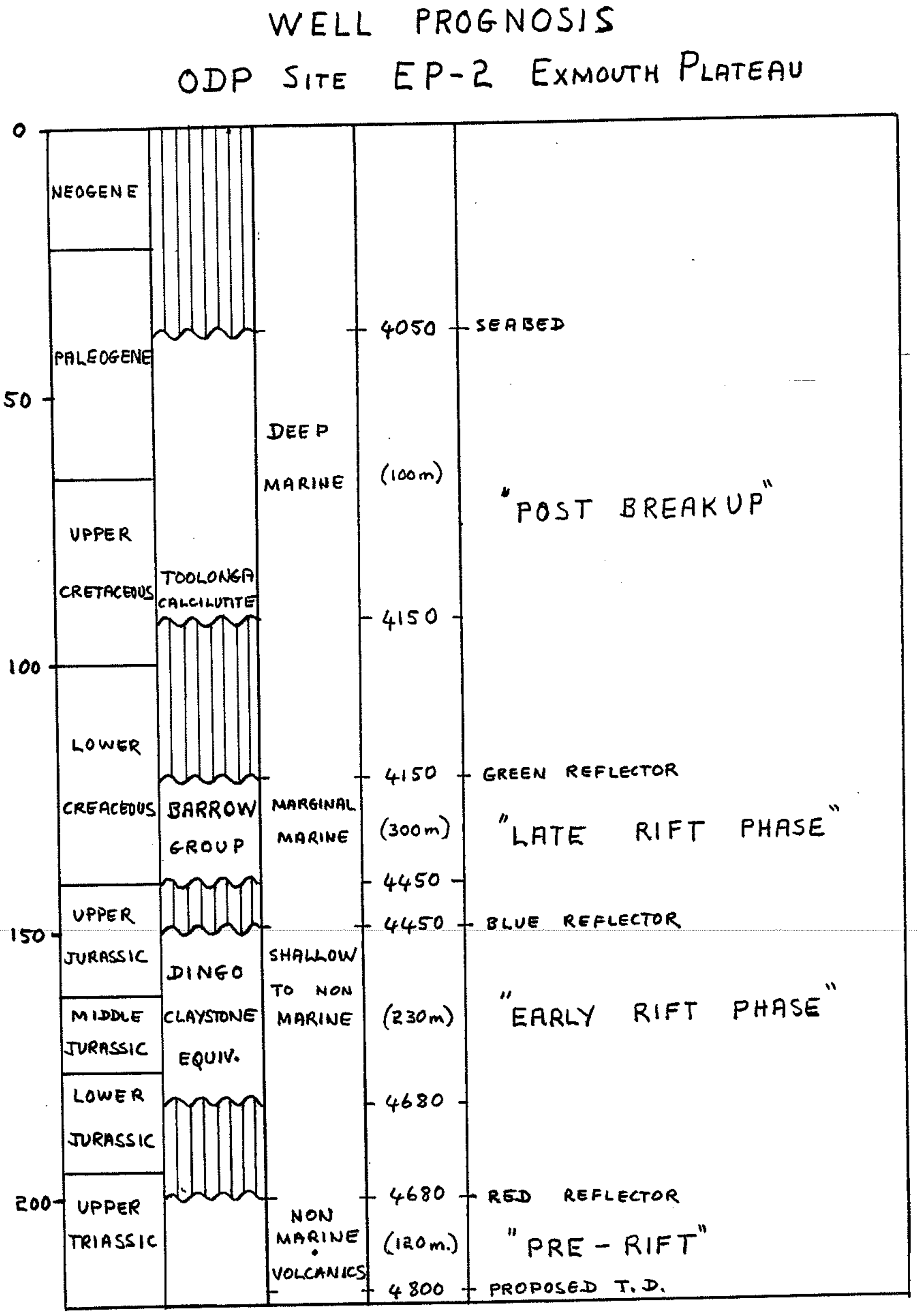
29. ODP site survey EP-2: isopachs of sediment from seabed to Triassic unconformity.

O.D.P. SITE SURVEY
EXMOUTH PLATEAU

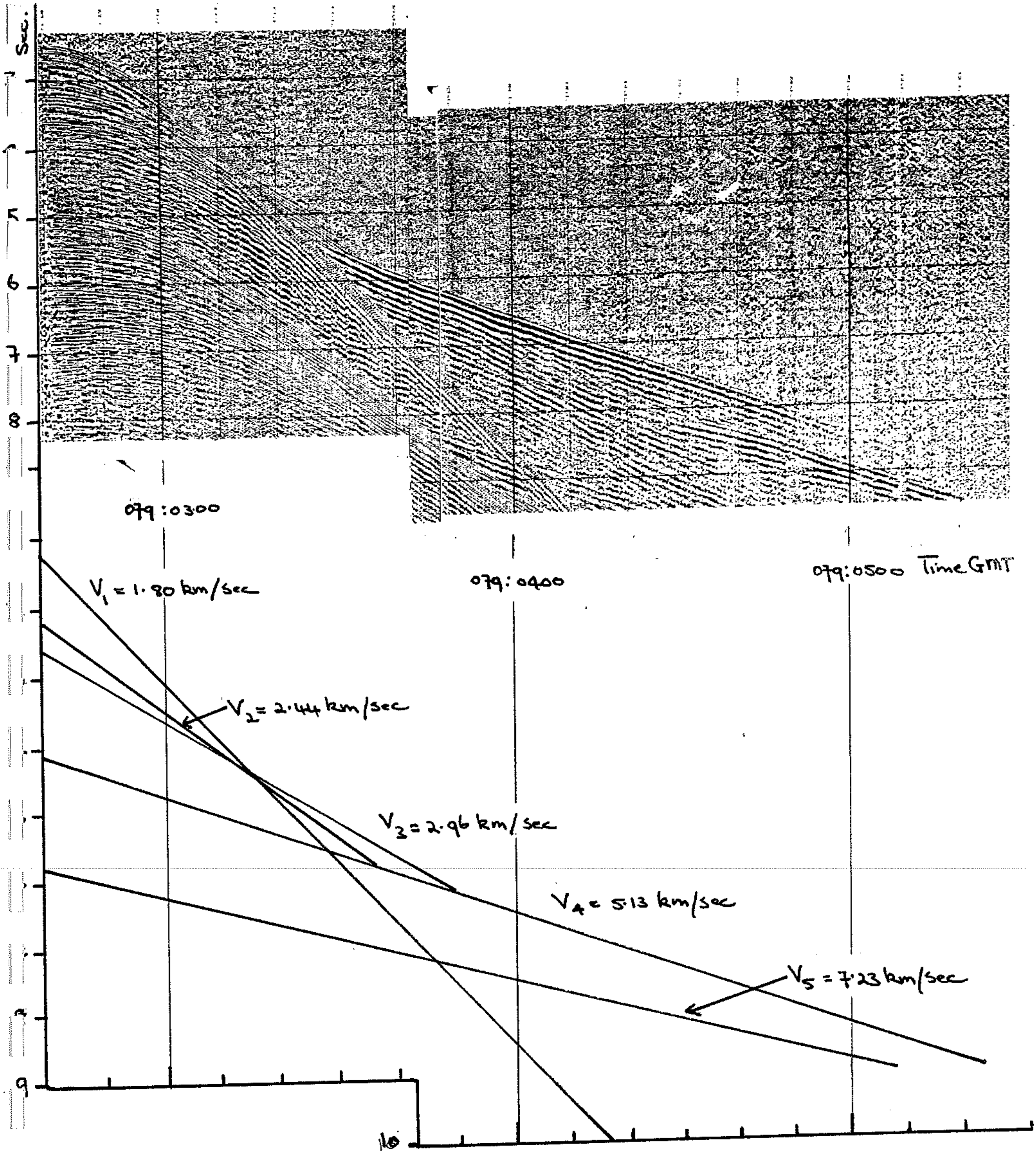




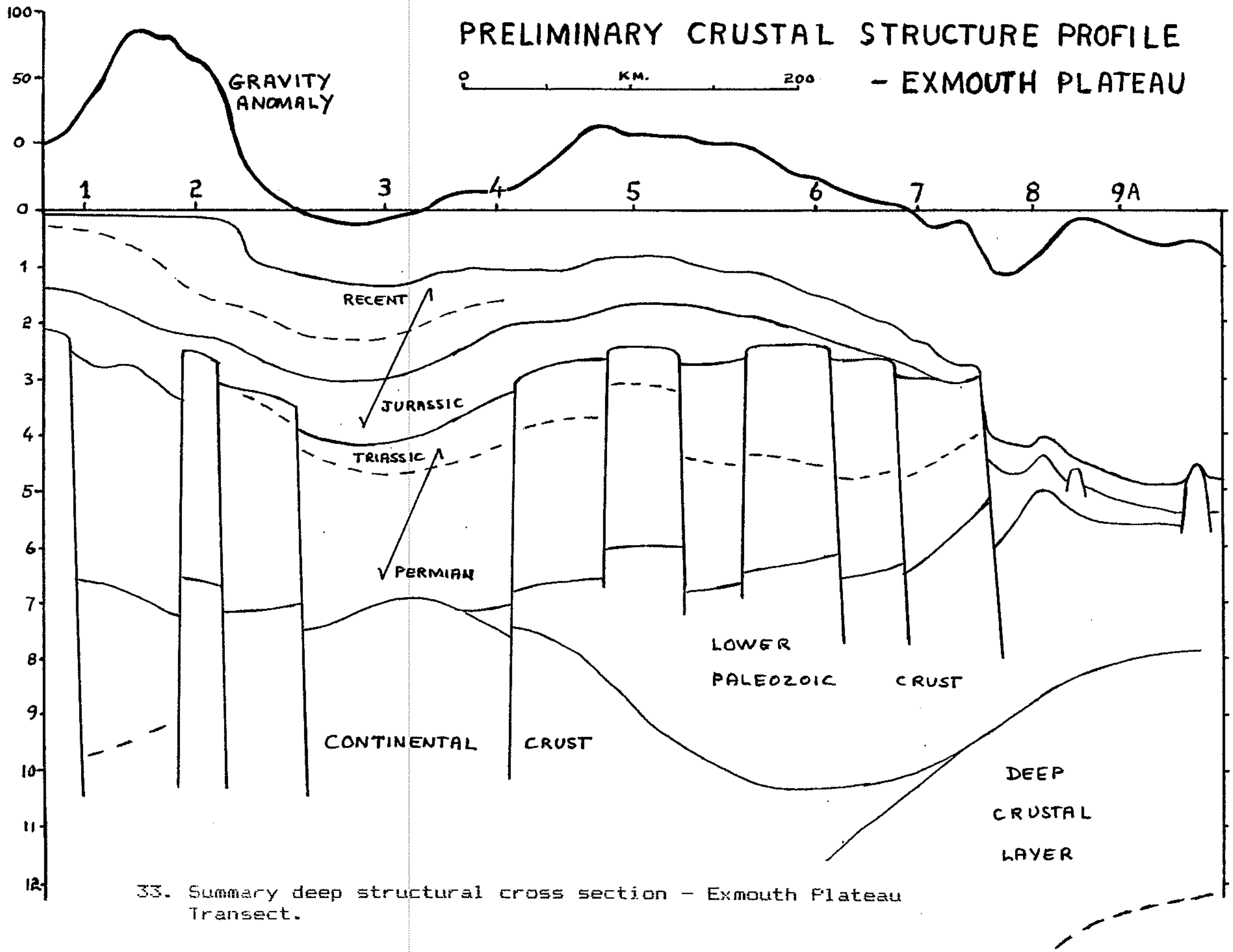
30. ODP site survey EP-2: seismic monitors for lines 55/02 and 55/03E.



31. ODP site survey EP-2: well prognosis.



32. Seismic monitor and interpretation of sonobuoy on line 55/09



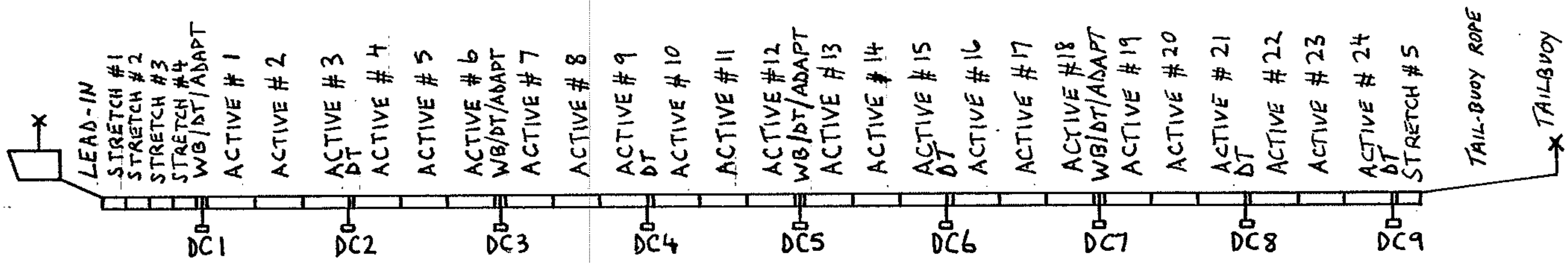
33. Summary deep structural cross section - Exmouth Plateau Transect.

R.V. RIG SEISMIC.

MARINE HYDROPHONE STREAMER CONFIGURATION

TELEDYNE: 48 CHANNEL : 2400M

EXMOUTH PLATEAU: RESEARCH CRUISE # 1. MARCH-APRIL 1986.



- ACTIVE SECTIONS: 100M IN LENGTH: 24 IN CABLE: 50M GROUPS: 80 PHONES PER 100M.
- STRETCH SECTIONS: 50M IN LENGTH: 4 AT HEAD; 1 AT TAIL.
- ARMOURED LEAD-IN: 93M-117M DEPLOYED / WEATHER AND SEA DEPENDENT.
- WATER-BREAK/DEPTH TRANSDUCER SECTIONS: 2M IN LENGTH: WB/DT.
- DEPTH TRANSDUCER SECTIONS: 2M IN LENGTH: DT.
- ADAPTER SECTIONS: 2M IN LENGTH: FORMATS CABLE TO 48 CHANNEL: 50M GROUPS.
- DEPTH CONTROLLER: SYNTRON RCL-2: REMOTE CONTROLLED: 9 ON CABLE. IDEPENDENTLY ADRESSABLE.
- TAIL-BUOY ROPE: 300M IN LENGTH.
- TAIL-BUOY: TELEYDYNE WITH SOLAR POWERED STROBE LIGHT.

Appendix B: Cable geometry.