2. INTRODUCTION[1]

Shipboard Scientific Party[2]

INTRODUCTION

The northwestern Australian margin extends from the Exmouth Plateau to the Scott Plateau. It is one of the oldest continental margins in the world that has both a relatively low sediment influx and a large biogenic component (Fig. 1). As such, it is an ideal margin for integrated sedimentologic, biostratigraphic, paleobathymetric, and subsidence studies. Two Ocean Drilling Program (ODP) legs were drilled in this area: Leg 122, planned as a transect of sites across the northern and central Exmouth Plateau, and Leg 123, intended to occupy one site on the western margin of Exmouth Plateau and one site on the Argo Abyssal Plain (Fig. 2).

The Exmouth Plateau off northwestern Australia is about 600 km long and 300–400 km wide with water depths ranging from 800 to 4000 m (Fig. 2). The plateau consists of rifted and deeply subsided continental crust covered by a 10-km-thick Phanerozoic sedimentary sequence. It is separated from the Northwest Shelf by the Kangaroo Syncline, and is bounded to the north, west, and south by oceanic crust of the Argo, Gascoyne, and Cuvier abyssal plains. The Canning and Carnarvon Basin sediments extend over the plateau from the east and abut the Pilbara Precambrian block (Exon and Willcox, 1978, 1980; Exon et al., 1982; Exon and Williamson, 1988; Barber, 1988; Hocking, 1988, Hortsmann and Purcell, 1988).

The Argo Abyssal Plain, about 5700 m deep, is located north of the Exmouth and Wombat Plateaus and west of the Rowley Shoals and Scott Plateau (north of the area shown in Fig. 1). It is underlain by oceanic crust that is the oldest known in the Indian Ocean and is slowly being consumed by the convergence of Australia and the Sunda arc.

The Exmouth Plateau-Argo Abyssal Plain transect was the first Mesozoic, sediment-starved passive margin to be studied since 1985 when *JOIDES Resolution* drilled the Galicia margin (Leg 103; see Boillot, Winterer, et al., 1987). Australian margins are characterized by large marginal plateaus with broad continent/ocean transitions and a different paleogeographic, tectonic and climatic setting. Drilling the Exmouth Plateau-Argo Abyssal Plain transect on Legs 122 and 123 will allow (1) comparison of tectonic and seismic sequences with Atlantic passive margins, (2) refinement of the Mesozoic geological time scale, and (3) characterization of old ocean crust prior to subduction under the Sunda arc.

Exmouth Plateau can serve as a model for an old sediment-starved (less than 1–2 km of post-breakup sediments) passive continental margin with a broad continent/ocean transition. The margin, because of its relatively thin sediment cover, is well suited to study the rift, breakup, "juvenile," and "mature" ocean paleoenvironmental and geodynamic evolution. The unusually wide marginal plateau between the shelf and the oldest Indian Ocean crust allows study of the structural development of the ocean/continent transition and testing of various tectonic models by geophysical methods and core analysis. This continental margin is associated with a continent which has shed very little post-rift terrigenous material. This and the paleo-water depths (0–4000 m) make it a prime target for detailed studies of biostratigraphy, sediment facies, paleoenvironment, and stratigraphic evolution owing to interplay between subsidence and sea-level fluctuations.

Leg 122 was planned using the drilling proposals by von Rad et al. (1984), von Rad et al. (1986), Arthur et al. (1986), Langmuir and Natland (1986), and Mutter and Larson (1987). Additional drilling proposals for alternative locations for Sites 762 and 763 based on industry multi-channel seismic and well-log data in the region were presented to the JOIDES Safety and Pollution Prevention Panel by Haq and Boyd in 1988. We also relied heavily on the pre-site survey information in the cruise reports of *Sonne* cruise SO-8 (von Stackelberg et al., 1980) and *Rig Seismic* cruises 55 and 56 (Williamson and Falvey, 1988; Exon and Williamson, 1988).

BACKGROUND

Tectonic and Stratigraphic Background

The geological development of the Exmouth Plateau has been discussed by Falvey and Veevers (1974), Veevers and Johnstone (1974), Veevers and Cotterill (1979), Powell (1976), Willcox and Exon (1976), Larson (1977), Exon and Willcox (1978, 1980), Wright and Wheatley (1979), Larson et al. (1979), von Stackelberg et al. (1980), Falvey and Mutter (1981), Willcox (1982), Barber (1982, 1988), von Rad and Exon (1983), Erskine and Vail (1988), and Mutter et al. (1989). The three Exmouth margins abutting oceanic crust (a sheared or transform margin to the south; a rifted and thinned margin to the west; and a mixed rifted and sheared margin to the north) were compared and contrasted by Exon et al. (1982). The structure and evolution of the Argo Abyssal Plain have been discussed by Hinz et al. (1978), Heirtzler et al. (1978), Cook et al. (1978), Veevers et al. (1985a), Veevers et al. (1985b), Audley-Charles (1988), and Fullerton et al. (1989).

The stratigraphy of Exmouth Plateau and Argo Abyssal Plain, as it is currently known, is outlined in Figure 3. Stratigraphic studies have been carried out by Apthorpe (1979), Crostella and Barter (1980), von Stackelberg et al. (1980), Colwell and von Stackelberg (1981), Sarnthein et al. (1982), and von Rad and Exon (1983). Paleontologic and biostratigraphic studies include those by Quilty (1980a, 1980b, 1981), Zobel (1984), and von Rad et al. (in press).

The present structural configuration of the Exmouth Plateau region was initiated in late Permian–Triassic to Jurassic time by rifting between northwest Australia, India, and other smaller Gondwanan fragments, such as South Tibet. The western margin has a normal rifted structure, whereas the southern margin has a transform-dominated structure. The complex rifted and sheared northern margin contains at least

[1] Haq, B. U., von Rad, U., et al., 1990. *Proc. ODP, Init. Repts.*, 122: College Station, TX (Ocean Drilling Program).

[2] Shipboard Scientific Party is as given in the list of Participants preceding the contents.

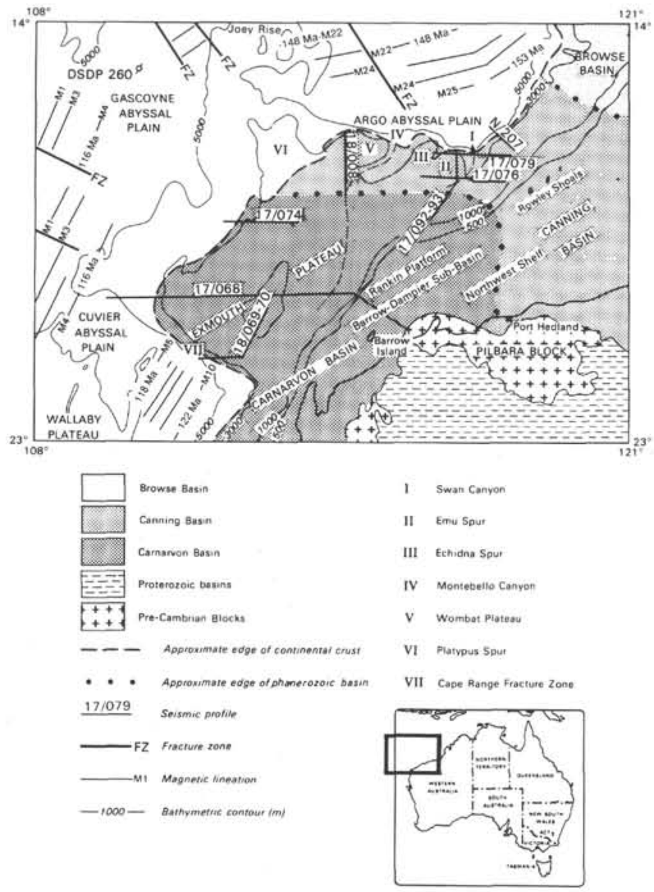

Figure 1. Regional setting of the Exmouth Plateau and its vicinity off northwestern Australia (from Exon et al., 1982). Bathymetry in meters.

one crustal block of post-breakup igneous origin (Exon et al., 1982).

According to Leg 123 results from Site 765 (Gradstein, Ludden, et al., in press), the northern margin of the plateau formed in latest Jurassic to earliest Cretaceous time, when seafloor spreading commenced in the Argo Abyssal Plain. The northeast-trending pattern of seafloor spreading anomalies was initially described by Falvey (1972). The basin age was originally established as Oxfordian-Kimmeridgian on the basis of results from Deep Sea Drilling Project (DSDP) Site 261 (Veevers, Heirtzler, et al., 1974). The magnetic lineations were mapped by Larson (1975), Heirtzler et al. (1978), and Veevers et al. (1985a, 1985b). Latest Triassic to earliest Jurassic intermediate and acid volcanics on the northern margin, which probably overlie a thick Triassic paralic sequence (von Stackelberg et al., 1980; von Rad and Exon, 1983), are most likely related to a major synrift phase.

North of an east-west hinge line, steady subsidence along the incipient northern margin allowed several thousand meters upper Triassic to middle Jurassic carbonates and coal measures to accumulate before breakup (Exon et al., 1982). Breakup occurred along a series of rifted and sheared margin segments; the tectonic setting was further complicated by northeast-trending Callovian horsts and grabens. The horsts were reduced in Jurassic time, and the whole northern margin was covered by a few hundred meters of Cretaceous and Cenozoic pelagic carbonates, as it subsided to its present depth of 2000–5000 m (Figs. 3 and 4).

Throughout the Triassic and Jurassic, pre-breakup rift tectonics affected the entire northeast-trending western margin of the Exmouth Plateau (Falvey and Mutter, 1981). Breakup occurred in the Neocomian, as "greater India" moved to the northwest and seafloor spreading anomalies started to form in the Gascoyne Abyssal Plain (Exon et al., 1982). Normal faults parallel this margin. A thick Triassic paralic sequence is unconformably overlain by a thin, upper Jurassic marine sequence indicating that the area was elevated in the early and middle Jurassic. Thin upper Cretaceous and Cenozoic pelagic carbonates cover the western margin, which now lies more than 2000 m below sea level (mbsl) (Figs. 3 and 4).

The northwest-trending southern margin of Exmouth Plateau formed along an incipient transform in the Neocomian, about the same time as the western margin (Exon et al., 1982). It is cut by northeast-trending normal faults, which formed in the late Triassic and Jurassic, and is paralleled by early Cretaceous (Neocomian) and later normal faults. A thick Triassic paralic sequence on this margin is unconformably overlain by a thick lower Neocomian delta complex (Barrow Delta). This suggests that the area was high in the early and middle Jurassic, but received sediments before and after that time. After mid-Cretaceous times this margin was covered by a thin sequence of pelagic carbonates, which now lie at 1500 mbsl (Fig. 4).

Available Data

Von Stackelberg et al. (1980) reported the results of 30 dredge hauls from the outer slopes of the Exmouth Plateau, mostly from the northern margin (*Sonne* cruise SO-8). More than half contain Jurassic and Triassic pre-breakup shallow-water sediments. Four dredges also contain acid volcanic rocks dated at about the time of rift onset (Triassic/Liassic boundary). This suggests limited continental crustal anatexis at the site of the later continent/ocean boundary.

In 1986, the Australian Bureau of Mineral Resources (BMR) conducted research surveys in the Exmouth Plateau area (Falvey and Williamson, 1986; Exon and Williamson, 1988) to prepare for Leg 122/123 drilling. These included:

1. A two-ship multichannel seismic cruise on the central and southern plateau margin using *Rig Seismic* and *Conrad* with expanded-spread and wide-angle common-depth-point (CDP) seismic profiling techniques. These methods provided reflection and refraction data valuable in interpreting deep crustal structural data.
2. Regional multichannel seismic reflection data collected on the northern and western plateau margins, as well as detailed site surveys for proposed sites EP2A (Site 766), EP9F (Site 764), EP10A (Sites 759/760), EP11B, and AAP1B (Site 765).
3. A heat-flow survey of the central plateau.
4. Dredging and coring on the northern plateau margin. Representative samples of all Mesozoic and younger sequences shown in Figure 3 were recovered. These can be tied into the seismic stratigraphy of Exon et al. (1982) and correlated with the facies of the *Sonne* SO-8 dredge results. The dredges included uppermost Triassic volcanics and shelf carbonates, lower and middle Jurassic shelf carbonates and coal measure lithologies, lower and middle Cretaceous shallow-marine sandstones and marine radiolarian mudstones, and upper Cretaceous and Cenozoic chalks, marls, and pelagic oozes (von Rad et al., in press).

Exploration wells have been drilled on the Exmouth Plateau by Phillips, Esso and BHP (Fig. 2; Barber, 1982, 1988). They resulted in several non-commercial gas finds. The lack of

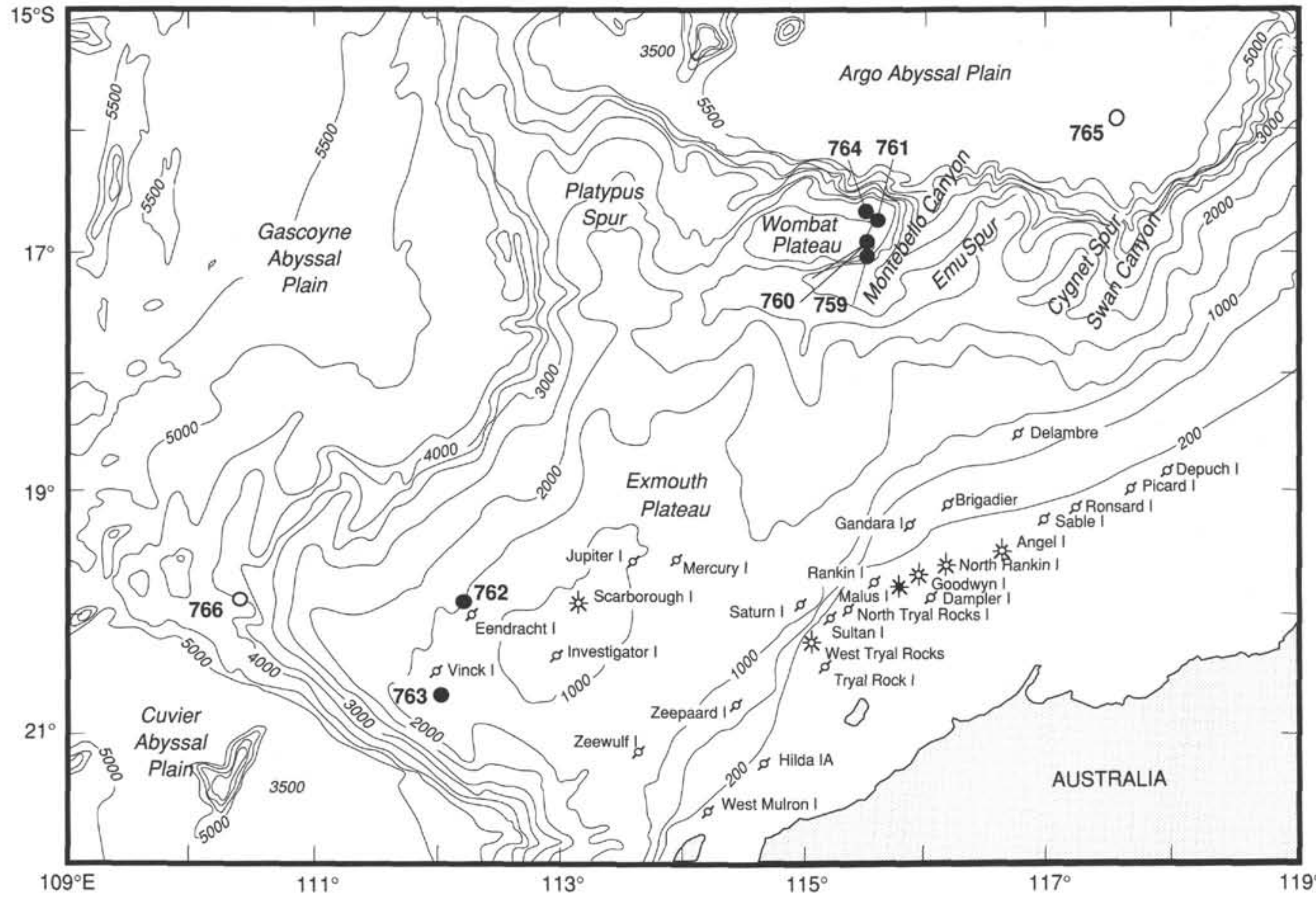

Figure 2. Bathymetric map of Exmouth Plateau with location of ODP sites (solid circles = Leg 122 sites; open circles = Leg 123 sites) and commercial wells. Bathymetry in meters (Exon, unpubl. data).

oil finds has resulted in the cessation of industry drilling and exploration on the plateau. Well logs and sidewall cores collected from these industry wells were used in site selection and are available to aid in the correlation between seismic lines and ODP drill sites. Of special importance for proposed Site EP7V (Site 763) is the information from Vinck-1, and for proposed Site EP12P (Site 762), information from Eendracht-1 (Table 1).

Three DSDP sites were drilled during Leg 27 in the vicinity of Exmouth Plateau (Veevers, Heirtzler, et al., 1974; Table 1):

1. Site 261, Argo Abyssal Plain (total penetration = 580 m), terminated in Oxfordian/Kimmeridgian nannofossil claystone overlying oceanic crust.
2. Site 260, Gascoyne Abyssal Plain (total penetration = 323 m), terminated in Albian radiolarian claystone and nannofossil ooze overlying oceanic crust.
3. Site 263, Cuvier Abyssal Plain (total penetration = 746 m), terminated in Albian-Hauterivian shallow-water quartz-rich silty claystone.

All of these sites were spot-cored, recovering only 18%–22% of the total section.

Exmouth Plateau has been extensively studied by both geological (commercial wells, dredges, some cores) and geophysical methods. Today the plateau has one of the densest seismic grids on any passive continental margin outside the Gulf of Mexico. Seismic control consists of 12,000 km of data from the 1972 BMR continental margin survey, 9300 km of additional industry seismic data collected in 1976 and 1977 (Wright and Wheatley, 1979) and 30,000 km of subsequent petroleum industry seismic data.

A great number of qualitative and semi-quantitative evolutionary models for passive continental margins have been proposed (e.g., Falvey, 1974; Mauffret and Montadert, 1987; Lemoine and Trümpy, 1987). The mechanism of continental margin formation has been described in terms of models that relate cycles of uplift and subsidence to the thermal evolution of continental and oceanic lithosphere (Falvey, 1974).

Recently, Mutter et al. (1989) discussed results of a two-ship seismic reflection and refraction experiment on Exmouth Plateau conducted by Lamont-Doherty Geological Observatory and BMR. They identified large rotated blocks, bounded by deeply penetrating normal faults under the outer plateau, and a set of prominent, subhorizontal, mid-crustal detachment faults under the central plateau. They infer that the deformation of the outer plateau (near Site 762) by lithospheric thinning and "pure shear" (high-angle normal faults, McKenzie-type stretching) postdates the "thin-skinned" deformation with "simple-shear" detachment systems (Wernicke-type deformation) under the central plateau (in the area of Site 763).

DRILLING OBJECTIVES OF LEG 122

The plan to drill a complete Exmouth-Argo transect during Legs 122 and 123 was a major, integrated, scientific venture.

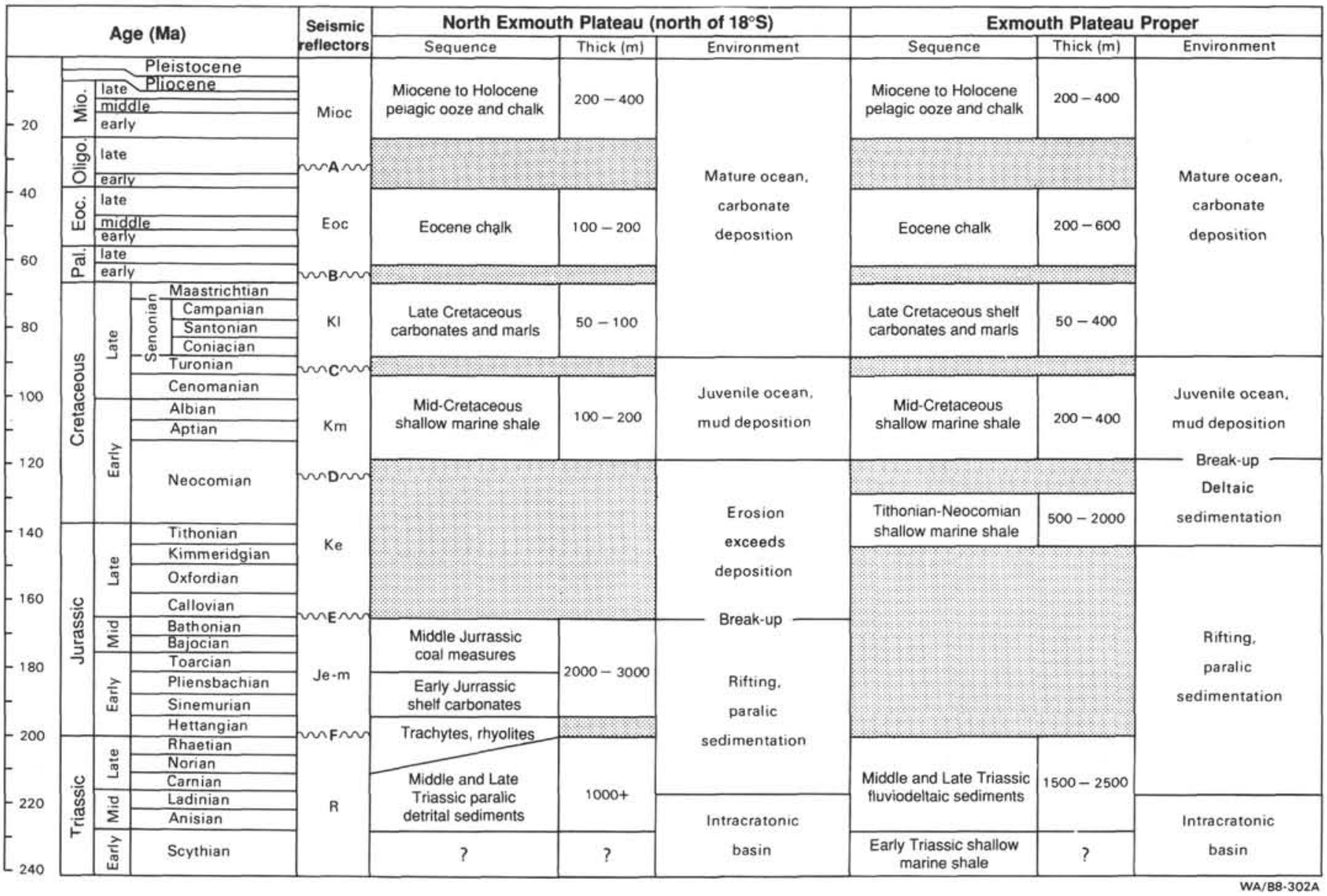

Figure 3. Simplified stratigraphy of Exmouth Plateau, based on seismic and geological evidence. Seismic reflector nomenclature is shown. From Exon et al. (1982).

The following is a list of the major objectives addressed by Leg 122 and Leg 123:

1. To understand the late Triassic–Jurassic pre- and syn-rift history and the rift-drift transition in a starved passive continental margin setting (Sites 759 through 764, and Site 766).
2. To study the Cretaceous to Cenozoic post-breakup development of sedimentation and paleoenvironment from a "juvenile" to a "mature" ocean (Sites 761 through 763, Site 765, and Site 766).
3. To study the temporal and spatial distribution of Jurassic, Cretaceous, and Tertiary depositional sequences in an almost complete, undisturbed, classic passive margin section, in order to evaluate the effects of basin subsidence, sediment input, and sea-level changes (Sites 759 through 764). This would allow the testing of the latest eustatic sea level curve (Haq et al., 1987, 1988).
4. To refine the Mesozoic geological time scale (magneto-, bio-, and chemostratigraphy).
5. To investigate middle Cretaceous anoxic sedimentation in terrigenous, shallow-marine, and deep-marine environments.
6. To document Cretaceous/Tertiary boundary stratigraphy.

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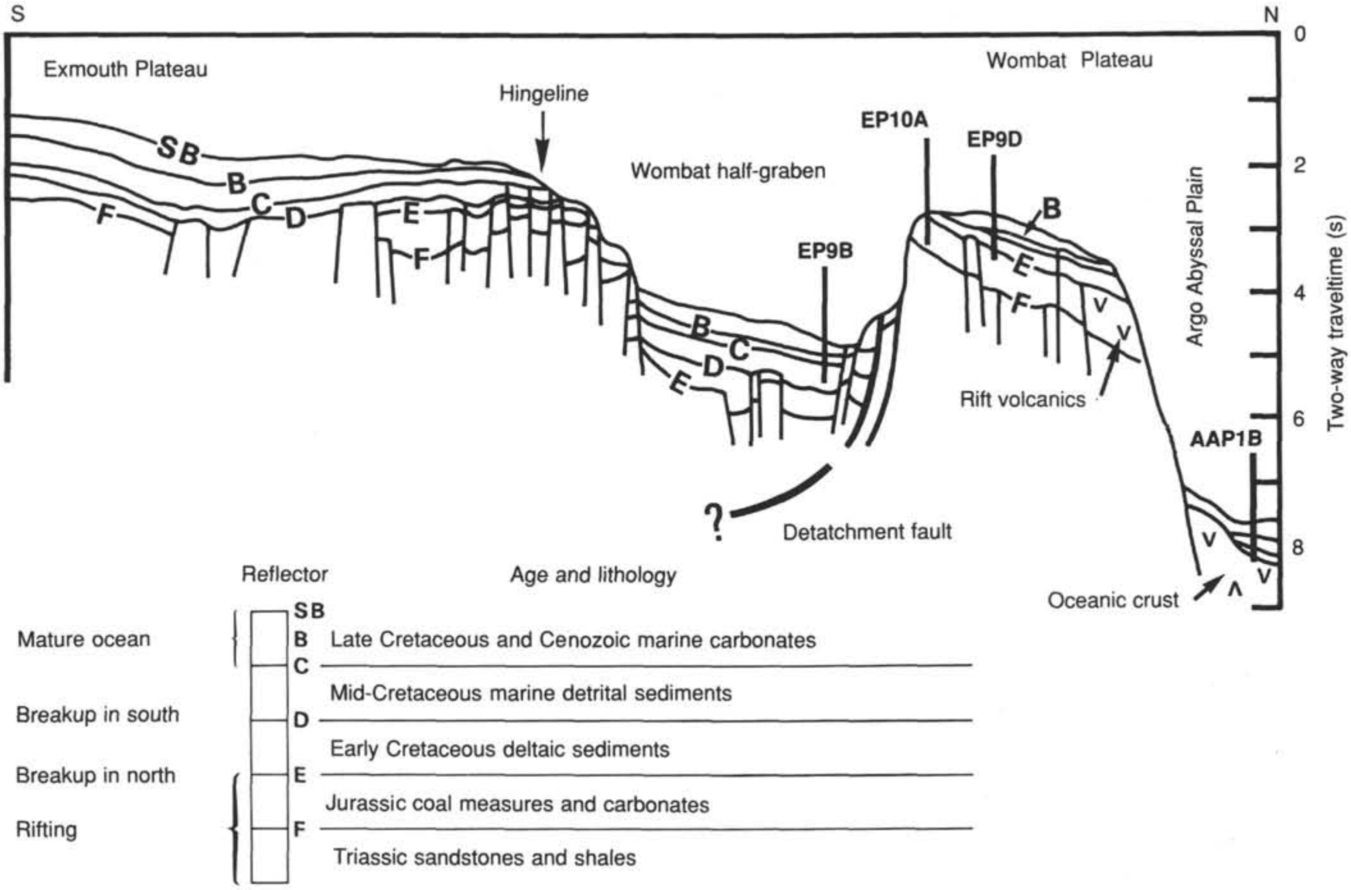

Figure 4. Schematic N-S cross section of northern Exmouth Plateau (Exon, unpublished data) compiled prior to Leg 122, with locations of proposed ODP sites (EP9B, 9D, and 10A).

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Table 1. Data from previous DSDP sites and industry wells near proposed ODP sites.

Site	Latitude	Longitude	Water depth (mbsl)	Total depth (mbsf)	Age, lithology (thickness)			
					Cenozoic	Late to mid-Cretaceous	Early Cretaceous	Jurassic-Triassic
DSDP 260 (Gascoyne Abyssal Plain)	16°8.7′S	110°17.9′W	5702	323	Quaternary-Oligocene(?) zeolitic (nannofossil) clay (140 m)	Coniacian-Maestrichtian nannofossil ooze, nannofossil radiolarian ooze (ca. 80 m)	Albian radiolarian clay, nannofossil ooze (ca. 100 m)	Aptian(?)/Albian oceanic crust (10 m+)
DSDP 261 (Argo Abyssal Plain)	12°56.8′S	117°53.6′W	5667	580	Quarternary–upper Miocene radiolarian clay, nannofossil ooze (ca. 160 m)	Upper–mid-Cretaceous brown/green claystone (200 m)	Hauterivian-Oxfordian nannofossil claystone (170 m)	Oxfordian(?) oceanic crust (50 m+)
DSDP 263 (Cuvier Abyssal Plain)	23°19.4′S	110°58.8′W	5048	746	Quarternary-Tertiary nannofossil clay (ca. 130 m)		Aptian-Neocomian(?) black quartzose claystone (shallow water) (610 m)	
Vinck-1 (near Site 763)	20°35.1′S	112°11.6′W	1373	4600	Marl(?) (ca. 4600)		Berriasian-Valanginian mainly Barrow delta (950 m)	Late Jurassic Dingo claystone (15 m) Rhaetian marl (45 m) Late Triassic Mungaroo Formation (sandstone) (1873 m+) (1933 m total)
Zeewulf-1	21°06.5′S	113°37.2′W	1194	3500	Marl/claystone (590 m)	Late Cretaceous marl/claystone (244 m) Albian (133 m)	Mainly Barrow Delta (sandstone and mudstone) (615 m)	Rhaetian carbonate (5 m) Late Triassic Mungaroo Formation (claystone, siltstone, sandstone) (409 m+) (504 m total)
Eendracht-1 (near Site 764)	19°54.5′S	112°14.6′W	1353	3410	Marl(?) (540 m)	Late–mid Cretaceous siltstone, marl (280 m)	Muderong Shale and Barrow Group (shale and siltstone) (160 m)	Early–Late Jurassic claystone (28 m) Late Triassic marl (47 m) Late Triassic Mungaroo Formation (sandstone) (991 m) (1066 m total)
Investigator-1	20°21.1′S	112°58.0′W	841	3746	Marl(?) (159 m)	Late–mid-Cretaceous marls(?) and siltstone (392 ml)	Mainly Barrow delta (including 100 m Muderong Shale) (siltstone, sandstone and claystone) (1828 m)	Early–Late Jurassic marl and calcareous claystone (59 m) Rhaetian marl (65 m) Late Triassic Mungaroo Formation (382 m) (506 m total)

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