

LEG 182
Great Australian Bight

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GREAT AUSTRALIAN BIGHT

Cenozoic Cool-Water Carbonates

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ABSTRACT

Leg 182 will drill a transect of 10 sites from the shelf-edge (200 m) to the middle continental rise (4465 m) in the western Great Australian Bight. The primary drilling objective is a more detailed understanding of global environmental change in high- to mid-latitude settings. Cores from different facies deposited in various water depths during a range of geologic periods will yield the detailed anatomy of a Cenozoic cool-water carbonate margin. The response of this depositional system to sea-level fluctuations will be compared to records from warm-water, rimmed and unrimmed carbonate platforms to test and refine the global sea-level curve, and most importantly to describe the reaction of cool-water carbonate depositional systems to different phases of the sea-level cycle. Biological and chemical paleoenvironmental proxies will be used to decipher a detailed paleoceanographic record to more precisely describe the timing and paleoceanographic effects of the opening of the Tasman Gateway and the influence of the Leeuwin Current on paleoproductivity over time. The shelf-to-basin transect will also provide high-resolution data on the tempo and pattern of biotic evolution in oceanic and neritic environments.

Secondary objectives are directed toward understanding the hydrology of a carbonate platform adjacent to a vast inland karst with sluggish water circulation, and the nature of early burial diagenesis (lithification and dolomitization) in a cold, seawater-dominated system.

INTRODUCTION

Carbonate sediments and sedimentary rocks contain a particularly sensitive record of paleoceanographic and biostratigraphic evolution. The focus of the Ocean Drilling Program (ODP) carbonate drilling on continental margins to date has largely been in warm-water environments. There is a complete sedimentary realm whose nature and history has not yet been investigated; that of continental margin cool-water carbonates. These sediments, formed where seawater temperatures rarely rise above 20°C, are biogenic sediments which commonly mantle continental margins in mid- and high-latitudes. They are an untapped storehouse of information regarding the evolution of global climates, eustasy, and marine biology.

The southern Australian continental margin is the ideal location to study cool-water carbonate facies and evolution. The shelf has been the site of cool-water carbonate sedimentation since Eocene time, resulting in an almost 1-km-thick succession, and it is now the largest area on the globe composed of such sediments. In addition, slight tectonic tilting in the late Miocene has led to subaerial exposure of Eocene-middle Miocene strata in extensive, shallow basins. These sediments form a more compressed and less continuous section than exists offshore, yet they have permitted the development of actualistic models for the formation and development of these carbonates that can be tested and greatly expanded by drilling.

A critically important benefit of drilling in the Great Australian Bight is that, as the shelf is latitudinally parallel to the southern margin of the Australian plate, the sediments contain a record of the development of the Southern Ocean. In particular, the region offers the potential to collect high-resolution stable isotope and biostratigraphic profiles to clarify several important stages in the evolution of the Southern Ocean.

Drilling in the Great Australian Bight will also provide essential and original information on the contrast between the sedimentological, paleontological, paleoceanographic, and climatic records from warm- and cool-water realms, and will allow the development of well-constrained and much needed models that can be used in the interpretation of older Mesozoic and Paleozoic continental

margin carbonate systems.

BACKGROUND

Tectonic Setting

The southern margin of the Australian continent is a divergent, passive continental margin that formed during the protracted period of extension and rifting that led to the separation of Australia and Antarctica in the Cretaceous, and evolved during the subsequent northward drift of the Australian continent. The initial extension phase prior to breakup in the mid-Cretaceous (96 Ma), together with the following period of slow spreading (until the middle Eocene—49 Ma), resulted in deep continental margin basins filled with up to 12 km of mainly terrigenous clastic sediments (Willcox et al., 1988; Davies et al., 1989). These basins broadly correspond to the sites of modern upper slope terraces (e.g., the Eyre Terrace at 400-1600 m depth in the western Great Australian Bight; Fig. 1). The onset of faster spreading in the middle Eocene also corresponded with establishment of fully marine conditions, and initiation of carbonate sedimentation in the widening 'gulf' between Australia and Antarctica. Carbonate sedimentation continued throughout the remainder of the Cenozoic, as the gulf evolved first into a broad, open seaway, and then into the modern Southern Ocean. Cenozoic sedimentation resulted in an extensive, relatively thin (up to 800 m thick; Feary and James, in press) Eucla Basin succession deposited in a predominantly platform-sag to platform-edge tectonic regime (Stagg et al., 1990).

Throughout the Cenozoic, the western Great Australian Bight portion of Australia's southern continental margin has been particularly stable, with geohistory analysis of the Jerboa-1 well indicating minimal Tertiary subsidence (Hegarty et al., 1988). Slight regional tilting (<1°) in the middle Miocene resulted in uplift and exposure of the Nullarbor Plain, and restriction of Neogene sedimentation to the modern outer shelf and upper slope.

Cenozoic Stratigraphy of the Eucla Basin

The Eucla Basin extends inland up to 350 km from the present coastline, and seaward some 200

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km to the modern shelf edge and upper slope. Inland, the Eucla Basin succession thins and 'feathers' out against Precambrian basement; it gradually thickens southward to be thickest beneath the modern shelf edge (Fig. 2). Apart from the basal siliciclastic sequence both offshore (Sequence 7) and onshore (Hampton Sandstone), and a thin, transgressive, paleovalley-filling and strandline succession of terrigenous clastics on the inland margins of the basin, the Eucla Basin succession is entirely carbonate.

The succession is basically divisible into two mega-sequences; a Mesozoic (?Late Jurassic-Cenomanian; Stagg et al., 1990) siliciclastic-dominated syn- to early post-rift section and a Cenozoic (Paleocene to Holocene), predominantly carbonate-dominated section, separated by a major, basin-wide unconformity. The subject of the bulk of this drilling leg is the upper succession, which makes up an overall sigmoid-shaped series of sequences reaching a maximum thickness beneath the present-day outer shelf (Fig. 2). The stratigraphy of the lower, Mesozoic succession can be derived from the sequence intersected in the Jerboa-1 exploration well (Fig. 1); however little information on the upper, Cenozoic section can be obtained from this hole.

The extensive erosional unconformity at the top of the synrift section forms an easily recognizable and mappable surface. Seven unconformity-bounded seismic sequences have been recognized overlying this unconformity (Fig. 2). One of the most striking elements of this seismic stratigraphic analysis is the identification of numerous mound-shaped structures, occurring throughout the Cenozoic succession, which have been interpreted as biogenic mounds (Feary and James, 1995). These structures are likely to preserve a detailed record of cool-water faunal community relationships, and potentially provide an analogue for cool-water mounds recognized in the rock record, but for which no modern analogues have previously been identified.

The ages assigned to this succession are extremely tentative, and are based on: (1) correlation of Sequence 6B with the onshore Eucla Group (Fig. 2); (2) the similarity in depositional style between the Sequence 7 progradational wedge and ?Paleocene-early Eocene progradational sequences elsewhere along Australia's southern margin; and (3) the division of the remainder of the sequences into a reasonable time-stratigraphic framework. On this basis, the offshore sequences can be placed

in a stratigraphic framework (based on Feary and James, in press):

- Sequence 7: Paleocene-middle Eocene progradational siliciclastic wedge deposited in a depositional sag, representing initial transgressive sedimentation.
- Sequence 6A: middle-late Eocene to early-middle Miocene deep-water carbonates forming a multilobed sediment apron.
- Sequence 6B: cool-water ramp carbonates with biogenic mounds (middle-late Eocene to Oligocene), overlain by an upper, warm-water, flat-topped platform rimmed by the ?early-middle Miocene "Little Barrier Reef" (Feary and James, 1995).
- Sequence 5: small late middle Miocene lowstand sediment wedge with restricted distribution, lying at the foot of the steepest part of the progradational carbonate shelf escarpment zone.
- Sequence 4: extensive late Miocene aggradational deep-water carbonate ramp sequence.
- Sequence 3: latest Miocene and early Pliocene highstand aggradational deep-water carbonate ramp sequence.
- Sequence 2: thick succession of highstand, Plio-Pleistocene cool-water carbonates with spectacular clinof orm ramp geometry that forms most of the modern outer shelf, and contains large deep-water biogenic mounds.
- Sequence 1: thin Quaternary deep-water drape.

Existing Data

Present knowledge of the western Great Australian Bight margin is based on extensive, high-quality seismic reflection data, together with a single oil exploration drillhole which provides little information about the Cenozoic succession. The original Leg 182 drilling proposals (James and Feary, 1993; Feary et al., 1994) were based on detailed seismic stratigraphic interpretation (Feary and James, in press) of a grid of 2,350 km of high-quality, regional 2-D seismic reflection lines. These lines were collected and processed by the Japan National Oil Corporation (JNOC) in 1990/1991, over an area of 155,000 km² on the continental shelf and upper slope of the western Great Australian Bight. An additional 1380 km of moderate-quality regional 2-D seismic lines, collected by Esso Australia in 1979 and reprocessed by JNOC, were also used to fill gaps in the

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JNOC dataset. The 1996 seismic-site survey cruise (Feary, 1995) collected high-resolution, 80-channel GI-gun seismic data as 0.5 nmi-spaced grids centered on each site, together with tie-lines between sites. These data permitted minor refinements of some site locations to avoid potential safety concerns.

Jerboa-1 was drilled by Esso/Hematite in 1980, as a wildcat oil exploration well in 761-m water depth, above a prominent tilted basement fault block located in the southern half-graben of the Eyre Sub-basin (Bein and Taylor, 1981). Jerboa-1 penetrated 1738 m of a Cenozoic and Cretaceous sedimentary section before bottoming in Precambrian metabasalt basement, and did not encounter any significant hydrocarbon shows. The top 232 m were washed down and cased, so that only 145 m of Tertiary section were actually drilled and logged. No cores were cut in this interval, so lithological and biostratigraphic inferences are based on cuttings and downhole logs. Thermal modelling and vitrinite data (Stagg et al., 1990) indicate that the entire sedimentary section at Jerboa-1 is thermally immature ($R_v < 0.65\%$).

SCIENTIFIC OBJECTIVES

Leg 182 drilling in the Great Australian Bight will allow six fundamental scientific topics to be addressed:

1. The paleoceanographic history of a carbonate-dominated, mid-latitude continental margin and adjacent basin during evolution of the Southern Ocean. As the Southern Ocean is one of the major controlling influences on global circulation and climate, it is imperative that the oceanic history of this region be refined as much as possible. However, at present the paleoceanographic development of this area is not nearly as well known as that of the high-latitude North Atlantic (Kennett and Barron, 1992). Although there are numerous paleoceanographic problems that can be answered by the Leg 182 drilling transect, four stand out as critical.

(a) *The relationship between circulation patterns in the deep ocean and on the shelf during times*

of warm vs. cold ocean conditions. The stratigraphic record in the Southern Ocean is punctuated with numerous breaks in sedimentation that are attributed to erosive periods, related to increased circulation during initiation of the Circum-Antarctic Current (Miller et al., 1987; Kennett and Barker, 1990). Although such hiatuses are thought to develop on deep margins during times of lower sea level and to correlate with unconformities on the continental shelf, there are apparently continuous onshore sequences of Oligocene shelf carbonates deposited while there was erosion or nondeposition of the entire Oligocene on the adjacent ocean floor.

(b) *The precise timing and nature of the opening of the Tasman Gateway.* Subsidence of the Tasman Rise, which permitted initiation of the cold circum-Antarctic circulation and thermal isolation of Antarctica, is one of the most important developments in Cenozoic paleoceanography (Kennett, 1982). The history of this event is poorly constrained because so much of the oceanic record is missing due to seafloor erosion. The Leg 182 shelf-to-basin transect is sufficiently proximal to the Tasman Rise that it should contain an excellent record of the paleoceanographic development of this seaway.

(c) *The evolution and effect of the Leeuwin Current.* The first evidence for the existence of the Leeuwin Current occurs in middle Eocene time, when currents from the Indian Ocean were deflected into the elongate proto-Great Australian Bight embayment. In support of this, the record of warm-water intervals is more common in the west than it is in the east, implying that the source of the water is from the west. Studies of Quaternary cores from the Great Australian Bight suggest a complex interplay between the Leeuwin Current and the West Wind Drift. This interplay appears to have had dramatic effects on primary productivity, as the Leeuwin Current is a source of warm oligotrophic waters, while the West Wind Drift causes upwelling of cooler eutrophic waters.

(d) *The relationship between primary productivity and cool-water carbonate development.* The Leg 182 shelf-to-basin transect should contain an important record of paleoproductivity linked to upwelling. Such periods should be recorded in the biota by low species diversity, high numbers of individuals, increased sedimentation rate, and distinctive changes in stable-isotopic and trace-

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element compositions.

2. *The formulation of models for carbonate sedimentation on continental margins bathed predominantly by cool oceanic waters.* The deposition and accumulation of platform (neritic) carbonate sediments under cool-water ($\sim < 20^{\circ}\text{C}$) conditions is poorly understood compared to warm-water carbonates, primarily because the database is so small (Nelson, 1988; James and Kendall, 1992). Yet, because of their dominantly skeletal composition, nutrient-dependent biology, and low diagenetic potential, cool-water carbonates record the history of oceanic change in ways that are profoundly different from tropical carbonates. In hydrodynamic terms, cool-water carbonate shelves are hybrids, possessing some of the characteristics of both terrigenous clastic shelves and warm-water carbonate shelves. Sediments are produced on the shelf, in contrast to terrigenous clastic shelves where sediment is transported onto the shelf from the hinterland. Without the elevated rim that typifies warm-water carbonate shelves, however, the sediments are subject to the full sweep of oceanic waves and swells, as they are on terrigenous clastic shelves. Cenozoic exposures of inner-shelf facies in Australia suggest that storm- and wave-dominated processes tend to control deposition. By contrast, many contemporaneous deposits in New Zealand are clearly tide-dominated. Are the models of wave-dominated shelf deposition developed onshore applicable throughout the Cenozoic? All seismic profiles across the southern margin of Australia indicate that a large proportion of the youngest part of the succession is made up of prograding clinoforms (James and von der Borch, 1991; Feary and James, in press). Such clinoforms seem to be a signature of cool-water platforms and ramps, and are postulated to be a product of accumulation dynamics (Boreen and James, 1993). There is little information regarding the composition of these deposits; specifically, are they produced by in-place, enhanced bioproduction along the shelf edge, or are they made up of finer grained material produced on the shelf and swept offshore to accumulate below wavebase?

3. *Determination of the Southern Ocean basin sea-level record, and the effect of sea-level fluctuations on stratigraphic packaging and early diagenesis of cool-water carbonates.* The Eucla margin is rich in biogenic carbonate sediments that respond in a sensitive way to variations in sea level, and contain vital geochemical information needed for linking sea-level changes to

paleoceanography. This information can then be utilized to address two major questions of global and temporal significance.

(a) *What is the detailed sea-level history of the Southern Ocean basin, and can it be linked to paleoceanographic variations?* Specifically, the southern Australian neritic shelf record, derived largely from onshore successions in which the marine record is preserved only in highstand systems tracts, appears to be at odds with the global model (Haq et al., 1987) during several critical periods. Is this because the sediments were deposited in cool-water? By using a combination of physical stratigraphy and proxy paleoenvironmental parameters, in a much more expanded section than exists onshore, the well-preserved Eocene to Oligocene and early to middle Miocene successions will permit a thorough testing of this part of the sea-level curve and resolution of specific eustatic events. The late Miocene to Pliocene sequence is unknown onshore except for the early Pliocene highstand, and so this will be the first clear record of this component of the sea-level record in the region.

(b) *How do cool-water carbonate platforms respond to changes in sea level?* Carbonate platforms, with their chemically metastable sediments born largely in place, are particularly responsive to changes in seawater temperature and chemistry and variations in sea state and sea level. To date, most information on carbonate platforms comes from rimmed, warm-water platforms (Kendall and Schlager, 1981; Sarg, 1988). There is almost no information on the manner in which cool-water carbonate platforms respond to changes in these critical parameters at a variety of different time scales. Specifically, we require information describing how different segments of the shelf react during different parts of the sea-level cycle, and to determine whether cold- and warm-water carbonate platforms have basically different depositional geometries as a result of the different ways the carbonate factory responds to sea-level changes.

4. *The circulation patterns of shallow subsurface fluids in an area of low hydraulic gradient and minimal recharge.* The Eucla margin is one of the few modern shelves where the onshore recharge zone is an areally vast, flat-lying karst (the Nullarbor Plain). The high primary depositional permeability of winnowed grainstones of the Eucla Shelf, and the lack of early cementation,

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suggest that significant groundwater circulation may occur, at least at shallow depths. The drive for such a circulation may come from temperature contrasts between cool ocean waters and groundwaters warmed by geothermal heat flux (and possibly volcanics) within the shelf, concentrating waters on the shelf margin (Simms, 1984). Alternatively, despite inland aridity, recharge occurring over the vast continental hinterland may drive brackish to saline waters southward to discharge through the flooded shelf. Such a circulation has been recognized by James (1992), and is associated with cave development on the Nullarbor Plain (James et al., 1989). In contrast to the long-lived nature of the above systems, differences in sea-surface elevation, on and off the shelf, associated with regional wave buildup (Feary, 1995), current flow (Rockford, 1986), and atmospheric pressure system changes may cause pumping of marine waters into and out of the platform (Marshall, 1986).

5. Early seafloor and shallow burial diagenesis and dolomitization of calcite-dominated sediments.

Cool-water carbonates exhibit a radically different pattern of diagenesis to that of tropical aragonitic carbonates. Slow sedimentation permits seafloor lithification by intermediate Mg-calcite cements, but these appear to be volumetrically limited and localized to omission surfaces and hardgrounds, which are ubiquitous in the inner platform. Indeed, both shallow marine and meteoric cements appear to be very sparse, with magnesium being lost from high-Mg calcite to low-Mg calcite during grain recrystallization. Sparse calcium-rich dolomites may be present (Reeckmann, 1988; Bone et al., 1992), and at some locations replacement can be pervasive (James et al., 1993), although the fine subtidal evaporation related dolomites typical of tropical platforms are absent. It is not known whether dolomitization is episodic, as recognized in other present-day platforms (Vahrenkamp, et al. 1991; McKenzie et al., 1993), or occurred over extended time periods. The Eucla margin carbonates will provide an opportunity to determine the present-day associations between groundwater circulation, fluid geochemistry, and diagenetic products, and by inference from the temporal and spatial distribution of ancient diagenetic components, those that occurred under different conditions in the past. This has the potential to provide fundamental insights into the diagenesis of cool-water, open-shelf carbonates, which are direct analogues for the comparable carbonate platforms that were ubiquitous during Paleozoic and other times.

6. *The pace and style of evolution of mid-latitude oceanic and neritic biotas.* The Leg 182 drilling transect offers the opportunity for pioneering analysis of the Cenozoic evolution of cool-water calcareous biota, with direct applicability to studies of ancient carbonate platforms presently lacking modern analogues. Linked information from the neritic and oceanic high- to mid-latitude carbonate realm should produce an unmatched record of paleobiological information. Specifically, the patterns and modes of speciation and diversification of coeval shallow- and deep-water benthic organisms as well as contemporaneous planktonic biota should be revealed. By comparing these results with those from Antarctica and the northeast Australian shelf, the geography of such processes and their relationship to physiochemical factors should be discernible.

DRILLING STRATEGY

The Leg 182 drilling strategy must be developed with the knowledge that although ODP has great experience with drilling deep-water pelagic carbonates, it is difficult to predict drilling conditions in the cool-water carbonates at the shallower sites. Accordingly, operational considerations may dictate that significant changes to drilling strategies are necessary on site. In particular, although easily drilled nanno-foram and foram-nanno oozes are expected to dominate the upper sequences at each site, there is the possibility that thin bioclastic grainstone horizons and/or thin chert horizons may complicate drilling at the shallowest sites. In addition, the order in which sites are drilled will need to be flexible, to accommodate operational restrictions dependent on sea state for the sites in less than 650-m water depth (Sites GAB-05B, GAB-06B, GAB-07A, GAB-08A, and GAB-09A). This will be particularly important for the sites located in less than 300-m water depth (Sites GAB-06B and GAB-09A), where calm conditions will be imperative.

Triple coring with the advanced hydraulic piston corer (APC), extended core barrel corer (XCB), and rotary core barrel corer (RCB) will be carried out at the four high-resolution paleoceanography and sea-level sites (Sites GAB-01C, GAB-02B, GAB-06B, and GAB-13B), which comprise the shelf-to-basin transect (water depth range of 332-4465 m). After the cores and downhole logs have been tied to the extensive seismic data in the area, these sites will provide the fundamental basis for

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regional stratigraphic and lithologic characterization. Lithologies intersected at all these sites should pass from carbonate oozes in the upper part of the holes down into more indurated calcareous siliciclastic sediments at the base. The 500- to 600-m high-resolution records of Plio-Pleistocene sea-level fluctuations within carbonate oozes targeted at Sites GAB-07A, GAB-08A, and GAB-09A should be achievable with double APC and XCB drilling, with triple APC at Site GAB-08A providing additional resolution as the shallowest (uppermost slope) component of the shelf-to-basin transect.

The sites predominantly targeting cool-water carbonate facies objectives (Sites GAB-03B, GAB-04B, and GAB-05B) should be drilled using double APC and XCB, with the deeper (Cretaceous) parts of Site GAB-04B possibly requiring RCB and the siliciclastic sequence in the deeper part of Site GAB-05B certainly requiring RCB.

Direct seismic ties connecting the dry oil exploration well Jerboa-1 (Fig. 1) to all sites except Site GAB-01C and GAB-13B demonstrate that there is negligible likelihood of encountering hydrocarbons, and vitrinite reflectance data show that most or all of the sedimentary succession underlying these shallower sites is thermally immature. Water depths at Sites GAB-01C (3884 m) and GAB-13B (4465 m) are too great for any significant safety risks.

LOGGING PLAN

All sites should be logged with standard logging tool strings (Triple-combo, Formation MicroScanner [FMS]/Sonic), together with deployment of the well seismic tool (WST), Geological High-sensitivity Magnetometer tool [GHMT], and geochemical logging tool (GLT) at selected sites. The geophysical logs (Triple-combo) will be important for evaluating the lithostratigraphic response of cool-water carbonates to sea-level and climatic fluctuations. The fine-scale characteristics of the bedding, including pore spaces, bioturbation, fractures and stylolites may be imaged through FMS.

Integrated interpretation of FMS and geophysical logs should provide a good complement to cores in describing the lithostratigraphy. Diagenesis in carbonates usually is well expressed through changes in porosity and chemical precipitation of soluble elements (such as uranium), leading to large changes in log properties seen on sonic, resistivity, density, and neutron logs, as well as gamma-ray logs. Thus, the diagenetic changes in the carbonate sediments, another key objective of the leg, may be evaluated through the petrophysical response measured in the wireline logs. Magnetostratigraphic characterization at selected deeper penetration sites using the GHMT string should also contribute to the sedimentary/stratigraphic objectives and intersite correlation.

Interstitial fluid characterization from cores will be the primary tool for the fluid-flow objectives, with logging data being of secondary importance. However, the assessment of fracture networks and basic fluid properties using sonic and resistivity logs, together with FMS images and GLT profiles at selected sites, should provide an important contribution to this leg objective.

A detailed correlation between cores/logs and the extensive suite of high-quality seismic reflection data, including the closely-spaced site survey grids and regional 2-D lines, will be critical for understanding the three-dimensional architecture of the Cenozoic sequences and compiling a detailed sequence stratigraphy. Accordingly, check-shot (WST) surveys, at 50-m spacing, should also be run at all sites except Site GAB-08A (where data from adjacent Sites GAB-07A and GAB-09A will be applicable).

PROPOSED SITES

Sites GAB-01C, GAB-02B, and GAB-13B

Sites GAB-01C (southern Australian upper continental rise), GAB-02B (mid-upper slope), and GAB-13B (middle continental rise) are paleoceanographic sites located to intersect pelagic sections that collectively span the entire Cenozoic succession, and a substantial part of the Late Cretaceous section. These sites comprise the deeper water component of the shelf-to-basin transect. The principal objective at these sites is to obtain a complete record of the Cenozoic section in a deep oceanic setting, with the principal aim of elucidating the evolution of the circum-Antarctic Current

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within the evolving seaway between Australia and Antarctica. As the condensed section in the Jerboa-1 well contains early Oligocene faunas, there is a high probability that the intermediate and deep pelagic successions will together contain a more expanded record of this critically important time of Antarctic ice-cap evolution and Southern Ocean paleoceanographic development.

Sites GAB-03B and GAB-04B

Sites GAB-03B and GAB-04B are located to intersect the Eocene to early middle Miocene section deposited in lobes on the upper slope, coeval with deposition of the extensive carbonate platform on the continental shelf. In addition, these sites will also intersect an early Neogene succession poorly sampled at other sites; a highly condensed late Neogene succession; and the upper part of the marine Cenomanian section at Site GAB-04B. The principal objective at these sites is to collect a detailed record of Paleogene-early Neogene temperate to subtropical, mid-latitude sedimentation in an upper slope environment; and to recover a record of marine flooding of the evolving rift basin in the Cenomanian (Site GAB-04B).

Sites GAB-05B and GAB-06B

Sites GAB-05B and GAB-06B are located to intersect distal (Site GAB-05B) and proximal (Site GAB-06B) parts of the Paleocene to middle Eocene progradational siliciclastic wedge. In addition, these sites will intersect a major portion of the overlying Neogene succession (Seismic Sequences 2 to 4). The principal objective at these sites is to recover a detailed record of shelf-edge siliciclastic deposition to evaluate the sedimentary response to Paleogene sea-level fluctuations; and to evaluate the complex interaction between sea-level variation, accommodation space, and subsidence evident in stratal patterns.

Sites GAB-07A to GAB-09A

Sites GAB-07A, GAB-08A, and GAB-09A will intersect a spectacular set of late Neogene (?Plio-Pleistocene) clinoforms immediately seaward of the present-day shelf edge. Site GAB-07A will intersect the lowest, more condensed portion of the clinoform sequence, but will also have the best record of the youngest clinoforms; Site GAB-08A will intersect a ?Pleistocene-Holocene biogenic mound immediately below the seafloor, together with the best record of the middle part of the clinoform sequence; and Site GAB-09A will intersect a buried biogenic mound originally formed

immediately below the paleoshelf edge, together with the best record of the oldest part of the clinoform sequence. The principal objective at these sites is to collect detailed, high-resolution profiles through a late Neogene shelf-edge (high energy) to upper slope (low energy) succession deposited within a cool-water carbonate environment to determine the response of such a depositional system to Plio-Pleistocene sea-level fluctuations.

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TABLE 1

PROPOSED SITE INFORMATION AND DRILLING STRATEGY

SITE: GAB-01C	PRIORITY: 2	POSITION: 34°23.4672'S, 127°35.4393'E
WATER DEPTH: 3884 m	SED THICKNESS: ≈5950 m	TOTAL PENETRATION: 615 m
SEISMIC COVERAGE: Intersection of AGSO Lines 169/08 (SP 729.5) and 169/11 (SP 1962.5)		

Objectives: (1) Recover pelagic ooze from the upper continental rise to construct a Cenozoic and Late Cretaceous paleoceanographic record of the opening of the Southern Ocean and development of the circum-Antarctic Current. (2) Determine the history of Cenozoic and Late Cretaceous CCD fluctuations and deep-water mass variations during the evolution of the Southern Ocean (in conjunction with Sites GAB-02B and GAB-13B). (3) Determine depositional and diagenetic facies on the upper continental rise.

Drilling Program: Triple APC, XCB, RCB

Logging and Downhole Operations: Triple Combo, FMS/Sonic, WST, GHMT

Nature of Rock Anticipated: Nanno-foram ooze and chalk (590 m), sandstone (24 m); volcanics (1 m)

SITE: GAB-02B	PRIORITY: 1	POSITION: 33°32.3730'S, 128°54.3002'E
WATER DEPTH: 1043 m	SED THICKNESS: ≈4600 m	TOTAL PENETRATION: 1710 m
SEISMIC COVERAGE: Intersection at SPs 428 and 3550 on AGSO Line 169/07		

Objectives: (1) Recover pelagic ooze from the middle-upper slope to construct a Cenozoic and Late Cretaceous paleoceanographic record of the opening of the Southern Ocean and development of the circum-Antarctic Current. (2) Determine the history of Cenozoic and Late Cretaceous CCD fluctuations and intermediate-water mass variations during the evolution of the Southern Ocean (in conjunction with Sites GAB-01C and GAB-13B). (3) Determine depositional and diagenetic facies on the middle-upper slope.

Drilling Program: Triple APC, XCB, RCB

Logging and Downhole Operations: Triple Combo, FMS/Sonic, WST, GHMT, Geochem

Nature of Rock Anticipated: Nanno-foram ooze and chalk with minor wackestone (1400 m); indurated sandy calcareous mudstone (310 m)

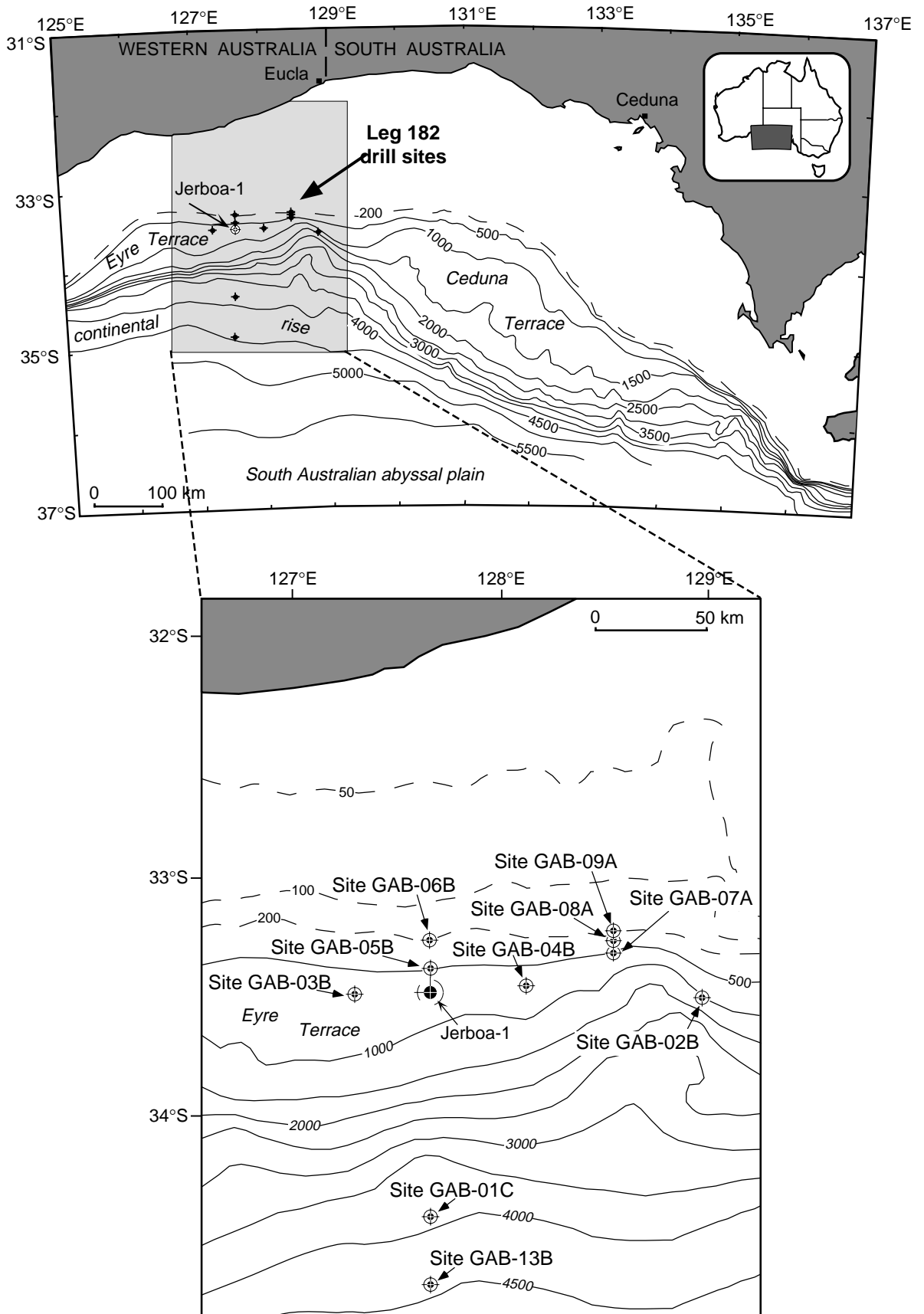


Figure 1. Location of the proposed ODP drill sites in the western Great Australian Bight.

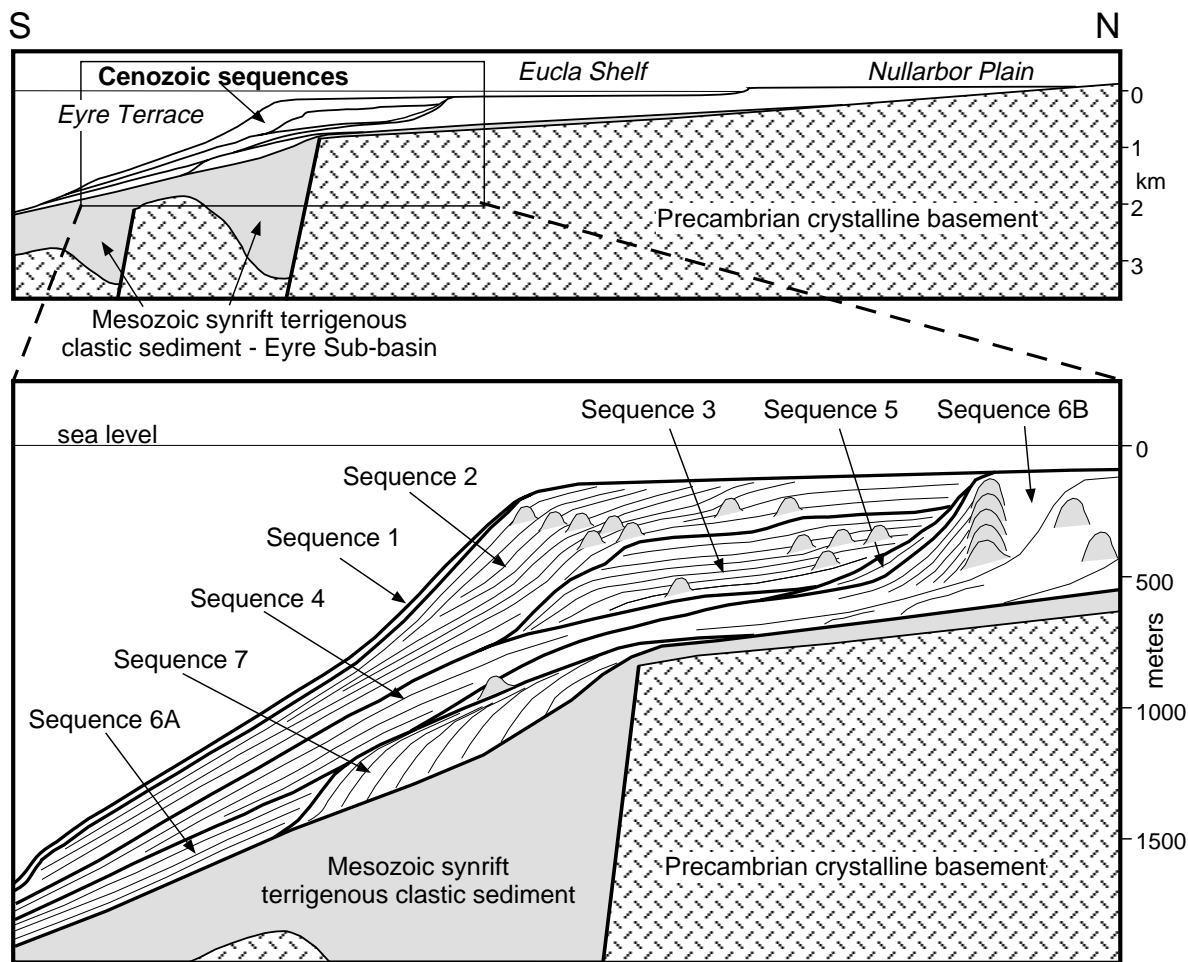


Figure 2. Schematic N-S diagram from the Nullarbor Plain to the upper continental slope, across the Eyre Terrace (along longitude 128°E), showing the distribution and internal relationships of seven Cenozoic sequences (unshaded) defined from seismic data, overlying Mesozoic synrift siliciclastic sequences and Precambrian crystalline basement (after Feary and James, in press). Vertical scales are approximate.

SITE: GAB-03B	PRIORITY: 1	POSITION: 33°31.7255'S, 127°15.8565'E
WATER DEPTH: 704 m	SED THICKNESS: ≈2830 m	TOTAL PENETRATION: 510 m
SEISMIC COVERAGE: Intersection at SPs 1668.5 and 4696 on AGSO Line 169/01		

Objectives: (1) Collect a detailed record of Paleogene-early Neogene temperate to subtropical, mid-latitude sediments deposited as lowstand sediment lobes in an upper slope environment. (2) Contribute to the upper slope component of the shelf-to-basin paleoceanographic transect. (3) Evaluate sea-level control on Neogene facies within an upper slope setting; in particular, to evaluate stratigraphic response to eustatic oscillations by comparison with equivalent time intervals in shelf and deep oceanic settings. (4) Determine diagenetic history and processes within Neogene upper slope facies.

Drilling Program: Double APC, XCB, ?RCB

Logging and Downhole Operations: Triple Combo, FMS/Sonic, WST

Nature of Rock Anticipated: Nanno-foram ooze and chalk with minor wackestone (320 m); sandy calcareous mudstone (190 m)

SITE: GAB-04B	PRIORITY: 1	POSITION: 33°30.5568'S, 128°03.9950'E
WATER DEPTH: 790 m	SED THICKNESS: ≈950 m	TOTAL PENETRATION: 540 m
SEISMIC COVERAGE: Intersection at SPs 1131.5 and 3209.5 on AGSO Line 169/03		

Objectives: (1) Collect a detailed record of Paleogene-early Neogene temperate to subtropical, mid-latitude sediments deposited as lowstand sediment lobes in an upper slope environment. (2) Contribute to the upper slope component of the shelf-to-basin paleoceanographic transect. (3) Evaluate sea-level control on Neogene facies within an upper slope setting; in particular, to evaluate stratigraphic response to eustatic oscillations by comparison with equivalent time intervals in shelf and deep oceanic settings. (4) Determine diagenetic history and processes within Neogene upper slope facies. (5) Collect a record of marine flooding of the evolving rift basin between Australia and Antarctica from the Cenomanian.

Drilling Program: Double APC, XCB

Logging and Downhole Operations: Triple Combo, FMS/Sonic, WST

Nature of Rock Anticipated: Nanno-foram ooze and chalk with minor wackestone (330 m); sandy calcareous mudstone (210 m)

SITE: GAB-05B	PRIORITY: 1	POSITION: 33°25.2122'S, 127°36.1382'E
WATER DEPTH: 488 m	SED THICKNESS: ≈3910 m	TOTAL PENETRATION: 580 m
SEISMIC COVERAGE: Intersection at SPs 995 and 13195 on AGSO Line 169/13		

Objectives: (1) Recover a detailed record of shelf-edge siliciclastic deposition (at a 'distal' site compared with Site GAB-06B) in order to evaluate the sedimentary response to Paleogene sea-level fluctuations, and to evaluate the complex interaction between sea-level variation, accommodation space, and subsidence. (2) Determine the characteristics of cool-water carbonate facies within the Neogene succession (Sequences 2 to 4). (3) Determine paleoceanographic parameters within a shelf-edge setting in Sequences 2 to 4, to complement other components of the shelf-to-basin transect. (4) Evaluate sea-level control on Neogene facies within an upper slope/shelf-edge setting (cf. Sites GAB-03B and GAB-04B). (5) Evaluate the diagenetic history and processes within Neogene facies in an upper slope/shelf-edge setting.

Drilling Program: Double APC, XCB, RCB

Logging and Downhole Operations: Triple Combo, FMS/Sonic, WST, GHMT, Geochem

Nature of Rock Anticipated: Nanno-foram ooze/chalk and wackestone with minor grainstone (350 m); interbedded calcareous mudstone and sandstone (230 m)

SITE: GAB-06B	PRIORITY: 1	POSITION: 33°18.9842'S, 127°36.1287'E
WATER DEPTH: 220 m	SED THICKNESS: ≈1405 m	TOTAL PENETRATION: 695 m
SEISMIC COVERAGE: Intersection at SP's 1916 and 7400 on AGSO Line 169/13		

Objectives: (1) Recover a detailed record of shelf-edge siliciclastic deposition (at a 'proximal' site compared with Site GAB-05B) to evaluate the sedimentary response to Paleogene sea-level fluctuations, and to evaluate the complex interaction between sea-level variation, accommodation space, and subsidence. (2) Determine the characteristics of cool-water carbonate facies within the Neogene succession (Sequences 2 to 4). (3) Determine paleoceanographic parameters within a shelf-edge setting in Sequences 2 to 4, to complement other components of the shelf-to-basin transect. (4) Evaluate sea-level control on Neogene facies within an upper slope/shelf-edge setting (cf. Sites GAB-03B and GAB-04B). (5) Evaluate the diagenetic history and processes within Neogene facies in an upper slope/shelf-edge setting.

Drilling Program: Triple APC, XCB, RCB

Logging and Downhole Operations: Triple Combo, FMS/Sonic, WST

Nature of Rock Anticipated: Nanno-foram ooze/chalk and wackestone with minor grainstone (560 m); interbedded calcareous mudstone and sandstone (135 m)

SITE: GAB-07A	PRIORITY: 1	POSITION: 33°21.4498'S, 128°28.8772'E
WATER DEPTH: 480 m	SED THICKNESS: ≈2645 m	TOTAL PENETRATION: 540 m
SEISMIC COVERAGE: Intersection at SPs 600 and 10569.5 on AGSO Line 169/05		

Objectives: (1) Collect detailed, high-resolution profiles through a late Neogene succession deposited within a low-energy, cool-water carbonate environment to determine the response of such a depositional system to Plio-Pleistocene sea-level fluctuations. (2) Obtain a high-resolution record of late Neogene paleoceanographic variation within a middle-upper slope setting, as a component of the shelf-to-basin paleoceanographic transect. (3) Evaluate the diagenetic history of calcitic sediments deposited within a low-energy environment below storm wave base, for comparison with the higher energy environments at Sites GAB-08A and GAB-09A.

Drilling Program: Double APC, XCB

Logging and Downhole Operations: Triple Combo, FMS/Sonic, WST

Nature of Rock Anticipated: Foram-nanno ooze and chalk; minor wackestone

SITE: GAB-08A	PRIORITY: 2	POSITION: 33°19.5628'S, 128°28.8788'E
WATER DEPTH: 332 m	SED THICKNESS: ≈2880 m	TOTAL PENETRATION: 590 m
SEISMIC COVERAGE: Intersection at SPs 879 and 8253.5 on AGSO Line 169/05		

Objectives: (1) Collect a detailed, high-resolution profile through a late Neogene succession deposited within a moderate-energy, cool-water carbonate environment to determine the response of such a depositional system to Plio-Pleistocene sea-level fluctuations. (2) Obtain a high-resolution record of late Neogene paleoceanographic variation within an upper slope setting, as a component of the shelf-to-basin paleoceanographic transect. (3) Evaluate the diagenetic history of calcitic sediments deposited within a moderate-energy environment below storm wave base, for comparison with the higher-energy environment at Site GAB-09A.

Drilling Program: Triple APC, XCB

Logging and Downhole Operations: Triple Combo, FMS/Sonic, WST, GHMT

Nature of Rock Anticipated: Wackestone; foram-nanno ooze and chalk; minor grainstone

...Leg 182 - Great Australian Bight Carbonates...

SITE: GAB-09A	PRIORITY: 1	POSITION: 33°17.3793'S, 128°28.8748'E
WATER DEPTH: 200 m	SED THICKNESS: ≈2480 m	TOTAL PENETRATION: 585 m
SEISMIC COVERAGE: Intersection at SPs 1202 and 5574.5 on AGSO Line 169/05		

Objectives: (1) Collect detailed, high-resolution profiles through a late Neogene succession deposited within a high-energy, cool-water carbonate environment to determine the response of such a depositional system to Plio-Pleistocene sea-level fluctuations. (2) Obtain a high-resolution record of late Neogene paleoceanographic variation within a shelf-edge setting, as a component of the shelf-to-basin paleoceanographic transect. (3) Evaluate the diagenetic history of calcitic sediments deposited within a high-energy environment below storm wave base, for comparison with the lower-energy environments at Sites GAB-07A and GAB-08A.

Drilling Program: Double APC, XCB

Logging and Downhole Operations: Triple Combo, FMS/Sonic, WST

Nature of Rock Anticipated: Wackestone and grainstone; minor foram-nanno ooze and chalk

SITE: GAB-13B	PRIORITY: 1	POSITION: 34°45.4940'S, 127°35.4358'E
WATER DEPTH: 4465 m	SED THICKNESS: >3.5 km	TOTAL PENETRATION: 985 m
SEISMIC COVERAGE: Intersection of AGSO Lines 169/08 (SP 3987.5) and 169/09 (SP 3457.5)		

Objectives: (1) Recover pelagic ooze from the middle continental rise to construct a Cenozoic and Late Cretaceous paleoceanographic record of the opening of the Southern Ocean and development of the circum-Antarctic Current. (2) Determine the history of Cenozoic and Late Cretaceous CCD fluctuations and deep-water mass variations during the evolution of the Southern Ocean (in conjunction with Sites GAB-01C and GAB-02B). (3) Determine depositional and diagenetic facies on the middle continental rise.

Drilling Program: Triple APC, XCB, RCB

Logging and Downhole Operations: Triple Combo, FMS/Sonic, WST, GHMT, Geochem

Nature of Rock Anticipated: Nanno-foram ooze and chalk (610 m), calcareous mudstone (375 m)