OCEAN DRILLING PROGRAM

LEG 194 SCIENTIFIC PROSPECTUS

MARION PLATEAU

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This Scientific Prospectus is based on precruise JOIDES panel discussions and scientific input from the designated Co-chief Scientists on behalf of the drilling proponents. The operational plans within reflect JOIDES Planning Committee and thematic panel priorities. During the course of the cruise, actual site operations may indicate to the Co-chief Scientists and the Operations Manager that it would be scientifically or operationally advantageous to amend the plan detailed in this prospectus. It should be understood that any proposed changes to the plan presented here are contingent upon approval of the Director of the Ocean Drilling Program in consultation with the Science and Operations Committees (successors to the Planning Committee) and the Pollution Prevention and Safety Panel.

Technical Editors: Karen K. Graber and Lori J. Cagle

ABSTRACT

Cretaceous rifting in the western Coral Sea (offshore northeast Australia) formed continental fragments that are now capped by carbonate platforms. The Marion Plateau carbonate platform, which has grown on one of these fragments, provides a natural laboratory to study the causes, magnitudes, and effects of sea-level change on continental margin sediments. One of the fundamental controls on the nature and geometry of continental margin sediment deposition is sea level; however, much of the information on the relationship between sea-level and depositional facies is qualitative. Leg 194 coring will provide a superb and unique opportunity to determine the absolute magnitude of the major Cenozoic sea-level falls.

The drilling strategy outlined for Leg 194 utilizes the stratigraphic relationship between a lower to middle Miocene second-order highstand carbonate platform complex and an upper Miocene second-order lowstand platform complex to establish the magnitude of the middle Miocene N12-N14 sea-level fall. An important characteristic of this platform relationship is that the proposed sites are essentially located along a single strike line without intervening structural elements. Thus, subsidence of the platform will have affected all sites equally, enabling determination of the true amplitude of the sea-level fall that caused a shift in the locus of carbonate platform deposition.

The carbonate platforms and adjacent slopes of the Marion Plateau also preserve a superb record of third-order sea-level variations within a mixed carbonate-siliciclastic depositional environment. High-resolution seismic data collected for the Leg 194 site surveys provide quasi-three-dimensional images of Oligocene-Pliocene depositional geometries. The correlation of these seismic images with drill core and logging data will provide a synoptic view of depositional processes in a mixed carbonate-siliciclastic carbonate platform setting.

INTRODUCTION

Importance of Determining the Magnitude of Eustatic Sea-Level Variations

Measuring the amplitude and timing of eustatic sea-level fluctuations is essential both for the establishment of an accurate eustatic sea-level curve for the Phanerozoic and for the accurate interpretation of sediment sequences on continental margins. Several attempts have been made to determine the amplitude of glacioeustatic fluctuations, including passive-margin sequence stratigraphy (Vail et al., 1977; Vail and Hardenbol, 1979; Haq et al., 1987); modeling of sedimentary depositional regimes (Watts and Thorne, 1984); calibration of the oxygen isotope curve (Majors and Mathews, 1983; Miller et al., 1987; Williams, 1988); and analysis of the depositional history of carbonate sediments on atolls (Schlanger and Premoli-Silva, 1986; Halley and Ludwig, 1987; Moore et al., 1987; Lincoln and Schlanger, 1987, 1991). These analyses yield a wide range of results, and although the different independent data sets often agree with regard to the timing of sea-level events, significant differences between estimates for the magnitude of sea-level fluctuations remain. The establishment of a eustatic sea-level curve has major implications for global stratigraphic correlation and basin analysis, and defining the amplitude of such a curve remains one of the major challenges in sea-level research (COSOD II, 1987; Sahagian and Watts, 1991; JOIDES Planning Committee, 1996). The excellent record of Miocene sea-level fluctuations preserved in the carbonate platforms of the Marion Plateau, southern Coral Sea (Figs. 1, 2), provides an ideal opportunity to test sea-level models and quantify the magnitude of eustatic variations.

Growth Phases of the Marion Plateau and their Record of Sea-Level Variations

Carbonate platforms and their slopes are sensitive indicators of sea-level variations, as they predominantly record growth during sea-level highstands and shutdown during sea-level lowstands. Sampling through carbonate platforms records sea-level effects in a "dipstick" fashion. On the other hand, sediments on platform margins and slopes record sea-level variations as alternations of shallowing and deepening sequences. The geometric relationships between the carbonate platforms and adjacent slope sediments of the Marion Plateau have been clearly imaged by seismic data, enabling the investigation, correlation, and dating of sediment sequences. The information recovered from Leg 194 sites (Fig. 2) will provide an independent basis for development and assessment of the global sea-level curve.

The lower-middle Miocene MP2 platform appears to have formed as a series of transgressive and highstand system tracts (Figs. 3, 4). Five highstand events are recorded by MP2 (MP2a - MP2e), providing a record of third-order sea-level variations. Only MP2e was sampled during Leg 133, and thus the age at which the other events occurred is not known (Davies, McKenzie, and Palmer-Julson, 1991). Newly acquired site survey seismic data indicates that MP2 prograded over its former slope sediments. These pulses of progradation are strongly controlled by sea-level fluctuations, as was shown for the progradation of the Great Bahama Bank (Eberli and Ginsburg, 1989; Eberli, Swart, and Malone, et al., 1997).

The upper Miocene MP3 platform began to form during a lowstand on the outer slope sediments of MP2. The MP3 phase subsequently evolved into a series of highstand systems tracts but remained structurally lower than the top of MP2 for most of its history (Fig. 3). The upper Miocene MP3 platform records four sea-level cycles (MP3a-MP3d; Fig. 4). The sea-level rise during MP3d corresponds to the last phase of platform growth. This rapid sea-level rise, in conjunction with other environmental factors, resulted in the drowning of most of the MP3 platform (Pigram et al., 1992).

At present, it is difficult to compare the growth phases seismically imaged within the MP2 and MP3 platforms to global events, as the exact timing of their development will not be known until the sequences are cored. In addition, the internal structure of the MP3 platform, whose top is exposed with a nondepositional hardground at the seafloor, shows no internal seismic structure because of the nonpenetrating seismic signal and the probably well-cemented and homogeneous lithology. However, the recovery and dating of sediments from these sequences will provide important information on Miocene sea-level events and their influence on continental margin sedimentation. Data from these sediments may also be used in conjunction with other "sea-level" legs cored as part of the Ocean Drilling Program (ODP) global sea-level strategy.

To determine the sea-level event stratigraphy on the Marion Plateau through drilling, it will be necessary to establish

1. The depositional history of the Miocene carbonate platforms (Fig. 3) of the Marion Plateau by
    - establishing a detailed chronostratigraphy for each platform phase;
    - determining the depositional environment of each platform phase;
    - determining the age and duration of each unconformity;
    - inferring the paleowater depth of each phase; and
    - establishing the total thickness of each platform.

2. The amplitude of the middle Miocene (N14-N12) sea-level fall by determining
   - the age, depth, and paleowater depth of the older (MP2) platform; and
   - the age, depth, and paleowater depth of the initial phase of the younger (MP3) platform.

To establish the magnitude of the sea-level fall that led to the formation of the lowstand MP3 platform, it is first necessary to determine the paleowater depth of the top of the lower-middle Miocene MP2 platform (Fig. 3). Leg 133 coring (Sites 816 and 826) showed that the top of this platform consisted of a tropical reefal assemblage deposited in water depths no greater than 20 m (Davies, McKenzie, Palmer-Julson, et al., 1991). This depth defines the approximate point from which sea level began to fall (Pigram et al., 1992). Sampling evidence indicates that the top of MP2 has been subjected to subaerial exposure. The dissolution and erosion that is likely to have resulted from exposure would have made the present-day top of MP2 lower than it was originally, introducing an error in determining the highest position of sea level immediately before the fall. The extent of erosion is difficult to quantify, but it can be expected that the loss would be small because the high diagenetic potential of these tropical carbonates would tend to create a carbonate pavement that would be difficult to erode. Any sediment loss from the top of MP2 will result in the underestimation of the true amplitude of sea-level fall (Pigram et al., 1993).

The low-point of the sea-level fall is defined by the paleowater depth at the time the first sediments of the upper Miocene lowstand MP3 platform were deposited (Pigram et al., 1992; Fig. 2). The MP3 platform was not sampled during Leg 133 drilling, and therefore the biofacies that compose this platform can only be inferred seismically. The seismic characteristics of MP3 are poorly imaged and difficult to assess, but appear to have both "tropical" (vertically accreted) and "temperate" (mound like) signatures. The presence of cooler water fauna would indicate that the depth of platform initiation was deeper than that for purely tropical carbonate. Without sampling the MP3 platform, we can only speculate on the paleowater depth of the MP3 formation. Three possible scenarios are

- If MP3 is entirely tropical, its formation depth was likely to be ~20-25 m, resulting in a N12-N14 sea-level fall of 185-190 m. This eustatic change is greater than other estimates for this time interval (30-90 m, Miller et al., 1987; >100 m, Vail and Hardenbol, 1979).
- If MP3 is subtropical in composition, the depth of initiation could have been ~50-70 m. Thus, the

N12-N14 sea-level fall would be ~135-155 m.

- It is also possible that sea level fell below the level on which MP3 was established, thus also affecting the estimate of sea-level change, but no seismic evidence supports this conclusion (Pigram et al., 1992).

The Influence of Subsidence on Sea-Level Magnitudes

The inability to remove tectonic subsidence effects from relative sea-level signatures has hindered the quantification of eustatic sea-level variations in many areas. However, a sea-level shift that occurs between two sites of equal tectonic subsidence will provide an accurate record of the magnitude of eustatic change.

For the difference between the top of MP2 and the initiation of MP3 to be an accurate measure of the N12-N14 eustatic fall, it is necessary to demonstrate that there is no differential subsidence along the drilling transect. There are two lines of evidence to support this. First, the Marion Plateau is not structurally compartmentalized and therefore behaves as a single structural entity (Symonds et al., 1988). Seismic lines between the proposed sites show that there are no structural elements, such as faults, between the sites that could cause them to have relative differential subsidence. Second, because the Marion Plateau basement surface is planated with minimal dip to the northeast, depths to basement surface contours can be considered isosubsidence lines (Fig. 5). The eight proposed sites are all near the 1-s basement contour, indicating a minimal basement gradient between the sites and thus negligible differential subsidence.

Calibration of eustatic sea-level variations can only be realistically estimated on slowly subsiding, structurally well-understood margins where an accurate tectonic subsidence history can be established and where sites of equal tectonic subsidence, which have both the highstand and the lowstand history preserved, can be located. The advantage of such areas is that although falling sea level follows the slow tectonic subsidence of the platform, the relative depth change recorded between two sites is self-correcting because they both subside by the same amount. For the predicted middle Miocene Marion Plateau subsidence rates, the increase in water depth at both sites as a result of tectonic subsidence (<10 m) is an order of magnitude less than the eustatic sea-level change over the same interval. The tectonic component of sea-level change is therefore within the error of paleowater depth estimates achievable in these sediments.

BACKGROUND

Geologic Setting of the Marion Plateau

The Marion Plateau is located between 18°S and 23°S, seaward of the south central Great Barrier Reef on the northeastern Australian continental margin. This plateau is the most southerly of the northeast Australian marginal plateaus, forming a deeper extension of the Queensland continental shelf. The plateau is bounded along its northern margin by the Townsville Trough; by the Cato Trough along the eastern margin, and by the south central Great Barrier Reef to the west (Fig. 6). The Marion Plateau is part of a slowly subsiding margin. It is believed that the plateau top remained exposed throughout much of the Paleogene and became planated to form a gently northward-dipping, relatively smooth plateau surface (Pigram et al., 1993).

Tectonics of the Marion Plateau

The eastern Coral Sea has been affected by two distinct tectonic events. The earlier event, late Jurassic-Early Cretaceous in age, was responsible for the formation of the Queensland and Townsville Basins, which underlie the present-day bathymetric features of the Queensland and Townsville Troughs (Fig. 6). These basins formed because of oblique extension along pre-existing Paleozoic structural trends (Struckmeyer and Symonds, 1997). The Queensland and Townsville Basins do not appear to have been affected by the later tectonism responsible for seafloor spreading in the Tasman and Coral Sea Basins (Struckmeyer and Symonds, 1997).

In the Late Cretaceous, rifting in the Coral Sea Basin created numerous continental fragments, which are now capped by carbonate platforms, such as the Marion and Queensland Plateaus (Fig. 6). Rifting in the Coral Sea was an extension of Late Cretaceous (80 Ma) seafloor spreading in the Tasman Basin, which extended to the north to form the Cato Trough and the Coral Sea Basin by 65 Ma (Fig. 6; Weissel and Hayes, 1971; Hayes and Ringis, 1973; Shaw, 1978). Spreading is believed to have ceased along the length of this system by the earliest Eocene (52 Ma; Gaina et al., 1999). Thus, the main physical elements of the western Coral Sea were in place by the early Tertiary (Davies et al., 1989). Although the exact structural style and development history of the rift system is still not completely understood, it is clear that the late Jurassic-Early Cretaceous rifting event controlled the gross architecture of the margin in addition to the form of the high-standing structural elements on which the carbonate platforms in the area are located.

The Marion Plateau is a largely undeformed basement block with faults occurring only on its margins. Basement along the northern margin consists of gently dipping ramps that gradually deepen toward the Townsville Trough until a fault is encountered. Normal extensional faults along this northern margin are restricted to the edge of the plateau and include both down-to-basin faults with dips to the north-northwest and normal faults of opposite polarity that dip beneath the plateau (Symonds, et al., 1988). The eastern margin of the plateau is free of major structural offsets (Mutter and Karner, 1980), and the slope is apparently simple and continuous. Faults along this margin are steeply dipping to vertical and the margin of the plateau downfaults into the Cato Trough. The southern part of the plateau is formed by a southeasterly plunging, gently arched basement high. The top of the arch is unstructured, and faults are confined to the flanks of the arch and appear on conventional seismic data to be high-angle, down-to-basin normal faults (Pigram et al., 1993).

The basement of the Marion Plateau is likely to be similar to that of the Queensland Plateau to the north. This basement was cored during Leg 133 (Sites 824 and 825; Fig. 1) and consists of fine-grained, dark gray, poorly foliated, well-lithified quartz-feldspar-mafic metasediment or metavolcanic rocks. These rocks are similar to those found in the onshore Queensland Hodgkinson Province (Ordovician-Devonian), which outcrops as part of the northern Tasman Fold Belt (Feary et al., 1993). Planation of the surface occurred during subaerial exposure in the Mesozoic and Paleogene prior to the deposition of Megasequence A.

As stated previously, no direct sampling of the basement under the Marion Plateau has occurred, but seismic data and a recently developed plate model indicate that basement crustal blocks of the Queensland and Marion Plateaus had roughly similar tectonic histories in regard to rifting and extension (Gaina et al., 1999; Struckmeyer and Symonds, 1997). The presence of shallow-water (~20 m) carbonate sediments directly overlying basement at Sites 824 and 825 on the Queensland Plateau indicates that the planated basement surface of the Queensland Plateau was at or near sea level immediately prior to the onset of sedimentation. Using this information, we can estimate the thickness of the crust under the Queensland Plateau. Assuming average crustal density, the upper surface of a 30-km-thick crust would exist at sea level. Tectonic subsidence models show almost no change in the depth of the Queensland Plateau surface between 25-10 Ma (Fig. 7). Thus, we can conclude that the early Tertiary opening of the Coral Sea resulted in little crustal thinning on the Queensland Plateau. Otherwise, we would not observe thermal subsidence rates equal or close to zero in the early Tertiary.

These results also show that thermal subsidence from the earlier Late Jurassic-Early Cretaceous event could no longer be detected on the Queensland Plateau during the Neogene.

Subsidence History of the Marion Plateau

The tectonic histories of the Marion and Queensland Plateaus are well constrained by Leg 133 sites and extensive multichannel seismic data. Subsidence curves for these plateaus have been produced using both benthic foraminifera (Fig. 8; Katz and Miller, 1993) and geohistory modeling (Fig. 7; Müller et al., 2000). Geohistory models were calculated using integrated geophysical logs, biostratigraphic/lithologic information, and seismic reflection data (Müller et al., 2000). These models predict post-9-Ma subsidence of 1300 ± 200 m in the Queensland Trough and 650 ± 200 m on the western margin of the Queensland Plateau and post-5-Ma subsidence of 500 ± 30 m on the southern margin of the Queensland Plateau and 660 ± 50 m on the northern margin of the Marion Plateau (Fig. 7; Müller et al., 2000). Although the Marion and Queensland Plateaus are located on a passive margin ~1000 km south of the Pacific-Australian plate boundary, geohistory models predict a greater amount of post-9-Ma subsidence than simple elastic models do. This subsidence occurred in pulses between 9 and 5 Ma on both plateaus. It is difficult to account for this observed subsidence, either by means of thrust loading in Papua New Guinea or by a combination of such thrust loading and in-plane stresses originating from collision along the Australian-Pacific plate boundary (Müller et al., 2000).

Müller et al. (2000) suggest that the observed post-9-Ma tectonic subsidence of the Queensland and Marion Plateaus and Queensland Trough is largely caused by dynamic surface topography resulting from Australia’s northeastern margin overriding a slab burial ground and modulated by flexural deformation resulting from collision tectonics north of Australia. This conclusion is supported by shear-wave tomography data (Zhang and Tanimoto, 1993) that shows a north-northwest to south-southeast trending band of anomalously high velocities in the upper mantle at depths between 300 and 650 km. Although unproven, this explanation appears to be the most reasonable for all available data.

Post-9-Ma subsidence rates on the Marion Plateau are much lower than those of third-order sea-level changes and can thus be differentiated from glacial eustasy. In addition, any unaccounted subsidence will be the same for all sites along the transect as they were selected along lines of equal subsidence. Although we will attempt to quantify in detail the additional water depth added to all sites as a result of tectonic subsidence, this increase is likely to be less than 10 m between N12-N14 and thus will not greatly affect our attempts to quantify eustatic sea-level variations.

Stratigraphy of the Marion Plateau: Evidence from Prior Drilling

Stratigraphies for the Marion Plateau were obtained during ODP Leg 133 (Fig. 9), and these data supplement previously acquired extensive seismic surveys over the plateau (Fig. 10). Both of these data sets have enabled a description of the Marion Plateau depositional history. Initiation of shallow marine carbonate sedimentation on the Marion Plateau began during the latest Paleogene as the sea transgressed across the metasedimentary basement of the plateau (Davies, McKenzie, Palmer-Julson, et al., 1991). We have no direct age controls on the sediments that form Megasequence A as they have not yet been sampled. Their age is inferred by their stratigraphic position under Megasequence B (Pigram et al., 1993; Figs. 3 and 10). These first sediments over basement are believed to be primarily siliciclastics, with temperate water carbonates occurring in the eastern part of the sequence.

Sedimentary facies recovered during Leg 133 and their correlation to seismic profiles indicate that tropical reef development was initiated on the Marion Plateau in the early Miocene, and by the middle Miocene there was extensive reef growth on the plateau (Davies, McKenzie, Palmer-Julson et al., 1991). These reefal sediments are part of Megasequence B and include the aggrading and prograding MP2 carbonate platform (Figs. 3, 10).

In the late middle Miocene, carbonate bank productivity rapidly diminished on the Marion Plateau, as shown by a reduced fine-grained bank-derived component in slope sediments. This decline was primarily the result of subaerial exposure resulting from a sea-level regression that caused the demise of the MP2 platform. During the low sea-level interval between 11 and 7 Ma, the MP3 platform was initiated on the eastern side of the Marion Plateau. Despite the fact that MP3 developed during a lowstand, the platform continued its development during subsequent highstand intervals. MP2, on the other hand, did not reinitiate even after being reflooded during the subsequent sea-level increases. During the development of MP3 the western two-thirds of the Marion Plateau was exposed, forming a broad, low-relief karstic surface. Unlike MP2, MP3 has not completely drowned but is now restricted to the area of Saumarez Reef. The limited sampling of MP3 inhibits speculation on the cause for partial drowning, although some likely factors are reduced sea-surface temperatures (Isern et al., 1996) and increased terrigenous inputs causing increased water-column turbidity (Pigram et al., 1993).

Carbonate production from the Pliocene to Holocene never again achieved the areal extent that existed in the Neogene. Instead, hemipelagic drift sediments dominated sedimentation on the Marion Plateau.

SCIENTIFIC OBJECTIVES

The Marion Plateau provides ideal targets to address the causes, magnitudes, and effects of sea-level change on continental margin sediments. Although one of the fundamental controls on the nature and geometry of continental margin deposition is sea-level fluctuations, much of the information on the relationship between sea-level and depositional facies is qualitative.

Extensive seismic surveys over the Marion Plateau have enabled the description of the various depositional sequences found on the plateau (Figs. 2, 10). These data, along with sedimentological information from Leg 133 cores and dredge samples, have been used to develop a growth model for carbonate platform phases on the Marion Plateau and the relationship of these platforms to sea-level change (Fig. 3). Coring and downhole measurements during Leg 194 will address the following objectives:

- *Magnitude of the N12-N14 second-order eustatic sea-level fall*
  Although difficult, determining the magnitude of eustatic sea-level fluctuations is significant not only for the establishment of a Phanerozoic sea-level curve but also for understanding the stratigraphic response of continental margin sediments to sea-level forcing. Leg 194 coring provides an opportunity to determine the absolute magnitude of one of the major Cenozoic sea-level falls.

- *Oligocene-Pliocene, third-order sea-level fluctuations*
  Coring will recover an Oligocene-Pliocene sea-level record preserved in the carbonate platform growth phases of the Marion Plateau. Seismically, this record appears to include a complete third-order event stratigraphy from 30 to 4 Ma within the second-order sea-level falls that dominate the sequence stratigraphic framework of the Marion Plateau. Analyses of these variations, and the higher order fluctuations contained within them, will provide

information on the timing and influence of sea level on the carbonate growth phases of the Marion Plateau.

• *Sedimentary facies change and development of sequence stratigraphic units controlled by sea-level changes*

Leg 194 coring will recover a detailed record of carbonate and siliciclastic sediment facies variations resulting from mixing of sediment from carbonate banks on the Marion Plateau and the continental margin of Australia. In general, carbonate sediment export increases during sea-level highstands as carbonate banks have additional accommodation space for increased growth of carbonate-producing organisms. On the other hand, terrigenous sedimentation generally decreases during highstands because of the elevated erosional base level. Leg 194 coring will enable detailed analysis of the cumulative result of these different sedimentological responses to sea-level forcing.

• *Impact of potential sequence of temperate to subtropical carbonates*

It is likely that the MP3 platform is at least partially composed of temperate to subtropical carbonates. Thus, the results of this coring will rely on and extend the results of Leg 182 (cool-water carbonates of the Great Australian Bight). Stable isotopic data from Leg 133 Site 811 showed that during the late Miocene, sea-surface temperatures (SST) were cool (~20°-22°C), as were global sea-surface temperatures (Isern et al., 1996). Given the more southerly location of the MP3 platform with respect to Site 811 (Queensland Plateau), temperatures were probably similar to, if not cooler than those over the Queensland Plateau. Sea-surface temperatures at or below 20°C would not prevent tropical coral growth but would make it more likely that the MP3 platform was constructed of a "cooler," more sub-tropical bioassemblage. If MP3 is indeed composed of cooler water fauna, the depth of platform initiation probably would be deeper than for purely tropical carbonate. Should the early growth phases of MP3 be temperate in nature, documenting the transition of these cooler water forms into the tropical forms existing for most of the MP3 growth phase will be an important outcome of Leg 194.

- *Fluid flow and diagenesis within pure carbonate and mixed siliciclastic/carbonate depositional environments*

The mechanisms, rates, and distributions of fluid transport through carbonate platforms and reef structures are critical to the understanding of diagenetic processes (Buddemeier and Oberdorfer, 1986) and for the geochemical cycling of many elements. Fluid movements have the ability to chemically alter the mineralogic composition of the sediment by converting metastable minerals such as high-Mg calcite and aragonite to more stable calcite and dolomite (Mullins et al., 1984; Simms, 1984). Alteration of carbonate sediments to dolomite has been significant in both the Bahamas (Varenkamp et al., 1991) and the carbonate platforms of northeast Australia (McKenzie et al., 1993; Davies, McKenzie, Palmer-Julson, et al., 1991). Recent studies have shown that carbonate sediments off northeast Australia were dolomitized by multigenerational fluids flowing through the platforms (McKenzie et al., 1993). The movements of fluids through the Queensland Plateau were demonstrated by using $^{87}Sr/^{86}Sr$ isotopic ratios and the Sr composition of interstitial waters (Elderfield et al., 1993).

Fluid flow can also alter the sedimentary structure, permeability, and porosity of the deposit, thus having important effects on flow pathways and reservoir potential. The existence of fluid flow has been described in tropical carbonate platforms such as the Great Bahama Bank and the Queensland Plateau (Eberli et al., 1997; Elderfield et al., 1993) and also in temperate water carbonates (Feary, Hine, Malone, et al., 2000). However, the mechanisms causing this flow are neither well documented nor understood.

- *Role of climatic and paleoceanographic change in the tropical South Pacific and its influence on carbonate platform development.*

Leg 194 coring will enable the investigation of paleoceanographic variations in the western Coral Sea and will provide the opportunity to correlate these variations with changes in sea level. Changes in paleocirculation in the study area have been modified both by the movement of continental fragments resulting from local rifting events and by the northward movement of the Indo-Australian Plate and its collision with the Asian Plate. Northward movement of the Indo-Australian Plate caused significant variations in climate because of movement across climatic boundaries. These changes, in addition to global climatic variations, had dramatic influences on the depositional environments in the Coral Sea, which today are dominated by tropical carbonates. An important paleoceanographic objective is to determine the effects of changes in paleocirculation and climate on the development of carbonate platforms and reefs off northeast Australia.

DRILLING STRATEGY

The establishment of a sea-level curve for the Miocene in the Coral Sea region is critically dependent on determining the facies and age of the MP2 and MP3 platforms of the Marion Plateau (Figs. 2, 10). Typically, precise dating of warm shallow-water carbonate platforms is difficult because of the broad stratigraphic range of larger foraminifers and diagenetic alteration of the sediments. Therefore, the drilling strategy described here involves paired holes chosen so that one is located within predicted shallow-water facies and a second is located downslope to obtain correlative facies in which planktonic forms are preserved for high resolution dating. Five primary and 10 contingency sites are proposed according to this strategy and defined on multichannel seismic lines collected in 1999 (Tables 1, 2; Figs. 11-34 and Site Summary section).

Primary Sites

The operational time estimates indicate that the five highest priority sites can be cored and logged in the time allocated for Leg 194 (Table 2). These include two platform sites (Sites CS-01 and 06), two sites to sample the adjacent paleoslope sediments (Sites CS-02 and 05), and a distal site (Site CS-10) to acquire a high-quality biostratigraphy that can be correlated to the other sites using high-resolution seismic data. The platform sites will first be penetrated to basement using the advanced hydraulic piston corer and the extended core barrel (APC/XCB) (e.g., Site CS-01) and/or the rotary core barrel (RCB) where the formation is too indurated (e.g., Sites CS-01 and 06). In an attempt to achieve better recovery in reefal carbonate intervals of interest (maximum 300 m per site), we plan to deploy the developmental advanced diamond core barrel (ADCB; see below). All sites are to be drilled to basement (including up to one barrel of basement rock) to form a facies transect from a position within the shallow facies of MP2, across the platform edge, and downslope to platform MP3. Sites between the two shallow phases of platform facies are designed to establish whether lowstand signals can be detected in slope sediments (Sites CS-03A and CS-05A). If such signals can be seen, it may be possible to establish rates as well as amplitudes of sea-level fluctuations.

The order of operations will greatly depend on weather conditions. Should conditions be favorable after transit from Townsville (1.2 days) and the Hydrate Autoclave Coring Equipment (HYACE) tests (2 days, see below), sites would be drilled in the following order: CS-01A, CS-02A, CS-06, CS-05, and CS-10A. After completing operations, including potential contingency plans (see below), there will be an 8-day transit to Guam.

Contingency Sites/Holes

Should time be available after completing operations at the five primary sites, the following contingency plans will be evaluated and ranked depending on available Leg 194 results. Three types of contingency plans have been developed:

- Additional sites: (in order of priority) CS-08A, CS-03A, CS-12A, CS-09A, CS-11A, CS-13A, CS-14A, CS-15A, CS-16A, and CS-17A.
- Third holes to improve stratigraphic coverage: CS-10A, CS-02A, CS-05A.
- Additional ADCB coring: Site CS-06A to recover the upper reefal carbonate interval and also Site CS-12A, if it is drilled.

All primary and some contingency sites have been approved by the Pollution Prevention and Safety Panel (PPSP). Sites CS-03A, CS-05A, CS-06A, and CS-09A are located within the Great Barrier Reef Marine Park. As such, it is imperative that care be taken during coring to prevent impacts on the reef ecosystems. All Leg 194 shipboard operations will follow the guidelines established by the Great Barrier Reef Marine Park Authority (GBRMPA) for scientific research within park boundaries.

As the site survey seismic data was collected using differential Global Positioning System (GPS) navigation, it is not expected that we will have to use the *JOIDES Resolution* to collect survey data prior to drilling Leg 194 sites.

Advanced Diamond Core Barrel (ADCB) Coring System

The ADCB coring system was designed to improve core recovery in indurated sediments and rocks by using a diamond-impregnated drill bit that cuts a core by grinding instead of chipping as does the conventional RCB system. The outer diameter and cutting area of the ADCB are smaller than those of the conventional RCB system (outer diameter = 7.5 in vs. 9.875 in), which potentially increases the penetration rates. In addition, circulation around the freshly cut core is better constrained, and flushing away recovered core material is minimized. The recovered ADCB core has a larger diameter than conventional RCB cores (3.345 in vs. 2.312 in), which results in greater recovery in friable sediments while also increasing available material for analysis.

Because this tool is still in development, there are a few operational limitations. First, only 300 m of smaller diameter drill pipe needed for the ADCB has been purchased by ODP to date. This means to core an interval greater than 300 m, the drill string needs to be tripped to the surface, a RCB bit must be deployed to ream the hole to the bottom of the first 300-m interval, and the pipe must be tripped again to deploy the next ADCB bit to continue coring. Second, the logging tools cannot be deployed through the ADCB bit. Thus, if downhole logging is desired, an additional pipe trip is needed to deploy the logging bottom-hole assembly (BHA). Third, as the diamond coring bit is more susceptible to wear, a pipe trip may also be required to change the bit before 300 m are penetrated. In addition, core splitting, sampling, and archiving issues have not been addressed for the larger core diameter and would have to be optimized during the cruise.

The ADCB system will be deployed for the first time on Leg 193. Since the recovery of reefal carbonates has traditionally been difficult with the ODP arsenal of tools, and because the recovery of these lithologies is a primary Leg 194 objective, the use of this system will be important for Leg 194. Deployment of this developmental tool at one or two sites is therefore an essential use of Leg 194 operational time. Unless some fatal flaws are discovered during Leg 193, the ADCB will be used at the first site to evaluate the usefulness of this tool in these sediments. Subsequent deployments will only occur if operational time does not exceed the time estimates and if coring results are truly superior to those obtained with the RCB system.

HYACE Testing

In July 2000, two days were added to the original Leg 194 operations schedule to accommodate feasibility tests of the developmental HYACE tool, which is a gas hydrate sampling and monitoring system. The HYACE was modified from the ODP Pressure Core Sampler (PCS) at the Technische Universität Berlin with support from the European Commission and from ODP. The tests will be carried out at the very beginning of the leg at one of the designated contingency sites. At least five dedicated personnel will sail for these tests. Since a full technical and scientific staff is needed during the scientific operations of Leg 194, the HYACE test personnel will be replaced by ODP technical staff arriving with a boat from shore two days into the cruise.

LOGGING PLAN

Downhole logging will be an essential component of Leg 194 scientific operations, particularly at those sites where low core recovery is likely (Sites CS-01A and CS-06A). All sites will be logged with standard logging tool strings (triple combo and Formation MicroScanner [FMS]/sonic), together with deployment of the well seismic tool (WST) and the geologic high-resolution magnetic Tool (GHMT; if available). The characteristics of these logging tools are as follows (additional information on these tool strings can be found at http://www.ldeo.columbia.edu/BRG; all logging tools Schlumberger):

- The triple combo toolstring includes the dual induction tool (DITE) that measures resistivity from deep and shallow induction, the accelerator porosity sonde (APS) that measures porosity from epithermal neutron measurements, and the hostile environment litho-density sonde (HLDS) that measures bulk density from Compton scattering and provides an indication of general lithology from the photoelectric effect. Commonly, the hostile environment natural gamma-ray sonde (HNGS) is added to this tool string. Depending on the success of its deployment during Leg 191, the multichannel gamma-ray logging tool (MGT) will be added to the triple combo, providing a vertical resolution three times higher than the standard gamma-ray sonde.

- The FMS/sonic tool string includes the Formation MicroScanner, which measures resistivity at centimeter resolution on four pads moving along the borehole, the general purpose inclinometry tool (GPIT), and the dipole sonic imager (DSI), which measures compressional and shear wave velocity, as well as cross-dipole and Stoneley waveforms.

- The WST is a single-axis check-shot tool used for zero-offset vertical seismic profiles (VSPs). It consists of a single geophone that is used to record acoustic waves generated by an air gun located near the sea surface.

- The GHMT includes the nuclear magnetic remanence sonde (NMRS), which measures total magnetic field, and the susceptibility measurement sonde (SUMS), which measures the magnetic susceptibility from induction.

The Leg 194 logging plan has been designed to achieve the following objectives:

- **Core-log-seismic correlation.** 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 two-dimensional lines) will be critical for understanding the three-dimensional architecture of the Marion Plateau sequences and for compiling a detailed sequence stratigraphy. Accordingly, check-shot (WST) surveys, at 30 to 50 m spacing, should be run at all sites.

- **Detailed description of cored sequences.** Integrated interpretation of the FMS and geophysical logs (triple-combo) will provide an essential complement to drill cores for describing the lithostratigraphy, particularly in intervals where core recovery is incomplete. Geophysical logs will also be important for characterizing the lithostratigraphic response of the carbonate sediments to sea-level and climatic fluctuations.

- **Characterization of sedimentary diagenesis.** Sedimentary diagenesis in carbonates is expressed through changes in porosity and chemical precipitation of soluble elements (such as uranium) that lead to large changes in log properties seen on sonic, resistivity, density, and neutron gamma-ray logs.

- **Detection of terrigenous sediment input to the sedimentary section.** The Marion Plateau is a mixed carbonate-siliciclastic depositional environment; thus, the GHMT tool will be useful for detecting variations in terrigenous sediment content intermixed with the platform and pelagic carbonate sediments, particularly in those intervals characterized by low core recovery. These data will be also be useful for intersite sediment correlation.

- **Assessment of fracture networks and basic fluid properties.** Fine-scale characteristics of sedimentary bedding, including pore spaces, bioturbation, and fractures, will be imaged using the FMS. The assessment of fracture networks and fluids will be accomplished using sonic and resistivity logs that, together with FMS images, should help achieve leg fluid-flow objectives.

SAMPLING PLAN

All sampling of recovered cores will be subject to the rules described in the ODP Sample Distribution Policy (http://www-odp.tamu.edu/curation/sdp.htm). Prior to Leg 194, the sampling program for the leg will be developed and approved by the Sampling Allocation Committee (SAC), consisting of the Co-Chief Scientists (Anselmetti and Isern), Staff Scientist (Blum), and Curator. The initial sampling plan is preliminary and can be modified depending upon actual material recovered and collaborations that may evolve between scientists during the leg. In the final shipboard sampling plan, sample requests will be closely linked to proposed postcruise research.

During the leg, samples for measurements of ephemeral properties will be collected. These measurements include those for organic geochemistry for safety monitoring (free gas and 20-cm^3 sediment samples), interstitial water chemistry (whole rounds 5-15 cm in length), and biostratigraphy (core catcher samples). After splitting of the cores, samples for moisture content (20 cm^3) will also be routinely collected. The study of fluid movement within the sedimentary section is an important goal of Leg 194. Thus, to characterize these fluid movements and sediment diagenesis, the collection of whole-round samples for pore-water geochemical analyses is anticipated to be at a higher resolution than typical for other ODP cruises.

Except for Sites CS-01A and CS-06A, all Leg 194 sites will be double cored in an attempt to recover a complete stratigraphic section. No archive halves (permanent or temporary) will be sampled aboard ship, and the permanent archive will be designated postcruise. Shipboard sampling for Leg 194 postcruise studies will be kept to a minimum. Only low-resolution sampling to support sediment facies description/characterization and facilitate pilot studies will be carried out aboard ship, and shipboard participants will only collect enough material for 6-months of postcruise research. The remaining samples required by participants and all high-resolution sampling will be deferred until after the cruise to enable the development of a composite sedimentary section from the multiple holes. All shipboard scientists will participate in shipboard sampling according to the shift schedule developed at the start of the leg.

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