OCEAN DRILLING PROGRAM

LEG 133 PRELIMINARY REPORT

NORTHEAST AUSTRALIAN MARGIN

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ABSTRACT

Leg 133 occupied 16 sites along two transects over the platforms and basins of northeast Australia. Previous studies have shown the area to be a complex product of horizontal tectonics, sea-level change, subsidence, and paleoclimate/oceanography.

Five main physiographic-structural elements are recognized in this region: the platforms of the Great Barrier Reef, the Queensland and Marion plateaus, and the intervening deep-water unbreached rift basins of the Queensland and Townsville troughs. The platforms represent the largest areas of neritic carbonate deposition currently on earth, and their tectonic setting on a young passive margin proximal to major depocenters makes them of immense scientific interest as analogs for similar associations that have occurred repeatedly throughout geological time. The overall objectives of Leg 133 were to define the evolution of the platforms, including their relations to adjoining basins, and to understand the effects of climate and sea level on their development in space and time. In achieving these objectives, over 5.5 km of core was recovered from 36 holes.

The first transect of sites extends eastward from the outer shelf and slope of the Great Barrier Reef (Sites 819 through 822) into the Queensland Trough (Site 823) and onto the Queensland Plateau (Sites 811/825 and 824). The second transect extends northward from the edge of the Marion Plateau (Sites 815, 816, and 826) across the Townsville Trough to the Queensland Plateau slope (Sites 812 through 814).

The specific scientific objectives of Leg 133 were to define:

1. the sedimentary response to global sea-level change in the late Cenozoic and, in particular, the Quaternary; and

2. the influences of paleochemistry, paleoclimate, and paleoceanography on the initiation, growth, and demise of carbonate platforms, particularly the Great Barrier Reef.

Secondary objectives included investigations of the following:

1. the slope-to-basin stratigraphic and facies variations on both sides of rift basins; and

2. the diagenetic history and processes operating on pure carbonate and mixed carbonate/siliciclastic margins.

Note that sites and main physiographic-structural elements are located in Figure 1. Figure 2 contains a lithostratigraphic summary of the Queensland Trough transect (from west-southwest to east-northeast, Sites 821, 820, 819, 822, 823, 824, 825, and 811). Figure 3 contains a lithostratigraphic summary of the Townsville Trough transect (from north-northwest to south-southeast, Sites 812, 814, 813, 817, 815, 816, and 826). Leg 133 coring statistics appear in Table 1.

SITE 811

Site 811 (proposed site NEA-8) is located on the western margin of the Queensland Plateau, 3.5 nmi east of Holmes Reef. The site was intended to sample the periplatform sequence on the Queensland Plateau and to determine the sea level and climatic signals for comparison with proposed sites NEA-1 through -3 (Sites 819-821). An additional objective was to determine the timing and mode of origin of the uppermost reef zones.

Results

Drilling penetrated a 392.5-m-thick sequence of calcareous (≥99% $CaCO_3$) platform-top sediments ranging in age from early-middle Eocene to Pleistocene. Based on benthic foraminifer assemblages, the depositional site was estimated to be at a middle bathyal paleobathymetric depth (600-1000 m) for at least the last 10 m.y. Below this datum level (i.e., >200 mbsf), the reworking and redeposition of shallower water deposits are indicated by the occurrence of larger benthic foraminifers. Below 270 mbsf, redeposited skeletal grains document the transition to a neritic environment, possibly fore- or back-reef. Sedimentation rates for the upper 270 mbsf were relatively low for a carbonate platform environment, ranging between 1.5 and 3 cm/k.y. Variations in the rate can be attributed to varying amounts of bank-derived carbonate detritus and the considerable removal of finer fractions by winnowing.

Seven seismic sequences are recognized, five of which equate well with the lithostratigraphic units defined from drilling results. Six major sedimentary units were recovered between the seafloor and 392.5 mbsf. The lithologic units are follows:

Unit I (0-33.15 mbsf; upper Pleistocene to upper Pliocene, 1.8-2.5 Ma): the dominant lithologies are foraminifer oozes with nannofossils and nannofossil oozes with foraminifers, intercalated with redeposited shallow-water carbonate sediments composed of unlithified bioclastic packstones with nannofossils and lithoclastic rudstones. The mixture of pelagic and bank-derived fine-grained components identifies these sediments as periplatform oozes. We have divided Unit I into three subunits based on the distribution of the redeposited sediments:

Subunit IA (0-7.7 mbsf; upper Pleistocene): these oozes contain pteropods and are intercalated with a series of 10- to 15-cm-thick unlithified foraminifer bioclastic packstone layers, which are interpreted as calciturbidites.

Subunit IB (7.85-18.0 mbsf; approximately middle Pleistocene): bioclastic packstone layers and pteropods are absent, but the fine-grained component consists of up to 75% fine-grained, bank-derived calcite particles.

Subunit IC (18.0-33.15 mbsf; upper Pliocene, 1.8-2.5 Ma): two debris-flow deposits, comprising unlithified bioclastic packstones with nannofossils and unlithified lithoclastic rudstones and floatstones, are separated by a 7-m-thick interval of nannofossil foraminifer ooze. Moldic porosity in some lithoclasts suggests meteoric diagenesis during exposure of the carbonate-bank source.

Unit II (33.15-147.5 mbsf; upper Pliocene to upper Miocene, 2.4-8.75 Ma): homogeneous nannofossil oozes with foraminifers to foraminifer oozes with nannofossils, which we divided into two subunits based on variations in the source of the fine-grained fraction.

Subunit IIA (33.15-70.0 mbsf; lower upper Pliocene, 2.5-3.75 Ma): although gravity-flow deposits are absent, the fine-grained fraction of the ooze contains up to 75% bank-derived calcareous particles, defining it as a periplatform ooze. The ooze grades into chalk at the base of the subunit.

Subunit IIB (70.0-147.5 mbsf; lower Pliocene to upper Miocene, 3.75-8.75 Ma): the oozes have a predominantly pelagic origin and contain more than 75% nannofossils and are devoid of calciturbidite layers. The degree of induration decreases downward, grading from chalky to unconsolidated at the base of the subunit.

Unit III (147.5-269.5; upper to middle Miocene, 8.75-12.5 Ma): periplatform oozes and chalks, which alternate with numerous 10- to 70-cm-thick bioclastic foraminifer wackestone, packstone, lithoclast floatstone, and rudstone layers; these commonly fine upward and are considered to be turbidites. The degree of induration tends to increase downward, although we cannot delineate the exact level and nature of the change from ooze to chalk because of the extremely poor recovery in the lower 50 m of the unit (exclusive of good recovery in a 5-m interval cored with the vibrapercussive coring tool, or VPC).

Unit IV (269.5-356.3 mbsf; middle to lower Miocene, 12.5-? Ma): a thick redeposited sand and rubble package containing mostly skeletal grains such as coral debris, alcyonarian spicules, mollusc fragments, small and larger benthic foraminifers (amphisteginids, miliolids, textularians), echinoids, crustaceans, bryozoans, and red algae. This unit documents the passage from a neritic environment, possibly representing a fore- or back-reef setting, into the middle bathyal environment of the overlying units. Very poor recovery of the neritic sediments and lack of good biostratigraphic markers limit the interpretation of this transition.

Unit V (356.3-365.9 mbsf; upper Oligocene, ? Ma): a poorly recovered, unlithified to well-cemented, fine-grained skeletal packstone, containing abundant planktonic foraminifers in a micritic matrix composed of silt-sized bioclastic particles. This unit documents that sedimentation at Site 811 occurred in a comparatively cold, open-water environment during the Oligocene.

Unit VI (365.9-392.5 mbsf; lower to middle Eocene): a pebble of shallow-water limestone was recovered from this interval; it may represent the sedimentary cover overlying basement at this site.

Aragonite concentrations up to 38% were recorded between 0 and 10 mbsf with traces detectable to depths of 30 mbsf. Dissolution of metastable carbonate phases is reflected in the interstitial water chemistry. Below 30 mbsf, the absence of aragonite and the monotonous interstitial water chemistry indicate that only a very minor amount of recrystallization is presently occurring. The chemical profiles suggest that the underlying basement cannot be composed of igneous rock, but the profiles would be consistent with the presence of limestone or quartzite. This cannot be confirmed, as the basement objective was not reached at Site 811.

The total organic carbon content of the sediments at Site 811 was low, ranging from 0.1% to 0.45%. Volatile hydrocarbons presented no safety problems, with methane concentrations ranging from 1.7 to 4.8 ppm and only trace amounts of ethane and propane present.

Shipboard paleomagnetic studies failed to resolve any magnetic polarity reversals because of severe downhole contamination by drill-string particles, possible viscous drill-string magnetization, and core disturbances.

SITE 812

Site 812 (proposed site NEA-10A/1) is located on the southern margin of the Queensland Plateau between the Flinders and Tregrosse reefs. It represents the lagoonal-bank end-member of a three-site transect, together with Sites 813 and 814, intended to study facies distribution in response to sea-level change across a platform-slope transition in a pure carbonate system.

Results

Drilling penetrated a 300-m-thick sequence of platform-top sediments (average carbonate content = 97%) ranging in age from middle Miocene to Pleistocene. Benthic foraminifers indicate progressive deepening of the depositional environment from a neritic setting (0-200 m) in the late Miocene to early Pliocene to an upper bathyal environment (200-600 m) during the late Pliocene and Pleistocene. Sedimentation during the middle Miocene occurred in a shallow-water, lagoonal, or back-reef environment.

The sedimentation rate for the latest Pliocene and Pleistocene is slightly more than 1 cm/k.y., whereas it was less, ~0.5 cm/k.y., in the early Pliocene. The presence of a hardground or condensed horizon separating the lower Pliocene (Hole 812A) or uppermost upper Miocene (Hole 812C) from the overlying upper Pliocene sediments is consistent with the lower sedimentation rate, suggesting a significant hiatus or a period of condensed sedimentation in the early Pliocene. Shipboard paleomagnetic studies revealed a good reversal stratigraphy downward into the upper Pliocene, recording the top of the Olduvai event (1.88 Ma) above the hardground. Below this level, the signal is all normal but should be resolvable with shore-based study of discrete samples.

Seven seismic sequences can be identified, all of which equate well with the lithostratigraphic units defined from drilling results. Three major sedimentary units were recovered between the seafloor and 300.0 mbsf. The lithologic units are as follows:

Unit I (0-27.9 mbsf; upper Pliocene to Pleistocene): Unit I contains white foraminiferal oozes with pteropods and bioclastic fragments consisting of fine-grained planktonic foraminiferal debris and bryozoan particles. The sediments were deposited in upper bathyal water depths (200-600 m). The nannofossil abundance comprises between ~20% and 60% of the fine fraction in these sediments and indicates predominantly periplatform sedimentation.

Unit II (27.9-141.6 mbsf; upper Pliocene to middle or lower upper Miocene): a 1.5-m-thick white to light gray dolomitized limestone hardground having a condensed upper surface separates Unit I and Unit II. The capping surface is composed of light reddish-brown to brownish fine laminations, presumably iron oxides and phosphate coatings. The degree of induration within the limestone decreases progressively downward from a solidly lithified grainstone to an unlithified packstone. Unit II is divided into subunits to distinguish various facies changes recorded in the sediments.

Subunit IIA (27.9-64.3 mbsf; upper Miocene to lower Pliocene): Subunit IIA contains white, partially lithified micritic chalks with nannofossils and foraminifers and silt-sized bioclasts. Well-crystallized dolomite rhombs, ~1% of the fine fraction, can be seen in smear slides. Deposition was in middle to outer neritic water depths (50-150 m). The nannofossil content, up to 20%, implies a mixture of fine-grained pelagic and bank-derived material, suggesting that the sediment was originally a periplatform ooze.

Subunit IIB (64.3-86.5 mbsf; upper Miocene): Subunit IIB differs from the overlying sediments in that the micritic chalks contain markedly fewer nannofossils (0%-10%) but show an increase in the number of foraminifers (20%-30%) and well-crystallized dolomite rhombs (2%-10%). The sediments were deposited in middle to outer neritic water depths (50-150 m).

Subunit IIC (86.5-105.5 mbsf; upper Miocene): Subunit IIC contains bryozoan molluscan (oysters, pectinids) packstones, wackestones, and floatstones intermixed with micritic chalk. Large benthic foraminifers (amphisteginids and nummulitids) are the dominant component of the sand-sized fraction. The sediments were deposited in shallow neritic water depths (10-50 m). The sediments at the base of Subunit IIC apparently grade into underlying Subunit IID. They are white, partially lithified packstones, wackestones, and floatstones containing from 25% to 50% clear, well-crystallized dolomite in the sand-sized fraction and up to 70% in the silt-size fraction.

Subunit IID (105.5-141.6 mbsf; upper middle Miocene to lower upper Miocene): Subunit IID comprises indurated sucrosic dolostone (100% dolomite) that is composed of sand-sized rhombs. Dolomitization has almost entirely obliterated any biologic components. Locally, the dolostone exhibits irregular bedding with a thickness of 1 to 1.5 cm.

Unit III (141.6-300.0 mbsf; middle Miocene?): based on downhole logs, the contact between Unit II and Unit III is sharp, with marked increases in resistivity, velocity, and uranium content between 141 and 145 mbsf. Unit III is divided into three subunits based on changes in the composition of the fossil assemblages and sedimentary features.

Subunit IIIA (141.6-218.2 mbsf; middle Miocene?): Subunit IIIA contains white to very pale brown, dolomitized coralline algal packstones with molluscs, rhodolith rudstones with larger benthic foraminifers, and bioclastic wackestones. The algal content ranges from 30% to 40%. The lithoclasts have a sucrosic fabric and show moderate (20%-40%) porosity developed either as vugs or molds after dissolution of shell fragments. They were deposited in a shallow lagoonal, low- to medium-energy environment (~5 m water depth).

Subunit IIIB (218.2-255.7 mbsf; middle Miocene?): the contact between Subunits IIIA and IIIB is marked by a sharp change in resistivity, velocity, and bulk density signals measured in downhole logs. The appearance of scleractinian corals differentiates Subunit IIIB from the overlying sediments. It is composed of white, pale brown, and light gray dolomitized bioclastic floatstones with large fragments of corals and coralline algal debris embedded in a peloidal packstone and wackestone matrix. Porosity is moderate, less than 20%, and was produced by dissolution of bivalve shells. The sediments were deposited in shallow water close to a reefal environment (5-10 m water depths).

Subunit IIIC (255.7-300.0 mbsf; middle Miocene?): the boundary between Subunits IIIB and IIIC is thought to be a gradual transition to sediments more enriched in large benthic foraminifers (*Lepidocyclina*) and peloidal grains. The sediments are white to very pale brown dolomitized bioclastic peloidal packstones, foraminiferal packstones, and coralline algal rudstones. Rare nannofossils are present. The sediments were deposited in a deeper lagoonal environment (<30 m water depth). Cemented lithoclasts exhibit moldic porosity.

Aragonite concentrations, up to 50%, were recorded at 1 mbsf and decrease downward to values between 2% and 20% at 22 mbsf. A slight increase in strontium concentrations above seawater values between 0 and 24 mbsf suggests dissolution of metastable carbonate phases. Below this level, the strontium concentrations remain constant. Whereas the chlorinity (salinity) values remain approximately constant throughout the upper 113 m, there is a perceptible but slight decrease in Mg^{2+} concentration with a corresponding increase in Ca^{2+} concentration. These small changes may reflect *in-situ* dolomitization of the calcareous sediments. X-ray diffractograms of selected samples illustrate the occurrence of authigenic dolomite in three intervals: at 23.5 mbsf (10% dolomitized ooze above the hardground), between 85 and 170 mbsf (10%-100% dolomitized chalk and packstone), and between 247 and 294 mbsf (10%-100% dolomitized packstone to rudstone). Smear-slide descriptions indicate that dolomite is consistently present below 24.5 mbsf, beneath the top of the hardground.

Downhole measurements were made using the standard Schlumberger seismic-stratigraphic combination tool string and the formation microscanner (FMS). In particular, interpretation of the resistivity logs shows a distinct zone between 140 and 222 mbsf in which measurements vary abruptly, indicating alternating layers of high and low porosity.

The uranium log through this interval shows increased values, consistent with an expected pattern for dolomitization of different platform facies. The temperature log gave isothermal readings (~11°C) down to 225 mbsf followed by a sharp increase to 17.6°C, which would represent a minimum temperature considering the mud-circulation operation to condition the hole prior to logging. Together, the geochemical data, downhole measurements, and lithologic descriptions suggest that seawater may be moving downward and/or laterally through the upper 225 m of the platform and may be currently dolomitizing the calcareous sediments.

The total organic carbon content of the sediments was extremely low, less than 0.15%. Volatile hydrocarbons, with methane concentrations of 2 ppm and no detectable ethane or propane, presented no safety problems.

SITE 813

Site 813 (proposed site NEA-10A/3), together with Sites 812 and 814, is located on the southwestern edge of the extensive Tregrosse/Lihou/Coringa Bank complex. This three-site transect was intended to study facies distribution in response to sea-level change across a platform-slope transition in a pure carbonate system. Site 813 represents the most distal part of an aggradational/progradational sequence.

Results

Double-APC coring penetrated a 231.5-m-thick sequence of drowned platform sediments (average $CaCO_3$ = >95%) ranging in age from middle Miocene to Pleistocene. Benthic foraminiferal assemblages indicate a progressively increasing water depth from a shallow neritic setting (0-100 m) in the middle Miocene to an upper bathyal environment (200-600 m) during the late Pliocene and Pleistocene.

Five major sedimentary units were recovered between the seafloor and 231.5 mbsf. The lithologic units are as follows:

Unit I (0-76.8 mbsf; Pleistocene to upper Pliocene): the sediments are essentially homogeneous, micritic, foraminiferal to foraminiferal nannofossil ooze with bioclasts. The generally high content of nannofossils (50%-80%) is consistent with a predominantly pelagic origin for the ooze, but variable degrees of induration throughout the interval suggest that the flux of metastable bank-derived carbonates - having a greater diagenetic potential - was not constant. Benthic foraminifers indicate an upper bathyal paleowater depth (200-600 m).

Unit II (76.8-117 mbsf; lowermost upper Pliocene-upper Miocene): this unit consists of nannofossil foraminiferal ooze with micrite. The upper boundary is marked by salmon-colored granular foraminiferal ooze containing reddish brown to reddish yellow, presumably iron-stained particles mixed with *in-situ* foraminifers, bioclasts, and grains of indeterminant origin. In the lower part of the unit, the ooze is characterized by the presence of dark grains that are phosphatized benthic foraminifers. Benthic foraminiferal assemblages indicate that deposition of Unit II occurred during the transition from an outer neritic to an upper upper bathyal paleobathymetric setting (100-300 m).

Unit III (117-160 mbsf; upper Miocene): bioclastic foraminiferal ooze with micrite and nannofossils; this unit differs from the overlying units in having a reduced nannofossil content (~20%-30%) in the fine fraction relative to the overlying oozes (which contain 50%-80% nannofossils). This difference suggests that there was a larger input of bank-derived metastable carbonate during this period. Such sediments are designated as periplatform oozes.

Unit IV (160-~195 mbsf; lowermost upper Miocene-middle Miocene): sediments of this unit are dolomitized semi-lithified to lithified foraminiferal micritic chalks containing bioclasts interbedded with dolomitized unlithified to semi-lithified micritic foraminiferal ooze containing bioclasts and nannofossils. The basal 3 m contains dolomitized bioclastic nannofossil chalk interbedded with dolomitic foraminiferal rudstone and packstone. The larger benthic foraminifers indicate that deposition occurred in the middle to outer neritic zone (50-200 m).

Unit V (~195-231.5 mbsf; middle Miocene or older?): extremely poor recovery in this interval yielded only fragments of completely dolomitized skeletal grainstones and microcrystalline dolomite. Dolomitization is largely fabric destructive, but we nevertheless recognized such skeletal elements as calcareous algae and foraminifers. This biota suggests a shallow neritic environment (10-50 m) adjacent to or on the carbonate bank.

The sedimentation rate for the upper Pliocene to Pleistocene interval was 2.2 cm/k.y., succeeding a rate of ~1.2 cm/k.y. in the early Pliocene. During the latest late Miocene, the sedimentation rate was 3 cm/k.y. Nannofossil foraminiferal oozes of lithologic Unit II were deposited during the earliest late Pliocene to late Miocene and are distinguished from the overlying and underlying oozes by the inclusion of numerous iron-stained and/or phosphatized particles. In addition, a major change in physical properties (e.g., lower velocity and increased porosity and water content) occurs between 64.2 and 102.4 mbsf, generally encompassing most of Unit II. These properties suggest that the fine particles in the ooze may have been winnowed away, leaving behind a coarser grained, more porous sediment. The concentration of iron-stained and phosphatized reworked particles in the oozes requires a source area wherein these chemical alterations occurred, possibly associated with the contemporaneous condensed sequence recovered at nearby Site 814.

X-ray diffractograms of selected samples detected the presence of authigenic dolomite, which increases in abundance with depth from 1.3% at 2.3 mbsf to 78.2% at 193.7 mbsf. Unit V contains 100% microcrystalline dolomite. Aragonite concentrations up to 32% were recorded at 2.3 mbsf and progressively decreased with depth, being absent below 22.7 mbsf. A slight increase in Sr^{2+} and Ca^{2+} concentrations above seawater values between 0 and 22.7 mbsf suggests dissolution of metastable carbonate phases. Below this dissolution level, the Sr^{2+}, Ca^{2+}, and Mg^{2+} concentrations remain constant until between 89.2 and 107.5 mbsf, where distinct shifts in the Sr^{2+}, Ca^{2+}, and Mg^{2+} concentrations occur. The values afterward remain constant to the base of the sampled section. The interstitial water chemistry suggests the possible existence of two aquifers; the boundary between them may be associated with the base of the low-velocity, increased porosity zone at 102.4 mbsf.

The total organic carbon content of the sediments was low, varying between 0.05% and 0.65%. Volatile hydrocarbons, with methane concentrations of 2 ppm and no detectable ethane or propane, presented no safety problems.

Shipboard paleomagnetic studies revealed a good reversal stratigraphy in the upper part of the section, registering the Matuyama/Gauss boundary at 54 mbsf (2.47 Ma). Below this level, the paleomagnetic reversal signal should be resolvable with shore-based study of discrete samples.

SITE 814

Site 814 (proposed site NEA-10A/2) is located on the southwestern edge of the extensive Tregrosse/Lihou/Coringa Bank complex and is part of the three-site transect, together with Sites 812 and 813, intended to study facies distribution in response to sea-level change across a platform-slope transition in a pure carbonate system. The site is positioned in front of the carbonate bank and represents the proximal transition between the lagoonal-bank (Site 812) and the distal part (Site 813) of an aggradational/progradational sequence.

Results

Drilling penetrated a 300-m-thick sequence of platform-slope sediments (average carbonate content = 96%) ranging in age from middle Miocene (or older) to Pleistocene. The benthic foraminifers indicate an overall deepening of the depositional environment from a shallow neritic setting (0-100 m) in the middle Miocene to an upper bathyal environment (200-600 m) during the late Pliocene-Pleistocene. The sedimentation rate for the late Pleistocene was 2.4 cm/k.y., whereas it was reduced to ~1.2 cm/k.y. in the late Pliocene-early Pleistocene. The late Miocene-early Pliocene at Site 814 is either missing or corresponds to a time of reduced sedimentation. A preliminary estimate of middle Miocene sedimentation rates based on initial data is ~1.4 cm/k.y.

Five major sedimentary units were recovered between the seafloor and 300.0 mbsf. The lithologic units are as follows:

Unit I (0-56.8 mbsf; Pleistocene to upper lower Pliocene): Unit I is divided into two subunits on the basis of intercalations of foraminiferal packstones within the predominant lithology, nannofossil foraminiferal ooze, near the base.

Subunit IA (0-53.4 mbsf; Pleistocene to upper Pliocene, 0-3.8 Ma): white nannofossil foraminiferal oozes with minor changes to foraminiferal nannofossil oozes make up this subunit. They exhibit scattered gray to brown mottled patterns caused by burrowing and contain minor amounts of lithoclasts and bioclasts, including bivalve shells and echinoid spines. The nannofossil content decreases downward from ~70% at the top to ~20% near the base. This trend may reflect decreased amounts of pelagic input and increased supply of bank-derived metastable carbonates in the older sediments, or a change from pelagic to periplatform sedimentation. Benthic foraminiferal assemblages indicate upper bathyal water depths (200-600 m).

Subunit IB (53.4-56.8 mbsf; upper lower Pliocene): Subunit IB consists of white foraminiferal packstones with minor phosphate grains and fish teeth interbedded within nannofossil micritic ooze. Benthic foraminiferal assemblages indicate neritic water depths (0-200 m).

Unit II (56.8-66.5 mbsf; lower Pliocene?-upper Miocene?): Unit II is a well-lithified yellow to white foraminiferal micritic limestone that contains fish teeth and phosphate grains and is capped by a well-developed hardground surface coated with a multilaminated iron-rich crust. The surface has been bored and filled in by several generations of cement. Moldic and vuggy porosity occurs, in addition to scattered silt-sized dolomite crystals and grains. Coring recovered only 0.6 m of limestone, but downhole logging suggests that Unit II is ~8 m thick with the degree of induration decreasing downward.

Unit III (66.5-136.0 mbsf; middle Miocene): Unit III is divided into two subunits based on a composition change from micritic ooze to bioclastic packstone.

Subunit IIIA (66.5-114.0 mbsf; middle Miocene, 10.4-13.2 Ma): Subunit IIIA contains micritic oozes with nannofossils and foraminifers and foraminiferal nannofossil oozes that show subtle color changes from reddish brown to white. The nannofossil abundance is less than 20%. Silt-sized monocrystalline calcite is locally abundant, together with minor amounts of dolomite. Between 96.5 and 98.3 mbsf, unlithified bioclastic floatstones with shelf-derived coarse skeletal grains are intercalated with the micritic ooze. The sediments were deposited in outer neritic water depths (100-200 m), which apparently shallowed to middle neritic (30-100 m) near the top of Subunit IIIA (76.0 mbsf). Downhole logging shows that this subunit has a uniformly high porosity.

Subunit IIIB (114.0-136.0 mbsf; middle Miocene): Subunit IIIB is characterized by unlithified to partially lithified white bioclastic packstones. The bioclastic components include bivalve shells, echinoid spines, shark teeth, and solitary corals. Benthic foraminiferal assemblages indicate outer neritic water depths (100-200 m).

Unit IV (136.0-263.9 mbsf; middle Miocene): the occurrence of coarse-grained lithologies at the top and base of this predominantly fine-grained interval defines three subunits for Unit IV.

Subunit IVA (136.0-150.0 mbsf; middle Miocene): Subunit IVA is a white dolomitized bioclastic packstone. Dolomitization has been so pervasive that only coralline algal fragments - a minor component - are recognizable. Downhole logging distinguishes the top of the subunit and indicates that it is the most indurated interval in Hole 814A.

Subunit IVB (150.0-256.1 mbsf; middle Miocene, older than 13.2 Ma but younger than 17.1 Ma): the lithologies of Subunit IVB vary between a calcareous ooze and a partially lithified mudstone. Bioclasts are locally abundant (up to 25%). Benthic foraminiferal assemblages indicate middle neritic water depths (50-100 m). The mudstones are composed predominantly of silt-sized calcite crystals with euhedral, bipyramidal elongate habits. These are thought to be originally detrital grains with later diagenetic overgrowth. Downhole logging shows this subunit to be relatively uniform in character.

Subunit IVC (256.1-263.9 mbsf; middle Miocene?): the upper part of Subunit IVC (256.1-258.9 mbsf) contains white partially lithified lithoclastic floatstones, whereas the lower part (258.9-263.9 mbsf) consists of white unlithified lithoclastic rudstones. Benthic foraminifers are abundant, and lithoclasts are exclusively dolomite.

Unit V (263.9-300.0 mbsf; age unknown): Unit V is a yellowish brown to pale brown dolomitized lithified packstone primarily composed of sucrosic dolomite with high intergranular porosity. Dolomitization has obliterated any original fabric and texture.

Aragonite concentrations, up to 63%, were recorded at 0.8 mbsf and progressively decreased downward, disappearing entirely by 32.4 mbsf. Aragonite reappears deeper in Hole 814A with values up to 34% at 258 mbsf. Interstitial water chemistry for the interval between 0 and 50 mbsf shows an increase in Ca^{2+} and Sr^{2+} concentrations above seawater values, indicating dissolution of metastable carbonate phases. Over the entire water chemistry profile, there is a perceptible downward decrease in Mg^{2+} concentration. This decrease may be related to *in-situ* dolomitization of the calcareous sediments. X-ray diffraction analysis of selected samples detected the occurrence of dolomite in two discrete intervals, between 96 and 138 mbsf and below 244 mbsf.

The Ca^{2+} and Sr^{2+} concentrations remain fairly constant below 50 mbsf to the bottom of the water profile at 257 mbsf. In particular, the Sr^{2+} concentration below 50 mbsf resembles that for seawater. Apparently, as at Site 813, two aquifers were penetrated during drilling, but in the case of Site 814 they are separated by a distinct lithologic boundary, i.e., the limestone hardground of Unit II. The chemistry of the lower aquifers at both Sites 813 and 814 appears to be the same, a possible indication for fluid flow between the two areas. In addition, the temperature logs for Hole 814A indicate that warm water (~19.5°C) is flowing upward out of the lowest penetrated portion of the formation. The lower boundary of the upper aquifer at both sites coincides with lithologic changes that correspond to upper Miocene-lower Pliocene condensed sedimentation intervals. Seismic profiles run between both sites show that the sediment package constituting the lower aquifer is apparently an aggradational/progradational wedge beneath the condensed surface.

Shipboard paleomagnetic studies revealed a good reversal stratigraphy in the upper part of the section, registering the Matuyama/Gauss boundary in Hole 814B at 43 mbsf (2.47 Ma). Based on an initial interpretation of the paleomagnetic data, the sediments directly overlying the hardground (lithologic Unit II) were deposited during the Gauss magnetic zone and are probably not older than 3.4 Ma. Below this level, the paleomagnetic reversal signal should be resolvable with shore-based study of discrete samples.

The total organic carbon content of the sediments was low, less than 0.30%. Volatile hydrocarbons, with methane concentrations of 2 ppm and no detectable ethane or propane, presented no safety problems.

SITE 815

Site 815 (proposed site NEA-14) lies along the southern margin of the Townsville Trough, ~3 km north and in front of the northwestern edge of the Marion Plateau. The site was intended to establish the composition and age of the forereef and the downlapping and onlapping sediments that overlie the platform, and to establish the cause and timing of the demise of the platform. Additional objectives were to investigate paleoclimatic history and the facies response to climatic variation and the initiation of boundary-current activity.

Results

Drilling penetrated a 473.5-m-thick sequence of sediments composed of a 416-m-thick package of uppermost Miocene-Pleistocene hemipelagic sediments overlying lower/middle-upper Miocene shelf carbonates. Benthic foraminifer assemblages in the uppermost Miocene sediments indicate outer neritic water depths (100-200 m) but also contain redeposited reefal taxa. During the period of hemipelagic sedimentation, Site 815 had deepened to upper bathyal depths (200-600 m). Sedimentation rates during the late Pliocene-Pleistocene were 1.7 to 3.2 cm/k.y., relatively normal for a pelagic setting, but increased tenfold during the early Pliocene with rates up to 32.4 cm/k.y. for the interval between 3.51 and 4.24 Ma. The expanded lower Pliocene section, with ~275 m of sediment, offers great potential for high-resolution biostratigraphic investigations.

Six major sedimentary units were recovered between the seafloor and 473.5 mbsf. The lithologic units are as follows:

Unit I (0-73.3 mbsf; Pleistocene to lower upper Pliocene): Unit I is divided into three subunits based on color and clay content of the predominantly foraminifer nannofossil to nannofossil foraminifer ooze. The nannofossil content varies between 20% and 30%.

Subunit IA (0-16.3 mbsf; Pleistocene): Subunit IA contains alternating pale brown and white foraminifer nannofossil to nannofossil foraminifer ooze with varying amounts of micrite and bioclastic debris and no to low clay content.

Subunit IB (16.3-35.3 mbsf; upper upper Pliocene): Subunit IB differs from the overlying oozes in that it has consistently higher clay content and exhibits alternating dark-light intervals.

Subunit IC (35.3-73.3 mbsf; lower upper Pliocene): Subunit IC differs from the overlying oozes in that it has a variable clay content (up to 25%) and is darker in color, changing from a light gray to a darker gray.

Unit II (73.3-280.5 mbsf; lower Pliocene): Unit II comprises the greatly expanded lower Pliocene section recovered at Site 815. The sediments are greenish gray to gray, slightly bioturbated nannofossil oozes to unlithified nannofossil mixed sediment. Unit II is divided into two subunits on the basis of the degree of induration and varying percentages of foraminifers and nannofossils.

Subunit IIA (73.3-111.3 mbsf; lower Pliocene): Subunit IIA is characterized by soft to very firm, dark gray to gray foraminifer nannofossil and nannofossil foraminifer ooze. Thin patchy chalk to lithified intervals occur between 92.3 and 111.3 mbsf. The nannofossil content is ~25%.

Subunit IIB (111.3-280.5 mbsf; lower Pliocene): Subunit IIB is characterized by local partial lithification of the dark to light greenish gray to varying gray nannofossil ooze with clayey nannofossil mixed sediment. Repetitive color changes suggest cyclic sedimentation, with the color pattern probably controlled by changes in both grain size and carbonate content. The nannofossil content varies between 10% and 35%.

Unit III (280.5-348.4 mbsf; lower Pliocene): the greenish gray to gray foraminifer nannofossil and nannofossil foraminifer chalks making up Unit III are distinguished by a marked increase in the degree of induration and intervals of contorted and folded bedding. The nannofossil content increases strikingly in Unit III with values up to 80%.

Subunit IIIA (280.5-306.25 mbsf; lower Pliocene): Subunit IIIA contains foraminifer nannofossil and nannofossil foraminifer chalks that are distinguished by the presence of numerous and generally larger burrow structures.

Subunit IIIB (306.25-348.4 mbsf; lower Pliocene): these foraminifer nannofossil and nannofossil foraminifer chalks are characterized by the occurrence of contorted and locally folded bedding within blocks of chalk and within the matrix sediment. There is evidence for several discrete intervals of slumping. Soft sediment deformation of the blocks apparently occurred during transport.

Unit IV (348.4-425.3 mbsf; upper upper Miocene): Unit IV contains predominantly greenish gray foraminifer nannofossil and nannofossil foraminifer chalks with a marked increase in the number of burrows preserved as sedimentary structures. Larger burrows appear to become more numerous with depth; recognized trace fossils include *Chondrites, Zoophycos, Planolites,* and possibly *Scoyenia*. The nannofossil content varies between 35% and 50%.

Unit V (425.3-444.5 mbsf; upper middle to upper Miocene): Unit V contains pale brown dolomitized lithified foraminifer packstones with bioclasts and minor amounts of chalk. Trace fossils are abundant in the upper part of the unit becoming less common with depth. Between Units V and VI (444.5-454.2 mbsf) there was no recovery, and downhole logging did not reach this level. As a consequence, any interpretation of this interval is impossible at this time.

Unit VI (454.2-473.2 mbsf; uppermost lower Miocene to lower middle Miocene): dolomitized white large benthic foraminifer rudstones to floatstones within a planktonic foraminifer packstone characterize the poorly recovered material of Unit VI.

The interstitial water chemistry of the hemipelagic sequence cored at Site 815 shows a downward trend of increasing ionic concentrations that point to an underlying source of water having an elevated salinity, probably associated with evaporite dissolution. Within the upper 200 m of the section, the chemistry is apparently controlled by clay mineral alteration, metastable carbonate dissolution, and bacterial sulfate reduction. The byproduct of the latter reaction, hydrogen sulfide, is consumed during the formation of pyrite and pyrrhotite. Higher magnetic susceptibility between 125 and 440 mbsf indicates the presence of pyrrhotite, which has a ferrimagnetic moment. Large nodules (~3 cm) of pyrite and pyrrhotite were observed below 350 mbsf. This correlates with increased bulk sulfur concentrations up to 0.45% between 350 and 440 mbsf. Apparently, all of the ingredients for pyrite formation (organic matter, sulfate, and ferrous iron) are available in this system; in particular, there is an unlimited supply of sulfate migrating upward from an underlying source, as shown by the progressive increase in sulfate concentration with depth below ~200 mbsf.

The predominant carbonate mineral is calcite, but aragonite is also present within the hemipelagic sequence. It disappears downward within the Pleistocene sediments but reappears in upper and lower Pliocene sediments with contents ranging between 2% and 23%. High Mg-calcite was recorded at 4.5 mbsf but was not found again below this level. The carbonate content exhibits a large range of variation from over 90% to as low as 34.3%, but there is an overall trend toward decreasing values downward between ~75 and 260 mbsf. This interval lies within the expanded lower Pliocene section. Estimates of the nannofossil content in core catcher samples remain rather constant throughout the high-sedimentation period (3.51 and 4.24 Ma), implying that the pelagic contribution to the sediments did not vary significantly. Thus, variations recorded in the carbonate content are probably related to changes in the carbonate composition of the detrital input and may reflect the relative contribution of material eroded from the regional carbonate platforms vs. the terrestrial contribution of clays.

The mechanism of lateral transport of fine-grained material and deposition as a drift or contourite best explains the rapid accumulation of the 275-m-thick wedge of sediments between 3.51 and 4.24 Ma at Site 815, as well as the geometric expression of the sedimentary deposit in seismic profiles. The interval of accelerated sedimentation is characterized by distinctive physical properties, as observed in both shipboard analyses and downhole-logging profiles. Shipboard measurements of porosity, bulk density, and water content of sediments through this interval show abnormally constant values with depth. This suggests that the very high sedimentation rate rapidly buried the sediments and, in combination with low permeabilities, did allow sufficient time for the sediments to dewater, as normally occurs with burial compaction. Velocity and density logs show a simple, first-order compaction profile with depth. In addition, these logs and the resistivity log contain high-frequency variations, indicating porosity anomalies related to a combination of changes in consolidation and lithology.

Shipboard paleomagnetic studies revealed a good reversal stratigraphy in the upper Pliocene-Pleistocene sediments, registering the Gauss/Gilbert boundary at ~62 mbsf (3.4

Ma). Based on the initial results, a good paleomagnetic reversal signal should be resolvable in the uppermost Miocene-lower Pliocene sediments with the shore-based study of discrete samples.

The total organic carbon content of the sediments was low but variable, ranging between 0% and 1.0%. Volatile hydrocarbons, with methane concentrations up to 9 ppm and rare trace amounts of ethane and propane, presented no safety problems.

SITE 816

Site 816 (proposed site NEA-13) is located on the northwestern corner of the Marion Plateau. This site was intended to determine the nature and age of the buildups on the northern edge of the Marion Plateau, the minimum position and timing of the middle Miocene sea-level fall, and to determine the cause(s) of the demise of these buildups.

Results

Drilling penetrated a 250-m-thick sequence of sediments composed of a 90-m-thick unit of lower Pliocene-Pleistocene hemipelagic sediments overlying very shallow-water (less than 5 m) lithified carbonates of earliest Pliocene or older age. The bio-assemblages of the shallow-water sediments are clearly chlorozoan, indicative of warm surface waters. Within the hemipelagic sediments, benthic foraminifer assemblages indicate upper bathyal depths (200-600 m) during the period of sedimentation. The sedimentation rate was low (0.5 cm/k.y.) during the late Pleistocene, whereas late Pliocene rates (2 cm/k.y.) were rather normal for a pelagic setting. Shipboard paleomagnetic studies show a reversed paleomagnetic signal for the sediments from the top 31 m of Hole 816A, indicating that most of the Brunhes and perhaps part of the Matuyama magnetic zones are missing. This could account for the low sedimentation rate in the Pleistocene. As at Site 815, the sedimentation rate apparently increased dramatically during the early Pliocene, but until there is better biostratigraphic control it is impossible to estimate how high the rate actually was. Shore-based studies of material obtained from this sedimentary sequence, together with that from Site 815, will provide important environmental information on the factors controlling carbonate platform growth and demise.

Three major sedimentary units were recovered between the seafloor and 250 mbsf. The lithologic units are as follows:

Unit I (0-90.0 mbsf; Pleistocene to lower Pliocene): at the top, Unit I comprises light gray foraminifer nannofossil ooze that grades into olive green nannofossil clayey ooze with dolomite and foraminifers at the base. It has been divided into four subunits based on the varying ratios of foraminifers, nannofossils, and clay.

Subunit IA (0-15.0 mbsf; uppermost Pliocene-Pleistocene): Subunit IA contains locally bioturbated light-gray nannofossil foraminifer ooze with clay and bioclasts. The carbonate content is usually greater than 80% but decreases to 77% at 9.5 mbsf.

Subunit IB (15.0-24.5 mbsf; upper Pliocene): Subunit IB contains olive-gray bioturbated mottled clayey foraminifer ooze with nannofossils. The carbonate content generally ranges between 71% and 75%.

Subunit IC (24.5-62.5 mbsf; Pliocene): Subunit IC contains olive-gray bioturbated mottled clayey foraminifer nannofossil ooze. Bioturbated areas are locally pyrite rich. The carbonate content ranges from 54% to 82%.

Subunit ID (62.5-90.0 mbsf; lower Pliocene): Subunit ID contains olive-gray to olive bioturbated nannofossil ooze to chalk with foraminifers and dolomite. The carbonate content varies from 58% to 84%.

Unit II (90.0-163.7 mbsf; age unknown, but probably older than nannofossil Zones CN 10-11 and planktonic foraminifer Zones N18-19): Unit II contains partially dolomitized rhodolith-bearing bioclastic floatstone and rudstone. Spheroidal to discoidal rhodoliths are cemented within a matrix consisting of coarse angular fragments of molluscs, coralline algae, coral, *Halimeda,* bryozoans, echinoid spines, and lithoclasts. Moldic and intraparticle porosity is well developed and geopetal fabrics partially fill some cavities. Deposition probably occurred in a shallow (less than 5 m water depth) back-reef environment.

Unit III (163.7-250.0 mbsf; older than lower Pliocene): Unit III consists of dolomitized coralline algal and coral (including *Porites* and *Acropora*) boundstone and framestone with white rhodoliths up to 5 cm in diameter. The minor bioclasts include fragments of coralline algae, molluscs, rare *Halimeda,* and coral. Moldic and intraparticle porosity are well developed. Deposition probably occurred in very shallow water on a reef flat, possibly in an intertidal regime.

The interstitial water chemistry of the hemipelagic sequence cored at Site 816 shows a downward trend of increasing Ca^{2+} and decreasing Mg^{2+} concentrations to 80 mbsf. This inverse correlation can be attributed to dolomite formation below 90 mbsf within the shallow-water carbonate units. The Sr^{2+} concentration increases downward, reflecting the dissolution of metastable carbonates. When normalized to the chloride concentration, the sulfate content decreases downward, an indication for bacterial sulfate reduction. The presence of sulfur in the bulk sediment, with concentrations as high as 14%, is consistent with sulfate reduction in the hemipelagic sequence.

From the top to 90 mbsf, the predominant carbonate mineral is calcite, but aragonite is also present (up to 12.6%) within the upper Pliocene hemipelagic sediments between 22.4 and 79.4 mbsf. In Units II and III, the dominant carbonate mineral is dolomite. The carbonate content of the hemipelagic sediments is variable, ranging from 50% to 90%, but with depth there is an overall trend toward decreasing values to 80 mbsf.

Extremely high variability in both resistivity and velocity logs was measured in the depth intervals corresponding to Units II and III, indicating correspondingly high variability in porosity, which is presumably controlled by diagenesis. The character of the record differs between the two units, suggesting different sedimentary/diagenetic histories. Unit II shows about four cycles of very large bimodal alternations between near-zero porosity and high porosity. The bimodality is probably related to the initial lithostratigraphy rather than diagenetic recrystallization, but the near-zero values, however, would require substantial recrystallization. Unit III shows a different velocity/resistivity relationship than that recorded for Unit II. With substantial porosity increases, the observed pattern in the logs suggests that the rocks in Unit III have experienced considerable cementation followed by a later stage of dissolution, which produced porosity with a high degree of pore connectivity but had little effect on the rigidity of the formation.

The total organic carbon content of the sediments was low but variable, ranging between 0% and 0.55% with slightly higher values for the hemipelagic sediments. Volatile hydrocarbons, with methane concentrations ~2 ppm and no ethane or propane, presented no safety problems.

SITE 817

Site 817 (proposed site NEA-11) is located on the northern side of the Townsville Trough, on the lower slope of the Queensland Plateau southwest of the Tregrosse/Lihou/Coringa bank complex. The site was intended to obtain stratigraphic and age data to interpret event stratigraphy in the Townsville Trough. Other objectives included obtaining paleoclimatic data on the change from temperate to tropical climates as Australia drifted north in the Neogene, and to determine the age and origin of carbonate deposition on the Queensland Plateau.

Results

Drilling penetrated a 700-m-thick sequence of carbonate platform slope sediments ranging in age from late early Miocene to Pleistocene. The sequence contains a record of the varying flux of platform-derived vs. pelagic-derived carbonate sediment to the slope deposit. The latest early Miocene to middle Miocene and the early late Pliocene to Pleistocene were periods when material derived from the carbonate platform dominated the slope sediments. During the intervening period, late middle Miocene to early late Pliocene, the Queensland Plateau was apparently drowned and did not produce significant amounts of sediment, allowing the pelagic flux to dominate.

The nature of the bank-derived sediment deposited at Site 817 varied with time; during the middle Miocene, bioclastic debris accumulated on the slope, whereas, in the Pliocene to Pleistocene, only periplatform ooze reached the depositional site. This implies that during the middle Miocene the slope was immediately adjacent to a producing carbonate platform margin. During the Pliocene to Pleistocene, the area of carbonate production had stepped back to the present position of the Tregrosse/Lihou/Coringa bank complex. This rejuvenated platform complex that developed after the apparent late Miocene to early Pliocene drowning was much smaller and at a considerable distance from Site 817, enabling only the fine-grained material to reach the preexisting slope.

Three major sedimentary units were recovered between the seafloor and 700 mbsf. The lithologic units are as follows:

Unit I (0-200.8 mbsf; Pleistocene to uppermost Miocene): Unit I contains white strongly bioturbated micritic ooze with foraminifers and nannofossils (0-120 mbsf) that grades with depth into a nannofossil ooze with foraminifers and micrite (120-200.8 mbsf). The change between the overlying periplatform (micritic) ooze and the underlying pelagic (nannofossil) ooze is transitional, as the micritic content decreases gradually over a 30- to 40-m interval below 120 mbsf. Thin interbeds (mostly <1 cm to 10 cm but up to 60-cm-thick) of graded, well-sorted foraminiferal ooze are found throughout the unit and are interpreted as calciturbidites. Near the base, small patches of chalk appear within the ooze. Soft-sediment deformation in the form of slump folds occurs at several points.

The Unit I sediments were deposited at middle to upper lower bathyal depths (~1000 m) in small channels or gullies on a slope immediately adjacent to a carbonate platform. During the late Miocene through the early Pliocene, the carbonate platform was apparently drowned, but in the early late Pliocene, bank-derived material began to reach Site 817. During the remainder of the late Pliocene and Pleistocene, periplatform ooze with minor coarser grained material was supplied to the depositional site from nearby active carbonate banks, such as the Tregrosse/Lihou/Coringa bank complex. During this later period, variations in sedimentation rate and the proportion of pelagic vs. periplatform ooze may be related to variations in platform productivity. In particular, decreased production may be associated with lower sedimentation rates in the latest Pliocene to early Pleistocene (2.29-0.93 Ma).

Unit II (200.8-426.7 mbsf; upper Miocene to uppermost lower Miocene): a possible unconformity, distinguished by an increased degree of induration from ooze to chalk, separates Units I and II. Unit II is divided into three subunits based on the redeposited nature of the sediments beneath the unconformity (Subunit IIA) and the relative contribution of pelagic-derived (Subunit IIB) vs. increasing platform-derived (Subunit IIC) carbonate sediments with depth.

Subunit IIA (200.8-214.7 mbsf; upper Miocene): Subunit IIA contains micritic chalk with detrital calcite and redeposited lower middle Miocene foraminifers intermixed with *in- situ* upper Miocene foraminifers. These sediments were probably derived from the erosion of middle Miocene sediment upslope from Site 817.

Subunit IIB (214.7-308.6 mbsf; middle Miocene): Subunit IIB consists of nannofossil chalk with foraminifers, micrite, sponge spicules, and radiolarians. An increased concentration of biogenic silica in these sediments is in accordance with the worldwide increase commonly observed in middle Miocene marine deposits. The nannofossil and siliceous fossil content decreases downward as the micrite content gradually increases.

Subunit IIC (308.6-426.7 mbsf; middle Miocene to uppermost lower Miocene): the transition from Subunit IIB to Subunit IIC represents the gradual change with depth from pelagic to periplatform-derived sediments. Subunit IIC contains micritic chalk with foraminifers and bioclasts. Bioclasts become increasingly more common with depth, as does the dolomite content. The gradual upward decrease in bioclastic components and the change in the fine-grained component from periplatform to pelagic ooze represent progressive drowning of the carbonate platform. In addition, the loss of the coarser grained material could indicate that there had been retrogradation from a debris apron into a more basinal environment.

Unit III (426.7-700.0 mbsf; uppermost lower to middle Miocene, not older than 18 Ma): the contact between Units II and III is apparently gradational and conformable. It is arbitrarily placed where the first coarse-grained bioclasts appear in the sediments. Unit III is characterized by its relatively coarse-grained bioclastic limestone and dolomite. It is divided into three subunits based on the amount of fine-grained sediment and the degree of dolomitization.

Subunit IIIA (426.7-465.3 mbsf; uppermost lower to middle Miocene): the dominant lithology is fine-grained dolomitic bioclastic packstone and grainstone interbedded with dolomitic bioturbated chalk containing foraminifers and bioclasts. The skeletal debris includes large lepidocyclinid foraminifers and other bioclasts, such as coralline algae, bryozoans, and molluscs, derived from neritic sources. The packstone and grainstone commonly show moldic and vuggy porosity. The probable depositional environment was a base-of-slope debris-apron position transitional into slope or basin.

Subunit IIIB (465.3-570.7 mbsf; uppermost lower to middle Miocene): Subunit IIIB consists primarily of dolomitic high-porosity bioclastic packstones and grainstones. Skeletal grains include benthic and planktonic foraminifers and fragments of coralline algae, molluscs, byrozoans, and corals. Glauconitic sand grains occur in many samples. Sedimentary structures include coarse planar lamination, small ripples, and bioturbation. A secondary lithology is finer grained dolomitic wackestones with very fine-sand- to silt-sized bioclasts and/or planktonic foraminifers. Scattered chert nodules were recovered. The probable depositional environment was on a base-of-slope debris apron.

Subunit IIIC (570.7-700.0 mbsf; uppermost lower to middle Miocene): the predominance of sucrosic dolostone distinguishes Subunit IIIC. At the top and base, the dolostone is fine grained and bioturbated, whereas in the middle it has a distinctive yellowish brown color and pervasive large vugs and molds. At the very base, white sucrosic dolostone capped by phosphatized glauconitic lithoclasts and phosphatized skeletal fragments was recovered and may represent a hardground. The extensive dolomitization obscures original fabrics, making determination of the depositional environment difficult, but it was probably similar to the base-of-slope debris apron of Subunit IIB.

The carbonate content of the Site 817 sediments ranges between 87% and 97%. In the upper Neogene sediments (Unit I), the content fluctuates but there are systematic trends. From the upper Miocene through the lower Pliocene sediments, the percentage of carbonate tends to increase, reaching a maximum value at ~3.5 Ma. Throughout the upper Pliocene to lower Pleistocene sediments, the trend reverses with a gradual decrease reaching a minimum value at ~1.0 Ma. In the middle Pleistocene sediments, the percentage of carbonate again increases. The observed changes in the carbonate content may be a function of such variables as the flux of bank-derived vs. pelagic-derived carbonate, dissolution rate at the seafloor and dilution by fine-grained terrestrial material.

The carbonate mineralogy of the upper Pleistocene sediments is a ~50/50 mixture of calcite and aragonite with detectable amounts of high-Mg calcite. The aragonite content can be as high as 61% but decreases gradually with depth in the lower Pleistocene sediments. The upper Pliocene sediments are devoid of aragonite. Dolomite is absent in Unit I and most of Unit II sediments. Increasing dolomite concentration, ~5% to 10%, with depth occurs in Subunit IIC. The sediments below in Subunit IIIA are increasingly more dolomitized (~32%), becoming pervasively dolomitized within Subunit IIIB and below.

The interstitial water chemistry of the sequence cored at Site 817 shows a downward trend toward decreasing Ca^{2+} and increasing Mg^{2+} concentrations with respect to seawater to ~20 mbsf. Below this depth, the Ca^{2+} concentration progressively increases, while the Mg^{2+} concentration decreases. The Sr^{2+} concentration increases steadily with depth reaching a maximum value at ~60 mbsf. The chemistry of the upper 100 m indicates that dissolution of metastable carbonates, aragonite, and high-Mg calcite occurs together with precipitation as low-Mg calcite. Below 100 mbsf, the Ca^{2+} and Mg^{2+} chemistry is apparently controlled by dolomite formation. The chloride concentration tends to increase steadily below 175 mbsf, resulting in a value 6% greater than seawater at 303 mbsf. The latter indicates that, in addition to the diagenetic imprint on the fluids, the presence of water with elevated salinity below the studied interval may influence the interstitial chemistry.

Hole 817C was cored specifically to secure an upper Pleistocene section for high-resolution shore-based interstitial water studies. A total of 268 samples were squeezed from 10-cm sections cut from three APC cores covering the upper 27.2 m at Site 817. Shipboard alkalinity measurements of the samples showed trends not seen in the analysis of less densely spaced samples (i.e., one per core), implying that geochemical signals are preserved on a high-resolution scale.

The total organic carbon content of the sediments was low but variable, with maximum values of 0.5%. Volatile hydrocarbons, with methane concentrations up to 11 ppm, ethane up to 2 ppm, and no propane, presented no safety problems.

SITE 818

Site 818 (proposed site NEA-9A) is located on a gently inclined terrace on the upper slope of the Queensland Plateau southwest of the Tregrosse/Lihou/Coringa bank complex. The location was selected to penetrate an uniquely thick pile of upper Neogene sediments accumulating on the terrace. The major site objective was to determine the composition and origin of the slope units immediately seaward of the Neogene carbonates of the southern margin of the Queensland Plateau.

Results

APC drilling fully recovered a 303-m-thick sequence of periplatform sediments ranging in age from early Pliocene to Pleistocene. Benthic foraminifer assemblages indicate that the depositional environment remained at middle bathyal paleodepths (600-1000 m) throughout this period. The occurrence of platform-derived carbonate throughout the sequence implies that banks were producing and that carbonate has been transported off the Queensland Plateau since the early Pliocene. The sequence, however, contains a record of varying flux of bank-derived carbonate to the upper slope that may be associated with changes in the rate of bank productivity and/or the amount of redeposited sediments accumulating at the site. Based on sedimentation rates, we have identified two periods with significantly modified rates of carbonate accumulation compared with the rate for the past 1.5 m.y. (5.7 cm/k.y.): between 1.5 and 2.42 Ma, a decelerated rate of 2.4 cm/k.y. is half as great, and between 2.42 and 2.6 Ma, an accelerated rate of 42 cm/k.y. is more than 7 times greater.

One major sedimentary unit was recovered between the seafloor and 293.4 mbsf. A second sedimentary unit was barely penetrated between 293.4 mbsf and the bottom of Hole 818B at 302.9 mbsf. The lithologic units are as follows:

Unit I (0-293.4 mbsf; Pleistocene to lower Pliocene): Unit I contains white to light gray homogeneous periplatform oozes composed of varying proportions of micrite and nannofossils with minor amounts of bioclasts, foraminifers and pteropods. The unit is divided into four subunits based on relative compositional changes of pelagic-derived vs. bank-derived carbonate, as defined by nannofossil to micrite ratios determined qualitatively from smear-slide descriptions.

Subunit IA (0-65.4 mbsf; Pleistocene): Subunit IA consists of periplatform ooze that is characterized by a greater proportion of micritic than nannofossil component and is thus a micrite ooze. The high aragonite content in this interval, with values between 44% and 68%, clearly demonstrates the major contribution of bank-derived carbonate. Near the base, two layers of floatstone with mud clasts and graded foraminiferal and lithoclastic packstone, interpreted as calciturbidites, occur in association with slumped sediments.

Subunit IB (65.4-103.4 mbsf; upper upper Pliocene): the periplatform ooze of Subunit IB contains a visibly greater amount of nannofossils and planktonic foraminifers than the overlying sediments and is predominantly a micrite nannofossil ooze. This indicates that the contribution of pelagic carbonate to the sedimentary deposit during this interval increased relative to the bank-derived carbonate. However, the presence of aragonite in the ooze, as recorded in X-ray diffractograms, implies that the carbonate banks continued to be a source of micrite to be transported to the depositional site.

Subunit IC (103.4-198.4 mbsf; lower upper Pliocene): the thick package of sediments composing Subunit IC contains predominantly micrite ooze. A transition from ooze to chalk occurs between 150 and 180 mbsf that is associated with celestite concretions and burrow fillings.

Subunit ID (198.4-293.4 mbsf; lower Pliocene): Subunit ID contains a mixture of ooze and chalk with a gradually decreasing micrite component with depth. The unit is mainly characterized by the occurrence of gravity-flow deposits, interpreted as calciturbidites, and slumps. Phosphatized benthic and planktonic foraminifers and glauconite grains are scattered throughout the coarser layers.

Unit II (293.4-302.9 mbsf; possibly upper Miocene): Unit II contains light gray well-indurated calcareous chalk with bioclasts and foraminifers.

The carbonate content of the sediments ranges between 92% and 100%. Throughout Unit I, the values show high variability and fluctuate up to 4%, although the mean value remains fairly constant. Between 40 and 80 mbsf, a sharp excursion to decreased values occurs with a minimum centered at 52 mbsf (at ~1.0 Ma). Dilution by noncarbonate material or dissolution could have produced the observed decrease. In the same interval between 45-50 and 90 mbsf, the sediments are characterized by lower porosity, higher bulk density and higher velocity than adjacent sediments. Perhaps variations in physical properties can be related to the composition of the carbonate components, neritic vs. pelagic. Interestingly, this anomalous interval has considerable overlap with the micrite nannofossil ooze of Subunit IB.

The carbonate mineralogy of the Pleistocene sediments is a ~50/50 mixture of calcite and aragonite with detectable amounts of high-Mg calcite only at very shallow depths. The aragonite content can be as high as 68% but decreases sharply within the upper Pliocene sediments, disappearing entirely below ~210 mbsf. Dolomite occurs below 80 mbsf with concentrations less than 3%.

The interstitial water chemistry succinctly reflects the diagenetic reactions occurring within the sediments. With the dissolution of metastable carbonates, aragonite and high-Mg calcite, the Sr^{2+} concentration increases steadily, reaching a maximum at ~70 mbsf. As a consequence, the interstitial water is saturated with respect to celestite ($SrSO_4$) between 75 and 230 mbsf. Distinctive celestite concretions and burrow fillings were recognized in two cores at ~160-170 and 220 mbsf, but microcrystalline celestite may be present elsewhere within the saturated interval. A downward trend of increasing Ca^{2+} and decreasing Mg^{2+} concentrations relative to the chloride concentration is apparently controlled by dolomite formation. The chloride concentration tends to increase with depth, reaching values up to 15% greater than seawater. As at Site 817, the interstitial water chemistry indicates the presence of a source of water with elevated salinity at depth below the sampled section.

The total organic carbon content of the sediments was low but variable, ranging between 0.05% and 0.45%. Volatile hydrocarbons, with methane concentrations up to 10 ppm, ethane ~1 ppm, and no propane, presented no safety problems.

SITE 819

Site 819 (proposed site NEA-3) occurs in 565.2 m of water in Grafton Passage, on the continental slope east of Cairns. The location defines the distal and deeper water end of a shelf-edge transect aimed at defining the relations between sea-level change, sedimentary sequences, and seismic geometries, and in particular the response of a developing slope sequence to rapid global sea-level changes. Site objectives were to determine (1) the nature of the most distal parts of the progradational and aggradational units beneath the upper slope terrace, and (2) the age and origin of the eight seismic sequences at this site. This site, along with Sites 820 and 821, was intended to allow us to investigate a complete shelf-margin series of prograding units.

Results

APC/XCB coring to 400 mbsf recovered 84.9% of the cored interval, showing an expanded Pleistocene section spanning <1.48 m.y. Preservation of nannofossils was excellent, although preservation of planktonic foraminifers is facies specific, with light-colored intervals containing abundant foraminifers. Whereas benthic foraminifers indicate an upper bathyal water depth for the entire Site 819 section consistent with the present water depth at the site, sediment studies suggest substantial variations in depth, controlled by sea-level change and fluvial contributions. A hiatus occurs between 275 and 465 k.y. Sedimentation rates vary in relation to lithologic changes, were modest (10-11 cm/k.y.) in the late Pleistocene, were even more modest (6 cm/k.y.) from 0.93 to 0.465 k.y., and were high (42.4 cm/k.y.) during the middle Pleistocene (1.27-0.93 Ma). Between 1.27 Ma and the base of Hole 819A (<1.48 Ma), an extremely rapid sedimentation rate of ~87 cm/k.y. occurred. Calculation of sedimentation rates and the definition of the main sedimentary units are complicated by the recognition of slumping within the drilled section at two levels, 32.5 and 75 mbsf, and a slump detachment surface at around 190 m observed in seismic data.

Five major sedimentary units have been identified in the section as follows:

Unit I (0-32.5 mbsf; <275 k.y. in age, upper Pleistocene): rhythmically interbedded couplets of dark green clay-rich and green gray carbonate-rich clayey pteropod ooze. The unit shows highly variable but upward-increasing carbonate percentages (24.9%-75.3%), with aragonite dominating as the principal carbonate mineral; within each couplet, calcium carbonate increases upward. The base of the three youngest couplets is composed of pteropod-rich, bioclastic debris. The estimated duration of each couplet is 104,000 yr. A possible slump surface at a depth of 32.5 mbsf separates Unit I from Unit II.

Unit II (32.5-97.0 mbsf; Pleistocene): the unit is composed of five rhythmic couplets made up of silty stringers toward the base, grading upward into dolomitized clayey nannofossil oozes. Carbonate varies up the unit from 19.1% to 76.2% and is dominated by aragonite, which forms 15%-45% of the carbonate minerals; dolomite forms up to 15%. The couplets average 13 m in thickness and, using a sedimentation rate of 4.8 cm/k.y., their accumulation time is estimated to be 183,000 yr each.

Unit III (97.0-179.7 mbsf; Pleistocene): the unit consists of rhythmically interbedded bioclastic and micritic oozes. Carbonate generally decreases upward with corresponding increasing siliciclastics. Seven poorly defined upward-coarsening rhythmic couplets are identified, composed of a sharp-based dark green gray clay-rich, quartz-rich lower half and an upper lighter green carbonate and bioclastic-rich clayey ooze to chalk. Major slumping has disturbed the base of the unit. The duration of the cycles within the unit cannot be estimated until better age control has been established. An unrecovered interval between Units III and IV occurs at 179.7-198.1 mbsf.

Unit IV (198.1-313.2 mbsf; >1.27 Ma and <1.48 Ma in age; Pleistocene): Unit IV consists of interbedded bioclastic wackestones and nannofossil clayey oozes with quartz and silt stringers. Carbonate contents are generally low, with the sediments reflecting an origin related to a mixed terrigenous/neritic to upper bathyal origin. Although higher percentages of quartz silt and sand characterize the unit as a whole, they are best seen near the base, where three upward-coarsening packages occur.

Unit V (313.2-400 mbsf; 1.27 to 1.48 Ma in age; Pleistocene): the unit is composed of a relatively homogeneous sequence of dark green gray bioclastic clayey chalk at the base, micritic clayey chalks in the middle, and clayey bioclastic nannofossil chalks in the uppermost part of the section. Carbonate contents are uniform, and quartz is most dominant in the middle micritic part of the section.

The mineralogy of the Pleistocene sediments is dominated by clays (kaolinite and illite) and carbonates varying from 10% to 90%. Aragonite occurs throughout the site as the principal carbonate mineral. Dolomite is present but variable; a correspondence of dolomite distribution with alkalinity variation suggests that the dolomite may be authigenic, with the source of magnesium being dissolution of high-Mg calcite and ambient pore fluids.

The interstitial water chemistry reflects the diagenetic reactions with the loss of calcium and magnesium tied to precipitation of calcite and dolomite and the alteration of clay minerals; strontium increases reflect dissolution of aragonite and high-Mg calcite and precipitation of calcite and dolomite, whereas decreases may reflect clay mineral diagenesis. Alkalinity variations track the removal of sulfate and the precipitation of carbonates, whereas considerable variations in chlorinity are thought to reflect changes in the chlorinity of seawater during glacial and interglacial periods.

The organic carbon content of the sediments varies from 0.2% to 0.65% and is essentially of marine origin. High concentrations of methane occur, of principally biogenic origin; the C_1/C_2 ratio in headspace samples ranges from 10,000 to 2000. Below 225 mbsf mixing of biogenic and thermogenic gases is suggested by the analyses.

Downhole measurements at Site 819 show the control of clay mineral variations on velocity, resistivity, density, and gamma-ray logs. All the logs are semiquantitative indicators of clay minerals. There is an excellent correlation between logging and drilling characters.

Shipboard paleomagnetic studies have revealed a complicated paleomagnetic story that may be resolvable only through further detailed shore-based studies. Two possible alternative explanations are currently favored. First, four normal polarity magnetozones are tentatively identified as Brunhes, Jaramillo, Cobb Mt. and, more speculatively, Olduvai;

short normal polarity units between the Cobb and Olduvai(?) are interpreted as excursions. Nannofossil ages and paleomagnetic interpretations are not in total agreement and will need to be resolved with detailed shore-based studies. The second interpretation, in accord with the paleontological data, is that extremely rapid sedimentation rates and faulting within the section may have extended the length of the Brunhes and repeated parts of the higher section. Shore-based studies should resolve these problems.

SITE 820

Site 820 (proposed site NEA-2) occurs in 278 m of water in Grafton Passage, on the upper continental slope east of Cairns. It is the central site in a transect of three holes aimed at defining the relations between sea-level change, sediment sequences, and seismic geometries, and in particular the response of a slope sequence to rapid global sea-level changes. Specific site objectives included determining the composition and origin of the prograding and aggrading units beneath the outer part of the upper slope. This hole, in conjunction with Site 821, allows calibration of the abrupt seismic facies evident on the seismic lines.

Results

Hole 820A was APC/VPC cored to 144.2 mbsf with 100% recovery. Hole 820B was APC cored to 160.2 mbsf and XCB cored to 400 mbsf; recovery overall was 81.2%. The section to 400 mbsf is an expanded Pleistocene interval; nannofossil and planktonic data suggest that the section is fairly complete and has an age range at the bottom of the hole from 1.27 to 1.48 Ma. Nannofossil preservation is related to subtle lithologic changes and is good in the upper 100 mbsf, moderate to poor between 100 and 300 mbsf, and improves again below 300 mbsf. The preservation of planktonic foraminifers is related to the lithologic variability. Benthic foraminifers suggest that sediments above 150 mbsf were deposited in an upper bathyal environment and that sediments below 150 mbsf were deposited in water depths fluctuating between upper bathyal and outer neritic. The pattern of sedimentation rates at Site 820 is comparable to that at Site 819. High rates of 41.1 cm/k.y. typify the middle Pleistocene; more modest rates of 8.2 cm/k.y., the latest middle Pleistocene; rapid rates of 35 cm/k.y., the earliest late Pleistocene; and a return to modest rates of 10-11 cm/k.y. in the latest Pleistocene.

Drilling at Site 820 recovered interbedded greenish gray to dark greenish gray wackestone/mixed sediment and coarser greenish gray bioclastic packstones, the lithologies reflecting the contribution of shelf marine and terrigenous components. Lithologic and grain-size variations have allowed the identification of three principal lithostratigraphic units:

Unit I (0-150.7 mbsf; age, 0 to 1.27 Ma; Pleistocene): generally finer grained than the underlying sediments, Unit I consists of bioclastic, very fine-grained wackestones and mudstones interbedded with bioclastic packstones. Bioturbation is pervasive throughout the unit. Dolomite increases gradually with depth in this unit, which may be divided into two subunits, an upper clay-rich subunit and a lower, more carbonate-rich subunit.

Subunit IA (0-64.3 mbsf; Pleistocene): the dominant lithologies are thick beds of dark greenish gray terrigenous clay and fine calcareous/clayey mixed sediments (<60% carbonate). Quartz and feldspar are common in the mixed sediments and in the dark terrigenous clays. Coarser grained sediments include gray to dark greenish gray silty to medium sand-sized packstones with siliciclastic material. At two levels, 6.6 to 7.65 mbsf and 31.2 to 33.6 mbsf, there are very coarse beds of gray packstones and rudstones containing pebble-sized rhodoliths and bioclastic debris, including corals, coralline algae, molluscs, echinoid fragments, and abundant benthic and planktonic foraminifers.

Subunit IB (64.3-150.7 mbsf; Pleistocene): the subunit is carbonate-rich and consists of greenish gray to dark greenish gray clayey wackestones with nannofossils interbedded with bioclastic packstones and wackestones. Silt-sized quartz and feldspar accompany the fine to medium sand-sized packstone and wackestone beds. Between 122.4 and 127.85 mbsf there are very coarse-grained *Halimeda,* bryozoan, and mollusc rudstones with a wackestone matrix.

Unit II (150.7-208.1 mbsf; Pleistocene): composed of a mixture of bioclastic packstones, bioclastic clayey mixed sediments, and silty claystones, the unit represents a transition from an even coarser Unit III below to the finer grained sediments of Unit I. The base of the unit is marked by an upward-fining sequence, grading from medium to coarse bioclastic packstone to silty calcareous mixed sediment containing bioclasts. This is in turn overlain by a 7-m-thick section of dark gray claystone containing silt-sized micrite, bioclasts, and quartz grains. The rest of the unit is composed of three upward-coarsening sequences, the lower two of which show greenish gray, clayey mixed sediments grading upward into medium-sand-sized, greenish gray nannofossil calcitic packstone. The uppermost unit consists of a thinner and finer upward-coarsening sequence of bioturbated nannofossil mixed sediment containing quartz and micrite exhibiting a size gradation from silt to fine sand-sized grains.

Unit III (208.1-400 mbsf; Pleistocene): the unit is dominated by bioclastic packstones with interbedded, finer grained calcareous mudstones, some laminated, and mixed sediments. Five cycles are recognized within the unit, each representing an upward-coarsening cycle from dark greenish gray calcareous mudstone with bioclasts and nannofossils up to medium to fine calcareous chalky packstone containing quartz, feldspar, nannofossils, and clay. Dolomite (maximum = 17.4%, at 224.4 mbsf) is present within the top three cycles of Unit III.

Downhole measurements were conducted in Hole 820B using the seismic-stratigraphic, geochemical, and FMS combinations. Velocity, resistivity, and density strongly correlate throughout the logged interval due to a porosity dominance in the logs. The changes in velocity and density suggest that mechanical compaction is dominant over diagenesis in controlling porosity at the site. Logged units closely correlate with those defined in lithostratigraphy. Between 69 and 150 mbsf in Log Unit 1, the smooth compaction profile is seen in the resistivity and velocity logs, whereas the high resistivity and velocity between 120 and 130 mbsf correlate well with the coarser grained *Halimeda* beds. Log Unit 2, between 150 and 205 mbsf, defines three upward-coarsening sequences related to the distribution of clay and carbonate. In Log Unit 3, the geochemical, resistivity, velocity, and density logs clearly define five subunits, which are clay-rich at the base and carbonate-dominated at the top. These interpretations agree substantially with the lithologic information.

The mineralogy of the Pleistocene sediments is dominantly carbonate and clay. Aragonite occurs throughout the section and represents 50% of the carbonate minerals at the top, decreasing to 40% at the base. High-Mg calcite is present down to 170 mbsf, disappearing between 170 and 265 mbsf and reappearing again below 265 mbsf. Dolomite occurs between 44.5 and 330.3 mbsf, varying from 0.8% to 17.4%, whereas low-Mg calcite occurs in all samples, with concentrations varying from 18% to 60%. Quartz is also present in all samples, ranging from 4.9% to 26%.

The interstitial water chemistry is dominated by diagenetic reactions involving (1) dissolution of metastable aragonite and high-Mg calcite, (2) the precipitation of dolomite and low-Mg calcite, (3) clay mineral alteration, and (4) the oxidation of organic material. These processes are reflected in a strong depletion of calcium, magnesium, and sulfate with increasing bottom depth, accompanied by an increase in strontium and ammonia. As a result of the hard nature of the sediments, the water samples obtained using the WSTP (water-sampler/temperature/pressure) tool were contaminated by annulus fluids.

Organic carbon at Site 820 was generally low, not exceeding 0.45%, representing a mixture derived from both marine and terrigenous sources. The sediments contained high concentrations of methane, although the C_1/C_2 ratio varied from 13,000 to 700. The observed low sulfate concentrations, and high methane and trace ethane/propane above 190 mbsf, suggest a bacterial origin for the methane and ethane/propane production. However, below 190 m, methane and ethane/propane generation is more likely related to both thermogenic and biological processes at greater depths.

Paleomagnetic results from Site 820 must await shore-based studies. A large part of the sediments from the Pleistocene cored sections was found to carry a remanence with a steeply dipping negative inclination. Many of the cores maintained this inclination after AF demagnetization of 15mT, the maximum field allowable by ODP for demagnetization on the archive half of the cores. Detailed AF demagnetization in peak fields greater than 15 mT and thermal treatment will be required to generate a clear magnetic polarity stratigraphy at this site.

SITE 821

Site 821 (proposed site NEA-1) occurs in 212 m of water in Grafton Passage, on the continental slope east of Cairns. The location defines the proximal and shallowest end member of a shelf-edge transect aimed at defining the relations between sea-level change, sediment sequences, and seismic geometries, and in particular the response of a slope sequence to rapid global sea-level changes. Specific site objectives were to determine the composition and origin of the most landward of the prograding and aggrading units beneath the upper slope terrace, and to define the sea-level signal within them.

Results

Hole 821A was cored with the APC to 145.9 mbsf and the XCB to 400 mbsf, with a final average recovery of 95%; Hole 821B was cored with the APC to 165.9 mbsf and 100% recovery. As at Sites 819 and 820, the section to 400 mbsf at Site 821 is an expanded Pleistocene section. Nannofossils indicate an age of 1.27 to 1.48 Ma for the bottom of the hole. Preservation of planktonic foraminifers and nannofossils varies from near pristine in clayey intervals to overgrown in sandy intervals. Benthic foraminifers indicate a depth range of neritic to upper bathyal for the sequence at Site 821. The pattern of the variation in sedimentation rates at Site 821 is similar to that at Site 820. Middle Pleistocene rates of 28.2 cm/k.y. are succeeded by 12.2 cm/k.y. between 0.930 and 0.465 Ma, 49.2 cm/k.y. in the succeeding 190 k.y., and 10.2 cm/k.y. from 0.275 k.y. to the present. However, in comparison with Site 820, the locus of increased sedimentation had shifted to Site 821 by the late Pleistocene, coincident with the aggradation phase of sedimentation.

Drilling at Site 821 has led to the identification of five lithostratigraphic units. Units I and II are aggradational, while Units III through V are thought to be progradational.

Unit I (0-145.5 mbsf; Holocene to upper Pleistocene; age, <0.456 Ma): principal sediment types include mixed sediments of siliceous and bioclastic components, calcareous silts and clays, bioclastic and nannofossil oozes and chalks, bioclastic packstones, and *Halimeda* rudstones. With the exception of the uppermost part, the unit is thought to represent a series of rapidly deposited aggradational packages. It is divided into seven subunits:

Subunit IA (0-16.5 mbsf; Holocene to upper Pleistocene): the subunit is an upward-fining sequence that is a fine to coarse sandy bioclastic/siliciclastic mixed sediment containing large benthic foraminifers, coralline algae, and bryozoans at the base, and grades upward into clays with bioclasts and nannofossils.

Subunit IB (16.5-40.3 mbsf; upper Pleistocene): two facies make up the subunit in ending order: (1) silt to fine sand mixed sediment with bioclasts and molluscan/ bryozoan fragments; the facies is partly a coarse, sandy bioclastic/siliciclastic mixed sediment with large benthic foraminifers, *Halimeda,* coralline algae, and pectinids and other molluscs, and (2) calcareous clayey and silty mixed sediment with some bioclasts.

Subunit IC (40.3-66.5 mbsf; upper Pleistocene): the subunit is an upward-fining sequence composed of clay or silty fine to medium bioclastic and siliciclastic sands grading upward into a homogeneous silty bioclastic or nannofossil clay.

Subunit ID (66.5-88.7 mbsf; age, 0 to 0.93 Ma; upper Pleistocene): the subunit is a rhythmic alternation of calcareous silty clays and clayey silts above and below a lithified and dolomitized mixed sediment unit.

Subunit IE (88.7-99.2 mbsf; upper Pleistocene): the subunit is composed of a dolomitized calcareous fine to medium bioclastic sand.

Subunit IF (99.2-132.1 mbsf; upper Pleistocene): the basis of the subunit is a poorly sorted fine to coarse bioclastic sand and bioclastic-nannofossil ooze or chalk. The sequence is repeated three times.

Subunit IG (132.1-145.5 mbsf; upper Pleistocene): this subunit is divided into three parts: (1) a lower lithified *Halimeda* rudstone with molluscan and bryozoan fragments, large benthic foraminifers, and lithoclasts of packstone and wackestone in a mud matrix, (2) calcareous mudstone containing sand-sized siliciclastic grains, and (3) at the top a medium- to fine-sand-sized bioclastic packstone.

Unit II (145.5-172.0 mbsf; age, > 0.465 to <0.93 Ma; upper Pleistocene): at the base of the unit is an upward-fining siliciclastic-dominated packstone and at the top is a glauconitic and siliciclastic lithified mudstone, perhaps representing a hardground. Sedimentation throughout the unit is low (12 cm/k.y.) compared with the units above and below. The unit is divided into two subunits:

Subunit IIA (145.5-156.3 mbsf; upper Pleistocene): partially to well-lithified bioclastic packstones are overlain by lithified chalk/mudstone containing glauconite and detrital grains.

Subunit IIB (156.3-172.0 mbsf; upper Pleistocene): lithified bioclastic/siliciclastic packstones exhibiting upward-fining textures are overlain by a 7-m-thick unit of bioclastic mudstones.

Unit III (172.0-215.8 mbsf; age, ≥0.93 to 1.27 Ma; lower Pleistocene): the unit is composed of dolomitized bioclastic wackestone/chalk and bioclastic packstone. Sedimentation rates are relatively high (28.2 cm/k.y.). The unit is composed of two subunits:

Subunit IIIA (172.0-184.3 mbsf; lower Pleistocene): the subunit changes from a lithified dolomitized bioclastic wackestone at the base through a 3-m-thick dolomitized bioclastic packstone to a nannofossil-rich chalk at the top.

Subunit IIIB (184.3-215.8 mbsf; lower Pleistocene): at the base, the subunit is composed of 50 cm of a coarse-grained dolomitized packstone/mixed sediment, which is overlain by bioclastic and nannofossil chalky wackestones with scattered dolomitized packstone/mixed sediment intercalations.

Unit IV (215.8-298.8 mbsf; age, >0.93 Ma to ~1.27 Ma; lower Pleistocene): the unit is composed of thickly bedded subunits of dolomitized chalk and bioclastic packstones and wackestones. The unit was deposited at a rate of 28 cm/k.y. Four subunits have been recognized:

Subunit IVA (215.8-246.3 mbsf; lower Pleistocene): the subunit is composed of a basal dolomitized micritic to nannofossil chalk containing siliciclastics, overlain by 6 m of dolomitized bioclastic packstone/wackestone exhibiting an upward-fining texture over the basal 1.5 m.

Subunit IVB (246.3-278.9 mbsf; lower Pleistocene): the subunit is made up of dolomitized micritic to nannofossil chalk alternating with upward-coarsening, less lithified clayey layers with coarse- to very coarse-grained bioclasts.

Subunit IVC (278.9-298.8 mbsf; lower Pleistocene): the base of the subunit is defined by a 30-cm-thick dark glauconitic packstone, which is replaced upward by a dolomitized micritic to nannofossil-rich chalk.

Unit V (298.8-400.0 mbsf; lower Pleistocene): the unit is composed of dolomitized bioclastic packstones and chalky mixed sediments interbedded with less calcareous sandy, silty, and clayey mudstones. The unit was deposited at an extremely rapid rate. Five subunits have been recognized:

Subunit VA (298.8-322.0 mbsf; lower Pleistocene): the subunit is composed of chalk with bioclasts and siliciclasts.

Subunit VB (322.0-350.0 mbsf; lower Pleistocene): upward-coarsening dolomitized bioclastic packstone and chalk with siliciclastic mudstones.

Subunit VC (350.0-360.0 mbsf; lower Pleistocene): dolomitized calcareous silt to medium-grained sands.

Subunit VD (360.0-377.0 mbsf; lower Pleistocene): upward-coarsening dolomitized bioclastic packstones and chalks with siliciclastic-rich muds.

Subunit VE (377.0-400.0 mbsf; lower Pleistocene): dolomitic calcareous silt to medium sand intercalated with a central section of clayey to silty mud.

Interstitial water sampling at Site 821 shows calcium, magnesium, and potassium decreasing with depth to 144.8 mbsf. This is due mainly to the precipitation of calcite and dolomite and to clay diagenesis leading to the formation of illite. An increase in strontium throughout much of the hole is due to the dissolution of aragonite and high-Mg calcite combined with the precipitation of low-Mg calcite and dolomite; decreases in strontium in the lower part of the core reflect clay mineral diagenesis and a lower rate of recrystallization of carbonates. Alkalinity increases to 11 mbsf and peaks again at 116.35 mbsf, coincident with the removal of sulfate. Chlorinity decreases are tied to salinity changes effected by the precipitation of carbonates and the removal of sulfate.

X-ray diffraction analysis indicates that the sediments at Site 821 are composed of aragonite, low-Mg calcite, high-Mg calcite, dolomite, quartz, kaolinite, albite, and illite. Variations in carbonate content are due to dilution by terrigenous material and may reflect sea-level alternations. Dolomite occurs at ~10% between 40 and 398.5 mbsf coincident with the depth of the removal of high-Mg calcite. As at Sites 819 and 820, it is proposed that high-Mg calcite provides the magnesium source for dolomitization.

Organic carbon at Site 821 was generally low, varying between 0.15% and 0.45 %. This is thought to be of mixed terrigenous/marine origin above 120 mbsf and of marine origin below this depth. Methane concentrations reached a maximum of 74,000 ppm at 220 mbsf, whereas the C_1/C_2 ratio varied with depth and temperature between 3600 and 800, showing no anomalous trend. There were no safety or pollution problems at this site; total ethane and propane never exceeded 40 ppm, with ethane greater than propane above 310 mbsf. Methane and propane above 250 mbsf are of bacterial origin.

Downhole measurements at Site 821 included runs with the seismic-stratigraphic logging tool combination and the FMS. The velocity, density, and resistivity are strongly correlated because of the dominance of porosity in all three logs. Three log units have been identified. Log Unit 1 occurs from the base of the pipe (65 mbsf) to 210 mbsf and is considered to be equivalent to lithostratigraphic Units I, II, and III. The resistivity log suggests upward-fining sequences 4-14 m thick caused by increases in the proportions of clay and decreases in carbonate. Log Unit 2 occurs between 210 and 293 mbsf and is equated with lithostratigraphic Unit IV. The resistivity log again shows a saw-toothed pattern, suggesting upward-fining sequences 10-20 m thick; however, the gamma log correlates positively with resistivity and velocity, suggesting that clay-rich intervals are low in porosity, perhaps due to diagenesis. Between 261 and 270 mbsf a comparison of velocity and resistivity indicates substantial cementation, which is borne out by the lithostratigraphic identification of an increase in dolomitization in the same interval. Log Unit 3 occurs between 293 and 392 mbsf and is considered to be equivalent to lithostratigraphic Unit V. The logs show four cycles of upward-coarsening sequences, as indicated by upward-decreasing clay contents and porosity as seen in the gamma, resistivity, and velocity logs.

Paleomagnetic results from Site 821 must await shore-based studies. A large part of the sediments from the Pleistocene cored sections was found to carry a remanence with a steeply dipping negative inclination. Many of the cores maintained this remanence direction after AF demagnetization with peak fields of 15 mT, the maximum field allowable on the archive half of the cores. Detailed AF demagnetization in peak fields greater than 15 mT, together with thermal treatment, will be required to generate a clear magnetic polarity stratigraphy at this site.

SITE 822

Site 822 (proposed site NEA-4) occurs in 955.2 m of water, on the foot of the slope east of the Great Barrier Reef offshore of Cairns. The location is northeast of the transect across the upper slope in Grafton Passage. Drilling was aimed at determining the age and facies of a lower slope fan in front of the present-day Great Barrier Reef; an additional objective was to define lower slope fan processes and to understand the sea-level signatures preserved in the lower slope facies.

Results

Hole 822A was APC cored to 95.9 mbsf and continued with the XCB to 433.9 mbsf, with an excellent recovery rate of 98.3%. Site 822 comprises a Holocene to upper Pliocene (>2.6 Ma) section of hemipelagic sediments with a hiatus between 275,000 and 465,000 years. Benthic foraminifers indicate that the sediments were wholly deposited within middle bathyal depths. Sedimentation rates are highly variable, with extremely high rates of

36-42 cm/k.y. occuring between 0.93 and 1.48 Ma. Relatively high rates of 16 cm/k.y. occur between 1.88 and 2.6 Ma. The lowest rates of 4.0 cm/k.y. occur at the base of the section, whereas relatively low rates of 8-12 cm/k.y. occur above the 930,000-yr level. High sedimentation rates may have been coincident with periods of global high sea level.

Sediments recovered at Site 822 are mainly muds containing varying amounts of carbonate ooze and terrigenous clays, with lesser bioclastic and terrigenous (mostly quartz) sand and silt. The sequence is, however, distinctly cyclical as seen in color and compositional variations related to the proportions of carbonate and terrigenous sediments. Two principal units have been identified. Unit I is dominated by clayey calcareous muds; Unit II is similar to Unit I except that it is darker in color and contains more terrigenous sediment; it also contains abundant quartz silt and sand.

Unit I (0-52.9 mbsf; age, 0 to <0.93 Ma; upper Pleistocene): the unit is composed of bioclastic ooze with nannofossils and micrite. Soft sediment deformation characterizes Subunits IA and IB, although a hiatus of 190,000 yr separates them.

Subunit IA (0-27.4 mbsf; age, 0.275 Ma; upper Pleistocene): the subunit is composed of clayey bioclastic calcareous, bioturbated ooze/mud with nannofossils, micrite, and scattered pteropods, and is finely laminated in the lower part of the section. Intervals of clayey calcareous mixed sediments (mud) containing terrigenous clay and silt occur, as do lenses of bioclastic packstones. Carbonate contents range from 53.3% to 70.0%.

Subunit IB (27.4-52.9 mbsf; age, 0.465 to 0.93 Ma; upper Pleistocene): the subunit is composed of greenish white to greenish gray bioturbated clayey nannofossil ooze with bioclasts. Carbonate contents of 59.5% to 79.3% are the highest recorded for Site 822. Rare interbeds of fine- to medium-grained bioclastic packstones, scattered shell fragments, and burrow infills occur throughout the subunit. The subunit gradationally overlies Subunit IIA.

Unit II (52.9-433.9 mbsf; age, 0.465 to >2.6 Ma; middle Pleistocene to Pliocene): the unit is a dark greenish gray clayey calcareous mixed sediment containing terrigenous clay interbedded with clayey nannofossil ooze. Claystones dominate the middle part of the unit whereas bioclastic sediments become more important downward.

Subunit IIA (52.9-202.5 mbsf; age, 0.465 to < 1.27 Ma; middle to upper Pleistocene); gradationally underlying Subunit IB, this subunit is more clay rich and darker colored, and consists of silty calcareous mixed sediment interbedded with clayey nannofossil ooze in the upper part. Quartz silt and very fine sand occur in the middle part of the subunit and increase downward to 32%. Intervals of silty calcareous claystone become more common downward, particularly below 150 mbsf. Dolomite was identified in Core 133-822A-14X (125 mbsf). Fine to very fine bioclasts occur in burrows and, less commonly, as thin beds of graded bioclastic to foraminiferal packstones. High sedimentation rates characterize the subunit, suggesting that the downward increase in siliciclastics is due to greater terrigenous influx.

The physical properties of Subunits IA and IB and the upper half of Subunit IIA are consistent with normal compaction trends; porosity values vary from 60% to 50%, and water content from 54% to 35%.

Subunit IIB (202.5-332.5 mbsf; age, 0.93 to 1.88 Ma; lower to middle Pleistocene): dark greenish gray well-compacted and partially lithified calcareous claystones (carbonate contents <50%) are interrupted between 260 and 308 mbsf by intervals of lighter greenish gray more calcareous (carbonate contents 40%-61%) chalky clayey mudstone. Bioclastic and quartzose turbidites occur in Core 133-822A-31X.

Subunit IIC (332.5-433.9 mbsf; age, >1.48 Ma to >2.6 Ma; lower Pleistocene to Pliocene): the subunit is composed of well-compacted and semilithified alternating nannofossil mixed sediments and dark greenish gray calcareous claystone. Bioclasts are common in the mixed sediments. Quartz and fine sand increase downward, reaching as high as 17% in the lower part of the hole. Intervals of foraminiferal bioclastic packstone represent turbidites.

Whereas the physical property values of the lower half of Subunits IIA, IIB, and IIC remain relatively constant with depth, both porosity and water content values exhibit large variations that generally correlate with alternating intervals of claystone and chalk.

X-ray diffraction studies at Site 822 indicate that the sediments are composed of calcite (9.5%-61.3%), aragonite (18.7%-83.1%), clay, and detrital quartz; these proportions remain relatively constant except for high concentrations of quartz between 75 and 175 mbsf. High-Mg calcite (up to 30%) occurs in the top 300 mbsf, whereas dolomite (up to 18.2%) occurs in the top 157.2 mbsf and is absent below this depth. Clay increases downward, alternating with carbonate to form distinct cycles.

Throughout Site 822, high-frequency cyclical variations in sediment character record changes in the flux of terrigenous and carbonate sediments, possibly related to glacioeustatic sea-level changes and/or climate changes.

Interstitial-water sampling has shown that Ca^{2+}, Mg^{2+}, and K^{2+} decrease in concentration with increasing sub-bottom depth. The decreases are thought to indicate the formation of authigenic calcite and dolomite and clay mineral diagenesis. Strontium shows an increase to a depth of 17.8 mbsf - the depth at which sulfate disappears - and thereafter decreases to the bottom of the hole. The small changes in Sr^{2+} at Site 822 suggest that the degree of carbonate recrystallization is low compared with other slope sites. WSTP samples were contaminated with seawater and did not accurately reflect variations in interstitial-water chemistry.

The concentration of organic carbon at Site 822 did not exceed 0.65% and was highest in the clay-rich sediments. The TOC/nitrogen ratio in the organic material seems to indicate a marine origin. Concentrations of up to 77,000 ppm methane and 4 ppm ethane were recorded at 55 mbsf but represented no safety or pollution problem; both gases decreased below this depth and are thought to be of bacterial origin. Propane, which did not exceed 4 ppm, appeared between 135 and 265 mbsf.

Seismic-stratigraphic logs, a geochemical log, and the formation microscanner were run at Site 822. As at almost all other sites off Northeast Australia, velocity changes generally follow a compaction profile, pointing to the importance of mechanical compaction in controlling porosity. Whereas the cores indicate that the stratigraphy is controlled largely by variations in clay and carbonate contents, all elements of the geochemical logs (potassium, aluminium, silicon, and calcium) correlate positively, indicating that an artifact (e.g., hole size) may be overprinting the log response. Four log-based units have been identified based largely on the resistivity and velocity response. Zones of dolomitization were identified and upward-coarsening and upward-fining sequences were defined between 263 and 323 mbsf.

Paleomagnetic studies at Site 822 indicate that the cored section spans the Pleistocene and the late Pliocene. The Brunhes/Matuyama boundary is placed at 165 mbsf and the Matuyama/Gauss boundary at 396 mbsf. Within the Matuyama reversed chron, five polarity zones were identified but at this time their correlation to subchrons within the Matuyama is uncertain. Discrepancies with the paleontological data, particularly over the depth of the Brunhes/Matuyama boundary, are likely related to a moderate magnetic overprinting or to early remagnetization, and will need to be addressed in post-cruise studies. Volume susceptibility at Site 822 shows several major peaks that correlate inversely with the percentage of carbonate, suggesting that the magnetic signals reflect terrigenous input.

SITE 823

Site 823 (proposed site NEA-5) is located in the central-western Queensland Trough, toward the deepest part of the basin. The location was selected to recover a basinal section that would provide material for paleoceanographic studies, as well as a record of basin-fill sediments to correlate with other drill sites on a transect from the Australian continental margin to the Queensland Plateau. Specific objectives for this site included obtaining a complete basinal section for paleoceanographic history and correlation of basin-fill response between the continental margin and the Queensland Plateau.

Results

With an excellent total recovery of 92%, APC/XCB/RCB drilling penetrated a 1011.0-m-thick sequence of uppermost middle Miocene to Pleistocene hemipelagic to pelagic sediments interbedded with numerous gravity-flow deposits that are interpreted as turbidites, debris flows, and slumps. Benthic foraminifer assemblages indicate that the depositional environment remained at lower bathyal paleodepths (1000-2000 m) during this period. Although over 1800 gravity-flow deposits were recognized, chronological integrity of the microfossil biostratigraphy was maintained throughout the sequence, indicating that there was nearly contemporaneous deposition of the redeposited material.

Seven major sedimentary units were recovered between the seafloor and 1011.0 mbsf. The lithologic units are as follows:

Unit I (0-120.7 mbsf; Pleistocene): Unit I contains pelagic to hemipelagic sediments interbedded with redeposited layers, interpreted as turbidites and debris flows. It is divided into two subunits based on differences in clay content and presence of debris flows.

Subunit IA (0-85.4 mbsf; Pleistocene): Subunit IA consists of light greenish gray to gray nannofossil micrite ooze with clay, foraminifers and bioclasts, clayey nannofossil mixed sediments with micrite, foraminifers, and bioclasts, nannofossil ooze with micrite and clay, and clayey nannofossil ooze. These sediments are interbedded with lithoclastic floatstone and rudstone, some containing mud clasts, that are interpreted as debris flows, and bioclastic packstone and grainstone, some showing normal grading, that are interpreted as turbidites.

Subunit IB (85.4-120.7 mbsf; Pleistocene): Subunit IIB consists of dark greenish gray claystone with nannofossils and in some cases quartz and micrite, dark gray nannofossil clayey to clayey nannofossil mixed sediment, clayey nannofossil ooze, and nannofossil clay mixed sediment with quartz. Interbedded layers of gray sandy packstone with foraminifers, quartz, and nannofossils and bioclastic packstone with quartz, micrite, and nannofossils are interpreted as turbidites.

Unit II (120.7-352.75 mbsf; Pleistocene to upper Pliocene): Unit II contains gray to greenish gray nannofossil ooze with clay and bioclasts interbedded with gray to dark gray lithoclastic rudstone, interpreted as debris flows, and gray to greenish gray bioclastic and skeletal packstones showing normal grading and abrupt basal contacts, sedimentary features indicative of turbidites. At 305 mbsf, there is a distinct transition from nannofossil ooze to chalk.

Unit III (352.75-535.7 mbsf; lower Pliocene): Unit III is distinguished by a subunit containing pelagic to hemipelagic sediments enclosed between two subunits composed of massive debris flows and slumps.

Subunit IIIA (352.75-440.3; lower Pliocene): Subunit IA consists of dark gray to gray nannofossil chalk with bioclasts and foraminifers or quartz, clayey nannofossil mixed sediment, and dolomitic nannofossil chalk with clay intermixed with dark greenish gray lithoclastic rudstone, conglomerate, and mixed sediment that are interpreted as debris flows and slumps. One of the debris flows is 30 m thick. Soft sediment deformation occurs below debris flows.

Subunit IIIB (440.3-516.8 mbsf; lower Pliocene): Subunit IIIB contains nannofossil siltstone with bioclasts, calcite and pyrite, light greenish gray to greenish gray nannofossil chalk, nannofossil chalk with micrite, and mixed sediments. In contrast to the common dark greenish gray gravity-flow deposits, the occurrence of a few light greenish gray carbonate-rich bioclastic packstones, interpreted as turbidites, indicates an increased influence of the carbonate platform source for the detrital input.

Subunit IIIC (516.8-535.7 mbsf; lower Pliocene): In Subunit IIIC two debris flows composed of mud clasts in a matrix of greenish gray to dark greenish gray mixed sediment with micrite are separated by an interval of relatively undeformed light greenish gray nannofossil chalk.

Unit IV (535.7-715.0 mbsf; lower Pliocene to uppermost upper Miocene): Unit IV is characterized by larger scale slump features. Compared with overlying Unit III, the sediments show variable clay content with accompanying color changes from light greenish gray to dark greenish gray. They are foraminifer nannofossil chalk, nannofossil mixed sediment to chalk with foraminifers and bioclasts becoming clayey nannofossil chalk with foraminifers, bioclasts and/or quartz, nannofossil chalk with clay or foraminifer nannofossil clayey chalk with depth. Dark greenish gray bioclastic foraminifer packstone layers, showing graded bedding indicative of turbidites, are sometimes found inverted within slumps. Microfaults are associated with some slumps. Clasts and matrix in greenish gray lithoclast rudstones, interpreted as debris flows, are cut by *Chondrites* and *Zoophycos,* indicating post-depositional bioturbation. The base of Unit IV is a debris flow.

Unit V (715.0-795.7 mbsf; upper Miocene): Unit V has a higher clay content in the dark gray nannofossil mixed sediment to nannofossil claystone. Greenish gray nannofossil chalk is present although less abundant than in overlying Unit IV. Unit V contains a few foraminifer skeletal packstone layers that are interpreted as turbidites. Laminations occur in the transitions from darker to lighter colored mixed sediments.

Unit VI (795.7-899.1 mbsf; upper Miocene): Unit VI is distinguished by distinctive color oscillations produced by alternations of white to light gray, strongly bioturbated nannofossil chalk to mixed sediment, limestone, and clayey nannofossil chalk with dark greenish gray nannofossil mixed sediment and claystone. Interbedded layers of partially graded lithified calcareous grainstone with siliciclastics and traces of glauconite and skeletal packstone, both interpreted as turbidites, are dark greenish gray. Multiple generations of microfaults and large-scale slump folds are present. Lithoclastic rudstone and floatstone, interpreted as debris flows, are common. In fact, Unit VI and Unit VII together contain ~50% of the total number of debris flows observed in the entire Site 823 sequence.

Unit VII (899.1-1011.0 mbsf; upper Miocene to uppermost middle Miocene): Unit VII is defined by the occurrence of shallow-water platform-derived pebbles and clasts within lithoclastic rudstones, interpreted as debris flows. The pebbles and clasts contain coralline algae, large benthic foraminifers, coral fragments and dolostone fragments. The sediments include nannofossil chalk with clay, foraminifers, and bioclasts, clayey nannofossil mixed sediments, and nannofossil claystone. Increases in the amount of clay, siliciclastics, and traces of glauconite give the sediments a dark gray color. Medium sand- to silt-sized gray bioclastic packstone and quartz foraminifer packstone layers with well-defined upward-fining sequences are interpreted as turbidites.

Bulk density, grain density, porosity and water content measurements define six physical property units that correlate quite well with both lithologic changes and downhole logs. The numerous gravity-flow deposits with varying compositions significantly influence and alter the normal compaction trend with depth. An excellent inverse correlation between the velocity and calcium logs indicates that, in addition to normal compaction and cementation processes, the calcium carbonate vs. clay content is controlling porosity variations in the sequence.

The carbonate content of the sediments ranges between 18% and 80%. As the Queensland Trough receives redeposited material from both the Queensland Plateau and the Australian continental margin, this large variability may reflect more or less dilution of the pelagic carbonate component by terrigenous input from the margin and by a fluctuating input of shallow-water carbonate sediments from the adjacent carbonate platforms. Changes in the relative contribution of gravity-flow deposits and suspended material from each source to the basin sequence would contribute to changes in the overall sedimentation rate. Between 0 and 3.5 Ma, the sedimentation rate was 11 cm/k.y., while, between 3.5 and 5.9 Ma, it increased to 16.6 cm/k.y. A tenfold decrease to 1 cm/k.y. occurred between 8.2 and 10.4 Ma. The upper Miocene to lower Pliocene sediments tend to have a higher clay content; this is particularly the case for the lowermost upper Miocene sediments. Between 3.5 and 5.9 Ma, the combination of high sedimentation rate and increasing clay content with depth points to an increased flux of terrigenous material that was manifested in the core as an increased number of debris flows and large slumps. In contrast, the low sedimentation rate and very high clay content between 8.2 and 9.4 Ma could imply a significant decrease in the flux of fine-grained plateau-derived carbonate, although the presence of debris flows with shallow-water pebbles and clasts indicates that material was being eroded from the platform margin. The quartz content remains comparatively constant throughout the sequence.

The carbonate mineralogy of the sediments deposited during the last ~2.6 Ma shows up to 50% aragonite with up to 30% high-Mg calcite. Below 200 mbsf, the high-Mg calcite disappears from the sediments with aragonite disappearing below 300 mbsf. The high concentration of metastable carbonates in the upper Pliocene to Pleistocene sediments provides definitive evidence for the contribution of shallow-water material to the basin during this interval. In fact, micrite is rare to absent in the sediments below lithologic Unit III but appears again in lithologic Unit VI, implying that production and transport of fine-grained carbonate from shallow-water environments bordering the Queensland Trough to deeper waters diminished dramatically between the latest late Miocene and the early Pliocene, ~6.0 to 4.2 Ma.

The interstitial water chemistry succinctly reflects the diagenetic reactions occurring within the sediments. With the dissolution of metastable carbonates, aragonite, and high-Mg calcite, the Sr^{2+} concentration increases steadily, reaching very high values at depth due to the lack of SO_4^{2-} to precipitate celestite. The SO_4^{2-} concentration is totally depleted between ~50 and 550 mbsf, as a result of sulfate reduction. A downward trend toward increasing Ca^{2+} and decreasing Mg^{2+} concentrations relative to the chloride concentration is apparently controlled by authigenic calcite and dolomite formation. The chloride concentration tends to increase with depth. As at other Leg 133 sites, the interstitial water chemistry indicates the presence of a source of water with elevated salinity at depth below the sampled section.

The total organic carbon content of the sediments was mostly very low, commonly 0.0% but never exceeding 0.55%. The organic matter has a mixed marine and terrestrial origin. High concentrations of methane were recorded but presented no safety and/or pollution problems, as the evolution of the methane-to-ethane ratio with depth was normal. Methane concentrations increased significantly below the sulfate reduction zone beginning at 50 mbsf, indicating a bacterial origin for the gas. Mixing of upward-migrating thermogenic free hydrocarbons with the biogenic gases was observed below 400 mbsf.

SITE 824

Site 824 (proposed site NEA-6) lies in 1009 m of water on the western slope of the Queensland Plateau west of Holmes Reef. The location defines a slope site aimed at understanding processes along the eastern margin of the Queensland Trough and obtaining as complete a section as possible of Paleogene sediments and the basement onto which they have transgressed.

Results

Four holes were drilled to a total depth of 431 mbsf: Hole 824A was drilled with APC/XCB tools after washing down to 50 mbsf; Hole 824B used APC coring to recover the top 50 mbsf, and Holes 824C and 824D used RCB coring to recover the sections below 300 mbsf, including the basement. The odd sequence of drilling defined above was due to the shortage of core liners aboard the vessel.

The sediments range in age from late Pleistocene to late Oligocene-early Miocene. Basement of probable Paleozoic(?) age was reached. Benthic foraminifers indicate that the sediments were deposited entirely within middle bathyal depths. Recovery averaged 28.4% for Site 824. Sedimentation rates were highest in the late Pleistocene if one assumes that the seafloor has a Holocene age. Thereafter, rates decreased to 12.9 cm/k.y. by 2.4 Ma before increasing again to 22-30 cm/k.y. for the section down to 11 Ma.

Sediments recovered at Site 824 are pure carbonates deposited as nannofossil oozes and allochthonous packstones and rudstones composed of molluscs, bryozoans, corals, and coralline algae. Seven lithostratigraphic units have been recognized on the basis of the dominance of the two depositional styles and facies.

Unit I (0-105 mbsf; Holocene-Pleistocene): the unit is characterized by two cycles of upward-fining bioclastic packstones and rudstones; alternating pelagic oozes and chalks occur in the upper part of this unit. The first cycle comprises Subunits IA and IB, and the second cycle, Subunits IC and ID.

Subunit IA (0-27 mbsf): composed of white micritic and bioclastic oozes and chalks with minor nannofossils and oozes. Lithification increases with depth in this subunit. Alternating bioclastic packstone beds occur regularly and show a general upward fining.

Subunit IB (27-55 mbsf): consists of upward-coarsening bioclastic packstone with foraminifers, micrite, and nannofossils representing turbidites. Thin layers of pelagic bioclastic micritic mudstones occur at the base of the subunit.

Subunit IC (55-68 mbsf): bioclastic packstones interbedded with micritic ooze to chalk with bioclasts. The packstone beds thicken with depth in this unit.

Subunit ID (68-105 mbsf): homogeneous white unlithified bioclastic packstones with fragments of *Halimeda* and bryozoans abundant. Very coarse packstones and rudstones containing coral fragments occur at the base of the subunit. The top of the subunit is medium to fine sand.

Unit II (105-135.5 mbsf; uppermost Pliocene): this unit consists of pelagic calcareous mudstones with varying amounts of nannofossils, micrite, and shallow-water-derived bioclasts and upward-fining packstones, which are thickest in the middle of the unit.

Unit III (135.5-166 mbsf; lower Pliocene): composed of white to dark gray densely cemented bioclastic rudstones and packstones. Large fragments of corals, coralline algae, and whole rhodoliths occur in a sand-sized bioclastic matrix.

Unit IV (166-242.3 mbsf; upper Miocene): composed of white to light gray nannofossil ooze and chalks with varying amounts of bioclasts, micrite, and calcite. Layers of fine to medium bioclastic packstones with nannofossils and micrite occur throughout and contain abundant shallow-water components. The degree of lithification varies with depth in this unit.

Unit V (242.3-338.7 mbsf; upper to middle Miocene or older): the upper half of the unit is composed of interbedded white foraminifer chalk and allochthonous shallow-water-derived molluscs, corals, coralline algae, rhodoliths, *Halimeda,* and benthic reef foraminifers. The shallow-water sediments exhibit upward fining, grading, and moldic porosity. The lower half of the unit is composed of dense skeletal packstone and rudstones composed of branching corals, molluscs, echinoids, and benthic foraminifers. Branching corals with coralline crusts form floatstones in the lower part.

Unit VI (338.7-401.9 mbsf; Miocene to upper Oligocene): white bryozoan-dominated bioclastic rudstone with poorly preserved coralline and large foraminifer fragments and ahermatypic(?) corals, all of which are recrystallized and cemented. The base of the unit is a dark yellowish brown to gray poorly sorted quartz bioclastic sandstone in a mud matrix. Identifiable carbonate grains are bryozoans and larger foraminifers (*Operculina* and *Assilina*). Milky to clear rounded and angular quartz are common, along with reworked black phyllite clasts.

Unit VII (401.9-431 mbsf; age unknown): comprises a deeply weathered orange to brown regolith overlying black to dark gray phyllite and schists with quartzitic lenses and a light gray to green finely crystalline metavolcanic rock.

Interstitial water chemistry on the cores shows that calcium and magnesium change little either as a result of seawater contamination or fluid flow in the hole. Strontium increases three times in concentration by 21.95 mbsf and then gradually decreases toward the bottom of the hole. Potassium shows no change, reflecting the lack of clay minerals in the cores. Alkalinity, sulfate, and ammonia also show little change.

X-ray diffraction analyses indicate that from 0 to 119.4 mbsf the sediments are mainly aragonite, but below 257.2 mbsf aragonite is absent. Calcite increases from 24.2% near the top of the hole to 100% at the base. Small amounts of dolomite occur between 95.4 and 238.6 mbsf, whereas calcium carbonate varies cyclically with depth.

The percentage of organic carbon in the sediments is very low (<0.25%). The sediments also contain very low concentrations of methane (2-12 ppm); ethane and propane were not detected.

NOTE: At the time of completing this report, no logging or paleomagnetics data were available.

SITE 825

Site 825 (proposed site NEA-8) is located on the windward western margin of the Queensland Plateau, immediately east of Holmes Reef. It was a reoccupation of Site 811 in an attempt to reach the basement objective and recover additional sediment from the poorly recovered intervals at Site 811.

Results

Hole 825A was washed to 200 mbsf after the retrieval of a 4.5-m APC mud-line core. APC/XCB drilling then penetrated to 381.5 mbsf before refusal. This operation was followed by RCB drilling of Hole 825B between 379.5 and 466.3 mbsf, with basement contact at ~453 mbsf.

The continental basement is a possible quartz-feldspar-mafic(?) metasediment or metavolcanic rock. Accurate identification of the rock type requires shore-based thin-section analysis. The age of the bioclastic grainstone and rudstone representing the inner-shelf facies that transgressed over the basement cannot be determined precisely, but sparse coccoliths indicate a range from middle Eocene to early Miocene. An age interpretation based on the abundant larger benthic foraminifers obtained in Hole 825B will be forthcoming after shore-based thin-section analyses.

Five lithostratigraphic units (possibly six based on the recovery of a single pebble dated as early to middle Eocene) were defined for the Site 811 sedimentary sequence. The sediments recovered at Site 825 correspond to these units in part, but, with the deeper penetration, Hole 825B extended below the level of the lowest Unit VI section defined at Site 811. Therefore, the same unit designations are used for Site 825 sediments, with a redefinition of Unit VI based on better recovery and an additional Unit VII to include the basement rock. Note that Units II and V recognized at Site 811 were not recovered at Site 825.

Unit I (0-4.5 mbsf; upper Pleistocene): the mud-line core from Hole 825A contained nannofossil foraminifer micritic ooze with interbeds of thin foraminifer pteropod packstone layers, interpreted as calciturbidites. These sediments correlate with the Pleistocene periplatform ooze of Subunit IA at Site 811.

No sediments from Site 811 Unit II were cored at Site 825.

Unit III (200.0-276.4 mbsf; middle Miocene): the sediments recovered in this interval are white micritic ooze and chalk with nannofossils and foraminifers alternating with white unlithified to partially lithified bioclastic packstone and floatstone.They are similar to the series of deep-water periplatform ooze and chalk alternating with gravity-flow deposits recovered at Site 811 in the same depth interval.

Unit IV (305.4-315.0 mbsf; upper lower Miocene): Unit IV contains white lithified bioclastic packstone with foraminifers, and yellow indurated bioclastic rudstone with larger benthic foraminifers, coralline algae, and coral molds, as observed at Site 811. This unit represents deposition in a tropical fore- or back-reef environment at water depths less than 50 m.

No sediments from Site 811 Unit V were recovered at Site 825.

Unit VI (408.4-453 mbsf; middle Eocene to lower Miocene): Unit VI contains white and pale yellow to yellow, alternating with more pinkish levels, indurated well-sorted bioclastic grainstone and rudstone. The dominant bioclasts are coralline algae, echinoids, molluscs, and small branching corals. Primary intergranular porosity is well preserved, with only minimum moldic porosity. The interpreted depositional environment is temperate to subtropical waters on the inner neritic shelf. These sediments probably represent the transgressive facies overlying the continental basement.

Unit VII (453-466.3 mbsf; age unknown): the basement rock is dark gray, poorly foliated, well-lithified fine-grained quartz-feldspar-mafic(?) metasediment(?) or metavolcanic(?) containing more coarsely crystalline zones of quartz and feldspar. Thin discontinuous quartz or feldspar veinlets are present and disseminated pyrite is common.

Three WSTP runs were made to obtain downhole temperatures and formation fluids. Temperature data indicate that the geothermal gradient at Site 811/825 is 8.0°C/100 m, comparatively greater than 5-6°C/100 m observed at other Leg 133 sites. Geochemical analyses of WSTP and squeezed interstitial waters correspond to the profiles obtained at Site 811. The higher thermal gradient, together with the monotonous geochemistry of the interstitial fluids measured at Site 811, confirmed by the Site 825 waters, indicates that there is massive fluid flow through the carbonate sediments. Physical property measurements of sediments recovered between 200 and 267 mbsf show high porosity (~52%) and water content (~40%), ~5% higher than normal for these depths. These measurements are consistent with the proposed fluid flow that essentially must be maintaining the higher water content by replacing water expelled with normal compaction.

SITE 826

Site 826 (proposed site NEA-13) occurs in 424 m of water on the northwestern margin of the Marion Plateau, in a position ~1.5 nmi south of Site 816. The location defines a lagoonal site immediately behind the Miocene(?) barrier reef drilled at Site 816. The drilling objective was not to establish the stratigraphy at the site but to penetrate postulated lagoonal sequences so as to obtain faunas with which to date Sites 816 and 826. After establishing the mud line, the hole was washed to 98.5 mbsf. Thereafter the hole was rotary cored to a depth of 250 mbsf.

Results

Sediments recovered at Site 826 included muds immediately above the lagoonal sequence at 98.5 mbsf and dolomitized skeletal packstones, rudstones, and minor boundstones between 98.5 mbsf and termination depth. One lithostratigraphic unit was identified:

Unit I (98-250 mbsf; middle Miocene?): the unit is composed of partially to completely dolomitized bioclastic rudstone and minor coralgal boundstone. Benthic foraminifers are common in some sections, so that accurate dates will be obtained from shore-based studies of the sediments. Such dates will have a substantial impact on the interpretation at Site 816 and the middle Miocene sea-level history on the Marion Plateau.

NOTE: No physical properties or chemical analysis, logging, or paleomagnetic sampling was conducted at the site.

DISCUSSION

Although shipboard results remain preliminary at this stage, Leg 133 drilling has provided valuable and sometimes surprising new information about the evolution of carbonate-platform environments. Combining litho-, chemo-, magneto-, and biostratigraphic analyses to estimate the timing of events, we interpret a Cenozoic record of environmental change on the northeast Australian margin that can tentatively be used to differentiate between the influences of sea-level fluctuation, tectonic subsidence, terrigenous flux, paleoclimate, and paleoceanography on carbonate-platform development, as suggested by previous studies (Davies et al., 1987, 1989).

Our interpretation of shipboard results indicates the initiation of carbonate sedimentation on the Queensland Plateau in the early middle Eocene, when the seas transgressed across the metasedimentary continental basement. Temperate faunas inhabited the local seas during the latest Oligocene, but by the latest early Miocene tropical fauna dominated on the Queensland and Marion plateaus. The transition from temperate to tropical waters reflects the northward movement of the Australian plate combined with the initiation of the southward flow of tropical waters from the equatorial Pacific. During the early middle

Miocene, the tropical waters supported robust reefal growth that gradually declined during the late middle Miocene, possibly in conjunction with paleoenvironmental changes induced by the steady drop in eustatic sea level during this period.

Carbonate production on the shallow-water banks diminished dramatically in the late Miocene in response to global climatic deterioration and continued eustatic sea-level falls, accelerated by a seasonal influx of colder waters into the tropical environment. The banks apparently were unable to respond to climatic amelioration in the earliest Pliocene. A pulse of more rapid subsidence on the Queensland Plateau, in combination with rising eustatic sea level, may have essentially drowned the banks. Conditions stabilized in the late early Pliocene when the carbonate banks were rejuvenated, remaining more or less productive until the present. The renewed bank production, however, was on a much reduced scale compared with the flourishing reefs and banks of the early to middle Miocene, and has barely been able to keep up with continued subsidence. Carbonate banks of the Marion Plateau have, however, never recovered from being suffocated by increased terrigenous influx. Initiation of reef growth on the Great Barrier Reef is even younger, beginning at about 1 million years ago.

Our initial results from drilling and shipboard studies remain preliminary, and attempts to relate the causes and consequences of the interpreted environmental changes recognized in the sediment record await further results obtained from future shore-based studies. New information toward resolving enigmatic problems surrounding carbonate-platform development will undoubtedly evolve from these studies.

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Davies, P. J., Symonds, P. A., Feary, D. A., and Pigram, C. J., 1987. Horizontal plate motion: A key allocyclic factor in the evolution of the Great Barrier Reef. *Science,* 238:1697-1700.

Davies, P. J., Symonds, P. A., Feary, D. A., and Pigram, C. J., 1989. The evolution of the carbonate platforms of northeast Australia. *Soc. Econ. Palaeontol. Mineral., Spec. Publ.* 44, 233-258.

Table 1. Coring statistics, Leg 133.

Hole	Dates occupied (1990)	Latitude	Longitude	Water depth (m)	Penet. (m)	No. of cores	Interv. cored (m)	Core recov. (m)	Recovery (%)
811A	17 Aug.-17 Aug.	16°30.977'S	148°9.436'E	937.1	213.6	23	214.5	213.2	99.4
811B	17 Aug.-19 Aug.	16°30.948'S	148°9.454'E	937.0	392.5	24	199.3	15.5	7.8
811C	20 Aug.-20 Aug.	16°30.942'S	148°9.451'E	936.8	237.5	6	55.2	55.3	100.1
812A	20 Aug.-21 Aug.	17°48.841'S	149°36.313'E	461.6	189.9	22	189.9	40.7	21.4
812B	22 Aug.-23 Aug.	17°48.842'S	149°36.306'E	461.6	300.0	18	149.2	8.5	5.7
812C	26 Aug.-27 Aug.	17°48.842'S	149°36.331'E	461.9	137.8	16	137.8	114.0	82.8
813A	24 Aug.-24 Aug.	17°49.959'S	149°29.669'E	539.1	231.5	26	231.5	199.4	86.1
813B	24 Aug.-25 Aug.	17°49.951'S	148°29.673'E	538.9	190.0	21	190.0	196.2	103.2
814A	25 Aug.-26 Aug.	17°49.985'S	149°30.831'E	520.4	300.0	33	300.0	162.4	54.1
815A	27 Aug.-30 Aug.	19°9.034'S	149°59.508'E	465.5	473.5	51	473.5	416.2	87.9
815B	30 Aug.-31 Aug.	19°9.034'S	149°59.524'E	465.9	36.4	4	36.4	37.8	103.8
816A	31 Aug.-31 Aug.	19°11.924'S	150°0.608'E	437.8	111.5	15	111.5	97.5	87.5
816B	31 Aug.-1 Sept.	19°11.911'S	150°0.601'E	437.8	77.2	9	77.2	10.5	13.6
816C	1 Sept.-2 Sept.	19°11.911'S	150°0.608'E	437.8	250.0	13	109.6	11.3	10.3
817A	3 Sept.-4 Sept.	18°9.496'S	149°45.494'E	1016.6	330.7	35	330.7	280.4	84.8
817B	4 Sept.-4 Sept.	18°9.477'S	149°45.505'E	1015.7	204.0	22	204.0	211.1	103.5
817C	4 Sept.-4 Sept.	18°9.489'S	149°45.534'E	1016.1	27.2	3	27.2	27.3	100.2
817D	4 Sept.-8 Sept.	18°9.499'S	149°45.509'E	1015.8	700.0	47	430.0	22.1	5.2
818A	8 Sept.-8 Sept.	18°3.767'S	150°2.533'E	748.6	9.6	1	9.5	9.6	101.0
818B	8 Sept.-9 Sept.	18°3.767'S	150°2.533'E	744.8	302.9	32	302.9	314.6	103.8
819A	9 Sept.-12 Sept.	16°37.439'S	146°19.486'E	565.2	400.0	44	400.0	339.5	84.9
820A	12 Sept.-12 Sept.	16°38.221'S	146°18.229'E	278.0	144.2	17	144.2	145.8	101.0
820B	12 Sept.-14 Sept.	16°38.219'S	146°18.218'E	279.0	400.0	44	400.0	324.9	81.2
821A	15 Sept.-16 Sept.	16°38.793'S	146°17.376'E	212.8	400.0	43	400.0	382.9	95.7
821B	16 Sept.-17 Sept.	16°38.794'S	146°17.366'E	211.3	165.9	20	165.9	167.4	100.9
822A	17 Sept.-20 Sept.	16°25.379'S	149°12.904'E	955.2	433.9	47	433.9	384.6	88.6
823A	21 Sept.-21 Sept.	16°36.981'S	146°47.037'E	1638.4	119.8	13	119.8	123.7	103.3
823B	21 Sept.-26 Sept.	16°36.982'S	146°47.053'E	1637.9	805.4	84	805.4	754.7	93.7
823C	26 Sept.-30 Sept.	16°36.983'S	146°47.066'E	1637.8	1011.0	82	227.0	186.1	82.0
824A	1 Oct.-3 Oct.	16°26.704'S	147°45.737'E	1000.4	377.3	36	327.3	129.7	39.6
824B	3 Oct.-3 Oct.	16°26.703'S	147°45.720'E	1001.9	52.5	6	52.5	1.8	3.5
824C	3 Oct.-4 Oct.	16°26.705'S	147°45.753'E	1000.3	183.2	19	183.2	3.2	1.8
824D	4 Oct.-6 Oct.	16°26.690'S	147°45.753'E	1001.9	96.5	10	96.5	1.1	1.1
825A	6 Oct.-7 Oct.	16°30.948'S	148°9.458'E	939.4	381.5	23	186.0	54.4	29.2
825B	7 Oct.-8 Oct.	16°30.961'S	148°9.457'E	939.3	466.3	10	86.8	3.0	3.5
826A	8 Oct-10 Oct.	19°13.530'S	150°0.597'E	425.3	250.0	18	156.5	7.1	4.5
			Leg 133 Total		10,897.8	879	7972.9	5504.9	69.0

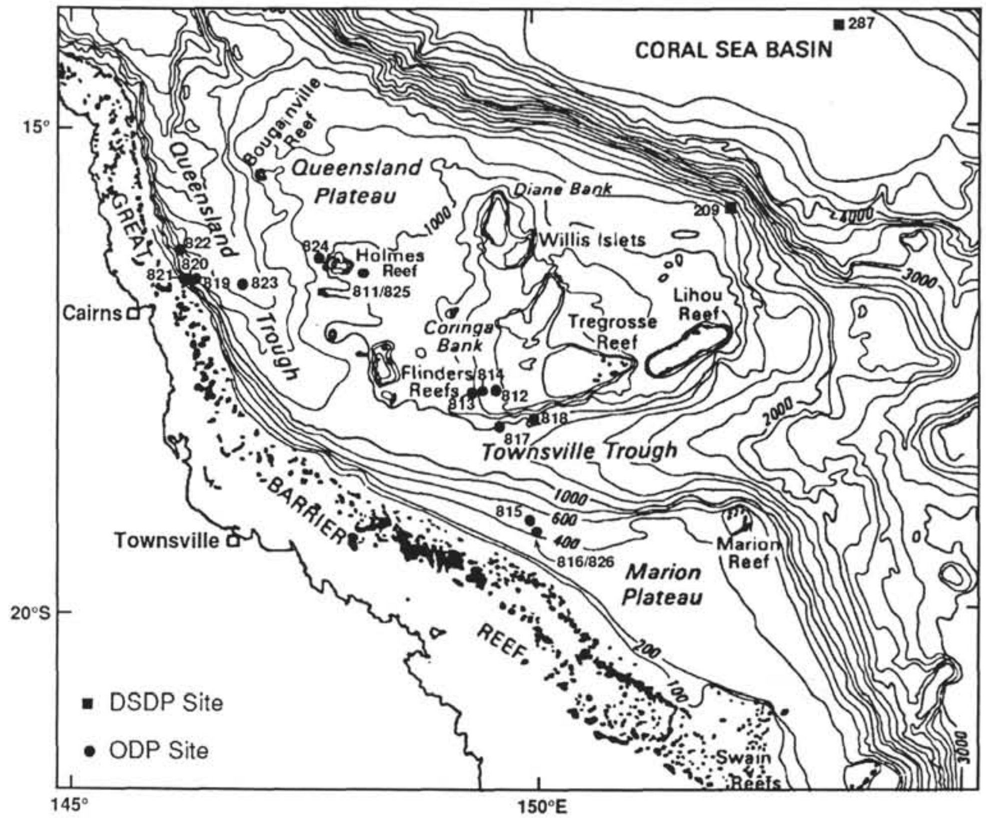


Figure 1. Map of Leg 133 drill sites, northeast Australian margin (bathymetry in meters).

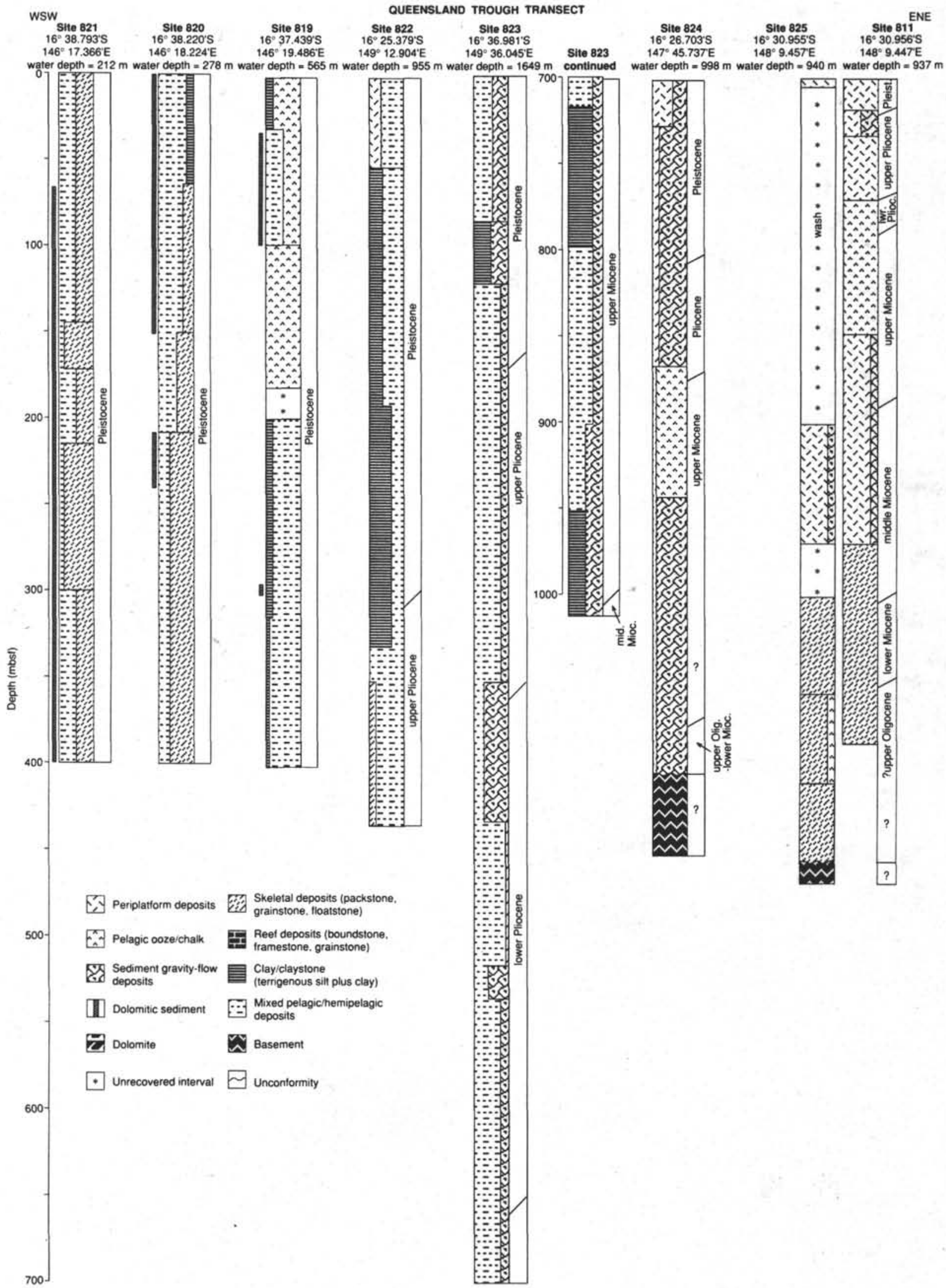


Figure 2. Lithostratigraphic summary of the Queensland Trough transect.

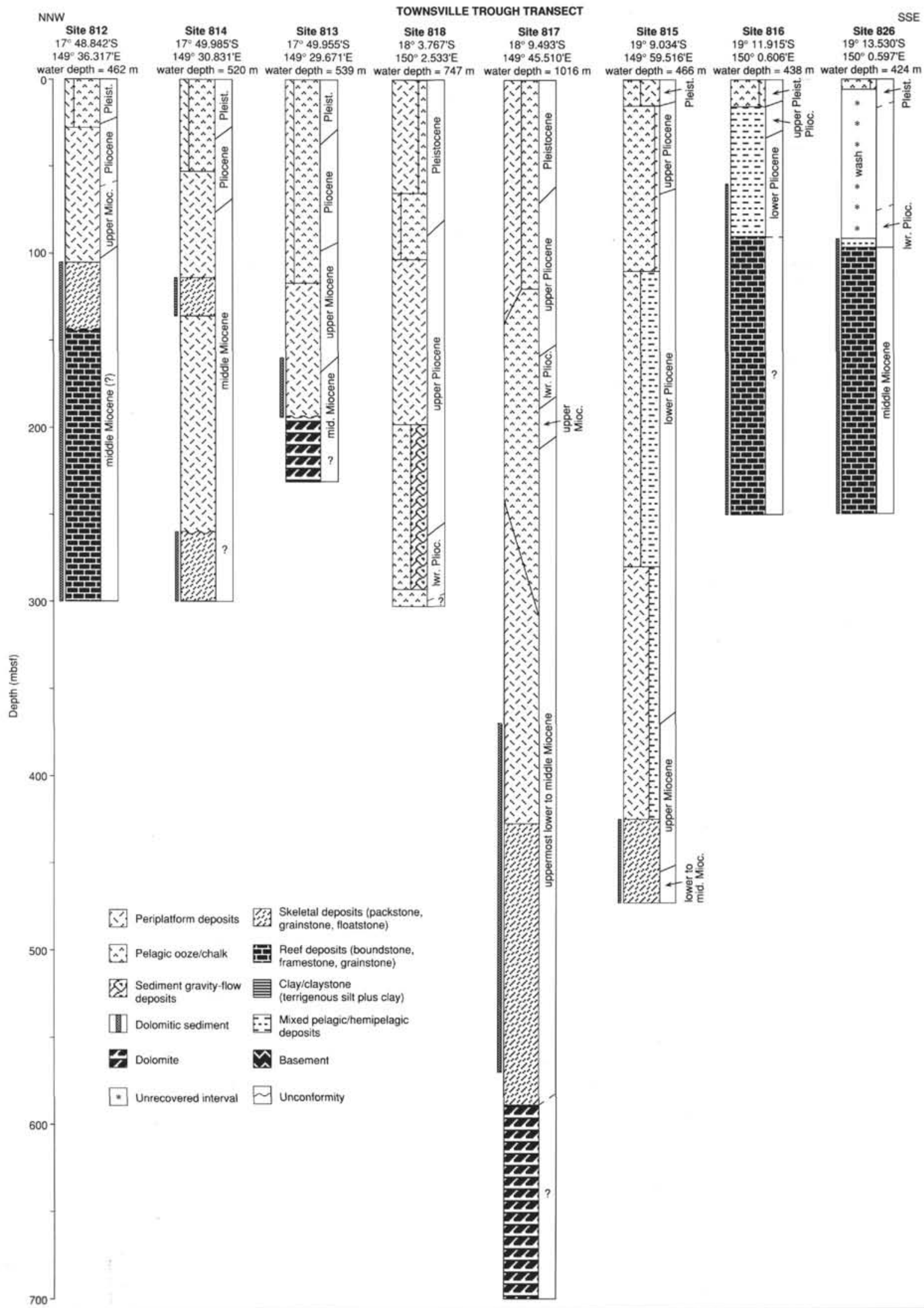


Figure 3. Lithostratigraphic summary of the Townsville Trough transect.

OPERATIONS REPORT

The ODP Operations and Engineering personnel aboard *JOIDES Resolution* for Leg 133 were:

Operations Superintendent:	Eugene Pollard
Visiting Engineer:	Jack Pheasant
Schlumberger Engineer:	Steve Kittredge

OVERVIEW

Ocean Drilling Program Leg 133 was dedicated to providing a detailed study of the evolution of the Queensland and Marion carbonate platforms and adjacent basins of the Queensland and Townsville troughs off northeastern Australia. Specific objectives were to define sedimentary response to global sea-level change and define the influences of paleo-chemistry, paleoclimate, and paleoceanography on the initiation, growth, and demise of the Great Barrier Reef. Twelve sites were cored in two transects, east-west across the Queensland Trough and Plateau and north-south across the Marion Plateau and Townsville Trough.

The approved coring plan was to use the advanced hydraulic piston corer (APC) to refusal, with orientation of cores; use the extended core barrel (XCB) from APC refusal to the approved depth or refusal; use the rotary core barrel (RCB) core to the approved depth, and conduct downhole measurements. Logs were scheduled for 10 of the 12 coring sites, and included the seismic-stratigraphy, geochemical, and formation microscanner logs. Vertical seismic profiling was planned for proposed sites NEA-2 and -11, and wireline packer deployment was planned for proposed sites NEA-10A/1, -10A/2, and possibly -13.

Operational highlights of Leg 133 included the first use of the new vibra-percussive corer (VPC) and first use of the new conical side-entry sub (CSES).

GUAM PORT CALL

Leg 133 began officially when *JOIDES Resolution* put the first line ashore at Berth Victor 6 in Port Apra, Guam, at 1900L (all times in this section are given in local time, or L) 4 August 1990. Customs and immigration formalities were not concluded until 2400L. Crew change, off-loading the diamond coring system (DCS), loading and off-loading ocean and air freight, and normal port-call activities proceeded slowly with frequent rain. Rigging down the DCS required longer than expected, and an attempt by Vetco/Baker/Hughes to inspect the 5-1/2-in. drill pipe ended after six stands because of delays. The American Bureau of Shipping completed an inspection of the explosives and radioactive material lockers and renewed the certificate for safe storage and handling. Divers welded straps over four notches in the moonpool wear ring caused by wireline wear. The ship moved to the fueling pier at 1515L 8 August. Fueling was completed and the final line was cast off at 1355L 9 August. The harbor pilot was away at 1423L, and the sea voyage to the northeast Australian margin began.

GUAM TO SITE 811

Proposed site NEA-8 (Hole 811) lay off the northeast coast of Australia, 2017 nmi southwest of Guam. The magnetometer was streamed at 1800L, shortly after leaving Guam. The new CSES was made up to 28,000 ft-lb torque and the releasing wireline packoff was tested. The VPC was assembled, and two drill collars were made up in the rotary for a test; however, the 60-ft length of the VPC required the drill collars to be lowered below the ship, so the test could not be conducted while under way.

The entire sea voyage to the first site covered 2017 nmi in 174 hr at an average speed of 11.6 kt. Seas and wind were calm for the first half of the voyage (12.3 kt average), but 35-kt winds, 8-ft seas, and the loss of two propulsion motors slowed progress thereafter to a 10.9-kt average.

SITE 811 (NEA-8)

An 18 nmi pre-site seismic survey was run over proposed site NEA-8 using optimal GPS positioning. The first beacon (a commandable recall model) was dropped at 0021L 17 August. The beacon drop initiated Hole 811A.

Hole 811A

The precision depth recorder (PDR) indicated the water depth to be 937.5 m from sea level. The ship moved 15 m west of the beacon, and a used 11-7/16-in. Security four-cone tungsten carbide insert bit was run to 933.1 m water depth for the first core. Hole 811A was spudded at 0751 hr, 17 August, at 16°30.977'S and 148°9.436'E. Core 133-811A-1H recovered 5.55 m of sediment and thus was accepted as a mud-line core. The mud line was estimated by drill-pipe measurement (DPM) at 937.1 m from sea level. Continuous APC cores (Cores 133-811A-1H through -23H) were taken from 0.0 to 214.5 mbsf, with 213.51 m recovered (91.9% recovery). Orientation surveys were taken from Cores 133-811A-4H through -23H.

The pump pressure bled from 2600 to 2000 psi after shooting Core 133-811A-23H. The core barrel was stuck and could not be freed even with as much as 12,500 lb core-line pull. The drill pipe was found to be plugged, making circulation impossible. The overshot would not release, so the Kinley cutter was used to sever the core line at the core barrel. The drill string stuck with the bit at 187.4 mbsf while starting the trip out of the hole. The drill string came free after being worked for 45 min using as much as 260,000 lb overpull. The bit cleared the seafloor at 2204L 17 August, ending Hole 811A (NEA-8). The core barrel was removed from the drill collars, but the APC upper section remained stuck in the barrel despite overpull up to 150,000 lb. The bottom drill collars were full of nannofossil ooze and reef debris; the back flow through the lockable flapper valve (LFV) may have filled the drill collar with sufficient material to hinder APC operation and interfere with the overshot release. The stuck APC upper section indicates that metal debris (possibly a shear pin) jammed the tool and prevented removal.

Hole 811B

The ship was moved 30 m east to 16°30.948'S, 148°9.454'E (15 m east of the beacon), and the same six-drill-collar APC/XCB BHA was run with Hydrolex jars added as a precaution. The PDR indicated a water depth of 938.4 m from sea level; the hole was spudded and washed to 194.0 mbsf. Continuous XCB cores (Cores 133-811B-1X through

-6X) were taken from 193.2 to 250.3 mbsf, with 57.1 m of sediment cored and 0.28 m recovered (0.5% recovery). Recovery was poor to none in soft nannofossil ooze and coarse calcareous sand sequences; therefore, a decision was made to try the new VPC.

Continuous VPC cores (Cores 133-811B-7V through -10V) were taken from 250.3 to 264.6 mbsf, with 14.3 m cored and 5.89 m recovered. This was the first operational test of the new VPC design. Bit advancement was by recovery on Cores 133-811B-8V through -10V in an effort to get a complete section. Core 133-811B-7V was wireline deployed, but the two shear pins sheared on release. Cores 133-811B-8V through -10V were dropped without shear pins. The heave compensator closed when 1200 psi pump pressure hydraulically lifted the BHA. Tool vibration was indicated by pressure-gauge fluctuations of ±30 psi. The VPC produced a good undisturbed core with horizontal banding still evident and only minor external fluidization. The VPC test was stopped due to slow penetration in coarse calcareous sands.

Continuous XCB cores (Cores 133-811B-11X through -24X) were taken from 264.6 to 392.5 mbsf, with 127.9 m of sediment cored and 7.37 m recovered (5.76% recovery). Verbal approval from ODP/TAMU was obtained to core the hole down to a seismic reflector estimated to be between 400 and 430 mbsf (450 mbsf maximum). However, before this objective was reached the drill string became stuck after coring 7.6 m of Core 133-811B-24X. The pipe was worked up to 250,000 lb overpull (280,000 lb string weight) but would not come free. The string came free after two 100,000-lb blows with the Hydrolex jars. The jars were clearly responsible for freeing the string. After regaining circulation and rotation, a 30-bbl gel hole-cleaning sweep was pumped. The string was pulled up slightly, and the core barrel was retrieved; however, the XCB shoe, core catchers, and sub had unscrewed and were lost in the hole along with the core. The junk in the hole terminated Hole 811B coring.

A 30-bbl gel sweep was circulated to clean the hole at 372 mbsf, and the drill string was run in the hole to condition the hole for logging. A 30-bbl gel sweep was circulated on bottom at 388.5 mbsf, and the bit was pulled up to 103.2 mbsf for logging. A go-devil was dropped to open the LFV for logging. The short trip encountered no drag while pulling out of the hole. Therefore, the indications are that the pipe was stuck at the bit by a coarse calcareous sand cave-in and/or cuttings accumulation. The coarse sand was unconsolidated, contained little fine-grained material, and washed easily with water; therefore, we carried out operations so as to minimize hydraulic effects.

The DITE/HLDT/sonic/caliper/NGTC/TCC tool string was run in at 1425L 19 August, but tagged a bridge in the BHA at 53 mbsf. The tool could not be worked or circulated past the obstruction; therefore, it was pulled out at 1500 hr. The less-rigid TCC tool was removed to shorten the tool string, which was then run with the same negative results. We thought it possible that the core catcher from Core 133-811B-24H had fallen off in the BHA and lodged in the BHA upset. When the go-devil was retrieved from above the obstruction, scars on its nose confirmed that it had landed on additional junk in the BHA; therefore, the logging program was terminated.

The APC/XCB BHA was pulled and cleared the seafloor at 0750L 19 August. The liner support ring from Core 133-811B-24H was found wedged in the head sub windows. Twelve hours remained before the departure for NEA-10A, timed so as to meet a GPS window. Therefore, we decided to run back in the hole to attempt to obtain a less-disturbed mud-line interval. The bit, LFV, APC/XCB BHA, and jars were checked and run in the hole.

Hole 811C

Hole 811C was spudded at 0128L 20 August, at 16°30.942'S and 148°9.451'E. The estimated water depth from the PDR was 938.4 m from sea level. The first core (133-811C-1H) was shot with the bit positioned at 934.9 mbsl and recovered 7.73 m of sediment. We accepted it as a mud-line core and determined the mud line to occur at 936.8 mbsf. Continuous APC cores (Cores 133-811C-1H through -6H) were taken from 0.0 to 55.2 mbsf, with 55.2 m of sediment cored and 55.28 m recovered (100.0% recovery). Orientation surveys were taken from Cores 133-811C-3H through -6H. Coring was ended when the allotted time ran out, and the BHA was pulled. The bit cleared the seafloor at 0440L 20 August, and the bit cleared the rotary table at 0625 hr 20 August, ending Hole 811C.

SITE 812 (NEA-10A/1)

Hole 812A

The transit to proposed site NEA-10A/1 (Hole 812A) covered 109 nmi in 9.4 hr at an average speed of 11.6 kt. During the transit we streamed the magnetometer. A 22-nmi seismic survey was run over Sites NEA-10A/2, -10A/3, and -10A/1 in 4.6 hr at an average speed of 4.8 kt. The survey was conducted within an optimal global positioning system (GPS) window. The ship returned to the GPS position indicated for Hole 812A, and a Benthos shallow-water beacon was dropped at 2150L 20 August 1990. The ship was unable to hold the GPS position because of low signal level. A second beacon was deployed on a taut wire, and the beacon was dropped at 0115L 21 August.

Hole 812A was spudded at 0218L 21 August at 17°48.841'S and 149°36.313'E. The PDR indicated that water depth was 460.4 m. The bit was positioned at 457.0 m and the first core was shot. Core 133-811C-1H recovered 4.89 m of sediment and therefore was accepted as a mud-line core; the mud line was determined to be at 461.6 m below sea level. Continuous APC cores (Cores 133-812A-1H through -4H) were taken from 0.0 to 27.9 mbsf, with 27.9 m of sediment cored and 26.08 m recovered (93.48% recovery). An orientation survey was taken at -4H. APC coring was terminated when the APC had a partial stroke on -4H that damaged the shoe and shattered the liner. Continuous XCB cores (Cores 133-812A-5X to -8H) were taken from 27.9 to 64.3 mbsf with 36.4 m cored and 1.56 m recovered (4.29% recovery). The circulation rate was held low in an effort to improve recovery of flowing dolomitic sands, and frequent mud sweeps were required. Overpulls of 20,000-40,000 lb were common.

We attempted to use the VPC for Core 133-812A-9V, but recovery was negligible (although the liner support ring had sand packed around it, indicating that some core had entered the liner).

Continuous XCB cores (Cores 133-812A-10X to -22X) were taken from 64.3 to 189.9 mbsf with 125.6 m cored and 13.09 m recovered (10.42%). The drill string was stuck repeatedly in interbedded hard dolomite and flowing dolomitic sands. The pipe stuck at 177.4 mbsf; it was worked to 270,000 lb overpull (230,000 string weight) without success. The Hydrolex jars were used for four 100,000-lb blows, and rotation and circulation were regained. A 30-bbl gel sweep was pumped and Core 133-812A-22X was cut. The string stuck again and was worked out of the hole with 250,000 lb overpull. The bit cleared the seafloor at 1950L and cleared the rotary table at 2130L 21 August.

Hole 812B

The ship was moved 15 m west to Hole 812B at 17°48.842'S and 149°36.306'E. A 9-7/8-in. four-cone insert bit was run with the RCB bottom-hole assembly (BHA). Four additional 8-1/4-in. drill collars were picked up for added weight on bit in a 12-DC BHA. Hole 812B was spudded at 0208L 22 August. A 9-7/8-in. hole was drilled with a wash barrel in place from 0 to 72.4 mbsf. After a 4-1/2-hr delay for rig repairs, the RCB BHA was run back to 72.4 mbsf and Core 133-812B-1W was retrieved. A second wash barrel was dropped and the 9-7/8-in. hole was drilled 72.4-150.0 mbsf. However, the pipe became stuck again; it was worked up to 410,000 lb maximum overpull (230,000 lb string weight) from 117.9 to 108.4 mbsf. The jars failed to free the pipe. We think that it may have been stuck above the BHA in a notch on one of the protruding dolomite ledges. Circulation rates had been reduced in a futile attempt to improve recovery, which probably aggravated hole-cleaning problems with fine sloughing dolomitic sands.

The hole was swept with 20 bbl of mud, rotation was restored, and the pipe was reamed back to bottom (as a precautionary measure), encountering rock rubble at the bottom of the hole. We think that the rock rubble came from dolomite ledges that were broken off as the stuck pipe was pulled up hole. The hole was swept with 20 bbl of mud and we retrieved Core 133-812B-2W, which yielded hard dolomite. Continuous rotary cores (Cores 133-812B-3R to -18R) were taken from 150.8 to 300.0 mbsf, with 149.2 m cored and 8.52 m recovered (5.71%). We credit an increase in circulation rate from 300 to 500 gal/min and a 15-bbl mud sweep in mid-core for successfully avoiding stuck pipe. A short trip, made to condition the hole for logging, encountered no drag and only 1 m of fill at the bottom of the hole, indicating that the hole was stable. A 20-bbl mud sweep was circulated before and after the conditioning trip. The 9-7/8-in. RCB bit was dropped with a mechanical bit release (MBR); however, the sleeve-shifting tool was also lost in the hole. The open-ended pipe was pulled to 68.8 mbsf for logging.

Logs were run as follows:

1. The induction/density/sonic/caliper/gamma ray (DITE/HLDT/SDT/MCDG/NGT) logging tool was put into the pipe at 0805L 23 August, and was out of the hole at 0955L.

2. The formation microscanner/gamma ray/temperature (FMS/NGT/TCC) logging tool entered the pipe at 1050L 23 August, and was back out at 1210L.

3. The wireline packer was picked up for two isolation packer tests. As the tool was being picked up it bowed and the electrical connections failed. This problem was indicated by erratic amperage to the swash plate pump motor. The tool was picked up again at 1230L 23 August, and electrical troubleshooting continued until 1945L when the RCB BHA cleared the seafloor at 2023L.

Drill pipe was pulled while the ship moved in dynamic positioning (DP) mode to Hole 813A (NEA-10A/3); the MBR cleared the rotary table at 2145L 23 August.

Return to Hole 812C

Operations at Site 814 demonstrated the potential of using the XCB to penetrate thin, hard layers (where these could be accurately predicted in the section) and subsequently returning to APC coring to recover the softer underlying sediments. We decided to return to Site 812 to attempt to recover the softer sediments underlying the hard layers at 40 mbsf. The transit to Hole 812C covered 5.2 nmi in 4.5 hr at an average speed of 1.2 kt. The beacon signal was regained after locating the site using GPS coordinates, and the ship was positioned 15 m west of the beacon at 17°48.842'S, 149°36.331'E. The bit was positioned at a water depth of 459.9 m from sea level for the first core. Core 133-812C-1H was spudded at 2150L 26 August 1990; 7.45 m of sediment was recovered, indicating a mud-line water depth of 461.0 m from sea level.

Continuous APC cores (Cores 133-812C-1H through -3H) were taken from 0.0 to 26.4 mbsf, with 26.4 m cored and 26.78 m recovered (101.44%). The hard dolomite and limestone layer encountered in Holes 812A and 812B was expected in the following core, so the XCB was run. Core 133-812C-4X was taken from 26.4 to 29.5 mbsf, with 3.1 m cored and 0.45 m recovered (14.52% recovery). The bit went back into soft nannofossil foraminifer ooze, so the APC was picked back up as planned.

Cores 133-812C-5H through -13H were taken from 29.5 to 115.0 mbsf, with 85.5 m cored and 86.78 m recovered (101.5% recovery) before the APC refusal point was reached.

Cores 133-812C-14X through -16X were taken from 115.0 to 137.8 mbsf, with 22.8 m cored and 0.04 m recovered (0.18% recovery). The hole was becoming tight and the pipe was worked with up to 300,000 lb overpull. A 20-bbl gel sweep was circulated and the pipe was pulled out of the hole. The bit cleared the seafloor at 0740L and was back on deck at 0900L 27 August.

SITE 813 (NEA-10A/3)

Hole 813A

The transit from Site 812 (NEA-10A/1) to Site 813 (NEA-10A/3) covered 6.2 nmi in 5.25 hr at 1.2 kt average speed (in dynamic positioning mode). Pipe was pulled during the transit, the jars were serviced, and the RCB BHA was stood back in the derrick for future use. The 11-7/16-in. bit, APC/XCB BHA, monel drill collar, and Hydrolex jars were run in to 474 m below the rig floor (mbrf) in transit. A Datasonics commandable recall beacon was dropped off location by mistake at 0150L 24 August. The beacon was swung out with the release line tied to the ship. The ship could not offset to the required site, so a second beacon was dropped at 0315L within an optimal GPS window at the previously surveyed GPS coordinates.

The PDR indicated the water depth at the site to be 539.3 m from sea level. The bit was run in to 535 m water depth, and Hole 813A was spudded at 0428L 24 August, at a position of 17°49.959'S, 149°29.669'E. The first core recovered 5.72 m of sediment, placing the mud line at a depth of 539.1 m from sea level. Continuous APC cores (Cores 133-813A-1H to -21H) were taken from 0.0 to 192.7 mbsf, with 192.7 m cored and 198.36 m recovered (102.94%). Core 133-813A-21H was a partial stroke. Continuous XCB cores (Cores 133-813A-22X to -26X) were taken from 192.7 to 231.5 mbsf, with 38.8 m cored and 1.19 m recovered (3.07%). Poor XCB core recovery led to a trial run with the VPC for Core 133-813A-24V. However, the VPC was apparently run on a hard ledge and had no penetration or recovery.

After dropping the XCB core barrel for Core 133-813A-27X, the drill string became stuck. Gel sweeps were pumped to clean the hole, but the pipe was freed repeatedly only to become stuck again in a notched "keyseat" above the jars. The pipe was worked from 193 to 222 mbsf, with 270,000 lb maximum overpull (230,000 lb string weight). Coring was ended due to hole problems and we pulled out of the hole. The seafloor was cleared at 1900L 24 August.

Hole 813B

The ship was moved 25 m east, and Hole 813B was spudded at 2013L 24 August at a water depth of 538.9 m and a position of 17°49.951'S, 149°29.673'E. Continuous APC cores (Cores 133-813B-1H to -19H) were taken from 0.0 to 179.5 mbsf, with 179.5 m cored and 185.37 m recovered (103.27%). Cores 133-813A-4H through -19H were oriented.

We took VPC cores (Cores 133-813B-20V to -21V) from 179.5 to 190.0 mbsf, with 10.5 m cored and 10.79 m recovered (102.76% recovery). Core 133-813A-21V apparently hit refusal. The APC/XCB BHA was pulled up and cleared the seafloor at 0835L 25 August. The bit was pulled to 410 m water depth for transit. The beacon was dropped by mistake, recalled, and recovered. Then the ship departed Site 813.

SITE 814 (NEA-10A/2)

Hole 814A

The transit from Site 813 (NEA-10A/3) to Site 814 (NEA-10A/2) covered 1.2 nmi in 1.3 hr at 0.9 kt average speed (in dynamic positioning mode). A Datasonics beacon was dropped at 1035L 25 August within an optimal GPS window at the coordinates previously surveyed with GPS.

The PDR indicated water depth to be 520.3 m from sea level at the site, 17°49.985'S, 149°30.831'E. The bit was positioned at 516.7 m from sea level, and Hole 814A was spudded at 1215L 25 August. The mud-line core (Core 133-814A-1H) recovered 5.86 m of sediment, and the mud line was determined to be at a water depth of 520.4 m from sea level. Continuous APC cores (Cores 133-814A-1H to -7H) were taken from 0.0 to 56.8 mbsf with 56.8 m of sediment cored and 58.61 m recovered (103.19% recovery). Core 133-814A-7H resulted from a partial stroke due to a hard formation. Core 133-814A-8X was taken from 56.8-66.5 mbsf, with 9.7 m cored and 0.57 m recovered (5.88% recovery). Core 133-814A-8X broke through the hard formation back into soft ooze, as had happened at the other holes at Site 812. Therefore, a decision was made to resume APC coring in the hope of improving recovery. Cores 133-814A-9H to -16H (76.0-136.0 mbsf) cored 66.5 m and recovered 71.51 m (102.89% recovery).

Cores 133-814A-17X to -33X from 667.4 to 831.4 mbrf (136.0-300.0 mbsf) cored 164.0 m and recovered 31.77 m (19.37% recovery). Coring ended at the target depth. A 30-bbl mud sweep was circulated to clean the hole, and a short trip was made to condition the hole for logs.

Logs were run as follows:

1. The caliper springs on the induction/density/sonic/caliper/gamma ray (DITE/HLDT/SDT/ MCDG/NGT) logging tool would not go through the 3.80-in. landing sub. The caliper springs were removed and the log was run to 296.1 mbsf (3.9 m above the bottom of the hole). The logging tool was in at 0901L 26 August and was out at 1220L.
2. The formation microscanner/gamma ray/temperature (FMS/NGT/TCC) logging tool was in the hole at 1450L.

After logging was completed, the beacon was recalled; the bit was back on deck at 1612L 26 August.

SITE 815 (NEA-14)

Hole 815A

The transit from Hole 812C to Site 815 (proposed site NEA-14) covered 78 nmi in 7.0 hr at an average speed of 11 kt. A seismic survey was conducted over proposed sites NEA-14 and -13, which covered 23 nmi in 4.75 hr at 4.8 kt average speed. A Datasonics commandable release beacon was dropped at 2155L 27 August 1990 at the previously surveyed GPS coordinates (19°09.034'S, 149°59.508'E) with optimal GPS positioning.

A used Security four-cone insert bit was run with a seal bore drill collar, monel drill collar, and Hydrolex jars in a 12-drill-collar bottom-hole assembly. The PDR indicated water depth to be 466.6 m from sea level. The bit was positioned at 462.8 m water depth and the first core was shot. Core 133-815A-1H recovered 6.8 m of sediment, placing the mud line at a water depth of 465.5 m from sea level. Continuous APC cores (Cores 133-

815A-1H through -9H) were taken from 0.0 to 82.8 mbsf, with 82.8 m cored and 85.38 m recovered (103.1% recovery). At that point the acoustic signal from the beacon was lost unexpectedly, and a back-up Benthos model was launched at 0430L 28 August. The ship drifted off location about 35 ft (about 2°); coring was resumed after repositioning the ship.

Continuous APC cores (Cores 133-815A-10H through -25H were taken from 82.8 to 225.8 mbsf) with 143.0 m cored and 148.1 m recovered (103.6%). APC coring ended in hard clay because of repeated core liner failure. Overpull was negligible.

Cores 133-815A-26X through -51X were taken from 225.8 to 473.5 mbsf, with 247.7 m cored and 184.1 m recovered (74.3% recovery). Approval was obtained to extend coring past the originally approved target depth of 400 mbsf in order to reach a seismic reflector objective. No hole problems were noted in the clay, although the circulation rate and pressure were increased to prevent bit-nozzle plugging.

A short trip was made to condition the hole for logs with no drag noted. The bit encountered 13 m of fill starting at the top of the poorly recovered interval. A 30-bbl mud sweep was circulated to clean the hole prior to logging.

Logs were run as follows:

1. The induction/density/sonic/caliper/gamma ray (DITE/HLDT/SDT/MCDG/NGT) logging tool was put into the hole at 0954L 30 August, encountered 31.3 m of fill at the bottom of the hole, and was out of the hole at 1420L. Problems presisted with the Schlumberger logging computer, despite the installation of new hardware and software.

2. The geochemical/aluminum clay tool/gamma ray (GST/ACT/CNTG/NGT/TCC) logging tool was put into the hole at 1615L 30 August, encountering 149.5 m of fill in the hole.The computer problems continued, and logging was terminated; the tool string was out of the hole at 2110L 30 August.

The BHA was pulled out of the hole to 409 m water depth, clearing the seafloor at 2215L 30 August. The ship was moved in DP mode 15 m east, arriving at Hole 815B at 2227L 30 August.

Hole 815B

The high recovery in Hole 815A eliminated the need for the planned RCB hole. Thus Hole 815B was cored to duplicate the upper part of the section with the APC. The new hole was located at 19°9.034'S, 149°59.524'E. Hole 815B was spudded at 2342L 30 August with the bit positioned at a water depth of 464.3 m from sea level. Core 133-815B-1H recovered 7.94 m of sediment, placing the mud line at a water depth of 465.9 m from sea level. Continuous APC cores (Cores 133-815B-1H through -4H) were taken from 0.0 to 36.4 mbsf, with 36.4 m cored and 37.79 m recovered (103.8% recovery). The beacon was recalled and the bit cleared the seafloor at 0113L 31 August.

SITE 816 (NEA-13)

Hole 816A

The transit in dynamic positioning (DP) mode from Site 815 to Site 816 (proposed site NEA-13) covered 3 nmi in 1.75 hr at an average speed of 1.8 kt. A Datasonics beacon was dropped at 0310L 31 August 1990, within an optimal GPS window at the previously surveyed GPS coordinates.

Hole 816A was spudded at 19°11.924'S, 150°0.608'E at 0428L 31 August. The PDR indicated a water depth of 437.7 m from sea level. The bit was positioned at a water depth of 433.8 m from sea level and the first core was shot. Core 133-816A-1H recovered 5.53 m of sediment, placing the mud line at 437.8 m. Continuous APC cores (Cores 133-816A-1H through -11H) were taken from 0.0 to 93.0 mbsf, with 93.0 m cored and 96.0 m recovered (103.2% recovery). APC coring ended in hard limestone when Core 133-816A-11H reached refusal.

Cores 133-816A-12X through -15X were taken from 93.0 to 111.5 mbsf, with 18.5 m cored and 1.60 m recovered (8.6% recovery). XCB coring ended due to a slow penetration rate (31 min/ft) and low recovery. The BHA was pulled out of the hole to the seafloor at 1527L and was back on deck at 1710L 31 August.

Hole 816B

The ship moved 15 m north in DP mode, arriving on location for Hole 816B (19°11.911'S, 150°0.601'E) at 1555L 31 August. A Hycalog four-cone insert bit was run with a mechanical bit release, outer core barrel, 11 drill collars, and Hydrolex jars. This RCB bottom-hole assembly was run to the seafloor and Hole 816B was spudded at 2030L. The 9-7/8-in. hole was washed down to 86 mbsf, the depth at which good recovery had ended in Hole 816A.

Continuous RCB cores (Cores 133-816B-1R through -8R) were taken from 86.0 to 163.2 mbsf, with 77.2 m cored and 10.49 m recovered (13.6% recovery). At that point the pipe stuck, so a 20-bbl mud sweep was circulated and the drill string was worked up to 270,000 lb overpull. One blow with the jars at 60,000 lb freed the pipe, and Core 133-816A-9R was drilled from 163.2 to 171.0 mbsf. However, during the attempt to retrieve this core we discovered that the core barrel was lost in the hole. The drill string was pulled and was back on deck at 0700 1 September. The bit and the MBR disconnect were left in the hole, apparently as a result of a split in the MBR disconnect.

Hole 816C

The ship was moved 15 m north in DP mode to 19°11.911'S, 150°0.608'E for Hole 816C. A used 9-7/8-in. RBI bit and MBR were run, and Hole 816C was spudded at 0853L 1 September. The hole was washed from 0.0 to 140.4 mbsf, recovering Core 133-816C-1W with the wash barrel.

Cores 133-816C-2R through -13R were recovered from 140.4 to 250.0 mbsf, with 109.6 m cored and 11.2 m recovered (10.2% recovery). A 15-bbl mud sweep was pumped during the middle part of the coring process to avoid overpull and pipe sticking as cuttings accumulated. The hard, brittle limestone and dolomite tended to jam in the core catcher and liner after about 1 m of recovery. A short trip was made to 93 mbsf to condition the hole for logs, the bit and MBR were released, and the pipe pulled up to 102 mbsf.

Logs were run as follows:

1. The induction/density/sonic/caliper/gamma ray (DITE/HLDT/SDT/MCDG/NGT) logging tool entered the hole at 0205L 2 September, and was back out at 0310L. The tool was run to within 2.6 m of the bottom of the hole.

2. The formation microscanner (FMS)/gamma ray/temperature (FMS/NGT/TCC) tool string entered the hole at 0445L 2 September, and was back out at 0640L; this tool likewise encountered 2.6 m of fill.

3. The wireline packer was run in at 0820L, and an unsuccessful attempt was made to set the packer at 229.8 mbsf. The tool was pulled out at 1255L. The lower packer assembly stuck in the adjustable latch sleeve in the head sub. The weak point was sheared at 8,000 lb to retrieve the upper electronics package. The suction screen was found to have plugged with silt and collapsed. Insufficient water was collected to provide a sample.

4. The water sampler temperature pressure (WSTP) tool was run on the coring wireline and obtained a water sample (which was later found to be seawater) from 87 mbsf (above the point at which the packer was stuck in the drill pipe.

The drill string was pulled, and the MBR cleared the seafloor at 1453L, and was back on deck at 1630L 2 September. The beacon was recalled and was retrieved within 15 min.

SITE 817 (NEA-11)

Hole 817A

The transit from Site 816 to Site 817 (proposed site NEA-11) covered 58 nmi in 5.1 hr at an average speed of 11.4 kt. A seismic survey was run over NEA-11, covering 23 nmi in 3.93 hr at 5.85 kt average speed. A Datasonics beacon was dropped at 0243L 3 September 1990, but the acoustic signal failed immediately. A Benthos model was dropped successfully at 0330L.

Hole 817A was spudded at 0508L 3 September, at 18°9.946'S, 149°45.494'E. The PDR indicated a water depth of 1018.2 m from sea level. A used 11-7/16-in. Security four-cone insert bit was run with a seal bore drill collar, monel drill collar, and Hydrolex jars. The bit was positioned at a water depth of 1012.8 m from sea level and the first core was shot. Core 133-817A-1H recovered 5.75 m of sediment, placing the mud line at 1016.6 mbsl. Continuous APC cores (Cores 133-817A-1H through -23H) were taken from 0.0 to 214.7 mbsf, with 214.7 m cored and 222.4 m recovered (103.6% recovery). WSTP water samples and temperature measurements were taken at 1069.3, 1117.5, 1164.8, and 1212.3 mbsf. APC coring ended due to overpull in soft chalk.

Cores 133-817A-24X through -35X were taken from 214.7 to 330.7 mbsf, with 116.0 m cored and 58.04 m recovered (50.0% recovery). A WSTP run was made at 1260.3 mbsf. XCB coring ended due to a slow penetration rate (23-34 min/core) and low recovery. The BHA was pulled out of the hole to the seafloor at 0954L 4 September.

Hole 817B

The ship was offset 15 m northwest, and Hole 817B (18°9.487'S, 149°45.505'E) was spudded at 1036L on 4 September, to duplicate the upper part of the section at Hole 817A. The mud line was estimated at 1015.7 m water depth. Continuous APC cores (Cores 133-817B-1H through -22H) were taken from 0.0 to 204.0 mbsf, with 204.0 m cored and 210.7 m recovered (103.9% recovery). The BHA was pulled out of the hole, clearing the mud line at 2055L 4 September.

Hole 817C

Hole 817C was intended to provide sediment from the uppermost part of the section to be dedicated to interstitial-water sampling. The ship was offset 15 m northwest, and Hole 817C was spudded at 2215L 4 September, at 18°9.489'S, 149°45.534'E. The mud line was estimated to lie at 1016.7 m water depth. Continuous APC cores (Cores 133-817C-1H through -3H) were taken from 0.0 to 27.2 mbsf, with 27.2 m cored and 27.6 m recovered (100.2% recovery). The BHA was pulled out of the hole and was back on deck at 0230L on 4 September.

Hole 817D

The ship moved 15 m northwest, arriving on location for Hole 817D (18°9.499'S, 149°45.509'E) at 1035L on 4 September. A Hycalog four-cone insert bit was run with a mechanical bit release, outer core barrel, 11 drill collars, and Hydrolex jars. This RCB bottom-hole assembly was run to the seafloor at 1027.0 m water depth, and Hole 816B was spudded at 0505L 4 September. The 9-7/8-in. hole was washed down to 270.0 mbsf in 3.25 hr.

Continuous RCB cores (Cores 133-817D-1R through -47R) were taken from 270.0 to 700.0 mbsf, with 430.0 m cored and 22.2 m recovered (5.2% recovery). The RCB yielded only small fragments of the hard calcareous sediments in this interval, despite numerous attempts to improve recovery by using different coring parameters and techniques, core catchers, etc.

After a short trip to 105.8 mbsf with no drag or fill, the bit and MBR were released and the BHA was pulled to 105.8 mbsf for logging. Logs were run as follows:

1. The induction/density/sonic/caliper/gamma ray (DITE/HLDT/SDT/MCDG/NGT) logging tool was put into the hole at 0050L 7 September, failed, and was recovered at 0250L. After troubleshooting the tool and taking out the sonic cartridge, the log was rerun at 0315L. The tool found 13.2 m of fill at the bottom of the hole, and was out of the hole at 0605L 7 September.

2. The geochemical/aluminum clay/gamma ray (GST/ACT/CNTG/NGT/TCC) logging tool was put into the hole at 0800L 7 September. The tool was run to 14.1 m above the bottom of the hole, and was back out at 1410L.

3. The formation microscanner/gamma ray/temperature (FMS/NGT/TCC) logging tool was in the hole at 1500L 7 September. The tool was run to 14.3 m above the bottom of the hole, and was back out at 1835L.

4. A vertical seismic profile was attempted next. The tool was run in for check shots at 1930L 7 September, but was unable to detect the seismic signal and was out at 2145L.

The RCB BHA was run into the hole to 692.2 mbsf and encountered 7.8 m of fill at the bottom. The hole was displaced with heavy mud and the pipe was pulled, clearing the seafloor at 0110L 8 September. The MBR was back on deck at 0310, the beacon was retrieved, and the ship made ready to depart Site 817.

SITE 818 (NEA-9A)

Hole 818A

The sea voyage to Site 818 (proposed site NEA-9A) began at 0315L 8 September 1990 and covered 14 nmi with an average speed of 9.3 kt. A seismic survey was run over the site, covering 12 nmi in 2.2 hr, at 5.5 kt average speed. A Datasonics beacon was dropped at 0550L 8 September but the acoustic signal was lost while we were running into the hole with the APC/XCB BHA. A second beacon, a high-powered Benthos model, was run on the taut wire but also gave an erratic signal and was retrieved. We dropped a third beacon, also a high-powered Benthos model, which also gave an erratic signal, leading us to suspect that either strong bottom currents were present or that the beacon's power level was too high for the water depth. A fourth beacon, a low-powered Benthos model, was run on the taut wire. Although this beacon initially gave an erratic signal it eventually steadied and the ship was finally positioned after more than 4 hr of effort.

Hole 818A was spudded at 1046L 8 September at 18°3.767'S, 150°2.533'E. The PDR indicated a water depth of 752.1 m from sea level. The bit was positioned at a water depth of 748.7 m from sea level and the first core was shot. Core 133-818A-1H recovered 9.6 m of sediment, which indicated that the mud line had been overshot by at least 0.1 m.

Hole 818B

Hole 818B was spudded at 18°3.767'S, 150°2.533'E, at 1112L 8 September with the bit positioned at a water depth of 743.7 m from sea level for the first shot. Core 133-818B-1H recovered 8.59 m of sediment, placing the mud line at a water depth of 744.8 m from sea level.

Continuous APC cores (Cores 133-818B-1H through -32H) were taken from 0.0 to 302.9 mbsf, with 302.9 m cored and 314.6 m recovered (103.8% recovery). The BHA was pulled out of the hole and was back on deck at 0240L 9 September. The beacons were recovered and the ship made ready for transit to Site 819.

SITE 819 (NEA-3)

Hole 819A

The sea voyage to Site 819 (proposed site NEA-3) began at 0300L 9 September and covered 229 nmi in 18.9 hr at an average speed of 12.1 kt. A seismic survey was run over proposed sites NEA-1, -2, and -3, covering 19 nmi in 3.35 hr at an average speed of 5.7 kt. A Benthos beacon was run on the taut wire at 0124L 10 September. To avoid the beacon problems experienced at Site 818 a spare wireline spool stand was made to hold the beacon upright and to give added stability.

The hole was located at 16°37.439'S, 146°19.486'E. The PDR showed a water depth of 561.6 m from sea level for this location. However, the first shot attempted at Site 819 yielded a water core, indicating that the actual mud line occurs between the upper two of the three bottom reflectors visible on 3.5- and 12-kHz profiles. The bit was positioned at a water depth of 564.2 m from sea level and the hole was spudded at 0435 L 10 September 1990. A total of 8.55 m of sediment was recovered, placing the mud line at a water depth of 565.2 m from sea level. Continuous APC cores (Cores 133-819A-1H through -14H) were taken from 0.0 to 123.0 mbsf, with 123.0 m cored and 133.5 m recovered, for 108.6% recovery. The excessively high rate of recovery is a result of gas expansion of the sediment.

Operations were slowed after problems with the APC core barrel and liners that were apparently caused by the high sediment gas content. Headspace analysis indicated gas concentrations to be an average of 10,000 ppm C_1, 4 ppm C_2, and 4 ppm C_3. The C_1/C_2 ratio indicated no safety problem in that the hydrocarbons evidently were generated *in situ* and had not migrated into the sediment.

Cores 133-819A-15X through -44X (123.0-400.0 mbsf) were taken, with 277.0 m cored and 205.5 m recovered (74.3% recovery). The age of the sediments was consistently 1.5 Ma throughout this interval, leading us to consider the possibility that the hole had been deflected along a steeply dipping hard layer. Multishot orientation surveys were conducted at 50-m intervals while Core 133-819A-44X was retrieved. These demonstrated that the hole was essentially vertical, with a maximum angle of deviation of 3.2° at 380 mbsf. The GPS window for the next site did not permit time to make a conditioning trip for logging. Therefore, a 30-bbl mud sweep was circulated, a go-devil was dropped to open the lockable flapper valve, and the bit was pulled to 98.6 mbsf for logging.

The only logging tool string run at Site 819 was the induction/density/sonic/caliper/gamma-ray tool (DITE/HLDT/SDT/MCDG/NGT). The tool was put into the hole at 0205L 7 September, and found bottom 17 m above total depth. The tool was back on deck at 0440L 12 September.

The BHA was run in to 384.8 mbsf and the hole was filled with heavy mud according to JOIDES Safety Panel guidelines. The BHA was pulled out of the hole, clearing the seafloor at 0650L 12 September. The beacon was pulled up to a water depth of 244 m on the taut wire for the short transit to the next site. The ship was under way in dynamic positioning mode at 0718L 12 September, with optimal GPS positioning.

SITE 820 (NEA-2)

Hole 820A

The ship moved 1.5 nmi in 1.32 hr at an average speed of 1.1 kt in dynamic positioning (DP) mode. The taut wire beacon was set on bottom at 0900L 12 September 1990.

The position for Hole 820A is 16°38.221'S, 146°18.229'E; water depth was estimated by the PDR to be 280.6 m from sea level. The bit was positioned at a water depth of 275.7 m and the first core was shot at 0948L 12 September. Core 133-820A-1H recovered 7.18 m of sediment, placing the mud line at a water depth of 278.0 m from sea level. Continuous APC cores (Cores 133-820A-1H through -15H) were taken from 0.0 to 140.2 mbsf, with 140.2 m cored and 143.8 m recovered (102.5% recovery; excessive recovery is due to gas expansion of the sediments).

VPC Cores 133-820A-16V and -17V were taken from 140.2 to 144.2 mbsf, with 4.1 m cored and 2.03 m recovered (49.5% recovery). The BHA was pulled out of the hole, clearing the seafloor at 1800L 12 September.

Hole 820B

The ship moved 20 m west in DP mode, and Hole 820B was spudded at 16°38.219'S, 146°18.218'E at 1907L 12 September. Based on the drill-pipe measurement from Hole 820A, the mud line was estimated to occur at a water depth of 279.0 m from sea level. However, the first core retrieved from Hole 820B was a water core. The bit was positioned at 277.7 m water depth, and Core 133-820B-1H was shot, recovering 8.23 m of sediment. The mud line was determined indeed to occur at 279.0 m water depth. Continuous APC cores (Cores 133-820B-1H through -17H) were taken from 0.0 to 160.2 mbsf, with 160.2 m cored and 161.4 m recovered (100.7% recovery).

Cores 133-820B-18X through -44X were taken from 160.2 to 400 mbsf), with 239.8 m cored and 163.5 m recovered (68.2% recovery). After a short trip to 1044.4 mbsf and back to the bottom with no drag or fill, the bit was pulled to 104.4 mbsf for logging. Logs were run as follows:

1. The induction/density/sonic/caliper/gamma ray (DITE/HLDT/SDT/MCDG/NGT) logging tool was put into the hole at 0900L 14 September. The tool found bottom 10.0 m above the total depth of the hole, and was back out of the hole at 1030L 14 September.

2. The geochemical/aluminum clay tool/gamma ray/temperature (FMS/NGT/TCC) logging tool was put into the hole at 1205L, found bottom 35.6 m above total depth, and was back out of the hole at 1615L 14 September.

3. The formation microscanner/gamma ray/temperature (FMS/NGT/TCC) logging tool was put into the hole at 1910L and found 40.8 m of fill at the bottom of the hole.

4. A vertical seismic profile was attempted. The tool was run into the hole at 2035 for check shots, logged to 65.5 m off bottom, and was back out of the hole at 2315L 14 September.

SITE 821 (NEA-1)

Hole 821A

The ship moved 1.0 nmi from Site 820 to Site 821 (proposed site NEA-1) in 0.95 hr, in dynamic positioning mode at an average speed of 1.05 kt. The same Benthos low-power beacon used at Sites 819 and 820 was run on the taut wire at 0330L 15 September. The location for Site 821 is 16°38.793'S, 146°17.376'E; the PDR-indicated water depth at the site was 212.6 m from sea level. The bit was positioned at a water depth of 207.6 m from sea level, and the first core was shot at 0429L 15 September. Core 133-821A-1H recovered 4.39 m of sediment, and the mud line was estimated to occur at a water depth of 212.7 m from sea level. Continuous APC cores (Cores 133-821A-1H through -16H) were recovered from 0.0 to 145.9 mbsf, with 145.9 m cored and 149.4 m recovered (102.4% recovery). Core 133-821A-16H hit a layer of coarse-grained bioclastic material, which shattered the liner.

Cores 133-821B-17X through -43X were taken from 145.9 to 400.0 mbsf, with 254.1 m cored and 233.5 m recovered (91.88% recovery). As hole conditions appeared to be excellent, we decided to cancel a hole-conditioning trip in the interest of time. The go-devil was dropped and the bit was pulled to 85.3 mbsf for logging. Logs were run as follows:

1. The induction/density/sonic/caliper/gamma ray (DITE/HLDT/SDT/MCDG/NGT) logging tool was put into the hole at 1035L 16 September, and found 4.5 m of fill on the bottom of the hole. The tool was back out of the hole at 1241L.

2. Owing to the excellent condition of the hole, the formation microscanner/gamma ray/temperature (FMS/NGT/TCC) logging tool was run. The tool was put into the hole at 1330L 16 September and found 8.4 m of fill at the bottom of the hole; the tool was back out of the hole at 1500L.

Hole 821A was filled with heavy mud, and the bit was pulled clear of the seafloor at 1710L 16 September to start Hole 821B.

Hole 821B

The ship moved 25 m west to start Hole 821B at 16°38.794'S, 146°17.366'E. The mud line was estimated to occur at a water depth of 211.6 m from sea level. The bit was positioned at a water depth of 211.5 m from sea level to spud the first core at 1825L 16 September. Core 133-821B-1H recovered 9.83 m of sediment, indicating the mud line to occur at a water depth of 211.6 m from sea level. Continuous APC cores (Cores 1333-821B-1H through -14H) were taken from 0.0 to 140.0 mbsf, with 140 m cored and 144.8 m recovered (103.4%). The APC coring ended at the top of the coarse bioclastic interval, and the VPC was picked up to attempt better recovery from this interval.

Cores 133-821B-16V to -18V were taken from 140.0 to 146.6 mbsf, with 6.6 m cored and 6.6 m recovered (100.0% recovery, using the adavnce-by-recovery method). As predicted, material in the VPC cores from this interval appeared to be less distrubed than

XCB cores would have been. However, only Core 133-821B-17V actually recovered material. Therefore, the XCB was picked up in the hope of obtaining better recovery.

Cores 133-821B-19X through -20X were taken from 146.6 to 165.9 mbsf, with 19.3 m cored and 15.9 m recovered (88.0% recovery). Hole 821 B was filled with heavy mud, and the bit was pulled out of the hole, arriving on deck at 0619L 17 September.

SITE 822 (NEA-4)

Hole 822A

A departing seismic survey was conducted over Sites 819, 820, and 821 and continued during the 14-nmi transit to Site 822 (proposed site NEA-4). The survey covered a total of 31 nmi in 6.5 hr at an average speed of 4.8 kt. A Datasonics commandable recall beacon was dropped at 1324L 17 September, but the connection to its weights broke upon deployment. The beacon was retrieved, the weights were securely reattatched, and it was redeployed at 1344L.

Hole 822A was located at 16°25.379'S, 146°12.904'E; the PDR-predicted water depth was 952.3 m from sea level. The bit was lowered to a water depth of 946.6 m from sea level for the first shot. Hole 822A was spudded at 1647L 17 September. Core 133-822A-1H recovered 0.93 m of sediment, indicating that the mud line occurs at a water depth of 955.2 m from sea level. Continuous APC cores (Cores 133-822A-1H through -11H) were taken from 0.0 to 95.5 mbsf, with 95.5 m cored and 101.5 m recovered (106.3% recovery; excessive recovery rates are due to gas expansion of the sediment).

Cores 133-822A-12X through -43X were taken from 95.5 to 400.0 mbsf, with 304.5 m cored and 244.4 m recovered (80.3% recovery). Gas concentrations determined by headspace analysis averaged 50,000 ppm C_1, 3 ppm C_2, and no C_3. The C_1/C_2 ratio started a normal logarithimic decline (20,000 to 2,500) down to 260 mbsf, at which point C_2 and C_3 concentrations started increasing. The Claypool graph of thermal maturity was in the normal range; this indicates that the hydrocarbons were generated *in situ* and had not migrated into the sediment from deeper in the section, thus presenting no safety problems. Temperature data from the Leg 133 Pollution Prevention and Safety Panel (PPSP) review and the WSTP data from Hole 822A indicate a 5.5°C/100 m gradient.

A short trip was made to 103.6 mbsf and back to the bottom of the hole, with 15,000 lb drag. A bridge was tagged at 373.4 mbsf, and the hole was washed and reamed to the bottom at 400.0 mbsf. Approval from shore was obtained to continue coring for an additional 50 m after logging, to reach a seismic horizon thought to represent 2.4 Ma, which evidently lay deeper than the 400 mbsf penetration originally planned for this hole. The go-devil normally dropped to open the lockable flapper valve was not run, but rather a special go-devil adapted to run on the bottom of the logging tools was used on each logging string. The bit was pulled up to 103.2 mbsf for logging, encountering no drag.

Logs were run as follows:

1. The induction/density/sonic/caliper/gamma ray (DITE/HLDT/SDT/MCDG/NGT)

logging tool was put into the hole at 2310L 19 September, but the tool could only reach 333.3 mbsf (66.7 m above bottom). The tool was back out of the hole at 0130L 20 September.

2. The geochemical/aluminum clay tool/gamma ray (GST/ACT/CNTG/NGT/TCC) logging tool was placed in the hole at 0320L, but the tool only reached 324.8 mbsf (75.2 m above bottom). The tool was back out of the hole at 0715L.

3. The formation microscanner/gamma ray/temperature (FMS/NGT/TCC) logging tool was placed in the hole at 0820L, but the tool only reached 176.3 mbsf (223.7 m off bottom). The tool was back out of the hole at 0955L.

The bit was run back to the bottom to continue coring another 50 m, or until the 2.4 Ma horizon was reached. Cores 133-822A-43X through -47X were taken from 400.0 to 433.9 mbsf, with 33.9 m cored and 38.6 m recovered (113.9% recovery). The hole was displaced with heavy mud as a precaution.

SITE 823 (NEA-5)

Hole 823A

The sea voyage to Site 823 (proposed site NEA-5) began at 2200L 20 September, and covered 27 nmi in 2.7 hr at 10.0 kt average speed. A seismic survey was run over Site 823 covering 13 nmi in 2.3 hr at an average speed of 5.6 kt. A Datasonics beacon was dropped at 0350L September 21.

Hole 823A was located at 16°36.981'S, 146°47.037'E; the PDR-predicted water depth was 1637.2 m from sea level. The bit was lowered to a water depth of 1634.7 m from sea level for the first shot. Hole 823A was spudded at 0739L 21 September. Core 133-823A-1H recovered 5.82 m of sediment, indicating that the mud line occurs at a water depth of 1649.7 m from sea level. Continuous APC cores (Cores 133-823A-1H through -11H) were taken from 0.0 to 119.8 mbsf, with 119.8 m cored and 123.73 m recovered (103.3% recovery; high recovery rates are due to gas expansion). APC coring ended when the overpull reached 120,000 lb. The hole was displaced with heavy mud as a precaution because methane concentrations reached 100,000 ppm.

Hole 823B

Hole 823B was located at 16°36.982'S, 146°47.053'E. The bit was lowered to a water depth of 1636.7 m from sea level for the first shot. Hole 823B was spudded at 1618L 21 September. Core 133-823B-1H recovered 8.28 m of sediment, indicating that the mud line occurs at a water depth of 1637.9 m from sea level. Continuous APC cores (Cores 133-823B-1H through -12H were taken from 0.0 to 112.8 mbsf, with 112.8 m cored and 117.6 m recovered (104.3% recovery; high recovery rates are due to gas expansion). WSTP water samples and temperature measurements were taken at 55.8 and 103.3 mbsf, but only seawater was recovered in the samples.

Cores 133-823B-13X through -84X were taken from 112.8 to 805.4 mbsf, with 692.6

m cored and 637.1 m recovered (92.0% recovery). XCB coring was terminated when recovery decreased to as little as 1.2 m per 9.5-m cored interval. Poor recovery in the last four cores was a result of jamming; rotating time increased to 100 min/core, and some of the cores were burned by the resulting friction. The hole was displaced with heavy mud as a precaution because methane reached 50,000 ppm, ethane was 14 ppm, and propane was 10 ppm. The C_1/C_2 ratio was subnormal, indicating no hydrocarbon migration at the 57°C/km geothermal gradient. Sporadic C_4 and C_5 levels as high as 12 ppm were detected from 718-776 mbsf.

Hole 823C

A used 9-7/8-in. RBI C-7 four-cone insert bit and MBR were run with an RCB outer core barrel, nine 8-1/4-in. drill collars, and Hydrolex jars with two drill collars above. Hole 823C was spudded at 0405L 26 September at 16°36.983'S, 146°47.066'E. The hole was washed down with a wash barrel in place from 0.0 to 573.0 mbsf, and the wash barrel material was discarded. The wash barrel was removed and a center bit was used to drill from 573.0 to 784.0 mbsf.

Cores 133-823C-1R to -24R were taken from 784.0 to 1011.0 mbsf, with 227.0 m cored and 186.1 m recovered (82.0% recovery). A short trip was made up to 108.0 mbsf and back, encountering 20,000 lb drag and 15 m of fill at the bottom of the hole. The RCB bit was released with the MBR, and the sleeve shifted. The open BHA was pulled with no drag to 107.7 mbsf for logging. Logs were run as follows:

1. The induction/density/sonic/caliper/gamma ray (DITE/HLDT/SDT/MCDG/NGT) logging tool was put into the hole at 2235L 28 September, but the tool could not go deeper than 344.7 mbsf. The hole was logged up to 88 mbsf. The new conical side-entry sub (CSES) was rigged up in 3-1/2 hr, and the logging tool was installed in the CSES. The drill pipe was run to 779.4 mbsf - the top of the hard formation - with occasional 20,000-lb drag. The logging tool encountered 28.4 m of fill at the bottom of the hole, and the drill pipe was pulled out of the hole while logging proceeded, with occasional drag to 20,000 lb. The logs indicated that occasional tight sections in the hole were closing back to 7 in. diameter as soon as the 8-1/4-in. drill string passed through. The tool was back out of the hole at 1240L 29 September.

2. The geochemical/aluminum clay tool/gamma ray (GST/ACT/CNTG/NGT/TCC) logging tool was installed in the CSES at 1432L, and the drill string was run to 779.4 mbsf, with occasional drag to 20,000 lb. The tool reached 34.3 m off bottom, and was back out of the hole at 0050L 30 September.

3. The formation microscanner/gamma ray/temperature (FMS/NGT/TCC) logging tool was placed in the CSES at 0340L 30 September. The pipe was run in the hole to 943.3 mbsf, with 20,000 lb occasional drag. The logging tool found bottom 55.8 m above the total depth of the hole. The drill pipe was pulled out of the hole while logging proceeded, with occasional drag of up to 20,000 lb. The logs indicated that the tight sections in the hole were closing back to 4-1/2-in. diameter as soon as the 8-1/4-in. drill string passed

through. The top of the CSES was pulled out to the moonpool. The logging tool was out of the hole at 1200L 30 September.

The first use of the new CSES was an operational success in all respects. The CSES should permit logging in troublesome holes, but will increase the risk to the BHA and logging tools. Some minor operational problems were encountered, such as having to remove the flapper valve because logging tools hung up in it when being removed from the CSES, damaging logging tool heads. The drill pipe was run in the hole, and the hole was displaced with heavy mud per PPSP guidelines as a precaution, because C_1 reached 70,000 ppm, C_2 was 35 ppm, and sporadic C_3-C_5 to 12 ppm was detected below 976 mbsf. The C_1/C_2 ratio was subnormal, indicating no hydrocarbon migration at the 57°C/km geothermal gradient.

SITE 824 (NEA-6)

Hole 824A

The sea voyage to Site 824 (proposed site NEA-6) began at 2342L 30 September, and covered 50 nmi in 5.2 hr at 9.6 kt average speed. A seismic survey was run over Site 824 covering 10 nmi in 2.1 hr at an average speed of 4.8 kt. A Datasonics beacon was dropped at 0806L 1 October 1990.

Hole 824A was located at 16°26.704'S, 147°45.737'E; the PDR-predicted water depth was 997.9 m from sea level. A used 11-7/16-in. Security four-cone insert bit was run with the standard APC/XCB bottom-hole assembly (BHA), nonmagnetic drill collar, four 8-1/4-in. drill collars, and Hydrolex jars with two drill collars above. The bit was lowered to a water depth of 995.5 m from sea level for the first shot. Hole 824A was spudded at 1123L 1 October. The first core recovered 4.6 m of sediment, indicating that the mud line occurs at a water depth of 1000.4 m from sea level. As core liners were in short supply, the decision was made to attempt to reach the deeper objectives at this site first; then, as the liner supply allowed, the shallow part of the section would be cored. Therefore, the first core liner was washed clean of sediment for later reuse. The hole was drilled from 0.0 to 35.0 mbsf. A partial core was taken from 35.0 to 40.0 mbsf but recovered no sediment. The hole was drilled to 50.0 mbsf, and continuous APC cores Cores 133-824A-1H through -10H were taken from 50.0 to 137.9 mbsf, with 87.9 m cored and 85.9 m recovered (97.7% recovery). APC coring ended when a hard layer was reached, resulting in a partial stroke and a split liner.

Cores 133-824A-11X through -13X were taken from 137.9 to 165.7 mbsf, with 27.8 m cored and 0.1 m recovered (0.4% recovery). Below this level sediment was soft, and the decision was made to return to APC coring.

Cores 133-824A-14H and -15H were taken from 165.7 to 184.7 mbsf, with 19.0 m cored and 18.4 m recovered (96.7% recovery). Core 133-824A-15H was a partial stroke, indicating an encounter with additional hard material.

Cores 133-824A-16X through -36X were taken from 194.0 to 377.3 mbsf, with 192.6

m cored and 24.3 m recovered (12.6% recovery). The pipe became stuck with the bit on the bottom after coring Core 133-824A-36X. This core had been cut with a low circulation rate in an attempt to improve extremely poor recovery in the unconsolidated, coarse-grained carbonates.

A 40-bbl gel sweep was circulated at 400 gpm and 2300 psi, and the pipe was worked to 170,000 lb overpull (450,000 indicator weight). The Hydrolex jars were engaged, and jarring was alternated with circulating mud sweeps while working the pipe. The jars hit 38 blows up with 100,000-150,000 lb, and 18 blows down with 40,000 lb. A total of 200 bbl of mud was circulated at as much as 400-600 gpm and 2300-2895 psi, with 170,000-460,000 lb overpull (740,000 lb indicator weight). The maximum allowable indicator overpull was 774,000 lb. The drill string moved 10 m in 4 hr, but showed no further response. We think that the low circulation rate initially contributed to packing off the annulus, permitting cobbles of hard sediment to settle and stick around the BHA. This was the fourth severe stuck pipe incident this leg, all having occurred in unconsolidated coarse-grained carbonates. Although the jars were still working and marginal progress had been made in working the pipe off the bottom, a decision was made to back off the drill string to conserve time.

A "stringshot" explosive charge was run to the bottom of the nonmagnetic drill collar, but failed to back off the drill string. A second charge was run to the drill collar below the jars and succeeded in backing off the drill collar so the remainder of the drill string could be recovered.

Hole 824B

The ship moved 25 m west, and an APC/ACB BHA was run. Hole 824B was located at 16°26.703'S, 146°45.720'E. The bit was lowered to a water depth of 997.4 m from sea level for the first shot. Hole 824B was spudded at 1815L 3 October. Core 133-824B-1H recovered 4.6 m of sediment, indicating that the mud line occurs at a water depth of 1000.4 m from sea level. Continuous APC cores (Cores 133-824B-1H through -6H) were taken from 0.0 to 52.5 mbsf, with 52.5 m cored and 53.2 m recovered (101.3% recovery). The bit cleared the seafloor at 1145L 3 October and the rotary table at 1330L.

Hole 824C

The ship was moved 50 m east, and an RCB BHA was run to 978.3 m below sea level. Hole 824C was spudded at 0927 3 October, at 16°26.705'S, 146°45.753'E. The mud line was estimated at 1000.3 m below sea level. A 9-7/8-in. hole was washed from 0.0 to 247.6 mbsf, and Cores 133-824C-1R to -19R were taken from 247.6 to 430.8 mbsf, with 183.2 m cored and 3.21 m recovered (1.75% recovery). Metamorphic basement rocks were penetrated at 406.7 mbsf. The bit cleared the seafloor at 2133L 3 October.

Hole 824D

The ship was moved 25 m south, and an RCB BHA was run to 987.6 mbsf. Hole

824D was spudded at 2233L 4 October at 16°26.690'S, 146°45.753'E. The mud line was estimated at 1001.9 m from sea level. A 9-7/8-in. hole was washed from 0.0 to 334.5 mbsf. Cores 133-824D-1R to -10R were taken from 3344.5 to 431.0 mbsf, with 96.5 m cored and 1.06 m recovered (1.1% recovery). Basement was penetrated at ~405.4 mbsf. A two-stand short trip to 380.1 mbsf and back down encountered no drag and only 3.0 m of fill at the bottom of the hole. The bit was released with the mechanical bit release and the pipe was pulled to 90.1 mbsf for logging:

1. The induction/sonic/caliper/gamma ray (DITE/SDT/NGT/MCDG) logging tool was put into the hole at 2233L 5 October and found bottom 19.5 m above the total depth of the hole.

The MBR cleared the seafloor at 0225L 6 October, and cleared the rotary table at 0425L. The beacon was recalled and recovered.

SITE 825 (NEA-8)

Hole 825A

The decision was made to return to Site 811 (proposed site NEA-8) to re-attempt penetration of the basement rock and overlying sediments. As the time expired since the previous operations at the site was more than a few weeks, a new beacon would be required and the site would be given a new number, Site 825.

The sea voyage to Site 825 (NEA-8) began at 0430L 6 October, and covered 33 nmi in 3.0 hr at 11.0 kt average speed. No seismic survey was run. A Datasonics beacon was dropped at 0808L 6 October 1990.

Hole 825A was located at 16°30.961'S, 148°9.457'E; the PDR-predicted water depth was 939.8 m from sea level. The bit was lowered to a water depth of 934.4 m from sea level for the first shot. Hole 825A was spudded at 1050L 6 October. The mud line was placed at a water depth of 939.4 m from sea level. A 9-7/8-in. hole was washed from 4.5 to 200.0 mbsf, with WSTP samples taken at 50.0, 100.0, and 150.0 mbsf. APC coring continued, with Cores 133-825A-5H through -8H taken from 200.5 to 238.0 mbsf, with 38.0 m cored and 38.3 m recovered.

Cores 133-825A-9X through -14X were taken from 238.0 to 295.7 mbsf, with 57.7 m cored and 10.87 m recovered (18.8% recovery). Overpull was 20,000-40,000 lb on the connections, and 20-bbl mud sweeps were necessary on each core due to sloughing sediment. After landing Core 133-825A-15X, the pipe stuck at 295.7 mbsf. The pipe was pulled with up to 190,000 lb overpull, the Hydrolex jars hit one blow, and the pipe came free. A 40-bbl mud sweep was circulated before and after reaming to the bottom.

Despite the bad hole conditions, we decided to continue operations. Cores 133-825A-15X through -23X were taken from 295.7 to 381.5 mbsf, with 85.8 m cored and 0.26 m recovered (0.3% recovery). Poor recovery in the flowing silt made continued coring inadvisable. The bit cleared the rotary table at 1115L 7 October.

Hole 825B

The ship moved 25 m west, and an RCB BHA with an MBR was run to 933.5 m water depth. Hole 825B was located at 16°30.961'S, 148°9.457'E. The mud line was estimated at 951.0 m water depth. A 9-7/8-in. hole was washed from 0.0 to 379.5 mbsf, with 0.31 m recovery.

Cores 133-825B-2R through -10R were taken from 379.5 to 466.3 mbsf, with 86.8 m cored and 3.0 m recovered (3.46% recovery). The hole was sloughing in, causing a drag of 20,000-40,000 lb with 3-6 m of fill on connections. A 20-bbl mud sweep was required on each core to avoid getting stuck. Hard basement was penetrated at approximately 453.0 mbsf. The bit was released with the MBR at 465 mbsf. The hole was not conditioned with a short trip, in order to save time, and the MBR sleeve was not shifted. The pipe was pulled to 96.3 mbsf for logging:

1. The induction/sonic/gamma ray/caliper (DITE/SDT/NGT/MCDG) logging tool was put into the hole at 1207L 8 October and found bottom 18.2 m of fill above total depth. The tool was out of the hole at 0355L.

The MBR cleared the seafloor at 1450L 8 October, and cleared the rotary table at 1857L. The beacon was recalled and recovered at 1880L.

The original Leg 133 port call plans called for the cruise to end in Townsville. Fuel was discovered to be unavailable in Townsville, so an alternate plan was developed to depart Hole 825B by 2300L 8 October so that the ship could be fueled in Cairns before finishing the transit to Townsville. However, fuel was also unavailable in Cairns, so plans were made to fuel the ship in Gladstone at the start of Leg 134.

SITE 826 (NEA-13)

Hole 826A

The decision was made to return to Site 816 (proposed site NEA-13) to re-attempt penetration of the Miocene shallow-water carbonates. As at Site 825, the time expired since the previous operations at the site was more than a few weeks, so a new beacon was required and the site was given a new number, Site 826.

The sea voyage to Site 826 began at 1918L 8 October, and covered 187 nmi in 16.2 hr at 11.5 kt average speed. No seismic survey was run. A Datasonics beacon was dropped at 1306L 9 October 1990.

Hole 826A (19°13.530'S, 150°0.597'E; the PDR-predicted water depth was 424.2 m from sea level. Hole 826A was spudded at 1448L 9 October. The RCB BHA was used to punch-core the mud line, and the 5.0-m core gave a mud-line depth of 425.3 m from sea level. A 9-7/8-in. hole was washed from 0.0 to 98.5 mbsf, with 0.31 m recovery (Core 133-826A-1W). Cores 133-826A-2R through -18R were taken from 98.5 to 250.0 mbsf, with 156.5 m cored and 2.07 m recovered (4.52% recovery). Recovery was very poor in flowing silts and porous soft reefal limestone. The bit cleared the rotary table at 0354L, ending Hole 826A. The beacon was recalled and on deck in 15 minutes, ending Site 826.

TRANSIT TO TOWNSVILLE

The sea voyage to Townsville began at 0430L October 10, and covered 197 nmi in 19.7 hr, at 10.1 kt average speed. The first line was ashore at 0600L October 11, 1990, ending Leg 133.

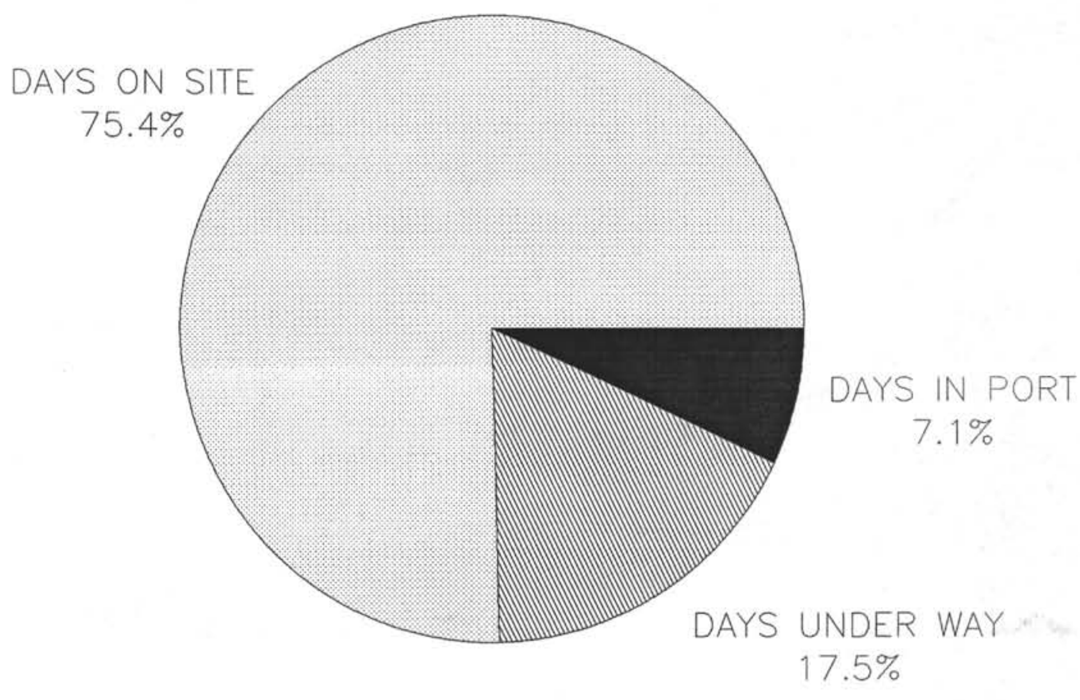
OCEAN DRILLING PROGRAM
OPERATIONS RESUME
LEG 133

Total Days (8/4/90-10/11/90)	67.5
Total Days in Port	4.8
Total Days Under Way	11.8
Total Days on Site	50.9

Trip Time	6.5
Coring Time	27.0
Drilling Time	2.5
Logging/Downhole Science Time	10.7
Repair Time (Contractor)	0.4
Repair Time (ODP)	0.2
Downhole Trouble Time	0.7
Survey Time	1.0
Development Engineering Time	0.7
Other	1.2

Total Distance Traveled (nautical miles)	3242
Average Speed (knots)	10.8
Number of Sites	16
Number of Holes	36
Number of Reentries	0
Total Interval Cored (m)	7972.9
Total Core Recovery (m)	5504.9
Percent Core Recovered	69.0
Total Interval Drilled (m)	2925.0
Total Penetration (m)	10897.8
Maximum Penetration (m)	1011.0
Maximum Water Depth (m from drilling datum)	1649.7
Minimum Water Depth (m from drilling datum)	437.0

LEG 133
TOTAL TIME DISTRIBUTION



TOTAL DAYS OF LEG 67.5

OCEAN DRILLING PROGRAM
SITE SUMMARY REPORT
LEG 133

HOLE	LATITUDE	LONGITUDE	SEA FLOOR DEPTH (M)	NUMBER OF CORES	INTERVAL CORED (M)	RECOVERED CORE (M)	PERCENT RECOVERED	INTERVAL DRILLED (M)	TOTAL PENETRATION (M)	TIME (HRS)
811A	16-30.98S	148-09.44E	1162.9	23	214.6	213.2	99.3	.0	214.6	21.72
811B	16-30.95S	148-09.45E	1340.5	24	199.3	15.5	7.8	193.2	392.5	46.77
811C	16-30.94S	148-09.51E	1003.0	6	55.2	55.3	100.2	.0	55.2	10.58
	SITE TOTALS:			53	469.1	284.0	60.5	193.2	662.3	79.07
812A	17-48.84S	149-36.31E	662.5	22	189.9	40.7	21.4	.0	189.9	22.00
812B	17-48.84S	149-36.31E	772.6	18	149.2	8.5	5.7	150.8	300.0	25.92
812C	17-48.84S	149-36.33E	610.9	16	137.8	114.1	82.8	.0	137.8	12.25
	SITE TOTALS:			56	476.9	163.3	34.2	150.8	627.7	60.17
813A	17-49.96S	149-29.67E	781.7	26	231.6	199.4	86.1	.0	231.6	17.17
813B	17-49.95S	149-29.67E	740.0	21	190.0	196.1	103.2	.0	190.0	13.58
	SITE TOTALS:			47	421.6	395.5	93.8	.0	421.6	30.75
814A	17-49.99S	149-30.83E	831.4	33	300.0	162.4	54.1	.0	300.0	29.25
	SITE TOTALS:			33	300.0	162.4	54.1	.0	300.0	29.25

OCEAN DRILLING PROGRAM
SITE SUMMARY REPORT
LEG 133

HOLE	LATITUDE	LONGITUDE	SEA FLOOR DEPTH (M)	NUMBER OF CORES	INTERVAL CORED (M)	RECOVERED CORE (M)	PERCENT RECOVERED	INTERVAL DRILLED (M)	TOTAL PENETRATION (M)	TIME (HRS)
815A	19-09.03S	149-59.51E	950.2	51	473.5	416.2	87.9	.0	473.5	73.00
815B	19-09.03S	149-59.52E	513.5	4	36.4	37.8	103.8	.0	36.4	5.25
	SITE TOTALS:			55	509.9	454.0	89.0	.0	509.9	78.25
816A	19-11.92S	150-00.61E	560.5	15	111.5	97.5	87.4	.0	111.5	12.45
816B	19-11.91S	150-00.60E	620.0	15	85.0	10.5	12.4	86.0	171.0	13.83
816C	19-11.91S	150-00.61E	699.0	13	109.6	11.3	10.3	140.4	250.0	33.50
	SITE TOTALS:			43	306.1	119.3	39.0	226.4	532.5	59.78
817A	18-09.50S	149-45.49E	1358.5	35	330.7	280.4	84.8	.0	330.7	31.18
817B	18-09.49S	149-45.51E	1231.0	22	204.0	211.1	103.5	.0	204.0	11.02
817C	18-09.49S	149-45.53E	1054.5	3	27.2	27.3	100.4	27.3	54.5	5.58
817D	18-09.50S	149-45.51E	1727.0	47	430.0	22.2	5.2	270.0	700.0	72.67
	SITE TOTALS:			107	991.9	541.0	54.5	297.3	1289.2	120.45
818A	18-03.77S	150-02.53E	769.5	1	9.5	9.6	101.1	.0	9.5	4.93

OCEAN DRILLING PROGRAM
SITE SUMMARY REPORT
LEG 133

HOLE	LATITUDE	LONGITUDE	SEA FLOOR DEPTH (M)	NUMBER OF CORES	INTERVAL CORED (M)	RECOVERED CORE (M)	PERCENT RECOVERED	INTERVAL DRILLED (M)	TOTAL PENETRATION (M)	TIME (HRS)
818B	18-03.77S	150-02.53E	1059.0	32	302.9	314.6	103.9	.0	302.9	15.90
	SITE TOTALS:			33	312.4	324.2	103.8	.0	312.4	20.83
819A	16-37.44S	146-19.49E	976.5	44	400.0	339.5	84.9	.0	400.0	53.43
	SITE TOTALS:			44	400.0	339.5	84.9	.0	400.0	53.43
820A	16-38.22S	146-18.23E	448.5	17	144.2	145.8	101.1	.0	144.2	9.00
820B	16-38.22S	146-18.22E	690.3	44	400.0	324.9	81.2	.0	400.0	55.67
	SITE TOTALS:			61	544.2	470.7	86.5	.0	544.2	64.67
821A	16-38.79S	146-17.38E	624.1	43	400.0	382.9	95.7	.0	400.0	37.67
821B	16-38.79S	146-17.37E	388.9	20	165.9	167.4	100.9	.0	165.9	13.00
	SITE TOTALS:			63	565.9	550.3	97.2	.0	565.9	50.67
822A	16-25.38S	149-12.90E	1400.5	47	433.9	384.6	88.6	.0	433.9	80.35
	SITE TOTALS:			47	433.9	384.6	88.6	.0	433.9	80.35

OCEAN DRILLING PROGRAM
SITE SUMMARY REPORT
LEG 133

HOLE	LATITUDE	LONGITUDE	SEA FLOOR DEPTH (M)	NUMBER OF CORES	INTERVAL CORED (M)	RECOVERED CORE (M)	PERCENT RECOVERED	INTERVAL DRILLED (M)	TOTAL PENETRATION (M)	TIME (HRS)
823A	16-36.98S	146-47.04E	1769.5	13	119.8	123.7	103.3	.0	119.8	11.37
823B	16-36.98S	146-47.05E	2454.6	84	805.4	754.8	93.7	.0	805.4	105.22
823C	16-36.98S	146-47.07E	2660.2	24	227.0	186.0	81.9	784.0	1011.0	118.83
	SITE TOTALS:			121	1152.2	1064.5	92.4	784.0	1936.2	235.42
824A	16-26.70S	147-45.74E	1389.2	36	327.3	129.7	39.6	50.0	377.3	46.07
824B	16-26.70S	147-45.72E	1066.0	6	52.5	53.2	101.3	.0	52.5	7.33
824C	16-26.71S	147-45.75E	1444.3	19	183.2	3.2	1.7	247.6	430.8	32.05
824D	16-26.69S	147-45.75E	1444.5	10	96.5	1.1	1.1	334.5	431.0	30.87
	SITE TOTALS:			71	659.5	187.2	28.4	632.1	1291.6	116.32
825A	16-30.95S	148-09.46E	1332.5	23	186.0	54.4	29.2	195.5	381.5	27.12
825B	16-30.96S	148-09.46E	1417.3	10	86.8	3.0	3.5	379.5	466.3	31.70
	SITE TOTALS:			33	272.8	57.4	21.0	575.0	847.8	58.82
826A	19-13.53S	150-00.60E	687.0	18	156.5	7.1	4.5	93.5	250.0	15.53
	SITE TOTALS:			18	156.5	7.1	4.5	93.5	250.0	15.53
	LEG TOTALS:			885	7972.9	5505.0	69.0	2952.3	10925.2	1153.76

TECHNICAL REPORT

The ODP Technical and Logistics personnel aboard *JOIDES Resolution* for Leg 133 of the Ocean Drilling Program were:

Laboratory Officer:	Burney Hamlin
Assistant Laboratory Officer:	Joe Powers
Yeoperson:	Jo Claesgens
Curatorial Representative:	Gretchen Hampt
Computer System Manager:	Edwin Garrett
Electronics Technicians:	Roger Ball Jim Briggs Eric Meissner
Photographer:	John Tenison
Chemistry Technicians:	Scott Chaffey Joe Demorett
X-ray Technician:	Joan Perry
Marine Technicians:	Daniel Bontempo Chester Jones Kuro Kuroki Mike Moore Frank Peerdeman Ahmet Tandircioglu

PORT CALL

The technicians flew into Guam after a scheduled overnight break in Hawaii as connecting flights did not permit continuation. A second night was spent in Guam. The following morning a provided bus transported the technical staff and some scientists to the Navy pier, a half hour drive West of Apra. *JOIDES Resolution* had arrived at the Navy pier the prior evening.

After a successful crossover Sunday, 5 August 1990, freight and core movement began. The small number of cores boxes was loaded into a container that was picked up in the evening.

ODP arranged for the U.S. military to transport a 250-liter dewar of liquid helium to refill the cryogenic magnetometer. There were no commercial air flights to Guam that would accept a liquid helium shipment. U.S. Navy personnel delivered the dewar to the ship where it was picked up by the ship crane and lowered into the casing hold. Technicians rolled it into the elevator and brought it back to the core lab level. Some magnetics equipment and the sampling table core rack were moved to allow the dewar to be rolled into the magnetics lab. Apprehension remained from the last refill attempt, which had been hampered by ice blockage in the fill line. Apparently the ice had moved or dissipated and the helium fill went very smoothly, with ~100 liters of liquid helium transferred.

The following day technicians and engineers loaded the Diamond Coring System onto nine flats and three 40-foot containers. It was dangerously hot work for those not accustomed to the tropical heat, and the daily afternoon deluge of rain did not help. Technicians built boxes, lids, cribbing, and bracing on the dock with the lumber and plywood shipped to Guam. After the equipment was loaded, blocked, and braced on the trailers, the arduous task of hand-operating the banding tools for 2-in. strapping remained. It was very awkward working from the ground or on top of the load with these tools instead of working from a loading dock.

Many individual pieces of equipment being shipped had been entered in our shipping program to initiate the shipping data file. Only after the containers and flats were loaded could the shipping papers be completed and given to the customs and shipping agents.

This port call's pacing job was the inspection of drill pipe. Baker Hughes Vetco personnel started working, but the job was cancelled due to a combination of equipment failure, illness, and rain. The U.S. Coast Guard and the A.B.S. concluded their ongoing inspection of the ship and the labs by signing off deficiencies noted at earlier Guam port calls. We were ready to sail.

UNDER WAY

Navigation tapes were started and *Joides Resolution* sailed a day early at 1400 hr on 9 August. The week-long transit to the first site was uneventful. Technicians distributed the last of the shipment, cleaned labs, conducted computer classes for shipboard scientists, and began familiarizing the scientists with lab equipment and procedures.

In Guam we received several hundred pounds of Australian seismic records and accompanying navigation records, to support the site selections for the leg. Our seismic system was rigged in the same configuration as was used to collect the Australian records. They had optimized their gear for 1/4 wave reinforcement at 120 Hz for better resolution in shallow water. This meant that we would need to operate our water guns and hydrophone arrays at shallower water depths than usual. As we have little control of gun depth, the water guns were suspended under Norwegian buoys at 3 m below sea level. The hydrophone array was stripped of weight at the eel head and filled with oil. The digital seismic acquisition software limits the gun firing rate to a nine second minimum. A four second firing rate would have been preferred. Site surveys were made at between 5 and 6 kt and our results were very satisfactory. With 90% Global Positioning System (GPS) coverage in this area, feature after feature was identified. Surveys over multiple sites confirmed previous selections, allowing the seismic gear to be retrieved and the ship returned to GPS coordinates where positioning beacons were launched.

The LDGO Borehole Research Group (BRG) uses a MASSCOMP computer to process logging records. A power supply failed in their computer and, because of the importance of this leg's logging program, we loaned them the power supply from our second seismic MASSCOMP computer. This resulted in running our NAVLOG program (records GPS positions) in the background while running HIRES. A computer crash at the conclusion of a survey resulted in the loss of 3-1/2 hours of navigation when the background file did not close correctly. The problem will be investigated at ODP after the leg.

Two large 30-ft-long signs were made and hung from ship's high rails to identified *JOIDES Resolution* as a RESEARCH VESSEL, a Nature Park prerequisite for drilling in the preserve. This was also to inform any curious boats passing our way of our intent. Boat traffic off Townsville and Cairns proved light and did not present a problem.

Drilling in a nature preserve posed ship waste disposal problems that were addressed thoroughly by the ship's officers and technical staff. Garbage was separated at points of origin into paper disposal bags. Flammables were carried to the burn basket daily; metals, cans and glass went to storage crates on the helideck for storage until they could be disposed of properly in Townsville at the end of the leg. No trash was thrown overboard and care was taken to collect all oil waste and prevent leaks.

An Australian film crew visited the ship by helicopter to take footage for a television science series. Trash crates, logging tools and stored items were cleared from the helideck for this visit.

DRILLING OPERATIONS SUPPORT

The core orientation equipment was used on one or more of the APC holes drilled at each site. The oriented cores allowed the paleomagnetists to determine land mass movement in the region.

The electronics technicians deployed the Barnes water-sampler/temperature/pressure (WSTP) tools 25 times in five holes. Heat-flow profiles for the area were developed and interstitial water was collected.

A request from shore prompted the staff to use the TOTCO recorder system during XCB drilling. System repairs and systems analysis left little time available for recording meaningful data. Key transducers were evaluated and the results will be reviewed ashore.

SHIPBOARD LABORATORIES

Curation

The record core recovery was reflected in the number of samples taken, over 35,000. The record number of samples was possible because several sedimentologists took 6-hour sampling shifts. This dedicated and diligent effort retained the same sampling standards as other legs and relieved the Gulf Coast Repository of much of the post-cruise sampling. Staging the samples for shipment was an interesting exercise as the advancing mountain of core boxes continued to displace each staging area.

D-tubes were scarce and some core sections were packaged in polyethylene tubing or shrink wrap. Most of these core sections remained on the ship, and will be repackaged during Leg 134. Priority sections were identified and included with the rest of the returning core shipment.

Frozen organic samples collected during the leg are scheduled to be shipped to ODP from Suva, Fiji after Leg 134.

Core Lab

An additional core rack was set up early in the leg with the onset of the cores from first shallow APC sites and was used continually till the RCB drilling at the last sites. Several sites produced gassy and slowly expanding cores that forced the caps off the cut sections. To alleviate the problem, the technicians drilled holes in the full liner to relieve pressure and then left the liner intact on the catwalk to allow the sediment to equilibrate for a couple hours. The core liner was then cut and capped, resulting in more core liner caps remaining in place.

The physical properties scientists and equipment worked around the clock, driven by the record recovery. Problems with the MultiSensor Track slowed core flow occasionally. The drive mechanism tended to slip when transporting heavy cores until the problem was rectified. The interpretation of susceptibility values and conversion from Pro350s to IBM-PCs caused minor delays. Thermal conductivity measurements were made at five sites to support temperature profiles generated with the WSTP downhole tool. The heavy use of the labor intensive Penta-Pycnometer, measuring index properties, underscored the need for a second automated unit on high recovery legs. The Hamilton frame velocimeter and shear vane instruments were used with few problems; resistivity equipment received limited use.

Core flow through the magnetics lab was slow even though the instrument operated normally. Magnetics signatures were weak at most sites so correlation with data from the developing paleostratigraphy helped define the trends and reversals measured. A correlation between high sea level indicators and low magnetic susceptibility in the upper sediments was studied. The Kevlar drive chain on the cryogenic magnetometer failed more often than usual and a slipping drive gear was a nuisance until it was repaired. A minor software discrepancy was noted between results from the spinner magnetometer and the cryogenic magnetometer. This problem will be demonstrated to the ODP Staff Scientist responsible for the lab, who is joining the ship for Leg 134, and will be resolved in port or during the following leg.

Some working halves of the double APC holes were used to evaluate a resistivity device that used a template and a circuit board covered with 64 1/4-in. pins. These pins penetrated the sediment surface and the data recorded were used to generate color images of the core.

Chemistry Lab

The chemistry technicians supported an aggressive interstitial water program that followed the solution and precipitation of the carbonate minerals present. This program kept the core presses for squeezing interstitial water presses in constant use. Ion analysis instruments--an Atomic Absorption, Dionex ion analyzer and titration equipment--were busy round the clock. Cores from one hole with only three APC cores were cut into 10-cm samples that the chemists squeezed within 24 hr to investigate ion variations at high resolution. Alkalinity was measured immediately, and chloride as time permitted. Further analysis of these samples was deferred to shore-based laboratories. Total carbonate values were determined using the CNS analyzer, and inorganic carbon using the Coulometrics instrument. The difference in the two values was very small, indicating little organic carbon. Because of this, the Rock-Eval, which determines organic carbon maturity, was not used. Very low hydrocarbon gas concentrations were measured at a few sites; the samples taken contained mostly biogenic methane and carbon dioxide. Few heavier gasses were detected.

X-Ray Lab

After replacing a defective circuit board with a replacement hand carried to port, the X-ray fluorescence unit functioned normally. A goniometer cable was air-freighted directly from Switzerland but was lost en route and was never received. This limited the instrument to one goniometer, but the limitation did not interfere with fulfilling the scientific objectives of the leg. A service call is scheduled for the Townsville port call for further repairs and tuning.

The X-ray diffraction unit was used to analyze 584 samples, primarily to distinguish the clays and carbonate minerals. The few problems noted were corrected promptly.

Thin Section Lab

Approximately forty thin sections were made from limestones, sands, and sediment samples. Surface impregnation of the material was sufficient for most of the individually made slides. Making thin sections was deferred to periods of poor recovery or logging, in order to maintain full-time technical support for the higher-priority core lab APC operations.

Computer Services

New versions of software, including WordPerfect 5.1 on the IBM-PC-clones, were added to the various systems in service. The VAX cluster preformed well with few problems noticeable to the users. The large data files created this leg nearly filled the storage hard disks. A new 120 meg hard disk was sent this leg and an attempt was made to bring it on line. After considerable time had gone into this effort, it was deemed incompatible with the shipboard computer system. The continuing effort to get the BRG logging MASSCOMP computer to communicate with the VAX via TELNET was stymied by old software and lack of documentation.

As in past legs the Macintosh computers were used extensively with few problems other than old mice that are getting "jumpy" and occasional system errors that were attributed to minor incompatibilities between the many software applications.

Photo Lab

A record number of black and white prints and color negatives were processed with few problems. Vigilance monitoring the chemistry of the solutions in the processor machines kept photo quality high.

A variation in the policy regarding close-up core photography was initiated this leg. Prints were given to the Staff Scientist, who gave them to the scientist(s) needing them most, rather than giving prints directly to the individual requesting the work.

Electronics Shop

Preventative maintenance was given to the Xerox and QMS copiers early in the leg to optimize the quality of the copies. Minor mechanical failures and maladjustments that developed during the leg were repaired as required. Support was required for the underway equipment: testing hydrophones and transducers and deck equipment and doing PM on the Versatec plotter. In the chemistry lab, alignment and calibration of the AA and spectrophotometer was necessary as was work on the Rock-Eval. A brief electrical fire in the XRD power supply, caused by connector or insulation breakdown, was put out immediately. The ETs tested associated components and renewed some wiring, after which the unit was put back on line.

Special Projects

Software was written and brought to ship to allow the replacement of the MST's Pro 350 computers with IBM clones. Installation was attempted on the transit to the first site, after the necessary hardware was selected from spare parts and components. The initial switch was unsuccessful and the MST system was returned to its original configuration for the first sites. As is not uncommon with a project like this, several problems occurred simultaneously confusing the solution. One problem was believed to be that the software was not developed on an identical system. Near mid cruise, with new information, the exchange was tried again. Code errors were corrected and clones were installed for all analytical units on the MST except the *P*-wave logger. The software author is expected to locate and correct the problem during the Townsville port call.

A developmental video imaging system was installed near the core lab's photography area for evaluation during this and the next cruise. It consisted of a high resolution TV camera, lights, monitors, computer, floppy and optical disk drives. Once a booting up problem was corrected the equipment was demonstrated and interest shown. The high core recovery for this leg--and much of it featureless--precluded much scientific use, although some color profile data were collected. Video duplicates of core close-up photographs at a few sites initiated a data base that can be used for future development. Camera lens quality was thought to be too low to make sharp focusing easy.

Air delivery velocity measurements (in meters per second) were made throughout the ship. This information will be kept in the Laboratory Officers' permanent files. New fans in the house air conditioner replaced the corroded ones this leg, increasing air flow 10%-20%, according to the chief engineer. Moderate outside temperatures eased the heat load and all areas were comfortable.

Problems

Elevator malfunctions occurred in the early part of the leg and were repaired. In one instance the elevator brake was staying on while the motor was trying to move the elevator causing the motor to overheat. Other problems were attributed to logic failure at the bridge deck level, causing the elevator to stop at each floor. One of the ship's high pressure air compressors, used for our seismic system, failed irreparably mid-leg. We were able to use the one remaining compressor so that our seismic work and VSP experiments were not jeopardized. The casing hold fire-extinguishing system was either turned on accidentally for a moment or the electric solenoid valve in the delivery manifold malfunctioned. A small amount of water sprayed on some cardboard boxes but no damage was done. Some irregular leaking occurred later and we rebuilt the suspect electric valve, which corrected the problem.

Safety

Minor back strains from moving the many heavy core boxes, and a finger pinched in the core lab's watertight door closing mechanism, summarize the leg's accidents. The door mechanism was tightened and the handles bent to give more clearance, removing the source of the problem.

Noise levels on the fantail remained high for this and probably subsequent legs. It has been past practice to reduce the exhaust fan velocities when ambient conditions permit.

After a thyrig bay fire on a recent leg, the Captain decided to maximize air flow at all times. The result of this decision is a continual loud fan noise in this area and required use of hearing protectors.

METS

Marine Emergency Technical Squad members participated in weekly fire and boat drills.

LABORATORY STATISTICS: LEG 133

GENERAL STATISTICS:

Sites	16
Holes	36
Interval Cored (m)	7973
Core Recovered (m)	5505
Number of Sediment Cores	879
Number of Samples Taken	37148

SAMPLES ANALYZED:

Inorganic Carbon ($CaCO_3$)	2556
Total Carbon - CNS	585
Water Chemistry	571
Thin Sections	40
X-Ray Diffraction	584
Multisensor Track Runs	~3300
Cryomagnetometer Runs	6417
Physical Properties - Velocity	1146
Index Properties	2650
Thermal Conductivity	499
Vane Shear	1268

UNDERWAY GEOPHYSICS:

Total Miles Traveled (nmi)	3242
Bathymetry, Magnetics (nmi)	3182
Seismics (nmi)	174

DOWNHOLE TOOLS:

Core Orientation Runs	67
WSTP Deployments	25