OCEAN DRILLING PROGRAM

LEG 171B PRELIMINARY REPORT

BLAKE NOSE

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ABSTRACT

Ocean Drilling Program Leg 171B was designed to recover a series of 'critical boundaries and intervals' in Earth history in which abrupt changes in climate and oceanography coincide with often drastic changes in the Earth’s biota. Some of these events such as the Cretaceous/Paleogene (K/T) extinction and the late Eocene tektite layers are associated with the impacts of extraterrestrial objects, like asteroids or comets. Other events, including the benthic foraminifer extinction in the late Paleocene and the mid-Maastrichtian extinction events, are probably related to intrinsic features of the Earth’s climate system. Two intervals of unusually warm climatic conditions, the early Eocene and the late Albian, represent periods when the Earth is thought to have experienced such extreme warmth that they are sometimes described as 'super-greenhouse' periods. The major objectives of Leg 171B were to recover records of these critical boundaries at shallow burial depth where microfossil and lithologic information would be well preserved, and to drill cores along a depth transect where the vertical structure of the oceans during the boundary events could be studied. The recovery of continuous Paleogene or Mesozoic sequences characterized by cyclical changes in lithology would help to establish the rates and timing of major changes in surface and deep water hydrography and microfossil evolution.

Accordingly, five sites were drilled down the spine of the Blake Nose, a salient on the margin of the Blake Plateau where Paleogene and Cretaceous sediments have never been deeply buried by younger deposits. The Blake Nose is a gentle ramp extending from ~1000 to ~2700 m water depth, and is covered by a drape of Paleogene and Cretaceous strata that are largely protected from erosion by a thin veneer of manganiferous sand and nodules. We recovered a record of the Eocene period that is nearly complete except for a few short hiatuses in the middle Eocene. The continuous expanded records show Milankovitch-related cyclicity that provides the opportunity for astronomical calibration of at least parts of the Eocene time scale, particularly when combined with the excellent magnetostratigraphic record and the presence of both calcareous and siliceous microfossils. The chemistry of the well-preserved calcareous microfossils will be used to document climate variability when the Earth’s climate switched from a greenhouse to an icehouse state.

Leg 171B successfully recovered a suite of critical events in Earth's history that includes the late Eocene radiolarian extinction, late Paleocene benthic extinction, the K/T boundary, the mid-

Maastrichtian event, and several episodes of organic-rich sediments in the Albian warm period. The upper Paleocene benthic foraminifer extinction occurs within an expanded interval of calcareous sediments unlike most regions of the Atlantic Ocean where calcareous fossils have been severely dissolved just above the extinction horizon. The K/T boundary was recovered at three sites, each with a biostratigraphically and magnetostratigraphically complete sequence that includes the earliest part of the aftermath of the Late Cretaceous extinctions. We managed to recover three copies of the boundary interval at one site in a section that includes a 10- to 17-cm-thick spherule bed, a rusty brown limonitic layer, a dark gray clay bed (planktonic foraminifer Zone P0), and white ooze that represents planktonic foraminifer Zone Pa.

INTRODUCTION

Cretaceous and early Cenozoic sediments on the Blake Nose in the western North Atlantic (Fig. 1) offer an ideal record for reconstructing variability in deep-water circulation and sedimentation history, both of which are closely linked to climate change across the Blake Nose. Paleogene and Barremian–Maastrichtian strata crop out, or are present at shallow burial depths, in present water depths of 1200 m to ~3000 m. The Blake Nose spanned a similar range of depths in the early Cenozoic, because margin subsidence was largely complete by the Early Cretaceous, and minor subsidence since then is partly offset by reduced sea level after the Eocene. Thus, a depth transect of cores along the paleoslope provides information on depth-dependent sedimentation, deep ocean chemistry, and biota that can be used to reconstruct the past vertical structure and circulation of the western North Atlantic. In addition, studies of well-preserved Paleogene and Cretaceous fossil groups from the Blake Nose area should make a significant contribution to the interpretation of their evolution in response to episodes of changes in deep-water circulation and impact events.

The Cretaceous and Paleogene contain numerous events of paleoceanographic and biological significance that may be studied with the cores from Blake Nose. Short-term perturbations like the mid-Maastrichtian cooling, the Cretaceous/Paleogene extinction, the late Paleocene extinction, and the late Eocene impact horizons are all preserved in sedimentary sequences from Blake Nose. Several longer term trends can also be documented such as the middle Cretaceous anoxic events, the Aptian-Albian warm period, the Paleocene carbon isotope increase, the early Eocene warm period, and the middle to late Eocene cooling. These events and trends are commonly associated with changes in the Earth's biota, biogeochemical cycling, and oceanographic circulation. Many of the previously obtained records of the Cretaceous and Paleogene events are poorly dated and poorly understood owing to their sparse representation in deep-sea cores or their occurrence at great burial depth. The sedimentary record on Blake Nose has the combination of good microfossil preservation, unlithified sediments of great age exposed near the seafloor, and continuity of sedimentary packages that span a variety of depths across the slope that are needed to reconstruct a detailed history of the Paleogene and Cretaceous periods.

Geophysical and Geological Background

Blake Nose, or Blake Spur, is a salient on the eastern margin of the Blake Plateau, due east of northern Florida (Figs. 1, 2). Water depths at the Blake Plateau are mostly less than 1000 m deep but drop sharply to >4000 m at the Blake Escarpment because of erosion of the continental slope. In contrast, the Blake Nose is a gentle ramp that reaches a maximum depth of about 2700 m at the Blake Escarpment. The Blake Plateau and Blake Nose are composed of an 8– to 12-km-thick sequence of Jurassic and Lower Cretaceous limestones that are capped by less than 1 km of Upper Cretaceous and Cenozoic deposits (Benson, Sheridan, et al., 1978; Fig. 3).

Depth-Transect Strategy

The water depths of the Blake Nose transect range from 1293 to 2586 mbsl (total vertical range of 1293 m; Fig. 2) and the transect spans the upper and lower boundaries of modern intermediate waters and Upper North Atlantic Deep Waters. The transect was designed to monitor the vertical structure of intermediate waters in the Cretaceous and Paleogene as well as depth-related changes in sedimentation and benthic fauna. In addition, our sites can be compared with recent onshore coring by the United States Geological Survey (USGS) to provide a total vertical depth range of nearly 3000 m and a horizontal transect of more than 320 km from the Carolina coast to the edge of the Blake Escarpment.

SCIENTIFIC OBJECTIVES

The objectives of Leg 171B were to drill sites (170–600 m penetration) in a transect from the margin of the Blake Plateau to the edge of the Blake Escarpment. Our main interest was to interpret the vertical structure of the Paleogene oceans and test the Warm Saline Deep Water hypothesis near the proposed source areas. A related objective was to provide critically needed low-latitude sediments for interpreting tropical sea-surface temperature (SST) by using well-preserved calcareous microfossils. We also hoped to develop a cyclostratigraphy tuned to orbital cycles that could be used to establish an extremely accurate chronology for biozones and magnetochrons in the Cretaceous and Paleogene. The Leg 171B Blake Nose depth transect drilled one of the best locations to recover distinct horizons such as the Paleocene/Eocene and Cretaceous/Paleogene boundaries to document critical paleoceanographic and biological evolutionary events surrounding the boundaries and water depth-related variations in sedimentation of the boundary beds. Paleomagnetic objectives were to refine the Paleogene/Cretaceous biochronology and magnetochronology of the Paleogene/Cretaceous period and constrain Eocene paleomagnetic poles for the North American plate.

SUMMARY OF PRIMARY BLAKE NOSE DRILLING RESULTS

Our strategy was to core multiple holes at each site to obtain a complete sedimentary sequence. We used MST track, lithologic, and color data to select which portions of cores from the multiple holes would be spliced together to form the "composite" section at each site. This has now become routine after development of this method during ODP Legs 138 and 154. The recovery was high in all of the advanced hydraulic piston core (APC) and extended core barrel (XCB) holes during Leg 171B, which allowed us to obtain the necessary complete sections. The initial results of Leg 171B are based on shipboard observations, which provide the framework for post-cruise investigations. First, we summarize overall cruise results, and then we present detailed results obtained from the individual sites.

Lithostratigraphy

The sedimentary record at Blake Nose consists of Eocene carbonate ooze and chalk that overlie Paleocene claystone as well as Maastrichtian and possibly upper Campanian chalk (Figs. 3, 4). In turn, Campanian strata rest unconformably upon Albian to Cenomanian claystone and clayey chalk that appear to form a conformable sequence of clinoforms. A short condensed section of Coniacian to Turonian nannofossil chalks, hardgrounds, and debris beds are found between Campanian and Cenomanian rocks on the deeper part of Blake Nose. The contact between the upper Albian and the lower Albian appears to be disconformable, whereas the lower Albian/Aptian boundary may be complete. Albian claystones are interbedded with Barremian periplatform debris, which shows that the periplatform material is reworked from older rocks. The entire middle Cretaceous and younger sequence rests on a Lower Cretaceous, and probably Jurassic, carbonate platform that is more than 5 km thick in the region of Blake Nose.

The middle to upper Eocene is exposed on the seafloor across much of Blake Nose (Fig. 3). The unconsolidated oozes are protected from erosion by a layer of manganese sand and nodules that are up to about 3 m thick in places. The manganiferous sand is composed largely of Pleistocene to Holocene planktonic foraminifers, but in the shallower parts of the Blake Nose mixed assemblages of Oligocene to middle Miocene foraminifers are present. Bivalves and gooseneck barnacle plates are mixed in the sand.

The Eocene consists largely of green siliceous nannofossil ooze and chalk. The upper part of the sequence is typically light yellow, but below this there is a sharp boundary where the color changes to green. This color change is diachronous and probably relates to a diagenetic front (produced by flushing the sediment with seawater?), but does not seem to have altered the microfossil preservation or sediment composition. Planktonic foraminifers, radiolarians, and calcareous nannofossils are well preserved through most of the middle Eocene, but calcareous fossils are more overgrown in the lower middle Eocene and lower Eocene. A distinct feature of the Eocene sequence is the presence of a high number of vitric ashbeds that were found at all sites. The ashbeds serve as excellent beds for marker correlation between the sites and will be very useful for control points when developing the cyclostratigraphic record.

The cyclostratigraphic record based on the color and MST track data is well developed at the shallowest site, Site 1052. The late-middle to late Eocene record displays clear cyclical color changes that were used to splice the records of the individual holes into a composite (Fig. 5). The Milankovitch-controlled cycles will be used to recalibrate the late-middle Eocene and late Eocene time scale. Radiometric dates on the ashes and dating by astronomical tuning will produce an integrated time scale to recalibrate magnetostratigraphy and biostratigraphy. The Eocene cyclostratigraphy is less well developed at the sites downdip of Site 1052, although a splice for most of the record at each site has been produced. Color cycles are also well developed in the Paleocene and early Eocene record and will help calibrate the magnetostratigraphy and biostratigraphy of those intervals as well as aid in intersite correlation (Figs. 6, 7). The color changes were also used to construct a Cretaceous spliced record from the three holes at Site 1049.

The Paleocene and lower Eocene are relatively clay-rich by comparison with the middle and upper Eocene. The upper Paleocene contains chert or hard chalk, and preservation of most fossil groups is moderate to poor. The lower Paleocene is typically an olive-green clay-rich nannofossil chalk or ooze. Calcareous microfossils are typically very well preserved, whereas siliceous components are nearly absent. The sequence is biostratigraphically complete except for a possible unconformity in the upper Paleocene where nannofossil Zone CP5 is missing at some sites. The Danian part of the sequence thickens upslope from ~20 m thick at Site 1049 (2656 mbsl) to ~80 m at Site 1052 (1300 mbsl). Clay-rich nannofossil chalk and ooze continues into the uppermost Maastrichtian. The K/T boundary consists of a 10-17 cm graded bed of green spherules capped by fine-grained, rusty-brown grains that are overlain by dark gray clay of the earliest Danian at Site 1049. This succession is interpreted as fallout from the Chicxulub impact structure on the Yucatan Peninsula and the succeeding deposition of lowermost Danian sediment following the K/T extinction event. Notably, neither of the two K/T boundary sections drilled updip of Site 1049 have well developed ejecta beds between lowermost Danian (foraminifer Zone P0) and uppermostx Maastrichtian (*M. prinzi*) deposits. The spherules at these sites were either slumped into deeper water very shortly after deposition, or turbidites carrying the ejecta debris bypassed the upper slope and deposited at least part of their load near the tip of Blake Nose.

Notably, the Maastrichtian sections at both Sites 1049 and 1052 are disturbed by slumping. Most of the section consists of gray nannofossil ooze or chalk. Laminations are well preserved but burrowing is not evident, presumably because the sediment was partially liquified during slumping. However, it seems that relatively little if any of the Maastrichtian section has been lost, because the sequence is biostratigraphically complete and in the correct stratigraphic order. It is possible that the slumping was associated with the large magnitude earthquake produced by the Chicxulub impact. At Site 1052, the middle Maastrichtian contains a large slump that lies between light gray, burrowed chalk above and more weakly burrowed, greenish-gray chalk below.

The Maastrichtian apparently unconformably overlies white ooze that contains nannofossil and planktonic foraminifers characteristic of the upper Campanian at Site 1049. A somewhat thicker sequence of upper Campanian strata is present at Site 1050 and overlies a highly condensed section of Coniacian to Turonian hardgrounds that is only ~9 m thick (Fig. 8). Updip at Site 1052, Campanian nannofossils are mixed into the lower Maastrichtian chalk, which rests directly upon the Cenomanian. Evidently, upper Campanian to Turonian sediments were deposited on Blake Nose but were largely eroded prior to deposition of the Maastrichtian sediments.

Cenomanian chalk and claystone are present only in a thin wedge on the upper part of Blake Nose but the wedge thickens considerably down the slope. Seismic data and Leg 171B drilling results suggest that the Cenomanian sequence expands considerably (~70 m) near the center of the Blake Nose and then thins again at the toe of the Blake Nose. Most of the Cenomanian deposits at Site 1050 are slumped black shales and gray claystones. Cenomanian strata are completely absent from the section at Site 1049, which is drilled on a small paleo-high near the northeast tip of Blake Nose.

Multichannel seismic data (MCS Line TD-5) show that the Cenomanian-Albian sequence consists of two sets of clinoforms built over and to the northeast of a buried reef complex. The lower Cenomanian lies on top of a thick package of late Albian aged clinoforms, and the two appear to be conformable. Within the clinoform stack, the Cenomanian includes dominant dark olive gray calcareous silty claystone to clay-rich siltstone and contains very well preserved calcareous microfossil assemblages. The sediment color varies from an olive gray to black, and darker intervals are rich in clay and fine silt.

The upper clinoform set was partly drilled at Site 1052 and proved to consist of alternating green claystone, silty claystone, green laminated claystone, and thin beds of cross-bedded mixed siliceous and calcareous grainstone. The laminated green claystones are rich in humic organic matter and occur in 0.5- to 1.5-m-thick sequences interbedded with thin limestone beds that are poor in organic matter. Age-equivalent strata in Europe are known as 'Oceanic Anoxic Event (OAE) 1d' and consist of a series of laminated beds deposited within oxygen-depleted waters. The upper Albian section appears to overlap the top of the Aptian reef and pinches out entirely near the toe of Blake Nose. Near the bottom of Hole 1052E, the Albian sequence becomes dominated by slight to moderately bioturbated dark olive gray sandy siltstones probably deposited in middle or outer shelf environments. These sandstones were probably deposited near storm wavebase, as suggested by the occurrence of well-sorted grainstone and sedimentary structures associated with sand waves. Apparently, the entire upper Albian clinoform stack represents a deepening upward package.

This clinoform sequence overlaps a second clinoform sequence that probably is represented by lower Albian and upper Aptian variegated claystones recovered at Site 1049 and Deep Sea Drilling Project (DSDP) Site 390. The lowermost Albian contains a 46-cm-thick black shale containing up to 11.5% marine organic matter. This black shale section is correlative with 'Oceanic Anoxic Event 1b'. The upper Aptian section is interbedded with periplatform carbonates that were either eroded from the reef complex located to the west or were deposited at the same time as the reef system.

Interstitial Waters

Interstitial waters were analyzed at every site across the Blake Nose depth transect. The results are consistent with the biogenic and volcaniclastic nature of generally organic carbon-poor sediments and extreme depth (>5 km) to basement.

Elevated silica concentrations in the pore waters are consistent with significant alteration of biogenic and volcaniclastic siliceous sediments, particularly in the lower Eocene and Paleocene sequence. Excellent preservation of radiolarians around ash layers, especially at Site 1051, may indicate that the volcaniclastics are the more important of these two silica sources in the Blake Nose area.

Volcaniclastics are dispersed throughout the section and also seem to be the dominant control on the pore-water calcium and magnesium concentration depth gradients (formation of authigenic dolomite is an additional control, especially at Site 1052). Calcium and magnesium gradients are weak in the Blake Nose in comparison to many deep-sea sequences where gradients are often controlled by seawater/basalt interaction in the underlying upper oceanic crust. The weakness of these gradients at Blake Nose is consistent with the extreme depth (>5 km) of basement in this area. General increases with depth in Sr concentrations and calculated Sr/Ca values at all Blake Nose sites are consistent with the recrystallization of biogenic carbonate in the sediment column and alteration of volcaniclastics.

Perhaps the most remarkable results from the interstitial pore waters at Blake Nose are the extreme concentrations of lithium (up to 20 times seawater concentration; Fig. 9). Extreme distance from basement and the shape of the pore-fluid lithium profiles suggest that the source for Li to the pore waters is likely within the sedimentary column and that high concentrations are most likely caused by alteration of the volcaniclastics.

Anoxic Events

Finely laminated sediments occur periodically through the middle Cretaceous section drilled during Leg 171B. One of our goals was to recover laminated deposits along a depth transect to study the vertical extent of low-oxygen waters in the Cretaceous Atlantic. Our results suggest that the laminated sediments recovered at the shallow Blake Nose transect sites have very different characteristics than those drilled on the deep end of the transect.

The upper Albian sections within drill sites located on the upper end of the Blake Nose transect consist partly of dark-green, laminated claystones that alternate with lighter colored limestones. We observed 15 cycles of light-colored, strongly bioturbated, coarse-grained clayey limestones with moderately bioturbated silty claystones and dark, laminated claystones. The organic carbon content of the laminated beds is less than 1%, and the kerogen is of terrestrial origin. These laminated deposits are part of a deepening upward cycle from strata deposited near storm wavebase to sediments deposited near the shelf-slope break. The pervasive lamination of the deeper water part of the sequence suggests that the top of the low-oxygen zone impinged on the margin near the depth of storm wavebase. The interval where the laminated dark-gray sediments occur is time equivalent to similar sediments deposited during 'Oceanic Anoxic Event 1d' found in Tethyan deposits (Fig. 10). The widespread occurrence of the cyclic alternation of dark laminated claystones and limestones indicates that environmental conditions were similar throughout the Tethys and the young Atlantic basin.

Although not the deep-water equivalent of the laminated claystones (OAE 1d) found updip on Blake Nose, the early Albian black shale (OAE 1b) recovered at Site 1049 probably reflects the relative clastic starvation of the deep-water seaward edge of the Blake Escarpment compared to the shallower areas that represent the ancient shelf and shelf-slope break (Figs. 2, 3, 10). The abundance of marine organic matter suggests that the black shale is the distal equivalent of more terrigenous sediments that are presumably present in a clinoform stack that overlaps the updip reef complex on the Blake Plateau (Fig. 3). The black shale may represent a relatively brief period during which low oxygen conditions extended well down into intermediate water masses, because most upper Aptian and lower Albian sediments at the seaward end of Blake Nose are not organic-rich.

Mid-Maastrichtian Deep Water Reversal

The Maastrichtian was a time of global cooling marking the end of the Cretaceous greenhouse climate. Widespread geochemical and biological shifts, including extinction among rudistid and inoceramid bivalves, seem to be concentrated in the middle of the Maastrichtian. It has been proposed that rudists thrived in a hypersaline 'Supertethyan' province and inoceramids at bathyal depths where the bottom water was warm and saline (e.g., MacLeod and Huber, 1996). Thus, extinction among both groups could be explained by reorganization of Maastrichtian oceans with temperature differences replacing salinity differences as the dominant force driving circulation. A reversal in deep ocean circulation patterns would affect many paleoclimatological and paleoecological variables such as latitudinal heat transport, benthic carbon budgets, and deep ocean ventilation. Whereas some data support each of these propositions (e.g., MacLeod and Huber, 1996), there are more predictions than actual evidence of this ocean circulation hypothesis.

Lower and upper Maastrichtian sediment was recovered at Sites 1049, 1050, and 1052. The shipboard studies of material from Site 1052 are particularly exciting because mid-Maastrichtian changes seem well defined and are provocatively ambiguous. The observed distribution of inoceramid shell fragments in paleontological sample residues indicates that the disappearance of inoceramids at Site 1052 falls within an ~40 m interval of good to excellent recovery. There is also a change in the amount of bioturbation across this interval from dominantly laminated or slightly bioturbated to thoroughly bioturbated. This is consistent with increasing ventilation of the bottom waters and, potentially, a reversal of bottom water circulation patterns. On the other hand, the abundance of organic carbon is lower in the less bioturbated intervals raising the possibility that food supply rather than benthic oxygenation might have limited the activity of (pre-extinction) burrowing organisms. Detailed documentation of the relationship among paleontological, geochemical, isotopic, and sedimentological data at this site and the others along the Blake Nose transect will provide better data than has previously been available to document paleoceanographic change during the last 5 m.y. of the Cretaceous.

Cretaceous/Tertiary Boundary

A complete Cretaceous/Tertiary (K/T) boundary interval was recovered in Holes 1049A, 1049B, and 1049C (Fig. 11). At Sites 1050 and 1052, partial K/T boundary sections were recovered. At Site 1049, boundary ejecta intervals are 17, 9, and 10 cm thick in Holes 1049A, B, and C, respectively. With the exception of the apparent compression in Holes 1049B and 1049C, the boundary interval seems to be virtually undisturbed and exhibits the same stratigraphic sequence in each hole (Fig. 11). The lowest bed is a graded, faintly laminated layer consisting almost entirely of green spherules that range in size from 2 to 3 mm at the base to less than 1 mm at the top. This spherulitic layer is capped by a 3-mm-thick orange limonitic layer that contains flat goethite concretions. The limonitic layer is overlain by 3 to 7 cm of dark, burrow-mottled clay that represents the P0 foraminiferal biozone. The final bed in the sequence is a 5- to 15-cm-thick, white foraminiferal-nannofossil ooze that contains a Zone Pa foraminiferal assemblage. The K/T boundary sections at Site 1049 are complete and, thus excellent for studying the response of marine biota to the extraterrestrial event. For instance, the planktonic foraminifers are extremely well preserved, ideal for stable isotopic studies that we hope will reveal the chain of climate events caused by the impact.

Paleocene/Eocene Boundary

Leg 171B recovered an apparently complete, or nearly complete, upper Paleocene carbonate sequence that should help resolve many of the issues concerning the biochronology and geochemistry of this period. Upper Paleocene sections are frequently interrupted by clay beds or a rapid switch from carbonate deposition to siliceous deposition that has been related to a short-lived intensification of low-latitude deep-water production. Added to this oceanographic switch in the deep-water source area is geochemical evidence for potential rapid release of buried gas hydrate, including the potent greenhouse gas methane. Unfortunately, the changes in type of sedimentation and the frequent unconformities typical in the upper Paleocene have previously inhibited study of this 'super greenhouse' event.

The uppermost Paleocene at Site 1051 consists of color-banded, greenish nannofossil chalk that contains moderately to poorly preserved foraminifera and calcareous nannofossils. Nonetheless, species are sufficiently well preserved that it will be possible to construct a detailed biochronology. The material is suitable to produce a very detailed carbon isotope profile from the late Paleocene to early Eocene that can be used to test the gas hydrate hypothesis for upper Paleocene warming as well as aid in correlation of Site 1051 to other localities around the globe. Finally, the sequence displays pronounced cyclic sedimentation of dark green and pale green alternations that may reflect orbital cycles. In conjunction with the magnetostratigraphy for this site, the color cycles should help produce a very detailed chronology of the duration of the thermal maximum.

Geological History of Blake Nose

Blake Nose is composed largely of Jurassic to middle Cretaceous carbonate platform deposits. The platform rests on basement rocks formed by intrusion and volcanism through attenuated continental crust during the rifting stage of the Atlantic. As much as 10 km of carbonates accumulated in this area. By Barremian-Aptian time, the reef stepped back 40-50 km from the lower Cretaceous margin and formed a long tract of coral-rudist reefs such as the one evident in seismic profiles in the shallow subsurface at the head of Blake Nose (Fig. 3).

The Aptian reef tract ceased growth during the late Aptian, at which time periplatform debris was no longer delivered to the outer edge of Blake Nose, and the deposition of green and red variegated clays began. These nannofossil clays must have been deposited at a depth of at least 1500 m since the top of the Aptian reef to the west does not appear to have been subaerially eroded and, hence, was probably near or below wavebase. Aptian clinoforms built out in front of the reef and also partially overlap the reef top. The nature of these rocks is not known except for where they have been recovered from the distal edge of the deep-water facies at Site 1049. At least part of the clinoform sequence is probably correlative with the black shale of latest Aptian age found at Site 1049, suggesting that the low-oxygen conditions associated with the organic-rich sediments extended to a water depth of at least 1500 m.

The lower Albian sequence at Site 1049 contains a number of hardgrounds and firmgrounds suggesting that there were periods of nondeposition or erosion. Some of these short hiatuses may correlate to the tops of deepening-upward sequences within the Aptian clinoform stack, similar to deepening-upward sequences within the overlying upper Aptian clinoforms. There are also some truncated clinoforms within the Aptian sequence that are visible on the seismic reflection profile across the Leg 171B drill sites (MCS Line TD-5), and these may correlate with nondeposition or erosion surfaces near the toe of Blake Nose. Unfortunately, the entire middle Cretaceous section at Site 1049 is so condensed that it is difficult to correlate reflectors unambiguously updip into the various clinoform wedges and, in any event, the Aptian/lower Albian section does not produce strong reflectors except within the clinoform stack.

Upper Aptian and lower Albian strata are overlapped unconformably by a second major clinoform wedge of late Albian age. These clinoforms are composed mostly of micaceous claystones that are interbedded with mixed carbonate and terrigenous grainstones near the base of the stack and that pass upward into cyclic limestone-laminated dark green claystones. The lower part of the clinoform sequence was probably deposited near storm wavebase as the sands are well washed and exhibit sedimentary structures indicative of megaripples or sand waves. The upper part of the sequence was apparently deposited in deeper water, perhaps near the shelf-slope break as it contains few, if any, sand layers and no evidence of substantial bottom current activity. Presently, the top of the clinoform sequence is located ~500 m below the top of the adjacent reef. Decompaction of the clay-rich strata in the Albian clinoforms by 60%-80% suggests that these sediments were deposited at about 100-200 m water depth if the top of the reef was at sea level. The presence of Albian marine rocks landward of the Blake Nose suggests that the Blake Plateau was also submerged and implies depths greater than those estimated above for the clinoform sequence.

Clinoforms within the upper Albian sequence pinch out against a surface of erosion or nondeposition, which is overlain by lower Cenomanian strata. There is little time missing across this hiatus at Site 1052, which is close to the center of the upper Albian clinoform stack, and there is no discernable hiatus judging from the planktonic foraminifer or nannofossil biochronologies. The hiatus probably represents a reduction in sediment supply to the slope either because of a sea level rise that trapped sediment inshore or diversion of sediment to some other location on the slope. Cenomanian sediments are absent from most of the Blake Plateau, suggesting that they may not have been deposited there. Alternatively, they may have been removed by later erosion and were only preserved on the upper slope. In any case, the downdip pinchout of Cenomanian strata in the middle of Blake Nose is evidence that the Cenomanian sediments recovered at Site 1052 were a relatively deep-water deposit near the most seaward extent of deposition. Deep-water conditions are supported by the presence of rich assemblages of planktonic foraminifera including the keeled rotaliporids that are rare or absent in epicontinental seas and shallow shelf strata.

There is a widespread, major unconformity above the Cenomanian on Blake Nose from which upper Cenomanian to lower Campanian strata were largely removed. A thin section of Turonian and Coniacian strata is present as a series of manganiferous hardgrounds, beds of ripup debris, and red nannofossil chalks. A very thin sequence of upper Campanian foraminifer ooze is present at Site 1049, but no sediment of corresponding age was recovered from the shallower parts of the slope. However, the Maastrichtian sequence contains numerous slumps, including one located at the Maastrichtian/Cenomanian contact at Site 1052, so it is possible that Campanian sediments were removed from the area of Site 1052 by downslope transport. Despite the slumping, much of the Maastrichtian appears to be present as a drape of nannofossil chalk and ooze. The preserved record has a well-developed color banding that may record orbital cycles. The sequence also appears to preserve an expanded record of the mid-Maastrichtian and changes in bioturbation intensity. The abundance of inoceramid prisms suggest that the biological crisis recognized in low-resolution sections from other parts of the globe is probably preserved at Blake Nose, as well.

The end of the Cretaceous and the earliest events of the Cenozoic are well preserved on Blake Nose. We recovered a thick spherule bed, which presumably represents the ejecta debris from the Chicxulub crater, only at Site 1049. Nonetheless, the K/T boundary sections drilled at all Blake Nose sites preserve the earliest Danian biozones and the nannofossil markers for the latest Maastrichtian (see above). Hence, we succeeded in coring the boundary beds along a depth transect and made it possible, for the first time, to study the boundary beds and events over a range of 1300 m water depths.

Deposition of a nearly uniform drape of pelagic sediment continued into the Paleocene. The Danian is unusually thick on Blake Nose in comparison with most sites in the deep sea, and the claystone preserved the calcareous microfossils very well. Paleocene strata are the first sediments to preserve geochemical and lithologic evidence of abundant volcanic ash on Blake Nose—a trend that continued throughout the Eocene. The upper part of the Paleocene is increasingly siliceous, and chert stringers are present where the Paleocene beds thin toward the landward and seaward ends of the Blake Nose.

By the latest Paleocene, deposition was concentrated into a major clinoform stack that reached its greatest thickness near the center of the Blake Nose transect. At least two hiatuses are present in this sequence. One is within the uppermost Paleocene and occurs close to the upper Paleocene 'Thermal Maximum' when the deep oceans appear to have abruptly warmed for a few hundred thousand years. However, the hiatus is either absent or very short near the center of the clinoform stack where the Paleocene/Eocene transition is biostratigraphically complete. A second hiatus is present near the lower-middle Eocene transition where almost 2 m.y. of the Eocene are absent. This hiatus is present across the whole of Blake Nose and is represented by foraminiferal packstones, grainstones, chert, and green clay. The hiatus cuts out the top of the Paleocene through the lower-middle Eocene on the upper part of Blake Nose, where foraminiferal packstones and nannofossil claystones contain highly mixed assemblages within a stratigraphic interval that is only about 5 m thick.

Sediment depocenters apparently backstepped up the slope of Blake Nose during the middle and late Eocene. Upper middle Eocene siliceous nannofossil oozes and chalks are thickest at Sites 1051 and 1053, which are probably close to the depocenter of these units. Indeed, analysis of the compaction state of the sedimentary sections at Sites 1050 and 1049 suggest that these areas probably were never buried by more than 100-150 m of sediment. This observation implies that the middle and upper Eocene thinned toward the toe of Blake Nose. The updip continuation of the middle and upper Eocene was removed almost completely by erosion, making it difficult to estimate how much Eocene strata were originally deposited there. However, our ability to piston core more than 150 m of the section at Site 1053 indicates that the sediment was not compacted by burial beneath a thick blanket of younger sediments.

Sea-level changes and current intensification have probably contributed to the fact that the youngest sediments on the Blake Nose are of latest Eocene age. The Oligocene is associated with widespread hiatuses in the North Atlantic. The Gulf Stream assumed its present course, for the most part, in the Oligocene and cut into the surface of the Florida Straits and the Blake Plateau. In addition, a sea-level highstand in the late Oligocene shifted sedimentation from the shelf to the coastal plain, starving the outer shelf and slope landward of the Blake Escarpment. In the Blake Basin, Oligocene cooling at high latitudes intensified the southward flow of deep water along the Blake Escarpment and formed the widespread A^u seismic reflector that represents an unconformity distributed over most of the western North Atlantic. Erosion of the base of the Blake Escarpment occurred during the Oligocene as well, and large blocks of debris are present on the northwest and southeast slopes of the Blake Nose. In contrast, the northeastern tip of the Blake Nose has likely experienced relatively little erosion. Not only are there no slump blocks at the base of the escarpment in this area, but all sedimentary sequences younger than the late Aptian appear to thin considerably or pinch out there. It appears that there has not been substantial erosion of the plateau in this area, whereas the northwestern and southeastern sides have experienced considerable erosion. Indeed, the Aptian reef is exposed in the escarpment on both sides of Blake Nose. If the reef tract stepped back a similar distance all along the Blake Plateau during the Aptian, more than 70 km of the escarpment must have been eroded to create the present bathymetry.

SITE RESULTS

Site 1049

Site 1049 is located on the eastern margin of the Blake Nose and represents the deepest site of the Blake Nose transect. The location was chosen to recover a sedimentary section of Eocene through Aptian-Albian deep-water strata to compare with age-equivalent, but more expanded, sections at shallower water depths. The site is at a present depth of 2656 m below sea level (mbsl) and is shallow enough to preclude significant dissolution in the lysocline, yet deep enough to record changes in bottom water chemistry produced by changes in the vertical structure of deep and intermediate waters during the Paleogene and Cretaceous.

The sediments were recovered with three adjacent APC/XCB holes in order to obtain complete recovery of the section. Although the middle Eocene, lower Paleocene-Maastrichtian and Aptian-Albian sequences are condensed, they will be useful for paleoceanographic studies. The microfossil faunas are well preserved and in combination with magnetostratigraphy provide a good chronostratigraphic framework. In the upper 50 m of the section (middle Eocene), the GRAPE density and magnetic susceptibility records are remarkably featureless and do not provide an unambiguous composite record. On the other hand, we observed cyclic records in all three holes from the K/T boundary and below, which allowed us to develop a well-constrained composite Cretaceous section.

At Site 1049, the sediment/water interface is covered by a manganese sand and nodule layer that contains Pleistocene-aged planktonic foraminifers and nannofossils. Below the manganiferous sands we recovered middle Eocene to Aptian sediments that we divided into four lithologic units:

1. Middle to lower Eocene nannofossil ooze, with several ash layers.

2. Upper to lower Paleocene nannofossil ooze with several intervals of limestone and chert.

3. Paleocene to upper Campanian clayey nannofossil ooze and chalk. The K/T boundary was recovered at all three holes within this unit and seems well preserved and complete. The biostratigraphically constrained boundary consists of a 0.3-cm limonitic layer containing brown yellowish spherules (and presumably microkrystites and the Ir anomaly) overlying a 9 to 17 cm, normally graded bed of green clay spherules that is interpreted as microtektite ejecta (Fig. 11). The limonitic layer is overlain by 4 cm of gray mottled clay, representing the earliest Cenozoic. Below the K/T boundary, the 20-m-thick interval of Campanian to Maastrichtian oozes shows signs of slumping below the K/T boundary.

4. Lower Albian to Aptian bioturbated clayey nannofossil chalk and claystone with high frequency variations in color and magnetic susceptibility among light gray, dusky red, and greenish gray beds and including a 46-cm interval of organic-rich (maximum 11.5% total organic carbon [TOC]) black shale laminated on a millimeter scale.

Middle Eocene through upper Aptian sediments are characterized by a low average sedimentation rate of approximately 6 m/m.y. Sedimentation rates during the lower Eocene (approximately 11 m/m.y.) appear to have been slightly higher than those of the middle Eocene. The upper lower Eocene is separated from the middle upper Paleocene by a hiatus of at least 2 m.y., encompassing the Paleocene/Eocene boundary. Planktonic foraminifers and calcareous nannoplankton within the Paleocene are abundant and well preserved, radiolarians are absent, and benthic foraminifers are common and well preserved. Most noteworthy is the exquisite foraminifer preservation and complete recovery of all lower Danian planktonic foraminifer and calcareous nannofossil zones, including the basal Danian P0 Zone and the Pa Zone (*P. eugubina* Zone), which are either poorly preserved or unrecovered at other deep-sea sites containing the K/T boundary. Studies of this early Danian interval will provide a highly detailed record of paleoceanographic and evolutionary changes associated with the earliest radiation of oceanic plankton and benthos following the terminal Cretaceous extinction event.

An excellent composite record of middle Campanian through latest Maastrichtian time was also recovered. Sedimentation rates for this interval are very low, averaging about 2 m/m.y. Rhythmically bedded red and green calcareous claystones and white chalks at the base of the cored interval contain calcareous nannofossils and planktonic foraminifers of the early Albian and late Aptian. Paleodepth estimates based on benthic foraminifers revealed a deepening trend through time at Site 1049: from middle bathyal depths (~800-1000 m) during Albian times to lower bathyal depths (1000-2000 m) throughout the latest Cretaceous (Maastrichtian) and Paleogene (Paleocene to middle Eocene).

Portions from nearly all cores yielded magnetostratigraphic data, and most of these polarity intervals were reproduced at similar depth intervals in all three holes. Early to middle Eocene Chrons C19n through C22n appear to be complete, although these preliminary chron assignments may change as the shipboard Middle Eocene biostratigraphy is further refined. The K/T interval is clearly in C29r, but it was not possible to delineate the exact positions of the chron boundaries. Upper Maastrichtian Chrons C30n-C30r-C31n are present. A brief lower Albian reversed-polarity zone could be the elusive M"-2" reported on Leg 40. Within the Albian, an interesting "reversed" polarity interval is present adjacent to a black shale that appears to be caused by redox-induced precipitation of iron during a post-Santonian reversed-polarity period.

Sediment porosity decreases from 75% near the top of the hole to 40% at approximately 160 m. Over the same depth interval compressional-wave velocity increases from 1500 m/s to 1740 m/s. The compaction state of the upper sediment column suggests that about 75 m of sediment was removed by erosion at Site 1049. The K/T boundary was well resolved with *P*-wave, magnetic susceptibility, and GRAPE data. Magnetic susceptibility increases in magnitude, and GRAPE bulk density and *P*-wave velocity decrease in magnitude. These changes may be due to the occurrence of more iron-rich noncarbonate material, which has a coarser grain size and is less consolidated within the boundary layer. The Albian organic-rich black shale was well defined by MST data, which show a decrease in magnetic susceptibility and an increase in natural gamma radiation. An organic carbon-rich interval occurs in Albian variegated claystones and ranges from 1.7% to 11.5% TOC with hydrogen indices of 451 to 699 mg HC/gTOC. The organic matter has a marine origin in contrast to the terrestrial-sourced organic matter from the Aptian-Albian of the Blake-Bahama Basin.

Site 1050

Site 1050 was drilled in 2311 m of water on the Blake Nose 10 km upslope from Site 1049. Two APC/XCB holes were drilled, which produced extremely high (up to 95%) recovery throughout the section except for two minor intervals. We returned to Site 1050 at the end of the cruise and rotary drilled Hole 1050C to recover Albian to lower Danian strata. Although Site 1050 is a short distance from Site 1049, the middle Eocene and upper Paleocene intervals are much more expanded at Site 1050 than at Site 1049. The sediments that contain well-preserved calcareous microfossils will be used to reconstruct the deep-water mass characteristics in the Eocene through correlation of stable isotope data, lithostratigraphy, and benthic fauna between sites at different water depths on the Blake Nose. The record of Eocene sediments recovered on Leg 171B will document how depth shifts of the boundary between deep waters and intermediate waters occurred as climate switched from the early Eocene warm period to Antarctic glaciation in the late middle to late Eocene.

The lithostratigraphy is remarkably uniform through most of the Eocene and Paleocene and consists of green to pale-yellow siliceous nannofossil ooze and chalk with minor amounts of chert and diatomaceous nannofossil chalk. We divided the section into three lithologic units based on color and microfossil content. Lithologic Unit I contains an uppermost layer that comprises manganese nodules that probably represents the present seafloor (lithologic Subunit IA), and a lower section (~38 m) of yellow middle Eocene siliceous nannofossil ooze with varying amounts of foraminifers and clay (lithologic Subunit IB). A distinctive 5-cm-thick vitric ash occurs in the upper portion of lithologic Subunit IB. A sharp color change from yellow to green at ~40 meters below seafloor (mbsf) was used to divide lithologic Unit I from Unit II, but it should be noted that there is no apparent change in sediment composition across the contact. The color change from yellow to green does not appear to represent a primary depositional feature and may represent differences in redox conditions within the sediment cover of Blake Nose. Lithologic Unit II (~276 m thick; middle Eocene to late Paleocene in age) is composed of light grayish green nannofossil ooze to siliceous nannofossil ooze that grades downhole to a light grayish green siliceous nannofossil chalk and nannofossil chalk with varying contents of radiolarians, sponge spicules, and diatoms. The transition from ooze to chalk occurs at a depth of ~90 mbsf. The contact between Subunits IIA and IIB is placed at the top of a manganese hardground at ~154 mbsf that occurs within an interval with common thin chert layers and corresponds to a decrease in carbonate. At least 10 vitric ashes occur in Unit II. The ashes, together with color reflectance, magnetic susceptibility, and GRAPE bulk density data, make it possible to produce a detailed correlation between the two holes at this site. The ash beds are composed largely of clear glass shards. Several ash layers also contain euhedral biotite and feldspar grains that may provide an absolute chronology for the section. Most ash beds are about 1 cm thick, but many thinner beds have probably been destroyed by bioturbation or drilling disturbance, because we found that many of the gray wisps in the chalk contain volcanic glass shards. Peaks in abundance of siliceous microfossils in both holes were observed at 140 to 155 mbsf and 180 to 220 mbsf. Sediments containing the latest Paleocene benthic foraminifer extinction were not recovered in either hole because this interval consists of hard chalk or chert that jammed in the core barrel. However, lowermost Eocene and the upper Paleocene sediments adjacent to this interval of extremely low recovery are biostratigraphically and magnetostratigraphically complete which suggests that the interval of poor recovery does not contain a major hiatus. Lithologic Unit III (14.8 m thick; late early Paleocene to early late Paleocene in age) is a diatomaceous nannofossil chalk to nannofossil diatomite.

Hole 1050C contains a record of the upper Albian to lower Danian. The Danian section consists largely of calcareous claystone and clay-rick chalk. Microfossil preservation improves in the lowermost Danian and faunas just above the K/T boundary are typically very well preserved. The K/T boundary is represented by an unusually thick lowermost Danian sequence. Planktonic foraminifer Zone P0 is more than 1.5 m thick and may be even thicker, because the K/T boundary cores were not sampled in detail on the ship. It is possible that the great thickness of the lowermost Danian section is due to slumping, but if this is so, the slumps did not pick up older sediments, because the Danian rocks contain only trace amounts of Cretaceous microfossils. The boundary itself is a slightly burrowed contact that does not contain a spherule bed like that found at Site 1049. The uppermost Maastrichtian appears to be present, as indicated by the co-occurrence of both the nannofossil, *Micula prinzi*, and the planktonic foraminifer, *Abathomphalus mayaroensis*.

The Cretaceous section below the K/T boundary contains many slumped beds. Most of the Maastrichtian consists of slumped nannofossil chalks between apparently coherent packages of sediment that still retain burrows and primary sedimentary structures. The lower Maastrichtian appears to be missing in part and rests on upper Campanian white foraminiferal chalks. In turn, the Campanian strata rest unconformably on a highly condensed sequence of Coniancian and Turonian red nannofossil chalk, manganiferous hardgrounds, and chalk containing abundant clay ripup clasts. The Turonian chalk is disconformable over Cenomanian claystones.

The Cenomanian and upper Albian deposits are primarily black, laminated claystones and black shale with thin interbeds of more calcareous claystones and hard chalk. Much of the section is strongly slumped. Most of the slumps were soft-sediment features, but some are associated with conjugate shear surfaces, slickensides, and microfractured fold hinges that suggest at least partial lithification occurred before downslope transport. The almost complete absence of coarse-grained rocks and green-laminated claystones at this site is in sharp contrast to the dominance of these lithologies at the updip Site 1052. It is very likely that we have actually recovered the deep water equivalents of Site 1052 rocks. Unfortunately, the severe slumping renders much of the Cenomanian-Albian section useless for high-resolution paleoceanography. This is a pity, because microfossils are typically very well preserved.

A combination of magnetostratigraphy and biostratigraphy provides a preliminary chronostratigraphic framework for the sedimentary sequences at Holes 1050A and 1050B. Shipboard magnetostratigraphy within the middle Eocene interval is not well defined, although there are distinctive changes from intervals of predominately reversed polarity to intervals of normal polarity. Notably, both holes display the same patterns of stratigraphic change in apparent polarity. These results suggest that discrete samples may produce a well defined polarity scale during post-cruise research. The upper Paleocene-lower Eocene section displays a complete, well defined, magnetobiostratigraphy from Chron C27n through C22r. The deepest part of Hole 1050A was dated within the very top of the Danian (upper Chron C27n). Shore-based refinement of the magnetostratigraphy will make Site 1050 a reference site for calibration of the Paleogene biostratigraphy to magnetic polarity chrons.

The preservation of the calcareous nannofossils and planktonic foraminifers is good in the middle Eocene section and moderate to good in the lower Eocene and Paleocene. The exception is the interval straddling the Paleocene/Eocene boundary, where all calcareous microfossils show poor preservation due to extensive overgrowth and calcite cementation. The radiolarian faunas are generally well preserved. The youngest Eocene deposits correspond to Calcareous nannofossil Zone CP14a and Planktonic Foraminifer Zone P12, whereas the oldest sediments recovered belong to calcareous nannofossil Zone CP3 and the earliest part of Planktonic Foraminifer Zone P3a. The apparent absence of calcareous nannofossil Zones CP12a and CP10 suggests the presence of two hiatuses in the Eocene that each have a duration between 1.5 and 2 m.y.

Bulk density increases gradually in the upper 140 m of both holes and shows an abrupt increase followed by a equally sharp decrease at 150 mbsf, where the first chert stringers were encountered. Below this, bulk density increases steadily to a high value near 200 mbsf, and bulk density remains high through the upper Paleocene section. The transition to diatomaceous nannofossil chalk from nannofossil chalk at 300 mbsf corresponds to an abrupt drop in bulk density and *P*-wave velocity. *P*-wave velocity increases dramatically about 90 mbsf corresponding to the transition from ooze to chalk and to the depth at which we were forced to switch from APC to XCB. Pelagic carbonates in Neogene sequences typically show a transition from ooze to chalk at ~160-200 mbsf. Hence, the relatively shallow depth of this lithologic and physical property transition at Site 1050 suggests that at least part of the sedimentary sequence has been WAS eroded. Estimates of the amount of sediment removed, based on measured shear strength and bulk density, suggest that as much as 147 m of section may have been eroded from the top of the Blake Nose at this site.

Interstitial water chemistry shows significant changes with depth. Strontium, lithium, potassium, magnesium, calcium, and alkalinity all display marked gradients, particularly between about 80 to 220 mbsf. Major cation changes are consistent with sea water interactions with the volcaniclastic sediments (such as the volcanic ashes found throughout the Eocene section) and/or the underlying Jurassic-Cretaceous carbonate platform. Strontium concentrations and strontium/calcium ratios are both consistent with recrystallization of biogenic carbonates and with pervasive calcite overgrowth and cements in the lower Eocene and upper Paleocene sequence. Carbonate content is about 70%-75% in the upper 150 m. Marked decreases in carbonate content occur between 150 and 160 mbsf and again at 300 mbsf, where carbonate drops first to 50% and then to 30%. Both decreases in carbonate content are associated with increases in biogenic silica.

Organic carbon content is extremely low throughout the section and averages about 0.05 wt% in the upper 200 m. Other than a few spikes of less than 0.3 wt%, total organic carbon is essentially zero below 225 mbsf. Methane decreases upsection, probably as a result of increases in methane consumption by aerobic bacteria in the shallow sediments.

Site 1051

The location of Site 1051 was chosen to recover a thick Paleogene and Upper Cretaceous sequence. We anticipated that the Paleogene sequence in particular would be much more expanded than those at the other sites along the Blake Nose transect, as indicated by the seismic profile across the Leg 171B sites (MCS Line TD-5). We also expected to recover the Cretaceous/Paleogene boundary at intermediate water depths along Blake Nose and a more expanded sequence of Upper Cretaceous sediments than at Site 1049. The drilling results demonstrate that the Paleogene section at ODP Site 1051 is substantially thicker and includes younger Eocene sediments that are not found in the deeper water sites on the Leg 171B transect. The detailed shipboard biostratigraphy indicates that an almost complete sequence was recovered from the lowermost part of the upper Eocene to the upper part of the lower Paleocene. Unfortunately we had to stop drilling in the lower Paleocene section as our drilling rate became too slow to justify continued XCB coring.

We recovered a 630-m-thick sequence from two holes drilled at Site 1051. The lowermost upper Eocene to lower Paleocene sequence contains mainly oozes and chalks predominantly composed of nannofossils, siliceous microfossils, and clay. The siliceous component consists of generally well preserved radiolarians, sponge spicules, and diatoms. The clay content increases downhole in the lower Eocene and Paleocene. Over 25 ash layers were identified, spanning the majority of the Eocene sequence.

The sequence at Site 1051 is divided into four lithologic units, based on color, microfossil contents and lithology. The top of Unit I consists of several meters of manganese nodules and phosphatic, foraminifer sand, representing the present seafloor (Subunit 1A). The 63.95-m-thick Subunit IB is characterized by yellow middle Eocene siliceous nannofossil ooze with foraminifers and clay. A sharp transition from yellow to green is used to divide Subunits IB and IC. This transition is not marked by any change in microfossil or lithologic components and is clearly diachronous relative to a similar color change observed at Sites 1050 and 1052. We interpret the color change as a downhole diagenetic change in oxidation state. Subunit IC consists of a 66-m-thick section of predominantly siliceous greenish-gray nannofossil oozes. The transition between Subunits IC and ID is at the ooze/chalk transition. Unit ID is a 257-m-thick sequence of siliceous nannofossil chalk and nannofossil chalk with siliceous microfossils.

Unit II is 6.6-m-thick (376.1-382.7 mbsf) and was only partially recovered. It consists of strongly altered dark green porcellanitic smectite clay and several interbeds of silicified, white, foraminiferal packstone. Several distinctive firmgrounds are present in the recovered material and display white foraminifer sand that infills burrows in the green clay. The entire interval of clay and foraminifer packstone appears to coincide with a hiatus of ~2 m.y. in which bottom currents were episodically sufficient to thoroughly winnow the silt and clay fraction.

Lithologic Unit III is a 144.2-m-thick dark siliceous nannofossil chalk with clay. An apparently complete Paleocene/Eocene transition was recovered at Site 1051 and is partially laminated in the lowermost Eocene and IN parts of the upper Paleocene, indicating decreased bioturbation. There is also a distinctive soft-sediment breccia ~10 cm thick about 10 m below the Paleocene/Eocene boundary. The breccia occurs just above Chron C25n (55.9 Ma) and may represent part of a small slump. The slump appears to be within or just below the stratigraphic interval at which many Paleocene benthic foraminifer became extinct. Benthic foraminifer are very rare for more than 10 m within the extinction horizon and the fauna is reduced from about 40 taxa to only seven. An impoverished benthic fauna is present for a least 50 m above the onset of the extinction interval.

Occasional cross-bedded foraminifer sands occur at 450-470 mbsf. Unit IV is the oldest unit (lower Paleocene) and was recovered only in Hole 1051A. It is a 76.41-m-thick sequence of dark green siliceous nannofossil chalk to siliceous claystone or clayey spiculite.

Excellent age control was provided by biostratigraphy. Planktonic foraminifers and nannofossils are well preserved in the upper and middle Eocene. Preservation of both groups is variable in the lower Eocene, and becomes poor near the Paleocene/Eocene boundary, where foraminifers are infilled with calcite and recrystallized. Nannofossil preservation improves in the upper Paleocene and is moderate throughout the lower Paleocene. Planktonic foraminifer are overgrown in the lower Paleocene but are still useful for biostratigraphy. Almost all lower upper Eocene to lower Paleocene nannofossil and planktonic foraminiferal zones were recognized indicating that the sequence is complete except for two 1- to 2- m.y.-long hiatuses. The first hiatus coincides with the Unit II claystone and foraminfer packstone in the lowermost middle Eocene. A second hiatus occurs in the upper Paleocene where calcareous nannofossil Zone CP5 is missing.

Shipboard magnetostratigraphy was noisy, but a useful polarity pattern was obtained in both holes. Polarity interpretations were straightforward for the middle Eocene and upper Paleocene portions of the section and corroborate the biostratigraphic information. A well-defined magnetostratigraphy was obtained for the lower Eocene, but the sequence of polarity zones does not match the nannofossil biostratigraphy. A sequence of normal-polarity zones appears to have the right pattern and spacing to correspond to Chrons C23n through the base of C24n. However, nannofossil biostratigraphy suggests that the lower sequence of apparent normal-polarity intervals should correspond with the middle of Chron C24r (calcareous nannofossil Zone CP9a).

Color cycles are visible in nearly the entire sequence, with the exception of lithologic Subunits IA and IB and Unit II. The lower half of Subunit ID between 300 m to 380 m is badly biscuited by XCB coring and the record of color cycles is incomplete. The cycles in the middle Eocene may represent the 41-k.y. obliquity periodicity as judged from sedimentation rates determined by the biostratigraphy. In contrast, the Paleocene and early Eocene color records correspond more closely to a 23-k.y. precessional periodicity. The combination of lithologic cycles in the core and downhole log data should provide a high quality cyclostratigraphy that could enhance both the magnetochronology and biochronologies, as well as improve correlation between sites in the depth transect.

Hole 1051A was logged with three tool strings: the Triple Combo (natural gamma-ray, resistivity and formation density), the Formation MicroScanner (FMS) and the Geological High-Sensitivity Magnetometer (GHMT). The Sonic Digital Tool (SDT) was not used because of an apparent electrical incompatibility between the sonic and FMS tools that we were not able to fix during the time available for logging. Hole conditions were excellent with average diameter of 11 in and occasional washouts to about 15 cm. The hole was logged between 120 to 643 mbsf. Most of the logs clearly define the structure and depth of the lower-to-middle Eocene unconformity, as well as a prominent interval of soft-sediment deformation in the lower Eocene between 455 and 475 mbsf. Likewise, there are pronounced increases in gamma-ray, thorium, and magnetic susceptibility at ~510 mbsf that correspond to the depth of the benthic foraminifer extinction horizon, the lithologic evidence for soft-sediment deformation, and an increase in clay content. The transition from the upper Paleocene siliceous nannofossil chalk to diatomaceous nannofossil claystones (lithologic Unit IV) is associated with a gradual drop in magnetic susceptibility, as well as increases in gamma-ray attenuation and uranium content. The FMS produced high quality logs in two separate runs. The resistivity and magnetic susceptibility data from the FMS should help to produce a complete cyclostratigraphy for the Paleocene to lower-middle Eocene that will complement and check the cyclostratigraphies compiled from core measurements.

Sediments at Site 1051 are very low in organic matter, and gas samples consist largely of small quantities of methane and ethane. Both the inorganic chemistry of pore waters and analysis of gas samples detected marked changes in composition above and below the claystone and foraminifer packstone at about 380 mbsf. For example, strontium, lithium, calcium, and magnesium all show a clear shift in concentration across the hiatus. Apparently, the claystone acts as a seal that prevents upward flow of gas and pore waters. The same level also corresponds to an abrupt drop in carbonate content from about 75% to about 50%.

Site 1052

Site 1052 is the shallowest site in the Blake Nose depth transect. The site is presently at 1342.9 mbsl and is within the depth range of modern intermediate waters. The MCS seismic profile Line TD-5 suggests that the lower-to-middle Eocene interval is substantially thinner at Site 1052 than it is at deeper sites. Conversely, the upper Eocene was expected to be thicker here than at the down dip sites. Principal objectives were to extend the depth transect up the slope of Blake Nose to study Eocene intermediate water structure, as well as to recover a sequence of upper Eocene strata that could be used to improve the chronology of this interval. As part of these Eocene objectives, we hoped to recover a continuous upper Eocene section that might include debris from upper Eocene tektite strewn fields. In addition, the site was chosen to recover a thick Cretaceous section that was deposited at water depths as much as 1500 m shallower than those cored at Site 1049. Recovery of the Cretaceous sequence we hope will include an expanded Maastrichtian and Aptian-Albian sequence for comparison with age equivalent strata at Site 1049. Of particular interest was recovery of a coeval upper Aptian laminated claystone ('black shales') horizon similar to the one found at Site 1049.

Virtually all these goals were met at Site 1052. The middle and upper Eocene section proved to contain well-preserved calcareous and siliceous microfossils, a very clean magnetostratigraphic signature, clearly defined cyclostratigraphy, and lacked unconformities between the top of Chron 19r (~41.6 Ma) and the top of the recovered section (~35 Ma). We recovered Chron C16n.1n in which the upper Eocene tektite strewn field is believed to occur, although we were not able to identify the tektite horizons. The completeness of the middle and upper Eocene section as defined by detailed chronostratigraphy will enable us to document the oceanic changes associated with the transition from the warm early Eocene to a cool late Eocene world in the low-latitude Atlantic Ocean. Cores from this site include a thick sequence of Danian and Maastrichtian strata that include a mostly complete K/T boundary sequence. We also penetrated a thick section of lower Cenomanian and upper Albian rocks at this site. These include laminated claystones that appear to represent low-oxygen environments near the shelf-slope break. The middle Cretaceous section contains a diverse assortment of calcareous microfossils, as well as ammonites that retain the iridescent luster of their aragonitic shells. The calcareous microfossils are extremely well preserved and ideal for meaningful stable isotope studies. Recovering the beautifully preserved middle Cretaceous assemblages was one of the main objectives of Leg 171B. Shore-based studies will document sea-surface and deep-water conditions during the middle Cretaceous warm period. Our one disappointment was not recovering the updip correlative section of the upper Aptian black shale sequence found at Site 1049.

Six holes were drilled at Site 1052. We divided the section into five lithologic units based on variation in microfossil and siliciclastic content, sedimentary structures, and color. Lithologic Unit I consists mainly of nannofossil or calcareous ooze with varying amounts of foraminifers and siliceous microfossils, and is subdivided into three subunits. The uppermost is a <5-m-thick layer of foraminifer sands and manganese nodules that is present across the entire Blake Nose transect. Foraminifers in this surficial layer range in age from Oligocene to Holocene and include substantial numbers of lower and middle Miocene taxa. The manganiferous foraminifer sands rest on pale yellow middle Eocene siliceous nannofossil ooze. As at Sites 1050 and 1051, a dramatic color change from pale yellow to light greenish gray occurs within the upper part of the Eocene ooze sequence. The Eocene section is generally well magnetized and contains an excellent record of cyclic variations in color and magnetic susceptibility, as well as a clear magnetic polarity stratigraphy. The youngest Eocene sediments belong to magnetochron C15r, planktonic foraminifer Zone P16 and the upper part of calcareous nannofossil Zone CP15b. There do not appear to be any substantial hiatuses within the Eocene section above Chron 19r, suggesting a long-term average sedimentation rate of about 2.8 cm/k.y.

Lithologic Unit II is divided into a ~33-m-thick interval with very pale upper lower to middle Eocene green nannofossil chalk and foraminifer chalk with chert layers and chert nodules and a ~38.4-m-thick interval composed of upper-lower to middle Eocene dark greenish gray to grayish green porcellanitic calcareous claystone. Recovery in the calcareous claystones was very poor, and drilling induced fragmentation is severe throughout due to the presence of chert layers. An extremely condensed section occurs at the base of this unit, where upper Paleocene to middle

Eocene microfossils are mixed in a 5-m-thick interval of foraminiferal packstones, claystones, and chert. The unconformity partially represents the updip continuation of the hiatuses present in the upper Paleocene and middle Eocene at Site 1051, with the addition of the updip pinchout of all of the lower Eocene and a large part of the middle Eocene. We did not recover most of the upper Paleocene at Site 1052 because we suspect that the lithified layers tended to jam in the bit and cause the softer interbeds to wash away. Still, it is apparent that highly condensed sections of upper Paleocene and lower Eocene rocks on Blake Nose, like those present at Sites 1049 and 1052, tend to contain much more chert than the relatively expanded sections cored at Sites 1050 and 1051.

Lithologic Unit III is characterized by an alternation of dark greenish gray lower-to-upper Paleocene calcareous claystones and lighter greenish gray nannofossils with clay, and the colors grade downhole into light greenish gray. The top of this unit is defined at the lowest occurrence of chert, but the nature of the contact is not known due to poor recovery. The base of the unit is the K/T boundary where color changes from more uniform light gray to variable, mostly olive, tones. All told, the Danian and early part of the late Paleocene are represented by nearly 100 m of section. Microfossils tend to be moderately preserved through most of the section, although preservation improves markedly in the early Danian. The lowest part of the Paleocene appears to include a small portion of the lowermost Danian planktonic foraminifer Zone Pa, but the boundary ejecta bed was not recovered. However, some green spherules and quartz grains occur within burrows in lowermost Paleocene sediment.

Lithologic Unit IV includes an 87-m-thick interval that contains mostly greenish gray to light greenish gray Maastrichtian clayey nannofossil chalk and an 89-m-thick light greenish gray Maastrichtian nannofossil chalk to nannofossil chalk with clay. The uppermost Cretaceous is present (calcareous nannofossil Zone CC26b). We suspect that only a short section of the K/T boundary was not recovered. The entire Maastrichtian section exhibits meter-scale color cycles and slump deposits. Parts of the unit are faulted, but the faults appear to be contained within this lithologic unit, because major displacements that cut across older and younger strata are not evident on the MCS seismic Line TD-5. The middle part of the Maastrichtian appears to be relatively complete and to be almost completely recovered. Therefore, this section should be useful for studies of the climate history and biotic turnovers associated with the middle Maastrichtian. The base of the Maastrichtian is associated with a series of slump beds that contain reworked Coniacian nannofossils and rest directly on Cenomanian limestones and interbedded siltstones.

Lithologic Unit V includes hemipelagic Cenomanian to upper Albian sediments with a greater amount of terrigenous components than overlying sediment. Seismic profile MCS TD-5 shows that the Cenomanian-Albian sequence consists of two sets of clinoforms built over and to the northeast of a buried reef complex. The lower Cenomanian is a thin drape over a much thicker package of late Albian clinoforms, and the two appear to be partly unconformable. However, neither planktonic foraminifer nor nannofossil stratigraphy identify a substantial unconformity in Albian and Cenomanian rocks.

The Cenomanian includes dominant dark olive gray calcareous silty claystone to clay-rich siltstone. The sediment color varies from an olive gray to black, and darker intervals have a greater abundance of terrigenous components. An interval of small slumps and glauconite beds separates the Cenomanian from upper Albian deposits. The Albian sequence consists of green massive claystone alternating with dark laminated greenish-black claystones. The laminated claystones are rich in pyrite and contain clay with varying amounts of calcareous nannofossils, fine silt-sized quartz, fish remains, well-preserved ammonites, and organic debris. Total organic carbon content is always less than about 1 wt% and even the darkest laminated claystones are poor source rocks, because they are dominated by humic material. Indeed, gas content is uniformly extremely low throughout the rocks at Site 1052 and consists mostly of methane. Interbedded with the laminated claystones are lithified, coarser grained intervals that contain foraminifers, shallow-water limestone fragments and quartz. Color varies from light olive gray in the limestones to very dark olive gray in the more laminated rocks. Laminated claystones are more abundant and thicker toward the top of the Albian section. Near the bottom of Hole 1052E, the Albian sequence becomes dominated by slight to moderately bioturbated dark (dark olive gray) sandy siltstones clearly deposited in middle or outer shelf environments. These sandstones were probably deposited near storm wavebase, as suggested by the occurrence of well-sorted grainstones that are often features associated with sand-waves. Apparently, the entire upper Albian clinoform stack represents a deepening upward package.

Albian and Cenomanian rocks all have normal polarity consistent with the Cretaceous Long Normal Chron C34n (Fig. 12). Rocks of this age were generally recovered in long coherent sections of core, which allowed us to collect high quality data on the inclinations associated with the natural remnant magnetizations of the rocks. Calculation of paleolatitude from these data suggests that Blake Nose was located at 23°N during the late Albian and early Cenomanian. These results are based on >700 data points and are statistically well constrained. The calculated paleolatitude is much less than the previously published estimates of North American paleolatitude of 30°N for Blake Nose during the Hauterivian to Santonian. Apparently, in previous reconstructions the middle Cretaceous North American pole has been placed approximately 1000 km too far southward with respect to the southeastern United States.

Site 1053

Site 1053 is located at the top of an escarpment cut into the upper part of Blake Nose. The location of Site 1053 was chosen to recover middle Eocene to upper Eocene deposits and extend the depth transect into water depths (~1652 mbsl) equivalent to the depth of modern intermediate waters. The MCS seismic profile Line TD-5 suggests that the middle Eocene interval is about as expanded at Site 1053 as it is at Site 1051. Reflectors in the MCS line indicate that a substantial thickness of upper Eocene and younger sediments not found at deeper sites is present at Site 1052. The upper Eocene section is expected to contain a high temporal resolution record of ocean structure, magnetic reversals, and biological evolution, particularly during times of rapid climate change like the late Eocene-Oligocene onset of glaciation and the early to middle Eocene cooling. The lithologic cycles should provide a high quality cyclostratigraphy to enhance both the magnetochronology and biochronologies, as well as improve correlation between sites in the depth transect. The primary reason for drilling this site was to extend the depth transect up the slope of Blake Nose for studies of Eocene deep-water structure. An additional goal was to recover sediments belonging to the upper Eocene and possibly the Eocene/Oligocene boundary that could be used to describe the timing of the onset of Antarctic glaciation and debris from upper Eocene tektite strewn fields.

Site 1053 recovered an exceptionally thick upper Eocene section consisting mainly of siliceous nannofossil ooze. This thick section might reflect periods of increased productivity in the surface waters or enhanced preservation on the seafloor.

The top of the cored interval is a 5- to 37-cm-thick layer with manganese nodules and a drilling slurry of clayey foraminifer ooze that is rich in phosphatic debris, including fish scales and vertebrae. Below this is ~12.5 m of pale yellow upper Eocene siliceous nannofossil ooze with varying amounts of foraminifers and clay. As at Sites 1050, 1051, and 1052, there is a sharp color change from pale yellow to light greenish gray. This sharp color change is time-transgressive across the four sites, and there is no discernible compositional difference in the sediment across this boundary. Green siliceous nannofossil ooze is ~126 m thick in Hole 1053A and ~114 m thick in Hole 1053B. Several ash layers are present, including a distinctive 8-cm-thick, highly altered, clay- and diatom-rich layer. At least 20 species of diatoms are present in this layer, whereas diatoms are not abundant or diverse elsewhere at Site 1053. Preservation of diatoms in this layer may have been enhanced due to leaching of silica during ash alteration. The lowermost 50 m of cored section consists of middle Eocene greenish gray chalk with varying amounts of nannofossils, siliceous microfossils, and clay. Drilling disturbance has resulted in slight to heavy biscuiting in the core.

Light/dark color alternations within the greenish sediment are often visible, with the darker intervals being more clay-rich. Correlating the two holes, however, by using magnetic susceptibility and GRAPE density data from the MST track and the Minolta color spectrophotometer proved to be difficult, as the signals were noisy mainly because of significant bioturbation. Nevertheless, the shipboard composite section shows that most likely a complete record was recovered.

Shipboard paleomagnetic results were not straightforward and need to be improved by post-cruise analysis of discrete samples. However, a detailed biostratigraphy was obtained by integration of nannofossil, planktonic foraminifer, and radiolarian datum levels. The radiolarians in particular appear to be very useful at this site. We expected to find evidence for upper Eocene meteor impacts near two well-defined extinction levels of radiolarians in the upper Eocene. The extinction levels were found, but tektites were not visible in the sediment, probably due to extensive bioturbation. We are hopeful that shore-based research will detect the tektites and other evidence for impact debris. Detailed biochronological control and excellent preservation of the calcareous microfossils make this site suitable for meeting our paleoceanographic objectives.

CONCLUSIONS

The objective of Leg 171B was to drill five shallow sites in a transect from the margin of the Blake Plateau to the edge of the Blake Escarpment. The primary cruise objectives in the Leg 171B

Prospectus are outlined below (italics) along with a brief description of how successful the cruise was in meeting these objectives.

1. *Interpret the vertical structure of the Paleogene oceans and test the Warm Saline Deep Water hypothesis near the proposed source areas, with a related objective to provide critically needed low-latitude sediments for interpreting tropical sea-surface temperature (SST) and climate cyclicity in the Paleogene.*

We recovered sediments of Eocene through middle Cretaceous age that form a drape over the Blake Nose. We were able to obtain depth transects of 600- to 700-m water depth in the middle and upper Eocene, and 1200 m in the Danian, the Maastrichtian, and the Cenomanian-late Albian. Sediments of all these ages contain well-preserved calcareous microfossils suitable for geochemical and paleontological study of the vertical structure of the ancient oceans. Furthermore, cyclostratigraphy expressed in color, magnetic susceptibility, and downhole logging data suggest that the duration of magnetozones and biochrons in much of the Paleogene section can be partially tuned to an astronomical time scale. The upper middle Eocene, upper Eocene and the Danian contain particularly well developed cyclic records.

2. *Recover complete Paleocene/Eocene and Cretaceous/Paleogene boundaries along a depth transect to describe the events surrounding the boundaries and water depth-related changes in sedimentation of the boundary beds.*

We had spectacular success recovering five copies of the K/T boundary at three sites along the Blake Nose transect. Cores at Site 1049 will become classic examples of K/T boundary stratigraphy and micropaleontology, as they contain well-preserved microfossils, an unusually thick ejecta deposit, and a well-preserved record of the repopulation of the world’s oceans after one of the largest extinctions to sweep the Earth. We also recovered a complete, or nearly complete record of the upper Paleocene benthic foraminifer extinction. This horizon was complete at only one site, but the sediments retain a record of calcareous microfossils, cyclostratigraphy, and magnetostratigraphy that will greatly advance our knowledge of an event that is represented by unconformities at nearly all sites in the Atlantic Ocean.

3. *Interpret the thermocline and intermediate water structure of the low-latitude Cretaceous oceans and refine the biochronology and magnetochronology of this period.*

Cores of Maastrichtian chalks and ooze are sufficient for detailed studies of the late Maastrichtian cooling and mid-Maastrichtian extinction event. Likewise, Site 1052 recovered a superb record of lower Cenomanian/upper Albian laminated sediments and well-preserved microfossils that will be used for studies of surface water temperatures during the middle Cretaceous warm period and the paleoceanography of the 'Oceanic Anoxic Events.' Finally, the excellent preservation of both nannofossils and planktonic foraminifers throughout the Aptian, Albian, and Cenomanian will lead to significant improvements in our understanding of the diversity and evolution of these microfossil groups.

4. *Study the rate and mode of evolution of marine biota in the Cretaceous and Paleogene oceans*.
Leg 171B recovered very well preserved calcareous microfossils, siliceous microfossils, and ammonites suitable for evolutionary and paleoecological study. Fossil material for the middle and late Eocene, Danian, Maastrichtian, and mid Cretaceous (Cenomanian-Aptian) is typically very well preserved. Both radiolarians and calcareous microfossils are abundant and well preserved throughout the middle and upper Eocene and will be used to improve our biochronology as well as in analyses of the evolution of these groups in relation to the upper Eocene meteorite impacts and the long-term Paleogene cooling trend. Foraminifers and diatoms are well preserved in the Danian, and the calcareous fossils all have excellent records across the K/T boundary. The boundary sections we recovered contain much more expanded records of the immediate aftermath of the K/T extinction than have been recovered before by deep-sea drilling. The Maastrichtian section is notable for a striking record of the mid-Maastrichtian extinction, which is marked by an abrupt change in bioturbation intensity and the disappearance of the inoceramid bivalves. The preservation of foraminifer assemblages in the Cenomanian and Albian is amazingly good and will be used in paleoceanographic studies, as well as analyses of paleoecology and depth habitats. Ammonites are frequently preserved in the Albian sequence with the original aragonitic shell and will be used to integrate ammonite and planktonic microfossil biochronologies as well as biogeographic studies.

5. *Investigate plate motions using the paleomagnetic signal.*
Shipboard data on Cretaceous magnetostratigraphy strongly suggest that the established polar wander path for North America requires fundamental revision. We have increased the number of measurements of middle Cretaceous paleomagnetic poles by a factor of more than 100. Data for the Eocene were not processed shipboard, but we collected oriented cores at all the sites that will be used to greatly improve the polar wander fits for the Eocene.

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FIGURE CAPTIONS

Figure 1. ODP Leg 171B Blake Nose paleoceanographic drilling area in the western North Atlantic. Box locates area shown in Figure 2.

Figure 2. ODP Leg 171B Blake Nose transect drill sites and the multichannel seismic Line TD-5. The MCS line with the drill site locations is shown in Figure 3.

Figure 3. Seismic interpretation of MCS Line TD-5 across Blake Nose showing the major reflectors, their ages, and location of drill sites. The location of the seismic line is shown in Figure 2.

Figure 4. Stratigraphic summary of Sites 1049-1053 on the drilling transect.

Figure 5. Susceptibility (bold line) and color (lighter line) in a series of 25-m panels that cover part of the mid-late Eocene section recovered at Site 1052. Both measurements show variability with a wavelength of ~1 m, which probably reflects variations in the Earth-Sun orbital geometry (Milankovitch cycles) that will be investigated post-cruise for use in cyclostratigraphy and orbital timing. Note that the color code is (L*a*b) times -1 to facilitate comparison to magnetic susceptibility data.

Figure 6. Middle and late Eocene magnetostratigraphy at Site 1052. This site has a very well defined magnetostratigraphy that we will attempt to calibrate in terms of the absolute duration of the various chrons using the cyclostratigraphy (Fig. 5) clearly documented at this site.

Figure 7. Susceptibility and color across the Paleocene/Eocene interval at Site 1049 displays what may be a precessional orbital cycle. The wavelength of the cycles in the Eocene (average sedimentation rate 25 m/m.y.) is consistent with an obliquity signal, whereas those in the Paleocene (average sedimentation rate 18 m/m.y.) are consistent with a precession signal. The change in the wavelength of the cyclicity across the Paleocene/Eocene boundary suggests that both a change in the response of the climate system from precession to obliquity control and an increase in long-term sedimentation rates occurred close to the Paleocene/Eocene boundary. Mcd = meters composite depth.

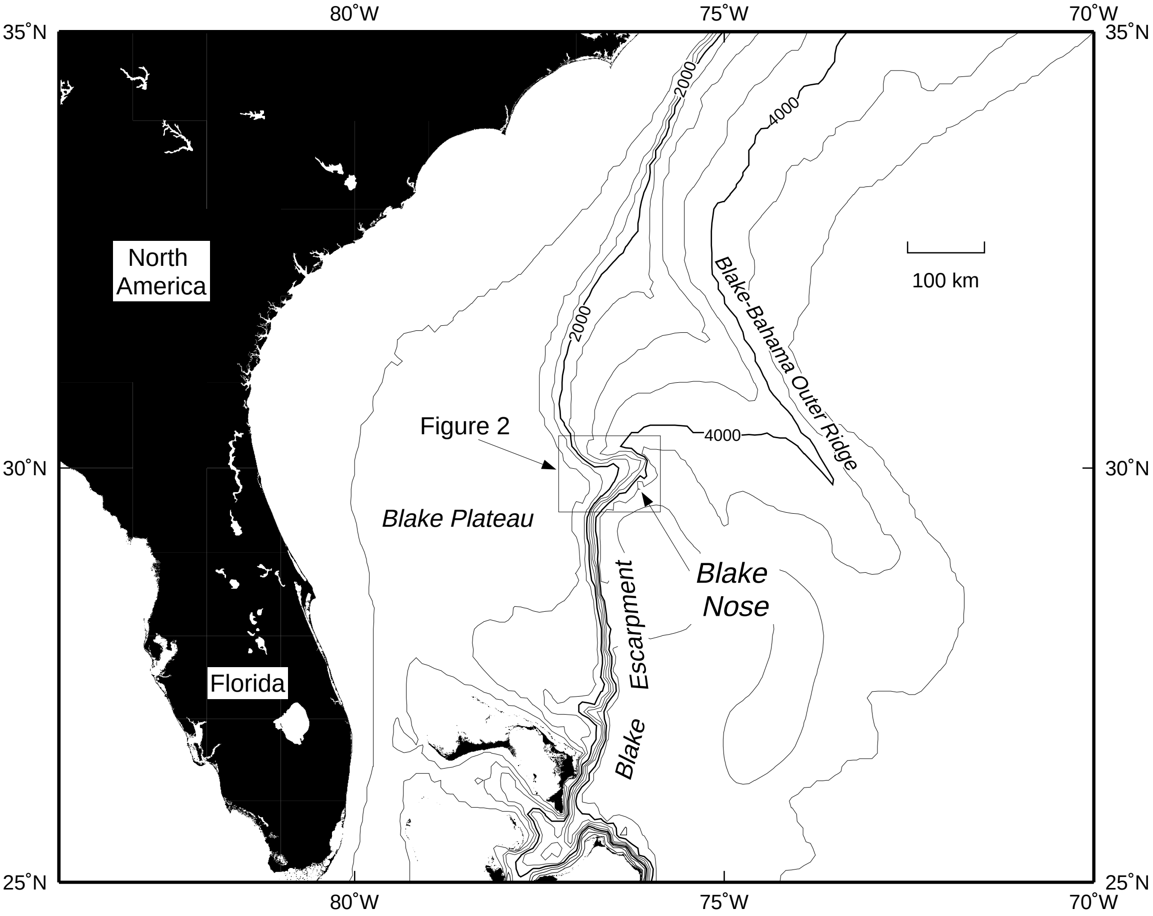
Figure 8. Summary of highly condensed interval in Core 1050C-20R that ranges in age from the late Turonian to late Campanian.

Figure 9. Lithium concentrations within pore waters at all Leg 171B sites.

Figure 10. The stratigraphic position of Cretaceous dark-gray laminated sediments recovered at Sites 1049, 1050, and 1052 in relation to the onlap curve of Haq et al. (1987).

Figure 11. Compilation of the three complete K/T boundary sections recovered at Site 1049 (Holes 1049A, 1049B, and 1049C).

Figure 12. Magnetostratigraphy of the lower portion of Hole 1052E. These high quality pmag data suggest Blake Nose was located at 23°N during late Albian and early Cenomanian, which is significantly different than the previously calculated paleolatitude of 30°N. Previous reconstructions have placed the middle Cretaceous North American pole 1000 km too far south.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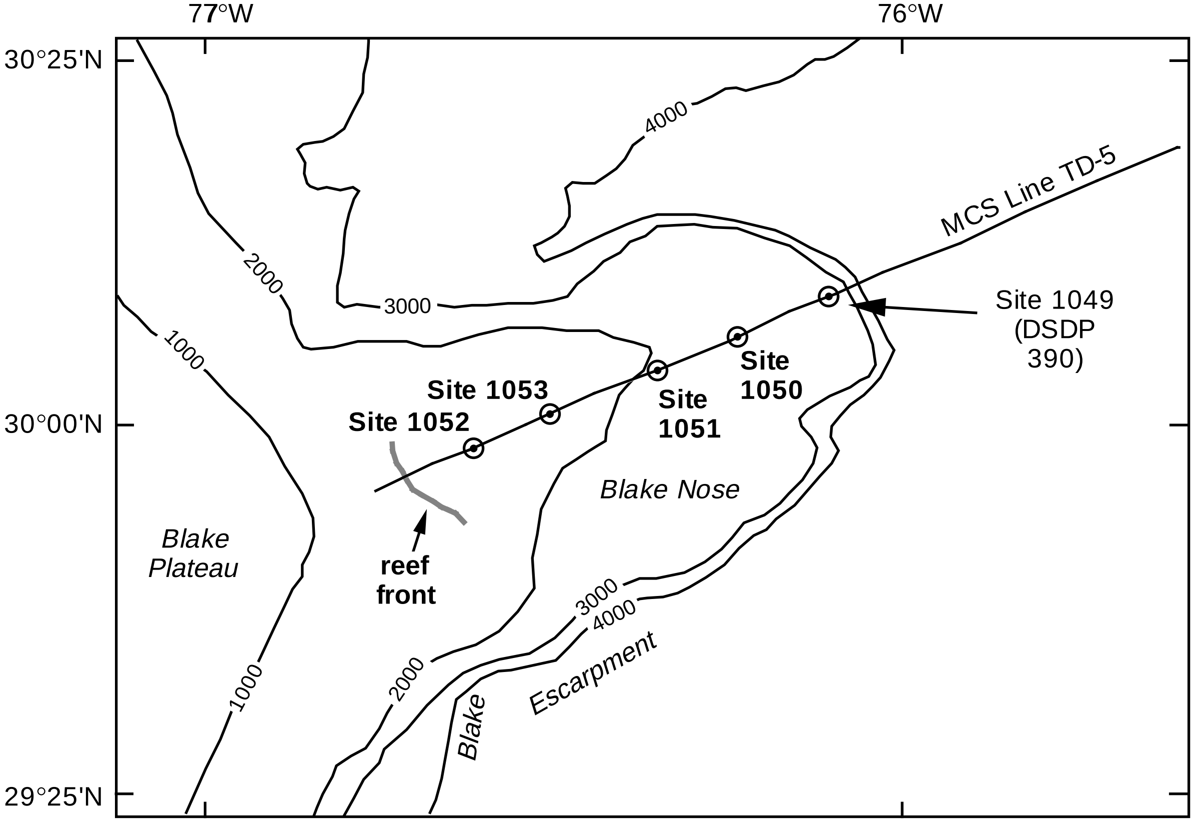
75°W
70°W
35°N
35°N
2000
4000
North America
100 km
2000
Blake-Bahama Outer Ridge
Figure 2
4000
30°N
30°N
Blake Plateau
Blake Nose
Escarpment
Blake
Florida
25°N
25°N
80°W
75°W
70°W

Figure 1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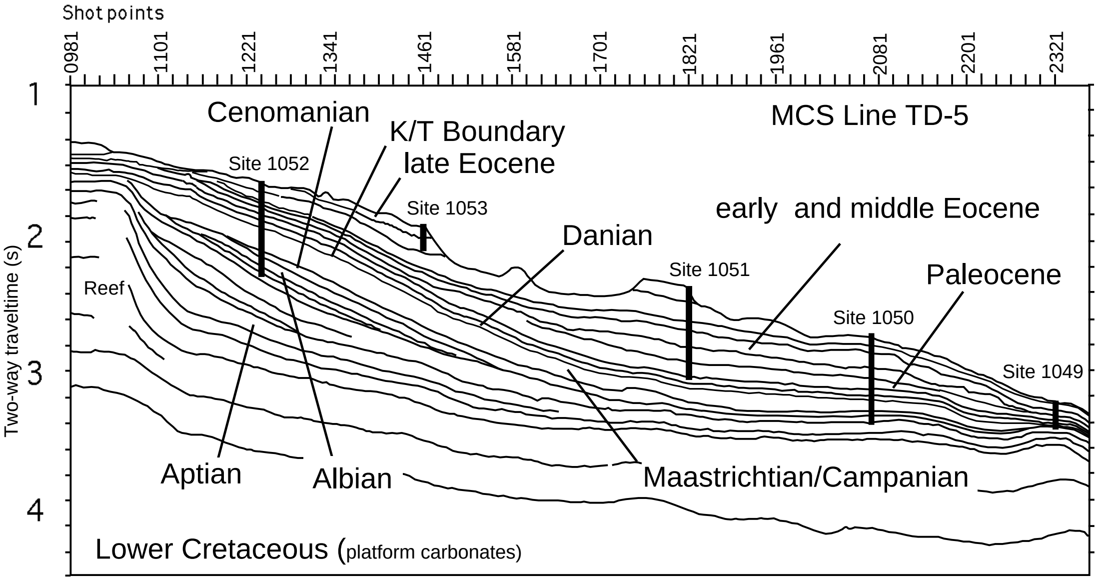
76°W
30°25'N
30°00'N
29°25'N
4000
3000
2000
1000
MCS Line TD-5
Site 1049
(DSDP
390)
Site 1050
Site 1051
Site 1053
Site 1052
Blake Nose
Blake
Plateau
reef
front
1000
2000
3000
4000
Blake
Escarpment

Figure 2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1221
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1461
1581
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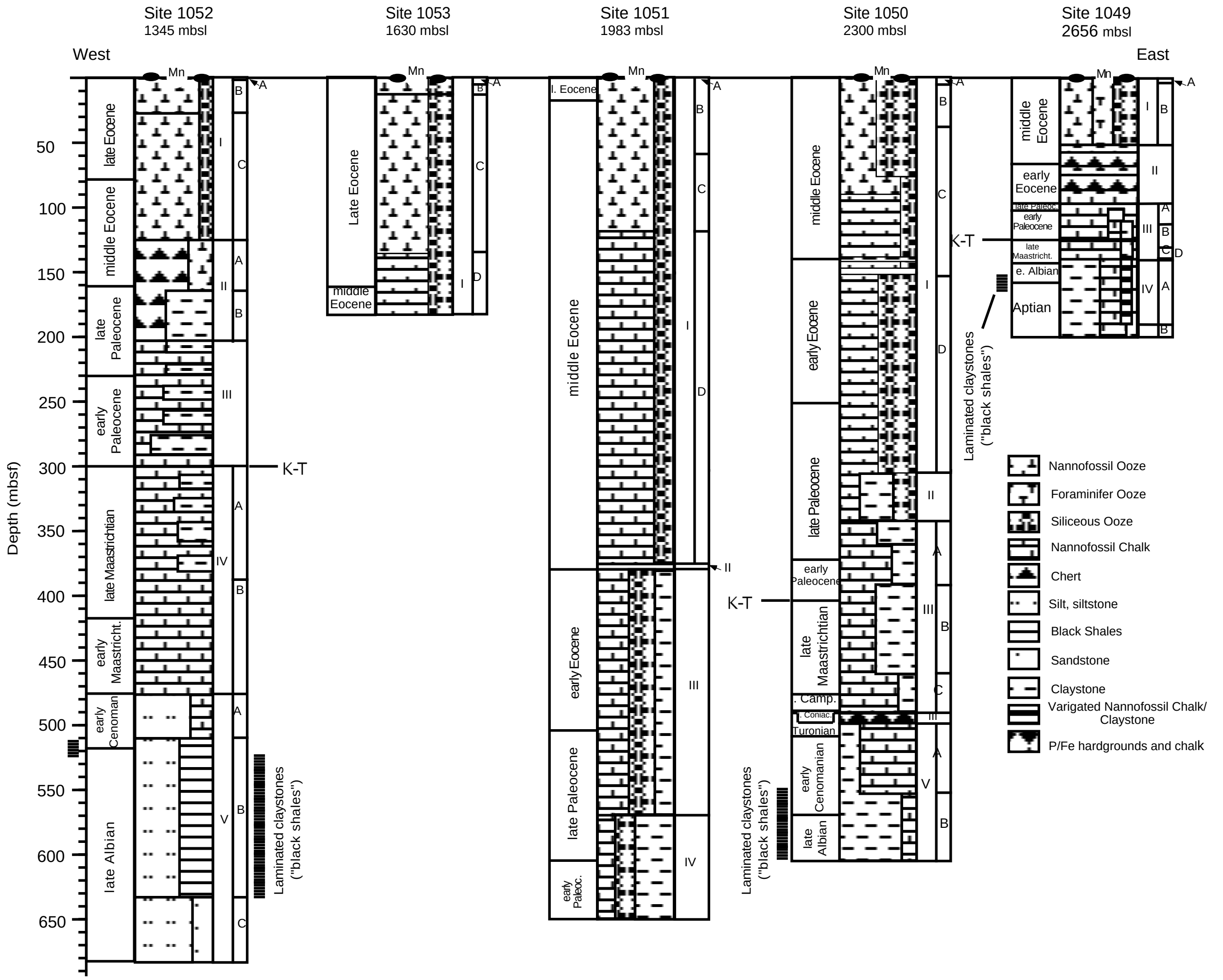
1961
2081
2201
2321
1
2
3
4
Two-way traveltime (s)
MCS Line TD-5
Cenomanian
K/T Boundary
late Eocene
Site 1052
Site 1053
Danian
early and middle Eocene
Site 1051
Paleocene
Site 1050
Site 1049
Reef
Aptian
Albian
Maastrichtian/Campanian
Lower Cretaceous (platform carbonates)

Figure 3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1345 mbsl
Site 1053
1630 mbsl
Site 1051
1983 mbsl
Site 1050
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West
East
Mn
A
B
C
D
I
II
III
IV
V
K-T
Depth (mbsf)
50
100
150
200
250
300
350
400
450
500
550
600
650
late Eocene
middle Eocene
late Paleocene
early Paleocene
late Maastrichtian
early Maastricht.
early Cenoman
late Albian
Late Eocene
middle Eocene
l. Eocene
early Eocene
late Paleocene
early Paleoc.
early Paleocene
late Maastrichtian
. Camp.
Coniac.
Turonian
early Cenomanian
late Albian
late Paleoc.
late Maastricht.
e. Albian
Aptian
Laminated claystones ("black shales")
Nannofossil Ooze
Foraminifer Ooze
Siliceous Ooze
Nannofossil Chalk
Chert
Silt, siltstone
Black Shales
Sandstone
Claystone
Varigated Nannofossil Chalk/ Claystone
P/Fe hardgrounds and chalk

Figure 4

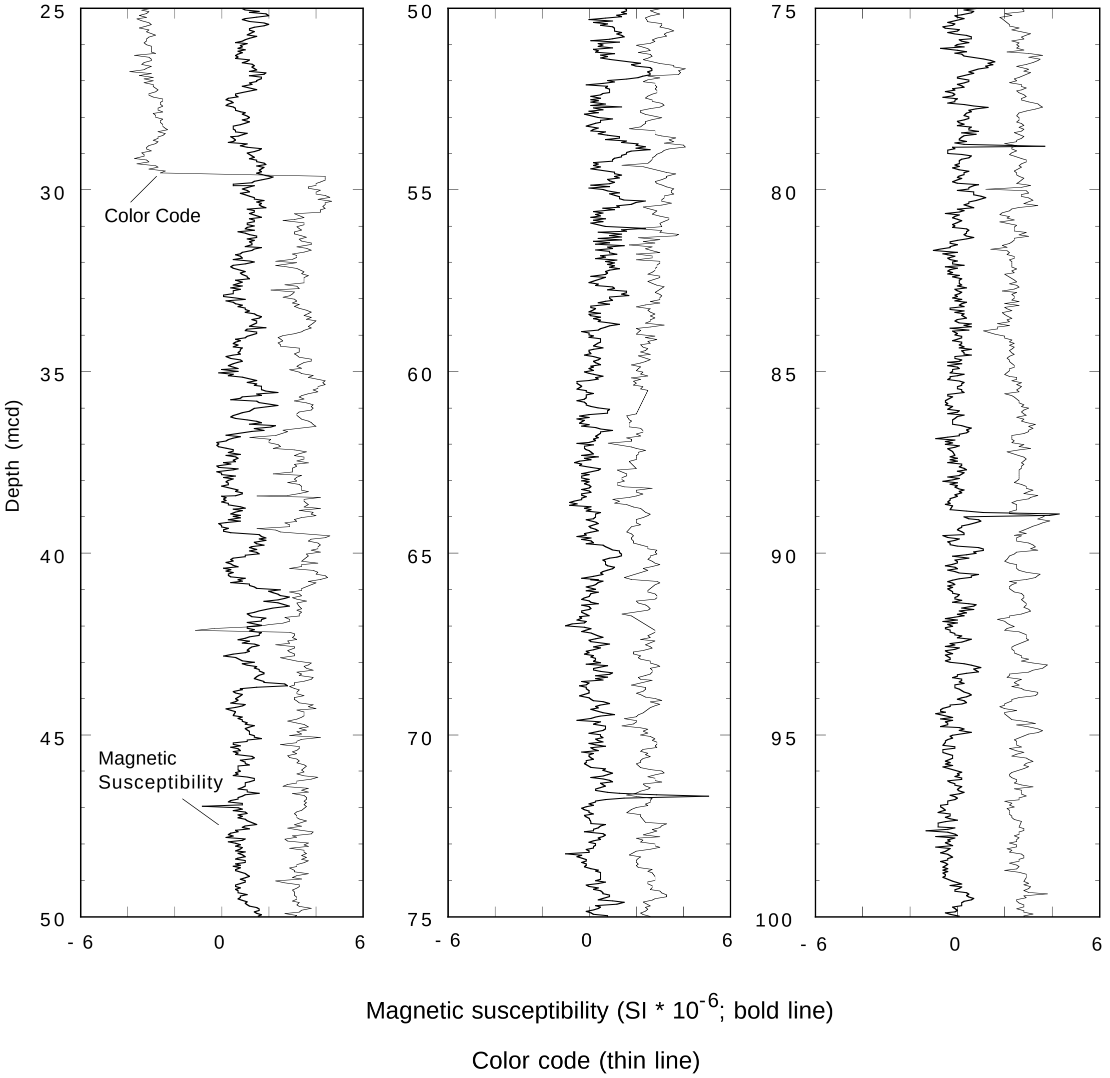

Depth (mcd)
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Color Code
Magnetic Susceptibility
- 6
0
6
Magnetic susceptibility (SI * 10^{-6}; bold line)
Color code (thin line)

Figure 5

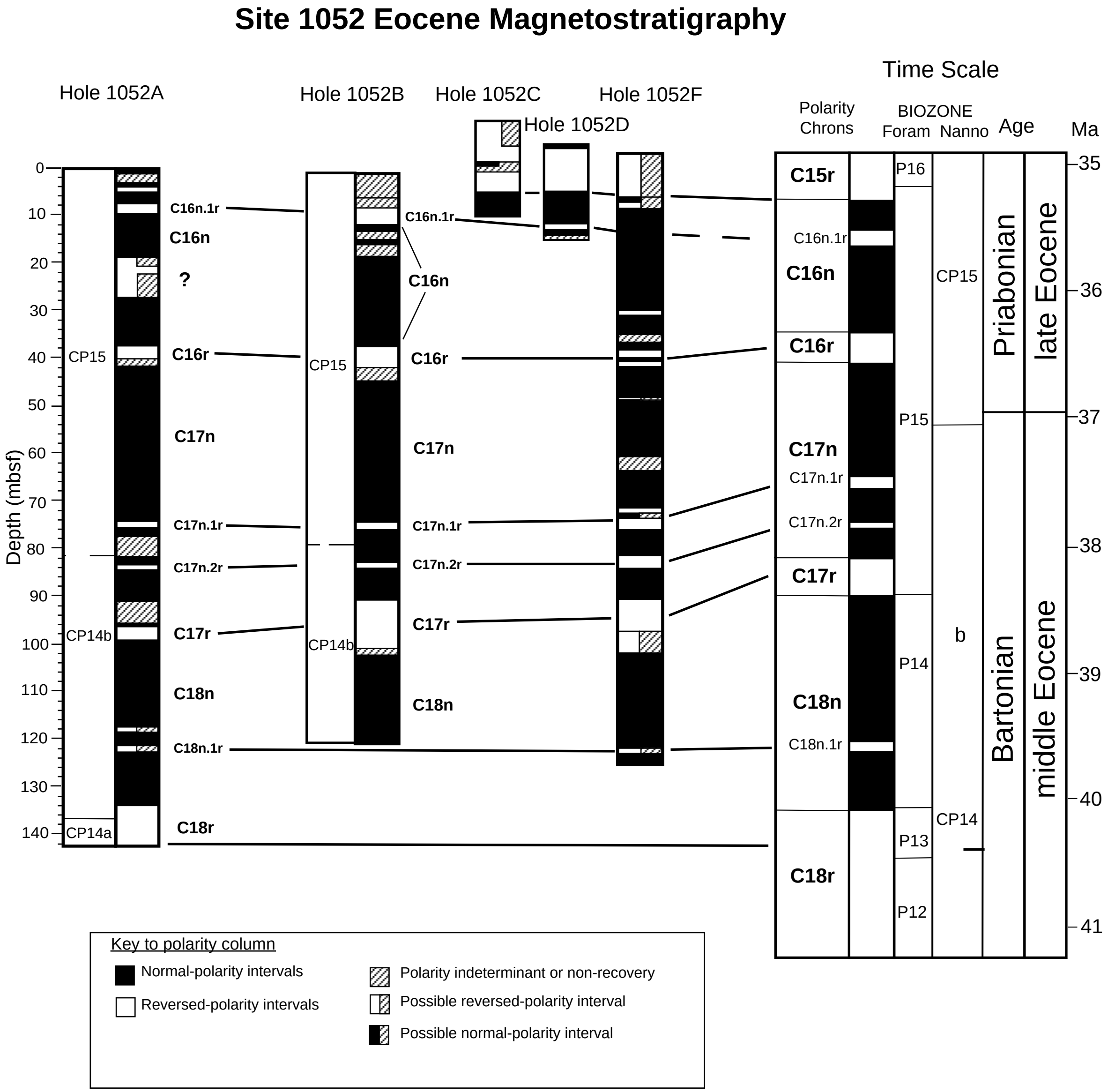

Site 1052 Eocene Magnetostratigraphy
Hole 1052A
Hole 1052B
Hole 1052C
Hole 1052D
Hole 1052F
Time Scale
Polarity Chrons
BIOZONE Foram Nanno
Age
Ma
Depth (mbsf)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
CP15
CP14b
CP14a
C16n.1r
C16n
?
C16r
C17n
C17n.1r
C17n.2r
C17r
C18n
C18n.1r
C18r
C15r
P16
P15
P14
P13
P12
CP15
b
CP14
Priabonian
Bartonian
late Eocene
middle Eocene
35
36
37
38
39
40
41
Key to polarity column
Normal-polarity intervals
Reversed-polarity intervals
Polarity indeterminant or non-recovery
Possible reversed-polarity interval
Possible normal-polarity interval

Figure 6

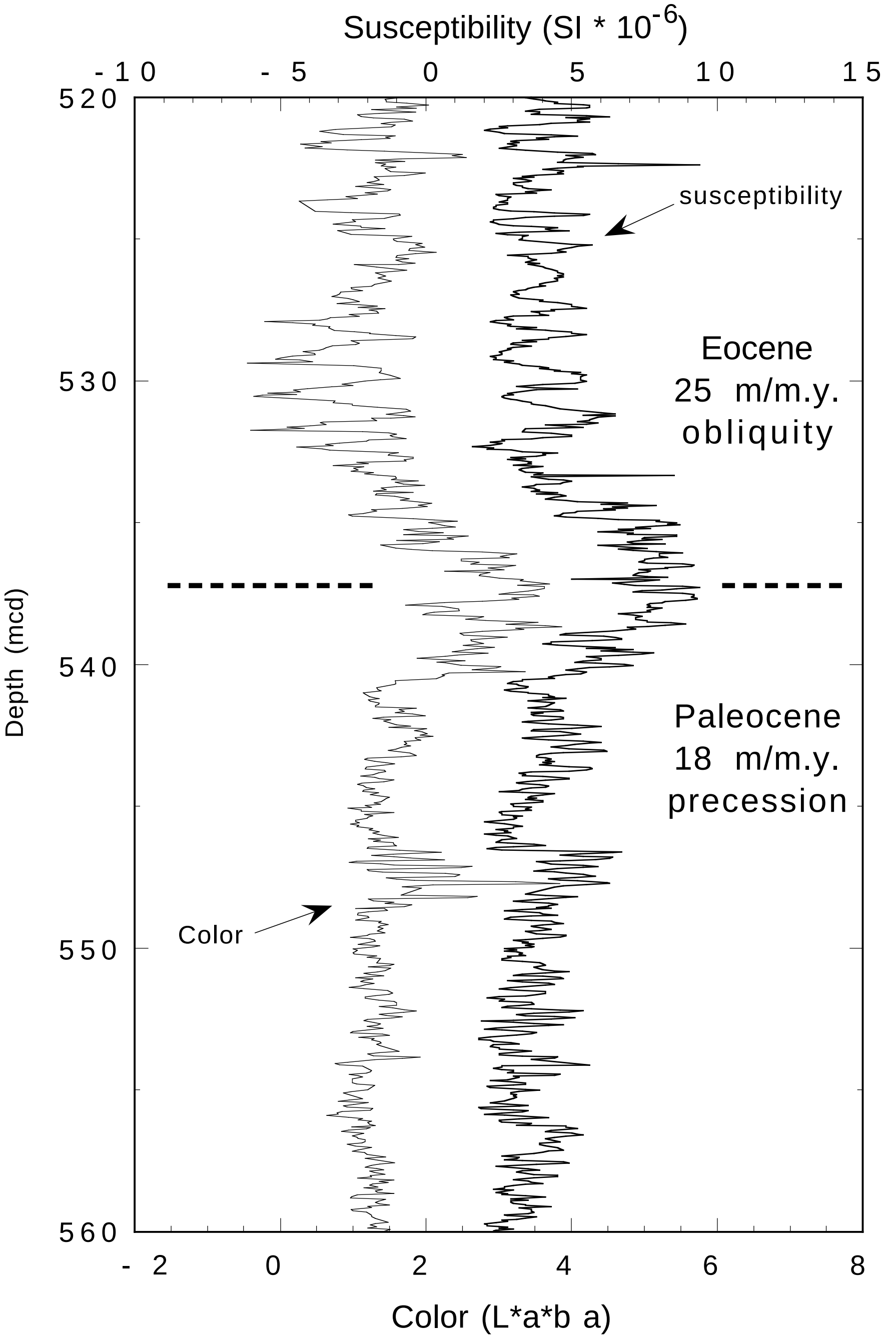

Susceptibility (SI * 10^{-6})
-10
-5
0
5
10
15
520
530
540
550
560
Depth (mcd)
susceptibility
Eocene
25 m/m.y.
obliquity
Paleocene
18 m/m.y.
precession
Color
-2
0
2
4
6
8
Color (L*a*b a)

Figure 7

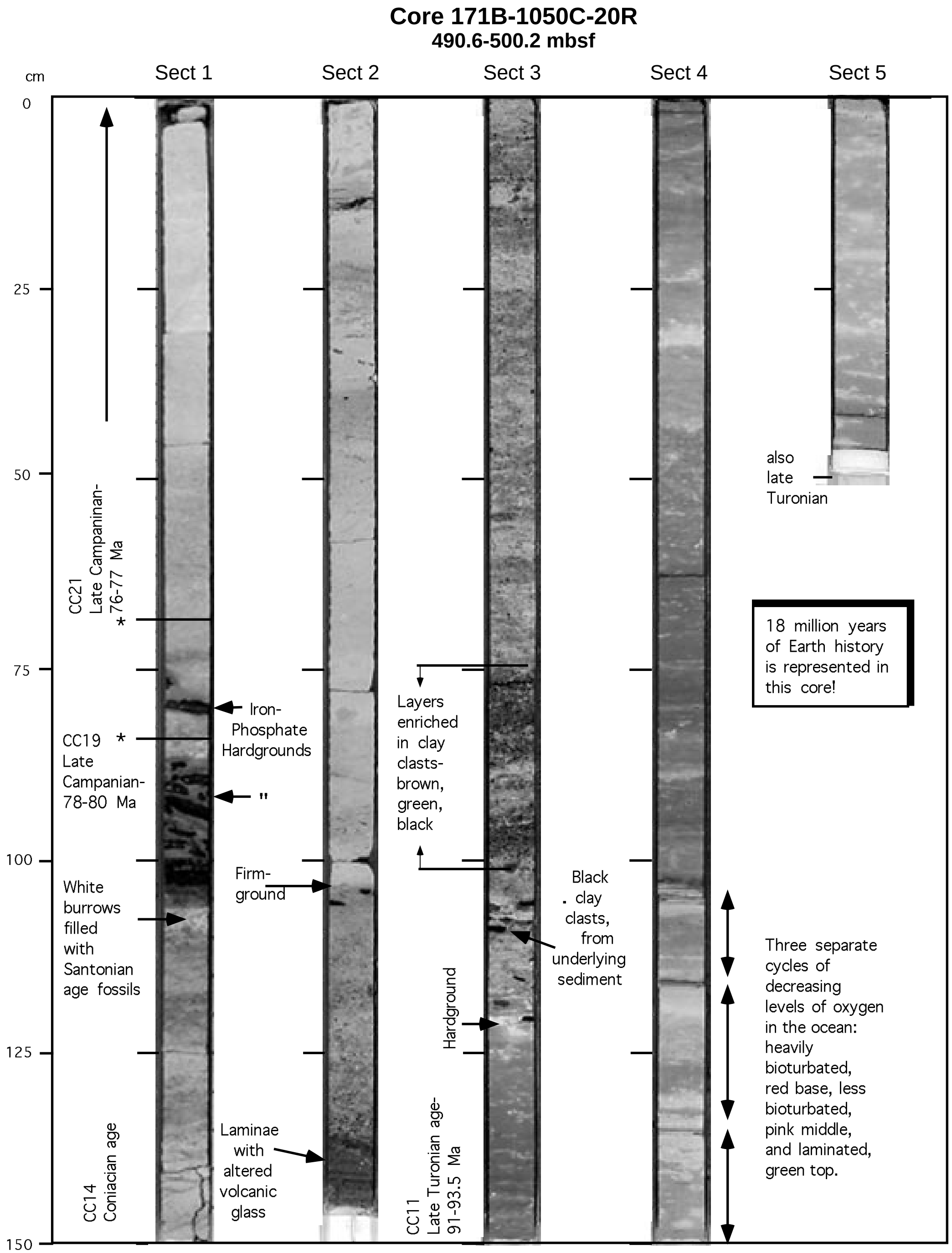

Core 171B-1050C-20R
490.6-500.2 mbsf
cm
Sect 1
Sect 2
Sect 3
Sect 4
Sect 5
0
25
50
75
100
125
150
CC21
Late Campaninan-
76-77 Ma
*
CC19 *
Late
Campanian-
78-80 Ma
Iron-
Phosphate
Hardgrounds
"
White
burrows
filled
with
Santonian
age fossils
Firm-
ground
CC14
Coniacian age
Laminae
with
altered
volcanic
glass
Layers
enriched
in clay
clasts-
brown,
green,
black
Black
clay
clasts,
from
underlying
sediment
Hardground
CC11
Late Turonian age-
91-93.5 Ma
also
late
Turonian
18 million years
of Earth history
is represented in
this core!
Three separate
cycles of
decreasing
levels of oxygen
in the ocean:
heavily
bioturbated,
red base, less
bioturbated,
pink middle,
and laminated,
green top.

Figure 8

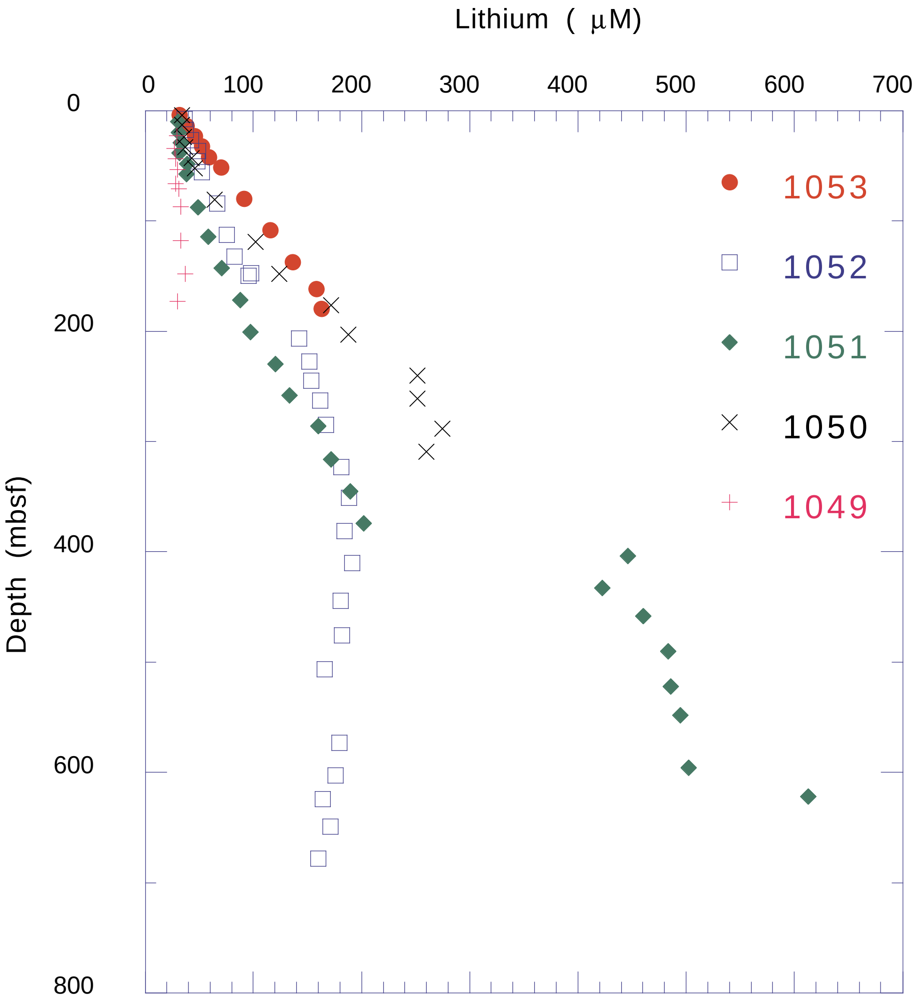

Lithium (µM)
0
100
200
300
400
500
600
700
0
200
400
600
800
Depth (mbsf)
1053
1052
1051
1050
1049

Figure 9

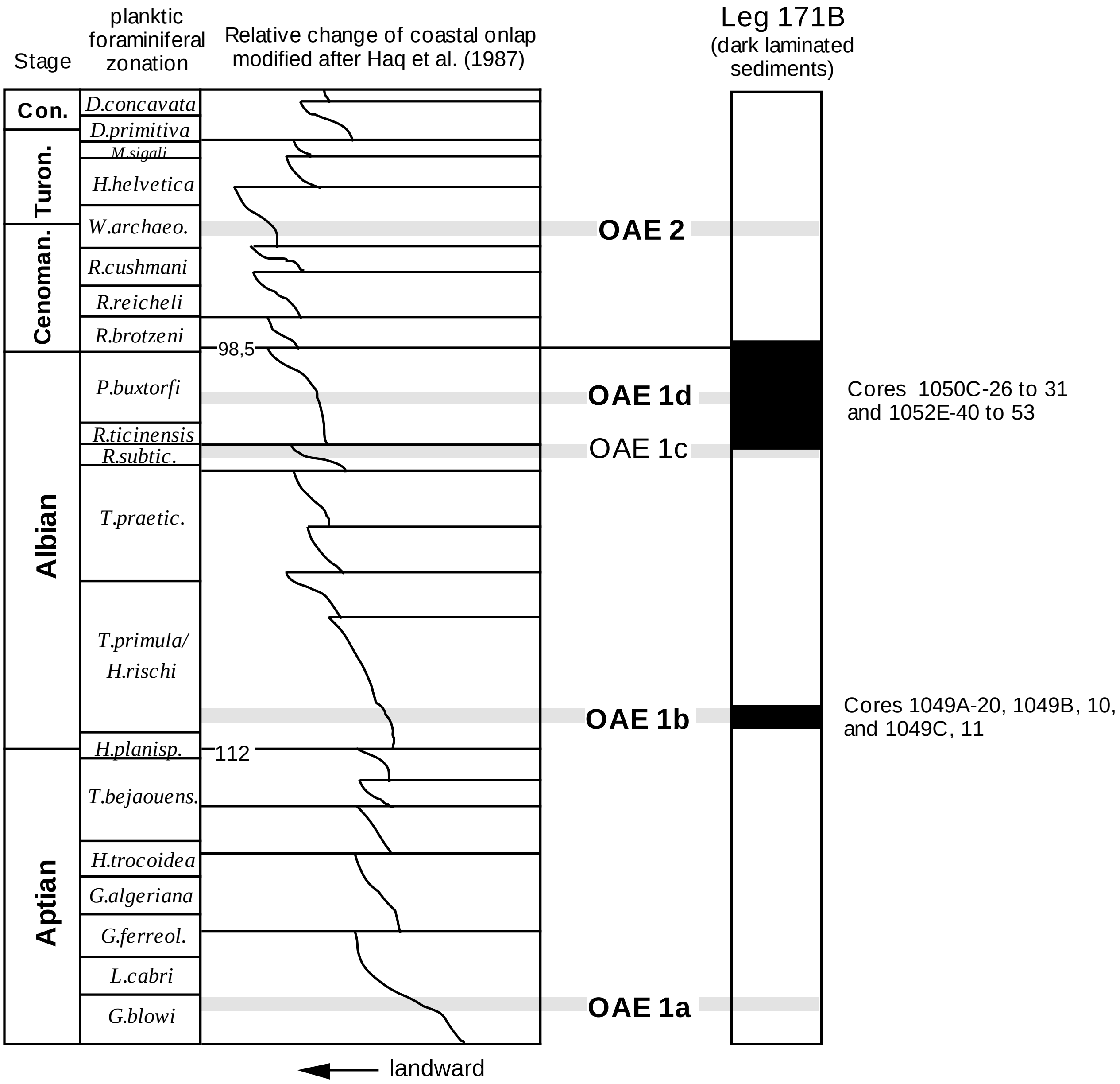

Stage
planktic foraminiferal zonation
Relative change of coastal onlap modified after Haq et al. (1987)
Leg 171B
(dark laminated sediments)
Con.
Turon.
Cenoman.
Albian
Aptian
D.concavata
D.primitiva
M.sigali
H.helvetica
W.archaeo.
R.cushmani
R.reicheli
R.brotzeni
P.buxtorfi
R.ticinensis
R.subtic.
T.praetic.
T.primula/ H.rischi
H.planisp.
T.bejaouens.
H.trocoidea
G.algeriana
G.ferreol.
L.cabri
G.blowi
98,5
112
OAE 2
OAE 1d
OAE 1c
OAE 1b
OAE 1a
Cores 1050C-26 to 31 and 1052E-40 to 53
Cores 1049A-20, 1049B, 10, and 1049C, 11
landward

Figure 10

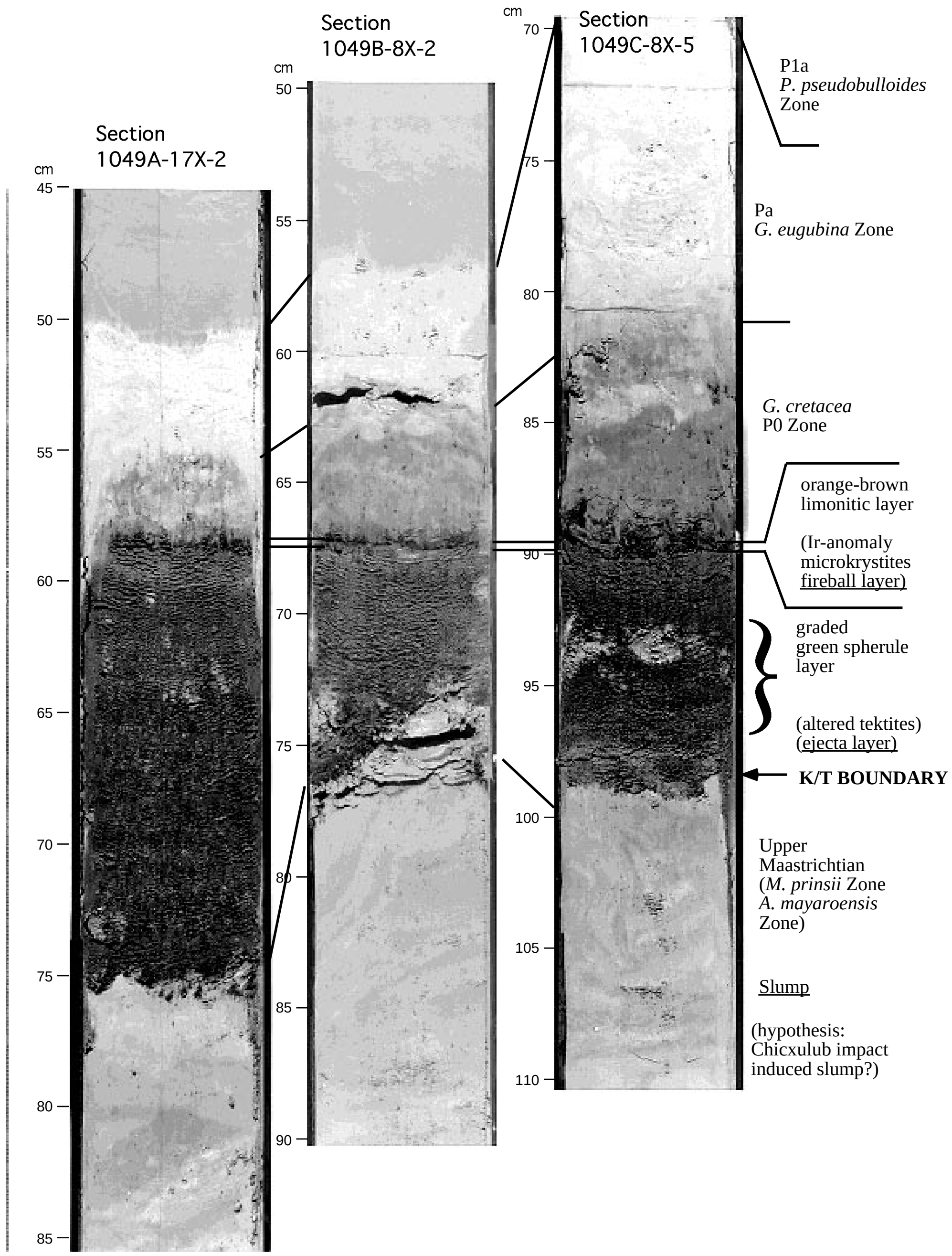

Section
1049A-17X-2
cm
45
50
55
60
65
70
75
80
85
Section
1049B-8X-2
cm
50
55
60
65
70
75
80
85
90
Section
1049C-8X-5
cm
70
75
80
85
90
95
100
105
110
P1a
P. pseudobulloides
Zone
Pa
G. eugubina Zone
G. cretacea
P0 Zone
orange-brown
limonitic layer
(Ir-anomaly
microkrystites
fireball layer)
graded
green spherule
layer
(altered tektites)
(ejecta layer)
K/T BOUNDARY
Upper
Maastrichtian
(*M. prinsii* Zone
A. mayaroensis
Zone)
Slump
(hypothesis:
Chicxulub impact
induced slump?)

Figure 11

Magnetostratigraphy of lower half of Hole 1052E

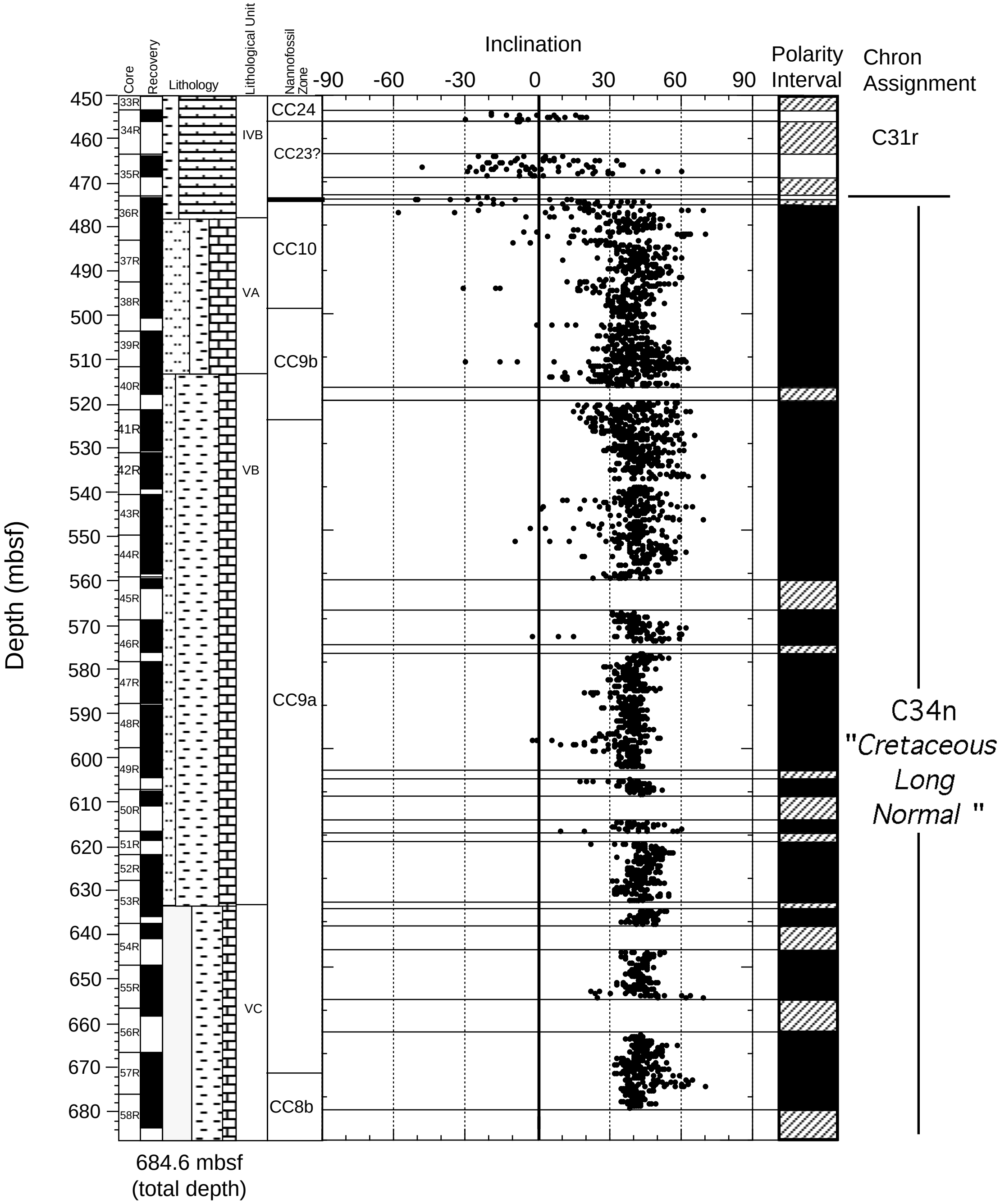


Figure 12

OPERATIONS SYNOPSIS

The ODP Drilling Services Department personnel aboard *JOIDES Resolution* for Leg 171B were:

Operations Manager:	Ron Grout
Schlumberger Engineer:	Jonathan Kreb

TRANSIT FROM BARBADOS TO SITE 1049

We departed Bridgetown at 1515 hr on 8 January and began the 1400-nmi transit to the first site of Leg 171B. Calm seas and a following current contributed to a rapid transit time to the first site.

During the transit, we passed to the west of the islands of Dominica, Guadeloupe, Monserrat, Nevis, St. Kitts, St. Eustatius, Saba, St. Martin, and to the east of the Virgin Islands. A warning had been issued by the government of Monserrat that the southwestern wall of Soufriere Hill Volcano could collapse and all ships were alerted to pass no closer than 10 nmi. The *JOIDES Resolution* sailed about 20 nmi west of the island and we passed under the ash cloud from the volcano, which was driven to the west by the trade winds.

We arrived at the beginning of the site survey over the Leg 171B drill sites at 0700 hr on 13 January after traversing 1380 nmi at an average speed of 12.3 kt. We then conducted a short seismic reflection survey over the sites, primarily to reconfirm the exact location of proposed Sites BN-3 and BN-4Alt. After the survey was finished (1245 hr, 13 January), we moved over the intended position of BN-1 (DSDP Site 390), extended the hydrophones and thrusters, and deployed a positioning beacon at 1315 hr. Depths reported in the operations sections are drill pipe measurements in meters below the rig floor (mbrf). The elevation of the rig floor above sea level was 11.2 m for Holes 1049A, 1049B, and 1049C.

SITE 1049

(Proposed Site BN-1)

Hole 1049A

Based on a precision depth recorder (PDR) depth of 2687.4 mbrf (corrected using Carter tables for local variations in water sound velocity), we positioned the bit approximately 5 m above the PDR-inferred mudline at 2682 mbrf. The bit apparently contacted the seafloor at 2682 mbrf (inferred from the weight indicator), so we raised the bit to 2681 mbrf to take the first APC mudline core. The APC did not fully stroke into the formation. When the core barrel was retrieved, the lower half of the inner barrel was missing.

Although the parting of the core barrel was a surprise, the difficulty in attaining an APC mudline was not unexpected because at DSDP Site 390 a veneer of manganese nodules and sand was recovered with RCB coring; it is present throughout the Blake Nose area. Farther up the slope of Blake Nose this surface veneer is lithified and it is possible that the surface veneer partially deflected the APC attempt and snapped the barrel off. When the core barrel was pulled out of the formation, there was no indication of excessive pull-out force, so the failure was not attributed to the core barrel being stuck in the formation. We decided to offset the vessel 10 m to the east to spud-in with the XCB.

This time we apparently contacted the seafloor at 2667.3 mbrf, based on an apparent 5,000-lb reduction in drill string weight. After advancing 20.6 m and retrieving two XCB cores with no recovery, the bit appeared to advance effortlessly into soft sediments. We then initiated APC coring and obtained Cores 3H-7H. Core 7H was not able to attain a full stroke and recovered 1.5 m of nannofossil ooze aa well as large chert fragment jammed in the cutting shoe.

We then took XCB Core 8X, which appeared to penetrate the chert layer after advancing only 1.8 m. This core recovered 0.76 m of chert fragments and nannofossil ooze. Another APC core (9H) was attempted, but it did not obtain a full stroke, so we resumed XCB coring. With the exception of one additional piston core attempt (13H; which did not attain full stroke), the rest of the hole was XCB-cored. Several zones of chert were encountered between 40 and 90 mbsf.

The K/T boundary was obtained in Section 17X-2. Coring was terminated at 172.7 mbsf after meeting the objectives to recover Aptian-aged sediments. The bit cleared the mudline, and Hole 1049A was officially terminated at 0400 on 15 January 1997.

The seafloor depths for Hole 1049A determined by reduction of drill string weight are most likely incorrect as compared to those in Holes 1049B and 1049C. The depth below seafloor of a marker horizon, such as the limonitic horizon at the top of the K/T boundary, indicates that the correlative horizon in Hole 1049A (125.88 mbsf) is ~12-14 m deeper than in Holes 1049B and 1049C (111.18 and 112.99 mbsf, respectively). When comparing data from Hole 1049A to the other holes at this site, one can adjust the depth by subtracting ~12-14 m from the reported Hole 1049A meters below seafloor (mbsf) depth.

Hole 1049B

We offset the ship 10 m east of Hole 1049A and spudded Hole 1049B using an XCB core barrel with a center bit. A water depth of 2682.0 mbrf was determined by the driller gently lowering the bit until he observed a gradual reduction in drill string weight. After drilling ahead for 2 m to penetrate the surface sediments that had caused problems at Hole 1049A, we deployed an APC core barrel. APC Cores 1H-5H were taken from 2.0 to 46.5 mbsf, and Core 5H contacted the expected (based on Hole 1049A results) chert layer after advancing 6.5 m.

We drilled through the chert zone (46.5 to 90.7 mbsf) using an XCB core barrel with a center bit because of the poor core recovery at the same interval in Hole 1049A and to make up for the slower than expected penetration rates. XCB Cores 6X-7X were then taken to 109.0 mbsf. We wished to APC core the K/T boundary, and fortunately, APC Core 8H recovered a full core spanning this target horizon. XCB Cores 9X-12X where then taken from 118.5 to 156.9 mbsf. The bit was pulled out of the hole and cleared the mudline at 0030 on 16 January.

Hole 1049C

We offset the ship 10 m east of Hole 1049B and spudded Hole 1049C using the XCB with a center bit. Based on the drill string weight indicator, the water depth was found to be the same as that at Hole 1049B (2682.0 mbrf). After drilling to 2 mbsf, we took APC Cores 1H-5H (2-45 mbsf) until contact with the first chert layer at 45.0 mbsf. After the hole was drilled without coring from 45.0 to 90.0 mbsf, XCB coring advanced to 120.2 mbsf. We obtained a third copy of the K/T boundary in Core 8X. Core 10H was shot at 120.2 mbsf, and recovered a full core even though it did not achieve a full stroke, indicating the bottom part was sucked in. XCB Cores 11X-13X were taken from 129.7 to a total depth of 158.5 mbsf. We then began to retrieve the drill pipe at 1945 hr on 16 January.

After pulling out of the hole, the drill bit was inspected at the surface and we discovered that one cone and cone leg were missing; no other bit damage was observed. We suspect the large heave experienced during 16 January possibly contributed to this failure by slamming the bit into the formation. Since the drillers did not observe erratic torque while drilling, the bit failure may have occurred just before (or during) pulling out of the hole.

While the vessel was coring Hole 1049C, the operator of the dynamic positioning system observed the sudden onset of a 3.4-kt current toward the east-northeast. Concurrent with this current, a front passed through with wind gusts as high as 35 kt from the south. Because of the direction of the strong current, it was not possible for the ship to head directly into the wind-driven sea. As a result of the different angles of the wind and current, there was considerable ship motion with heaves up to 3 m and roll angles of 6°, but the front did not affect drilling operations. After securing the drilling equipment, we began the ~7-nmi transit to BN-2Alt at 0030 on 17 January.

SITE 1050
(Proposed Site BN-2Alt)

Site 1050

After a 1-hr transit from the last site, we deployed a beacon at Site 1050 at 0130 hr on 17 January. After adding a new APC/XCB bit (RBI C-3) to the bottom-hole assembly (BHA), the drill string was run in to 2263 mbrf, the top drive picked up, and the bit was gently lowered to establish the mudline depth. The driller observed a reduction in drill string weight at 2311.0 mbrf, which was only 1.4 m shallower than the PDR measured depth of 2312.4 mbrf. Because of the possibility of damaging hardware by attempting an APC mudline core through the manganese nodules and sand cover (as occurred at Hole 1049A), we spudded Hole 1050A with the XCB at 0715 hr on 17 January. We rotated 15 min, coring from 0 to 10.1 mbsf, and recovered 6.9 m of nannofossil ooze with some manganese nodules. APC coring commenced with Core 2H and continued to 95.6 mbsf. Core 10H could not be extracted from the formation with 100,000-lb of overpull, and we had to free it by slowly drilling over the stuck barrel.

We then switched to XCB coring, which provided excellent core recovery, albeit with slow and ever decreasing rates of penetration (ROP). The high clay content of the sediments was apparently adhering to the cutting structure of the bit, reducing the penetrating ability and making it difficult to advance into the formation. The weight on bit, pump pressure, and rotary speed were varied in an attempt to increase the ROP, with negative results. The average rate of penetration on 19 January had decreased to 4.7 m/hr.

We considered the possibility of dropping a free fall funnel (FFF) so that we could trip the pipe to change the rotary cone bit to one more suited for this formation (e.g., 10 1/8-in PDC fixed cutter bit). However, after reviewing the condition of the microfossil preservation, the slow ROP, and the time/risk to round trip for a PDC XCB bit, we decided to terminate Hole 1050A at 319.9 mbsf. We decided to increase the penetration at Hole 1050B to ~240 mbsf and to not drill a third hole at this site as originally planned. The time saved would be used to achieve primary scientific objectives at another site. We pulled the drill string up to 100 mbsf, displaced the hole with 40 bbl of 10.5 ppg mud. Hole 1050A ended at 0015 hr on 20 January when the drill string was pulled above the seafloor.

Hole 1050B

We offset the vessel 10 m to the east and spent 1-hr to accomplish the routine task of cutting and slipping 115 ft of drilling line. After the driller verified that the seafloor depth was the same as at Hole 1050A (2311.0 mbrf; based on an observed reduction in drill string weight), we spudded Hole 1050B with the XCB at 0200 hr on 20 January. XCB Core 1X was cut from 0 to 7.0 mbsf. Then we took APC Cores 2H through 9H to 83.0 mbsf. We wanted to switch to XCB at this depth because this was just above the depth where we had to drill over the stuck APC core barrel at Hole 1050A. XCB coring continued to a total depth of 240.0 mbsf. After the last core was retrieved (1325 hr, 21 January) we started pulling the drill string out of the hole. As soon as the drill bit was a safe distance above the seafloor, the beacon was recovered, and the vessel was slowly offset toward the next site while the drill pipe was retrieved.

SITE 1051

(Proposed Site BN-3)

Hole 1051A

After the transit from Site 1050, we deployed a beacon at 1915 hr on 21 January at the GPS position of BN-3. The BHA was made up with a 10 1/8-in fixed cutter bit (PDC) in hopes of improving upon the performance (rate of penetration) of the roller cone bit used at the previous two sites. We decided to spud Hole 1051A with XCB because of the potential for damage if we spudded into the surficial layer of manganese nodules with the APC. The driller gently lowered the bit and, based on a reduction in drill string weight, determined the seafloor was at 1994.0 mbrf.

The rig floor was 11.3 and 11.4 m above sea level for Holes 1051A and 1051B, respectively. Core 1X was taken to 5.8 mbsf. APC coring continued from 5.8 to 138.8 mbsf with excellent recovery. Core 16H advanced from 138.8 to 148.3 mbsf with a full stroke. However, when 100,000 lb of overpull failed to retrieve the barrel, we had to drill over the stuck core barrel to release it from the formation. Cores 4H through 16H were oriented using the Tensor tool.

We then resumed XCB coring and proceeded with excellent recovery until Core 1051A-41X advanced only 2.3 m when it encountered a hard chert layer at 381.6 mbsf. The only practical manner of advancing beyond this depth with the XCB was to drop a core barrel with a center bit and drill ahead 8.3 m to 389.9 mbsf. Although the chert layer was approximately 1 m thick, the extra advance was necessary to verify that we had completely penetrated the chert layer and because we wanted to push the tungsten carbide inserts (TCI) that had been stripped from the XCB cutting shoe while attempting Core 1051A-41X into the borehole wall. The extreme hardness of the TCIs could damage the main PDC bit.

We resumed XCB coring at 389.9 mbsf and advanced past the original objective of 600 mbsf to a total depth of 644.6 mbsf, where coring operations were terminated due to a very slow rate of penetration (ROP on the last core was 2.0 m/hr). The K/T boundary was assumed to lie perhaps another 30-40 m beneath the TD. To attain this depth with the present ROP would have taken another 12 hr of rotation.

At 0815 hr on 25 January, the bit was raised back to 105 mbsf for logging. Raising the drill pipe to logging depth was complicated by the discovery of over 400 m of monofilament fishing line that was wrapped around eight joints of drill pipe. As each joint was lifted past the dual elevator stool, the rig crew would cut off small sections of the fishing line. This process was made more difficult due to the presence of large sharp fishing hooks. Because there were no fishing boats in the area, we assumed the line may have drifted in the Gulf Stream for some distance before adhering to the drill string.

By 2030 hr on 25 January, the logging equipment was being rigged up. This took longer than the normal half hour, due to the extra rigging required to work around the absence of the wireline heave compensator. The first log in the hole was the Triple Combo, which logged the entire hole. The data was of good quality and indicated that the hole was in excellent condition with a smooth bore that ranged in diameter from just under 10 in to a maximum of 14 in. The second log was the Formation MicroScanner (FMS), which required extensive troubleshooting before it was run successfully without the sonic tool. The heave of the ship and the lack of the wireline heave compensator will require considerable reprocessing to remove the effect of the tools vertical motion in the hole. The last tool run was the Geological High-Sensitivity Magnetometer (GHMT), which provided good quality magnetic susceptibility data.

Once logging was finished and the tools recovered, the borehole was displaced with 35 bbls of 10.5 ppg mud. At 0200 hr on 27 January, the bit cleared the mudline and the vessel offset 30 m northwest to start Hole 1051B.

Hole 1051B

The driller tagged the seafloor at 1992.0 mbrf and spudded Hole 1051B with the XCB at 0315 hr on 27 January. After passing through a 2-m-thick hard crust and advancing to 4.8 mbsf, the XCB barrel was recovered and APC coring initiated. We APC-cored to 135.0 mbsf, which was just above the depth of the last APC core on the first hole. This allowed us to avoid having to consume an extra hour drilling over another stuck core barrel. APC Cores 4H through 15H were oriented with the Tensor tool, and Adara temperature tool measurements were obtained at 33, 62, and 87 mbsf (Cores 4H, 7H, and 11H).

We advanced XCB coring to 374.1 mbsf with excellent recovery. At this depth, we drilled through the chert layer with a center bit. After 70 min of rotation and advancing 2 m, we finally penetrated the chert layer and the center bit was retrieved. We resumed XCB coring to a total depth of 526.6 mbsf.

After we displaced the hole with 35 bbls of 10.5 ppg mud, we retrieved the drill string. The PDC XCB bit was missing 8 of 13 cutting elements. Although the bit body was in gauge, the bit was too worn for service and was retired. At 1315 hr on 31 January, the drilling equipment was secured and the vessel began the transit to Site 1052.

SITE 1052

(Proposed Site BN-5Alt)

Site 1052

After the 15-nmi transit from Site 1051, we deployed a beacon at the GPS coordinates of BN-5Alt at 1500 hr on 30 January. After assembling the APC/XCB bottom-hole assembly with a rebuilt PDC XCB bit (similar to the one used at Site 1051), we ran the drill string in to 1329 mbrf.

Hole 1052A

Once the top drive was picked up and an XCB core barrel dropped, the driller slowly lowered the bit until he made contact with the seafloor at a depth of 1356.0 mbrf (based on a reduction in drill string weight). Cores 1052A-1X and 2X were taken to 13.2 mbsf to penetrate a 5-m-thick hard surficial crust. We then initiated APC coring and proceeded until 129.7 mbsf. Cores 1052A-4H through 15H were oriented using the Tensor tool. When Core 15H did not fully stroke, we switched to XCB coring. At 174.5 mbsf, we encountered a hard layer that effectively prevented further penetration with the XCB. To penetrate any deeper at this site, we would have to use the RCB. The drill string was then pulled out of the hole and the bit cleared the seafloor at 1200 hr on 31 January.

Hole 1052B

We offset the ship 30 m to the southwest and spudded Hole 1052B with the XCB at 1300 hr. Based on a reduction in drill string weight, the driller estimated the seafloor to be at 1356.5 mbrf. The driller did not observe the hard layer encountered at all the previous sites, so we retrieved the XCB barrel after penetrating only to 5 mbsf. We then took APC Cores 1052B-2H through 14H to 119.5 mbsf. The bit cleared the seafloor at 2045 hr on 31 January.

Hole 1052C

Because we did not observe a surficial hard layer at Hole 1052B, we felt it was possible to take a near mudline piston core without undue hazard to the drilling equipment. We also wanted to obtain slightly younger Eocene sediments that likely contained the tektites. Because there appeared to be local variability in the bottom topography on the PDR, we did not offset the ship. The driller observed a reduction in drill string weight at 1356.5 mbrf and attempted an APC core at this depth. It was a full stroke and recovered nearly 10 m so most likely was taken below the true seafloor. A second piston core was taken from 9.5 to 19.0 mbsf. The bit cleared the seafloor at 2200 hr on 31 January.

Hole 1052D

Without offsetting the vessel, we shot the first APC (at 2215 hr, 31 January) approximately 2 m above the inferred mudline. The first core was full, so we could not determine the seafloor depth by the recovery. We then took a second piston core from 9.5 to 19.0 mbsf. After recovering the second piston core, we tripped the bit to the surface to switch over to RCB coring to reach the deeper objectives at this site. The bit cleared the seafloor at 2330 hr on 31 January.

Hole 1052E

After the bit cleared the rig floor at 0200 hr on 1 February, we inspected the PDC XCB bit and found that it had lost most of its PDC cutting elements. It will be returned to ODP for refurbishing. The APC/XCB BHA was laid down and a new RCB bit (9 7/8 in RBI C-3) was assembled along with a mechanical bit release, so we could remotely release the bit to allow us to log this hole.

We spudded Hole 1052E at 0700 hr on 1 February and drilled without coring to 140 mbsf. After we retrieved the wash barrel and a core barrel was deployed, we started rotary coring at approximately 1100 hr on 1 February. The RCB had no trouble penetrating the hard formation that had stymied XCB coring in Hole 1052A. However, the recovery from 140 to 252 mbsf was poor (30%) due to the interbedded hard and soft sediments. Below this interval, core recovery improved as the sediments became more homogeneous and lithified. We recovered a nearly complete K/T boundary section in Core 1052E-19R (309.7 to 319.3 mbsf).

The recovery of the K/T boundary was due mainly to chance. When the core barrel for Core 19R was retrieved, it was empty. The driller, assuming that there was no recovery, dropped another core barrel to prepare for coring the next interval. While the core barrel was on the way down the pipe, a decision was made to drop a bit deplugger to make sure that the bit throat was clear. Before this could be done, we had to recover the core barrel that had just been dropped. When we recovered the core barrel, it contained approximately 1 m of core which coincidentally turned out to contain part of the K/T boundary sequence. We then decided to drop a second core barrel, which recovered an additional ~1 m of core. We suspect that both of these sections of core apparently fell out of the Core 19R core barrel. Finally, a bit deplugger was dropped, latched in, recovered, and we resumed RCB coring. Core recovery continued to improve with depth, and when we reached a total depth of 684.8 mbsf, the average recovery for the hole had improved to 60%.

In preparation for logging, we circulated 20 bbls of high viscosity mud and then made a wiper trip by pulling the drill pipe up to 213 mbsf and then lowering it back to the bottom of the hole. After washing and reaming with the drill bit from 674 to 685 mbsf, we circulated another 20 bbl of mud. The bit was then released and the bottom of the drill string raised to 222 mbsf for logging.

Once the Schlumberger equipment was rigged up, the first log Triple Combo (Temperature tool, DITE, HLDT, APS, HNGS) was run in the hole at 1045 hr on 5 February. The Triple Combo was able to log from the bottom of the hole (685 mbsf) up to 222 mbsf. A second logging pass was made over the section containing the K/T boundary (335 to 222 mbsf). The data appear to be of high quality. Caliper readings indicated good and very smooth borehole conditions with borehole diameters mostly around 10 in to 11 in. Vessel heave was approximately 1 m during logging (the wireline heave compensator was not available for this leg).

We then ran the Formation MicroScanner with the sonic tool. The FMS string was also able to log from the total depth up to 222 mbsf. As with the first log, a second pass was made over the K/T boundary. The deviation at the bottom of the hole was 1°. Our last logging run was the GHMT/NGT. The GHMT was also able to log the complete section and a second pass was made over the K/T boundary region.

After the logging equipment was rigged down, we pulled the drill string up to 100 mbsf and displaced the hole with 35 bbls of 10.5 ppg mud. After retrieving the drill string, securing the drilling equipment, retrieving the beacon, and retracting the thrusters and hydrophones, we began the transit to Site 1053 at 1930 hr on 6 February 1997.

SITE 1053
(Proposed Site BN-4Alt)

Hole 1053A

After the 5-nmi transit from Site 1052, we deployed a beacon at the GPS coordinates for BN-4Alt at 2030 hr on 6 February. By midnight the driller was attempting to spud Hole 1053A with the XCB. The driller gently lowered the bit to determine the seafloor depth and observed a reduction in drill string weight at 1622 mbrf. This was very close to the corrected PDR measurement of 1622.4 mbrf, and he assumed this was the seafloor depth. The bit was rotated and advanced with the XCB for 9.6 m without any discernable weight taken by the formation (reduction in drill string weight). When we retrieved the core barrel, it was empty. We then attempted an APC core over the next 9.6 m interval, but it too came up empty. On our third attempt at a mudline core, APC Core 1053A-1H recovered a nearly full barrel (9.42 m), which implied a mudline depth of 1641.0 mbrf. This was 18.6 m deeper than the observed PDR water depth.

APC Cores 1053A-1H through 15H were taken from 0 to 139.0 mbsf. APC Cores 1053A-3H to 15H were oriented using the Tensor tool. Core 15H did not achieve a full stroke, so we switched to XCB coring. XCB Cores 16X through 20X were taken to 183.2 mbsf, where coring was terminated. The bit was pulled out of the hole and cleared the seafloor at 1820 hr on 7 February.

Hole 1053B

Without offsetting the vessel, we spudded Hole 1053B with the APC at 1900 hr on 7 February. The mudline depth calculated from the recovery of the first APC core was 1641.8 mbrf. APC Cores 1053B-1H through 14H were taken from 0 to 127.4 mbsf after which we switched to XCB coring. Adara heat flow measurements were obtained at 22.9, 51.4, and 79.9 mbsf (Cores 3H, 6H, and 9H, respectively). XCB Core 1053B-15X through 20X were taken to 182.4 mbsf. The bit was pulled out of the hole and cleared the seafloor at 1220 hr. We retrieved the drill pipe and spent an extra 3 hr for the routine end-of-leg bottom-hole assembly inspection. At 1800 hr on 8 February, the drilling equipment was secured and we began the transit back to Site 1050 to core Hole 1050C.

SITE 1050
(Proposed Site BN-2Alt)

Hole 1050C

After the 16.5-nmi transit to return to Site 1050, we deployed a beacon at 1930 hr on 8 February. We wanted to reoccupy Site 1050 to core the deep objectives that were not attained earlier in the leg at Hole 1050A because the XCB coring system could not penetrate to the desired depth of at least 500 mbsf. We decided to use the RCB coring system to core deeper than Hole 1050A penetrated until operational time remaining for the leg expired.

Hole 1050C was spudded at 0045 hr on 9 February at a depth of 2308.0 m. We used an RCB BHA with a mechanical bit release and new bit (RBI C-3). We drilled without coring to 317.5 mbsf and then started RCB coring at 1545 hr on 9 February. Rotary coring advanced without incident to a depth of 606.0 mbsf, coring 288.5 m and recovering 200.19 m of core (69.4%). Operations were terminated at 2130 hr on 11 February after operational time for this leg expired. The average rate of penetration for the cored segment of this hole was 11.2 m/hr.

After a 20 bbl high viscosity mud flush was circulated, a wiper trip (105-606 mbsf) was conducted to prepare the hole for logging. The region from 586 to 606 mbsf had to be washed and reamed. The bit was then released at the bottom of the hole with the wireline and the hole displaced with 155 bbls of sepiolite mud. The end of the drill string was pulled up to the logging depth of 105 mbsf.

At 0245 hr on 12 February, the Schlumberger equipment was rigged up and the first logging tool (Triple Combo, DITE-HLD-APS-HNGS) was run in the hole. All data collected was of high quality. No problems were experienced during the run. The hole appeared to be in very good condition with an average diameter of 10 in. By 0900 hr on 21 February, the Triple Combo was retrieved, rigged down, and the second log prepared.

At 0910 hr, the second logging string (FMS/SDT(Array)/NGT) was run in the hole. All data collected were of high quality. No problems were experienced on the run with the exception of some noise on the analog sonic curves; however, the digital data appear to be good. FMS calipers indicated that the hole was slightly oval and washed out to 14 in near just below the bottom of the drill pipe. Maximum hole deviation was 1.5°. Two full passes were planned, but the second logging pass was canceled. When the tool reached the oval sections approaching drill pipe, it became apparent that the "track" in the borehole left behind by the caliper of the tool used on the first logging run could be seen in the image of the second run, so the second pass was shortened.

At 1500 hr, the second log was rigged down and the third and final logging suite made up. At 1515 hr, the third log, magnetic susceptibility (GHMT/NGT), was run in the hole. All data collected were of high quality. All three logging tools reached the bottom of the hole. Only the upper 40 m of the hole (105 to 145 mbsf) suffered significant washout. The hole was successfully logged between 103 and 606 mbsf. Sea conditions were mild with less than 1.5-m swells.

After the logging equipment was rigged down, the hole was displaced with 35 bbls of 10.5 ppg mud. The pipe was pulled out of the hole and the BHA was disassembled into individual drill collars and laid down. The main and a backup beacon were retrieved and the drilling equipment secured by 0600 hr on 13 February.

Transit from Hole 1050C to Charleston, South Carolina

After the drilling equipment was secured and the coring winch prepared for repair during port call, we began the transit to Charleston, South Carolina, at 0600 hr on 13 February. We arrived at the pilot station at 0530 and sailed the last 15 nmi in heavy fog. The first line was ashore at 0830 hr on 14 February.

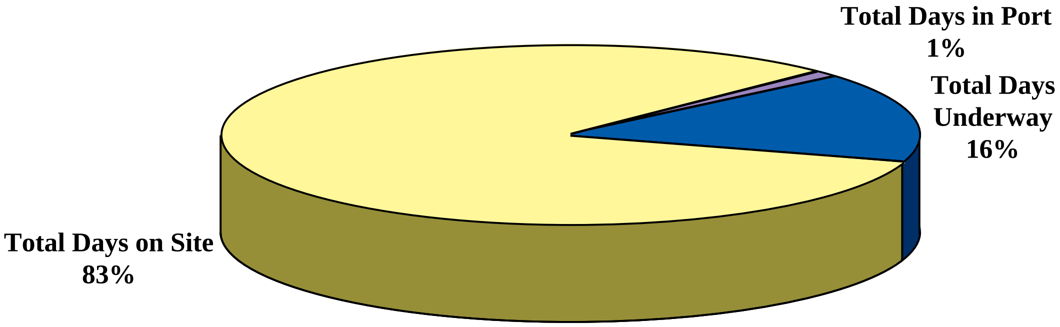
OCEAN DRILLING PROGRAM
OPERATIONS RESUME
LEG 171B

Total Days (08 January 1997 to 14 February 1997)	37.08
Total Days in Port	0.36
Total Days Underway	6.05
Total Days on Site	30.41

	days
Drilling	2.35
Other	0.46
Tripping Time	3.19
Stuck pipe/Hole Trouble	0.00
Logging/Downhole Science	3.71
Mechanical Repair Time (Contractor)	0.00
Reentry Time	0.00
W.O.W.	0.00
Coring	20.70

Total Distance Traveled (nautical miles)	1533.0
Average Speed Transit (knots):	9.7
Number of Sites	5.0
Number of Holes	16.0
Number of Cores Attempted	427.0
Total Interval Cored (m)	3794.3
Total Core Recovery (m)	3227.4
% Core Recovery	85.06
Total Interval Drilled (m)	561.0
Total Penetration	4355.3
Maximum Penetration (m)	684.8
Minimum Penetration (m)	19.0
Maximum Water Depth (m from drilling datum)	2682.0
Minimum Water Depth (m from drilling datum)	1353.5

LEG 171B
TOTAL TIME DISTRIBUTION



Total Days = 37

HOLE	LATITUDE	LONGITUDE	WATER DEPTH (mbrf)	NUMBER OF CORES	INTERVAL CORED (meters)	CORE RECOVERED (meters)	PERCENT RECOVERED (percent)	DRILLED (meters)	TOTAL PENETRATION (meters)	TIME ON HOLE (hours)	TIME ON SITE (days)
1049A	30 8.5436 N	76 6.7312 W	2667.3	23	191.9	104.32	54.4%	0.0	191.9	38.75	1.6
1049B	30 8.5423 N	76 6.7264 W	2682.0	12	110.7	81.60	73.7%	46.2	156.9	20.50	0.9
1049C	30 8.5370 N	76 6.7271 W	2682.0	13	111.5	88.86	79.7%	47.0	158.5	24.00	1.0
			1049 SITE TOTALS:	**48**	**414.1**	**274.78**	**66.4%**	**93.2**	**507.3**	**83.25**	**3.5**
1050A	30 5.9977 N	76 14.1011 W	2311.0	36	319.9	293.70	91.8%	0.0	319.9	70.75	2.9
1050B	30 5.9981 N	76 14.0958 W	2311.0	27	240.0	219.44	91.4%	0.0	240.0	41.25	1.7
1050C	30 5.9953 N	76 14.0997 W	2308.0	31	288.5	200.19	69.4%	317.5	606.0	106.50	4.4
			1050 SITE TOTALS:	**94**	**848.4**	**713.33**	**84.1%**	**317.5**	**1165.9**	**218.50**	**9.1**
1051A	30 3.1740 N	76 21.4580 W	1994.0	73	636.3	599.89	94.3%	8.3	644.6	126.75	5.3
1051B	30 3.1860 N	76 21.4712 W	1992.0	61	524.6	508.18	96.9%	2.0	526.6	83.25	3.5
			1051 SITE TOTALS:	**134**	**1160.9**	**1108.07**	**95.4%**	**10.3**	**1171.2**	**210.00**	**8.8**
1052A	29 57.0906 N	76 37.5966 W	1356.0	21	174.5	159.63	91.5%	0.0	174.5	21.00	0.9
1052B	29 57.0791 N	76 37.6098 W	1356.5	14	119.5	115.65	96.8%	0.0	119.5	8.75	0.4
1052C	29 57.0798 N	76 37.6104 W	1356.5	2	19.0	19.91	104.8%	0.0	19.0	1.25	0.1
1052D	29 57.0773 N	76 37.6123 W	1354.0	2	19.0	19.41	102.2%	0.0	19.0	4.00	0.2
1052E	29 57.0794 N	76 37.6094 W	1355.0	58	544.8	327.90	60.2%	140.0	684.8	122.50	5.1
1052F	29 57.0794 N	76 37.6098 W	1353.5	14	128.5	129.12	100.5%	0.0	128.5	15.00	0.6
			1052 SITE TOTALS:	**111**	**1005.3**	**771.62**	**76.8%**	**140.0**	**1145.3**	**172.50**	**7.2**
1053A	29 59.5385 N	76 31.4135 W	1641.0	20	183.2	189.5	103.4%	0.0	183.2	21.83	0.9
1053B	29 59.5391 N	76 31.4141 W	1641.8	20	182.4	170.11	93.3%	0.0	182.4	23.67	1.0
			1053 SITE TOTALS:	**40**	**365.6**	**359.61**	**98.4%**	**0.0**	**365.6**	**45.50**	**1.9**
			LEG 171B TOTALS:	**427**	**3794.30**	**3227.41**	**85.1%**	**561.0**	**4355.3**	**729.75**	**30.4**

TECHNICAL REPORT

The ODP Science Services Technical personnel aboard *JOIDES Resolution* for Leg 171B were:

John Dyke	Marine Lab Specialist (Storekeeper/Shipping)
Tim Fulton	Marine Lab Specialist (Photographer)
Edwin Garrett	Marine Lab Specialist (Paleomagnetics)
Dennis Graham	Marine Lab Specialist (UnderWay Geophysics)
Gus Gustafson	Marine Lab Specialist (Downhole Tools)
Burney Hamlin	Laboratory Officer
Michiko Hitchcox	Marine Lab Specialist (Yeoperson)
Terry Klepac	Marine Computer Specialist
John Lee	Marine Lab Specialist (Chemistry)
Kevin MacKillop	Marine Lab Specialist (Physical Properties)
Matt Mefferd	Marine Computer Specialist
Eric Meissner	Marine Electronics Specialist
Chieh Peng	Marine Lab Specialist (Chemistry)
Don Sims	Assistant Lab Officer/Marine Lab Specialist (X-ray)
Lorraine Southey	Marine Lab Specialist (Curator)
Joel Sparks	Marine Lab Specialist (X-ray)
Paula Weiss	Marine Lab Specialist (Curator)

From a technical staffing perspective, Legs 171A and B were considered to be one leg; therefore, the laboratory activities are combined into one technical report. Laboratory statistics were separated and so only 171B statistics are included at the end of this report.

GENERAL LEG INFORMATION

On the second half of Leg 171, 16 holes at five sites were drilled on the edge of the Blake Plateau. The Safety Panel directed us to drill from the deepest to shallowest sites, because of concern that gas may be a problem in the shallowest sites. Hole 1049A was spudded about 2000 hr on 13 January. Pipe was pulled and thrusters raised for each of the short transits between sites, as currents in the area were too strong to consider moving with the thrusters. Permission was granted to change the order of drilling the holes when gas problems were not observed. Drilling operations ceased after redrilling our deeper-water second site with RCB to collect another K/T boundary and to reach deeper objectives. Although a beacon was dropped at the former site, permission was received to continue using the earlier site number (Site 1050). After logging the hole and pulling pipe, the ship sailed at 0500 on 13 February for port call in Charleston, South Carolina.

Port Call Activities - Barbados

There was an 8 hr port call in Barbados at 0700 on 8 January 1997 to unload the LWD tools and support personnel, pick up air freight, and welcome the participants joining 171B. Care was made to ensure that all non-U.S.A. residents had proper visas for the return to the United States. Some fresh produce was received. There was a brief inquiry about an expected replacement valve that did not arrive. The ship was under way by 1515 for the Blake Nose region off northern Florida to begin Leg 171B.

Under way from Barbados

Leaving Barbados, navigation watch began at 2100 on 8 January. Magnetic data collection was delayed while passing to the east side the West Indies Islands and sailing in shallow water. The *JOIDES Resolution* arrived at the drilling sites on 13 January. A 6 hr seismic survey was conducted over several of the sites to link other records together. The initial deep site was close to a DSDP site where some of the navigation was done using LORAN. A Teledyne single channel hydrophone array was used beginning with a 200-in^3 water gun and ending with an 80-in^3 water gun for comparison. The analog records collected were good, and processed data was satisfactory.

LAB ACTIVITIES

Chemistry Lab

There was little gas and low organic carbon associated with the majority of the cores recovered during Leg 171B. Hydrocarbons were monitored at each site as there were safety concerns for this region. Gas values entered into the JANUS data were retrieved easily to monitor trends. Few problems were associated with the equipment, though new Gas Chromatograph (GC) Chemstation software was found to be incompatible with the valve switcher. A new version of the software is expected to work as anticipated. There was also a problem with a Coulometer application in LabView that will require more work. Replacement parts and valves for the Atomic Absorption's (AA) exterior acetylene manifold were ordered for port call service. Other maintenance in the lab was routine.

Computer Services

Many related tasks were performed with the implementation of the JANUS database on this leg. There were hardware upgrades, an OS upgrade, the initialization of the database, user training for the scientists and specialists, bugs to fix, user resistance to overcome, etc. Full user support was available from Tracor’s Paul Albright and Glen Corser for the JANUS applications, and they continued working on the Business Objects Users software queries throughout the leg. The deployment of JANUS on Leg 171 was a success; it is basically up and functioning as intended. There were problems mirroring data across the hard drives and implementing DecSafe, an application that switches computers if a processor fails. Those shortcomings will soon be addressed.

The latest version of AppleCORE was used successfully by the scientists to prepare barrel sheets. It was found to be flexible and allowed an almost unlimited amount of information to be entered. A VIDEO program was sent out to replace the old corelog video display. It was modified to some degree to change sort orders, precision, and to add scrolling. On several occasions at the end of the leg the maximum number of users on the Grosbeck/USERVOL server was reached. A license change is planned. There were several problems with cc:mail, aggravated by the holidays at Texas A&M University (TAMU). Bulletin boards failed to propagate for one period of time. There was a crash of the system shortly after leaving Barbados when new addresses were being added. The last short run of the FDDI fiber optics cable was run. These will be terminated with the rest of the system cables during the Charleston port call.

Core Lab

During Leg 171A's LWD effort, SUN workstations were set up in the aft end of the core lab to support the scientists reviewing the data collected. Working in the area during daylight hours was difficult as the entire deck above was being chipped, scaled, and then repainted. Some people used hearing protection, whereas others elected to work later hours.

There were few problems accommodating the recovered sediments studied on Leg 171B. Drilling breaks and logging activities provided time for the special requirements that support K/T boundary cutting and sampling efforts.

As this was the first leg for a fully implemented JANUS database, double entry into S1032 corelog was made as a backup. During the last sites, maintaining the core entry white board was dropped, as most of the drilling information is now available on the workstations that were logged onto JANUS. The white board is still handy for planning and scheduling Adara tool deployments, special sampling, and paleontological ages.

Curation

Core recovery was quite high from the relatively shallow-water sites during this five-week effort, but chert and harder layers encountered precluded achieving some of the higher estimates. Rotary coring and the logging program provided the time necessary for the lab to catch up and conduct sample parties.

Several critical boundaries, including the K/T boundary, were recovered, and many cutting and sampling suggestions and ideas were evaluated. Some special tools, now stored in a K/T kit, were used. Thin aluminum oxide cutting disks were tried on the rock saw with marginal success. They were too fragile for much regular use and they ablated material off onto the core that could not easily be cleaned off. Cores with organic-rich layers were recovered and handled in a special manner. They were placed in foil bags and purged with nitrogen to preserve them. They will be held until a sample plan is worked out. Some cores contained colorful laminated zones and were selected to join the K/T boundary cores as a part of an exhibit supporting port call Public Relation efforts. All of these sections will be shipped to the Bremen Core Repository for future work and storage. A second curatorial person was a fine complement to the staff, allowing full-time help and oversight in the lab and catwalk.

Magnetics Lab

This was the first heavy recovery leg for the new cryogenic magnetometer; both the hardware and the software performed satisfactorily. There were a few problems to puzzle over, but the extra sensitivity was appreciated. Core sections contaminated with metal bits possibly contributed to some unexplained flux jumps and slow recovery of stability after the chill water was off for 2 hr. While the data was modified by JANUS to add depths, the raw data files were stored on DATA1 file server.

The Tensor orientation tools were used regularly. The data retrieval program was modified to run on a Pentium laptop computer. One of the tools is being returned with a damaged battery contact and intermittent problems.

Microscope/Photography Labs

The microscopes were set up to meet individual preferences, and time was spent finding special equipment and supplies to fill requests. Occasionally, we were asked to change lenses or readjust the optics or illumination and replace bulbs. Notes were taken for a port call microscope service call so problems can be directly addressed and also for some instruction on aligning one new model microscope.

Close-up photographs of some of the critical boundaries were taken before and after the surfaces were scraped clean. Duplicate slides of the K/T boundary were taken so each of the scientists could have one, thereby reducing the number of times the boundary would be handled. Macrophotographs of some ammonite fossils were taken. No microphotographs were requested. There were no problems with the lab equipment.

Paleontology Lab

The facilities were fully utilized with seven paleontologists sharing the space. Once all requests were satisfied during the initial setup, no problems were reported. A situation attributed to gray water fumes was reported in the aft end of the microscope lab. Better termination of an old drain line seemed to fix the problem. The chemists responded to most of the consumable requests during the leg.

Physical Properties

The physical properties scientists were familiar with the instruments and had few problems. Those making thermal conductivity measurements found less scatter in the values with the newer TKO4, so it was preferred over the WHOI multiprobe device. The users found that core flow was not affected using the TKO4's single needle probe. Sets of Adara downhole temperature measurements were collected at two drill sites.

Storekeeping

The storekeeper travelled early to Panama to meet the ship's agent, to familiarize himself with the area, and to help locate the arriving equipment. Hotel reservations were verified, and outgoing travel arrangements verified. The port call in Panama went well once shipments started, and everything was received in good order.

During Leg 171A, time was spent with the engineer who joined the staff to study migrating the MATMAN S1032 database into an interim Foxpro database (the software the engineering group is accustomed to using). It had been discussed that the storekeeper would become involved with the engineering inventories, but there was no involvement this leg.

There was time to make a physical count of several of the storage areas, with Hold Stores (HS) getting the most attention. On-hand numbers were adjusted and orders made accordingly. Two pieces of laboratory equipment, the HP FAXATRON X-radiograph and the Spectrex PC-2000 particle analyzer, were included in the shipment to ODP. Core boxes will be sent to the Bremen Core Repository with trans-shipped supplies from the Gulf Coast Repository.

Underway/Fantail

The opportunity of sailing on the LWD part of Leg 171 afforded time for a JANUS mandated conversion of operating systems on the underway SUN workstations to Solaris 2.5. A UNIX specialist sailed to help with the hardware and software updates and to rewrite the applications as necessary for them to run under the new operating system. There was also the opportunity to write a new SiteFix program for the SUNs and for the underway geophysical specialist to be introduced to nuances of the seismic processing applications. A new a2d trigger was designed and built to replace the external SUN trigger, which did not work with the new version of a2d software.

Both the port and starboard seismic bundles were refurbished and signal leads replaced. The Teledyne single-channel streamer was used during the last leg and was reported to be noisy. A bad leak was located and repaired temporarily, the streamer connectors were cleaned, and the streamers were filled with oil. One magnetometer sensor was leaking fluid and the other sensor was noisy, so both sensors were serviced. A selector switch was added to a front panel in the lab that will allow easier comparisons between the two sensors.

X-ray Lab

The lab was used sparingly during Leg 171B with one scientist making the most use of it and the XRD to identify clay minerals in 45 samples. A few sediment samples were analyzed with the XRF. Some old or seldom-run XRF standards were re-analyzed for comparison with the original numbers. A routine preventative maintenance service call was scheduled for Charleston. Most time and effort was given supporting core recovery and the core lab routine.

MISCELLANEOUS

Electronics Support

Legs 171A and B were supported by one electronic technician each. Although there were few problems with lab equipment on the A part of the leg. Both of the Xerox copiers were cleaned and serviced to reduce jamming and improve copy quality. Signal leads and connectors on the fantail were checked and replaced as necessary.

Problems with the lab equipment during the second half of the leg were mostly in the first few days of the cruise as various instruments were turned on for the first time in awhile. Six successful heat flow Adara measurements were taken. It was necessary to put in some off-shift hours supporting one of the Adara deployments and the Minolta color scanner. Assistance was given removing TOTCO components that will be used as spares and testing Lamont's borrowed Marisat B installation.

Special Projects

A replacement piece of gym exercise equipment was received in Panama and assembled on the transit. There was much discussion on where the monolithic Promaxima assembly should be located. Users were very pleased with the smoothness, range of challenge, and varieties of exercise it offered.

Around a continual shuffle of alligator boxes of core liner, the core lab roof was completely chipped, primed, and painted. Scalloping was noted on thinning roofplates, to 2-3 inches in from the edges. The rails around the deck were replaced; the 4 in drain lines were replaced and moved.

A rain gauge sponsored and built by Grant Petty from Purdue University was brought aboard in Barbados for trial use. Scientist Jim Ogg assumed responsibility for the device. Actual rain values (ground truths) were to be compared with estimates derived from satellite images and used to refine the algorithms for area rainfall. Some good data were collected and some changes were suggested for a more rugged version. The instrument and software were returned at Charleston. Perhaps it will be deployed on another leg.

Safety

No METS participants sailed on the first half of the leg. Most of the usual participants on the second half of the leg were on night shifts and excused.

Air Quality /environmental survey forms from TAMU Health and Safety were available to the scientists and specialists for those who wished to participate. Sedco/Catermar did not participate. An abbreviated CO_2 survey of 10 areas in the ship house and labs was made for background information.

Problems

Water leaks from the hold access hatch below the catwalk persisted despite attention from the deck people on two occasions. Captain Oonk added the hatch to the drydock work list where a better design might be implemented. On one instance the captain had the area mopped while the area was being used to prepare the off-going shipment.

Although there were plans to install the new plastic-lined chemical pipes under the lab stack, it was not done this leg.

LEG 171B LABORATORY STATISTICS

General Statistics:

Sites:	5
Holes:	16
Total Penetration:	4353
Meters Cored:	3794
Meters Recovered:	3227
Time on Site (days):	30.4
Number of Cores :	427
Number of Samples, Total	11920
Chem samples	909
Samples	11011
Number of Core Boxes:	477

Samples Analyzed:

Magnetics Lab	
Half section measurements:	2150
Discrete measurements:	0
Tensor tool holes	6
Physical Properties	
Index properties:	664
Velocity :	574
Resistivity:	167
Thermcon:	26 (WHOI) 82 (TK04)
MST:	1915
Shear Strength:	114
Chemistry Lab	
Inorganic Carbonates ($CaCO_3$):	577
Water Chemistry (the suite includes pH, Alkalinity, Sulfate, Chlorinity, Silica, Phosphate, Ammonia, Ca, Mg, P, Li, Mn, Fe, Sr, Rb):	100
Head Space gas analysis:	248
Pyrolysis Evaluation, Rock-Eval:	27
X-ray Lab	
XRD :	45
XRF:	3 sediment
Thin Sections:	14

Underway Geophysics (est.)

Total Transit Nautical Miles:	1653
Bathymetry:	1413
Magnetics:	1413
Seismic:	28
XBT's Used:	0