OCEAN DRILLING PROGRAM

LEG 145 PRELIMINARY REPORT

NORTH PACIFIC TRANSECT

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SCIENTIFIC REPORT

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ABSTRACT

Scientific drilling in the high-latitude North Pacific during ODP Leg 145 has resulted in a new and detailed insight into the paleoceanographic and paleoclimatic record of this important region. Many of these accomplishments were made possible by the development of a new, much more aggressive, piston coring technique. This new technique resulted in very long APC cores which, in turn, allowed the construction of long and continuous magnetic reversal stratigraphies. Results fall into four categories, events of the Plio-Pleistocene, the Neogene, the Paleogene, and a special events category. The first category is the important changes at 2.6 Ma, the time of the onset of major Northern Hemisphere glaciation (timescale of Cande and Kent, 1992). Dropstones appear in abundance at 2.6 Ma and document sources in both Siberia and Alaska. The input of continentally derived, fine-grained clastics into the deep sea increases several fold at this time, and in the northwestern Pacific abyssal reworking of bottom sediments also begins at about 2.6 Ma and continues to the present. Finally, volcanic ash layers suddenly become abundant in sediments younger than 2.6 Ma all across the North Pacific, a volcanic event that dwarfs anything found earlier in the Cenozoic record. One of the important objectives of Leg 145 was to define better the onset and character of silica sedimentation in the North Pacific. We were able to document that opal fluxes began to increase about 12 Ma, with a pronounced maximum between about 6 and 3 Ma. Also starting in the early portion of the middle Miocene the calcite compensation depth becomes 1.5 km shallower, in marked contrast to a deepening of the CCD since the early Miocene found everywhere else in the world. Leg 145 recovered Oligocene and Eocene carbonate sediments at Detroit Seamount. The middle and upper Eocene sediments are characterized by episodes of downslope transport, reworking and slumping, the timing of which matches that of similar events in the central Pacific Basin. Several Eocene ash horizons occur, adding further definition to the poorly known Eocene volcanism history. The Meiji sediment tongue on the northeast flank of Detroit Seamount was an important drilling target. Leg 145 was able to show that the Meiji tongue is an Atlantic-type drift deposit that has been forming continuously since the early Oligocene. Many paleoceanographic implications follow this important discovery, the most important of which is the continual presence of southward thermohaline flow from the Bering Sea to the North Pacific for the past 35 million years.

INTRODUCTION

Subarctic Pacific sediments contain a critical record of late Mesozoic and Cenozoic oceanographic and climatic changes. Prior to Leg 145, existing sites were too few and generally too disturbed by rotary drilling to permit detailed reconstructions. This region thus presented a significant gap in our knowledge of the evolution of the Earth's climate and oceanic system.

In the middle and late Miocene, the ocean deep circulation underwent reorganization toward the modern pattern as the North Atlantic became an important source of deep water to the world's oceans. Waters from the North Atlantic, after a global tour of the ocean basins, end up in the North Pacific, where they rise to the surface and begin the return journey to the North Atlantic. These deep waters bring to the Pacific all the chemical species that have been dissolving in them over the centuries, including nutrients (particularly silica), and dissolved organic carbon and CO_2. This chemical delivery is recorded by enhanced biological productivity at the sea surface, especially of siliceous organisms, by enhanced dissolution of calcium carbonate at depth, and by more ^{12}C-enriched values in benthic foraminifers.

Results of the first round of North Pacific drilling, which was completed 21 years ago, showed that the middle Miocene was a time when the deposition of silica increased markedly. At the same time there was a significant decline in opal deposition in the Atlantic. This rather sudden change in the venue of oceanic silica sedimentation has been called the "silica shift." To investigate this phenomenon, Leg 145 used new, more aggressive drilling technologies to recover essentially undisturbed sedimentary sections, enabling the construction of long paleomagnetic reversal stratigraphies. Measurements of the physical properties of the sediments allowed the conversion of the linear sedimentation rates, determined by the biostratigraphy and magnetic reversal stratigraphy, to actual mass fluxes of each sedimentary component. These mass fluxes gauge how the input of each component of the sediments has varied through time. The unit of flux, referred to as mass accumulation rate or MAR, is measured in grams per square centimeter per thousand years or $g(cm^2 \cdot k.y.)^{-1}$.

During Leg 145, *JOIDES Resolution* completed 25 holes at seven sites at four locations (Fig. 1, Table 1). Extensive logging operations were conducted at four of the drill sites, and included the first ODP deployment of the French magnetometer and susceptibility tools. Overall sediment and rock recovery totalled 4321 m, 87% of the cored section, placing Leg 145 among only five cruises in the history of the Ocean Drilling Program and its predecessor, the Deep Sea Drilling Project, to recover more than 4 km of material.

Drilling Objectives

The objectives of Leg 145 were:

- To sample the high-resolution Miocene and younger sedimentary record at intervals as short as the 1- to 2-k.y. mixing time of the ocean to determine the detailed history of oceanic and climatic change in the high-latitude North Pacific Ocean;
- To recover high-latitude Paleogene and Cretaceous carbonate-bearing sediments to aid in deciphering the oceanographic record of the old Northern Pacific;
- To collect sediments along a depth transect down the flank of Detroit Seamount in an attempt to reveal oceanic behavior at different depths and times and between different water masses;
- To investigate the middle Miocene "silica shift" phenomena; and
- To seek evidence of a coherent bottom-current system in the North Pacific responsible for the production of the Meiji Tongue, proposed to represent a North- Atlantic type drift deposit.

RESULTS

Site 881

The Geologic Record

A total of 465.2 m of upper Miocene through Pleistocene ooze was recovered at Site 881, in four holes. The deepest penetration was in Hole 881C, an APC/XCB hole that reached 363.8 mbsf. The sediments at Site 881 are all diatom ooze that can be subdivided into an upper and lower portion based on the presence of clay and ash in the upper part of the section (Fig. 2):

> Lithologic Subunit IA, 0-164 mbsf, is a clayey diatom ooze, well bioturbated, that contains ash layers, dropstones, and rhodochrosite/dolomite concretions. Radiolarians, sponge spicules, quartz and feldspar occur in accessory amounts within Subunit IA. Volcanic ash occurs as both light-colored layers of unaltered glass that are commonly tens of centimeters thick and reach thicknesses of up to 1 m, and as brown to dark brown layers up to tens of centimeters thick that are somewhat altered. All ash layers more than a few centimeters thick have a sharp lower boundary and a gradational or bioturbated upper boundary, and the thicker ones show size gradation. Dropstones are common; the predominant lithologies are pyroxene basalt and felsic tuff. The size of the dropstones ranges from sand size to several centimeters in diameter. [The presence of so many pebbles in the sediment caused a problem for the APC/XCB bit. At the end of the time on site the drill crew removed about half a coffee-cup full of pebbles from the bit after it arrived on deck.] The rhodochrosite/ dolomite occurs as concretions and as burrow fillings, often near (in conjunction with ?) ash layers. Pore-water geochemistry is consistent with the authigenic formation of both rhodochrosite and dolomite.

> Lithologic Subunit IB, 164-363.8 mbsf, is dominated by diatom ooze and has accessory clay and radiolarians. Dropstones occur rarely and are of the same lithologies as in the overlying unit; the oldest one occurs 243.5 mbsf in lower Pliocene sediment about 4.7 m.y. old. Minor amounts of ash occur. Rhodochrosite/dolomite concretions are fewer than in Subunit IA. A distinct 18-cm-thick layer of this carbonate occurs at 158 mbsf in both Holes 881C and 881D, implying moderate lateral continuity for this unexpected (at 5542 m depth) lithology.

Physical properties of the formation measured both in the borehole and in the laboratory show distinct differences between Subunits IA and IB. The upper, relatively clay- and ash-rich unit is of lower porosity and water content and of greater bulk density and sonic velocity than the lower, more pure diatom ooze. The several transitions occur in the range of 160 to 180 mbsf and help to demonstrate the gradational nature of the boundary between the subunits. The seismic reflection profiles collected during the pre-site survey show four distinct acoustic units: a lowermost unit with strong reflectors, a nearly transparent unit, a unit with continuous reflectors showing aspects of pelagic drape, and an uppermost unit that displays aspects of bottom-current mediation of depositional processes. This uppermost acoustic unit thins over highs, thickens in lows, and displays onlap relationships onto the sides of the lows. Site 881 was positioned to recover a complete section of this unit and to avoid any brief, local hiatuses that may occur. The boundary between Lithologic Subunits IA and IB approximates the position where the seismic profiles indicate the change from pelagic drape to current-controlled deposition.

Throughout this section siliceous microfossils are moderately to well preserved. Foraminifers are entirely absent except for a few samples, and nannofossils are rare. Good magnetostratigraphic data back to the Gauss/Gilbert boundary may allow modification of zonal boundaries for the subarctic siliceous organisms.

Calculation of the mass accumulation rate or flux of the major sediment components permits insight into the depositional history of Site 881 (Fig. 3). Two important changes are apparent. The first occurs at the Pliocene/Miocene boundary, 5.4 Ma in the Cande and Kent (1992) time scale. At that time there was a threefold increase in the mass-accumulation rate of diatoms, from about 0.4 $g(cm^2 \cdot k.y.)^{-1}$ in the latest Miocene to more than 1.2 $g(cm^2 \cdot k.y.)^{-1}$ in the early Pliocene. Opal flux in the form of diatoms remained high, 1.2 to 1.5 $g(cm^2 \cdot k.y.)^{-1}$ throughout the entire Pliocene and Pleistocene. Values for organic carbon also appear to increase at the Pliocene/Miocene boundary and remained within a factor of 2 or 3 throughout the Pliocene and Pleistocene.

The fluxes of volcanogenic and terrigenous materials increased markedly in the middle of the late Pliocene, at the time of the Matuyama/Gauss reversal boundary, approximately 2.6 Ma. Clay fluxes, which are reasonably well constrained, increased by an order of magnitude from less than 0.1 to about 0.8 $g(cm^2 \cdot k.y.)^{-1}$. Quartz flux may have increased by even greater amounts, from not measurable in the mid-Pliocene to 0.2 to 0.3 $g(cm^2 \cdot k.y.)^{-1}$ the later Pliocene and Pleistocene. The input of volcanic ash also increased ten-to-twentyfold at this time.

Paleoceanography and Paleoclimatology

Opal-rich pelagic sediments accumulated in the northwestern Pacific during the late Miocene at a rate of 15 m/m.y. (0.7 $g(cm^2 \cdot k.y.)^{-1}$. Volcanic glass and clay accumulated along with the opal, suggesting a moderate volcanogenic input and the deposition of some continentally derived clays. At the close of the Miocene, biologic productivity, specifically silica productivity, increased several fold and has remained high ever since. Investigation of the causes of increased late Neogene silica productivity in the North Pacific was one of the important objectives of Leg 145.

Additional striking changes occurred at 2.6 Ma. The deposition of volcanogenic material increased by more than an order of magnitude. This increase in ash deposition in the latest Pliocene in the North Pacific has been known for many years (Kennett and Thunell, 1975; Kennett et al., 1977), but Site 881 provides a much better dated sequence for determining timing of onset of the northwestern Pacific portion of this oceanwide volcanic episode than was available previously. Examination of the individual ash layers will reveal geochemical trends in Kuril-Kamchatka volcanism.

The first occurrence of ice-rafted debris (IRD) at Site 881, early Pliocene at about 4.7 Ma, is evidence of local glaciers having reached sea level somewhere along the North Pacific rim. This age is older than the late Pliocene age of the oldest dropstones found in the Leg 86 drill sites several hundred miles to the south (Krissek et al., 1985). The sudden, large increase in dropstone abundance occurs at the time of the Matuyama/Gauss boundary at 2.6 Ma and is a clear demonstration of large-scale glacial activity around the North Pacific region and has been clearly identified from the Deep Sea Drilling Project drill sites. (von Huene et al., 1976; Rea and Schrader, 1985; Krissek et al., 1985). As in the case of the volcanic activity, results of coring at Site 881 provide the best dated record of North Pacific IRD.

The same climatic deterioration that resulted in glaciers and IRD probably enhanced the erosion of and runoff from the continents, especially Asia, resulting in the great influx of clays to the North Pacific. The clayey oozes of Subunit IA are most likely hemipelagic deposits, based on their closeness to land, very high sedimentation rates (also seen in the Leg 86 cores - Site 578, Janecek, 1985), and acoustic character. Dating the transition between the sediments of Subunits IA and IB establishes the beginning of relatively strong bottom-current activity in the North Pacific to coincide with the onset of Northern Hemisphere glaciation at 2.6 Ma. This determination is the major new paleoceanographic discovery of Site 881; surficial effects of bottom-current activity have been mapped in the region from seismic profiles (Damuth et al., 1983), but the geologic history of this activity had been unknown previously.

Quartz flux into the sediments also increased by more than an order of magnitude at 2.6 Ma. Much of this increased quartz flux may be associated with the increased hemipelagic input, but quartz also is considered to be transported by eolian processes (Leinen and Heath, 1981). Other workers have shown a large increase in the flux of eolian dust into the North Pacific at the time of onset of extensive Northern Hemisphere glaciation, a flux that corresponds to the initiation of the vast Asian loess deposits (Janecek and Rea, 1983; Janecek, 1985; Rea et al., 1985). Increased quartz fluxes in the late Pliocene sediments of Site 881 may have recorded both eolian and hemipelagic processes.

In summary, Site 881 provides a well-dated paleoceanographic record of the past 7.2 m.y. Opal fluxes, low in the late Miocene, increased suddenly at the Miocene/Pliocene boundary and have remained high ever since. A number of important changes occurred in conjunction with the late Pliocene onset of Northern Hemisphere glaciation. Dropstones became common, having been present but rare in earlier Pliocene sediments. The mass-accumulation rate of the clay and quartz components of the sediments rose sharply, indicating increased terrigenous input to the deep sea. Bottom-current mediation of the depositional process became dominant at 2.6 Ma, implying a rather vigorous circulation of Pacific Deep Water since then. And, coincident with all these paleoceanographic and paleoclimatic changes, volcanism in the Kuril-Kamchatka arc began a period of heightened activity.

Site 882

The Geologic Record

Sediments recovered at Site 882 comprise 398.3 m of diatom ooze of late Miocene through Quaternary age. The upper 105 m contains higher percentages of clay and relatively more ash layers and dropstones, forming the basis for subdividing the section into two lithologic subunits (Fig. 2):

> Subunit IA, 0-105 mbsf, is clayey diatom ooze and diatom ooze with clay. The ooze is dark greenish-gray in color and bioturbated. Clay averages roughly 10% of the sediment and some reaches 20% abundance. Ash layers and dropstones are much more abundant in Subunit IA than farther downcore. The ash layers are light gray, reddish gray, or black in color and range in thickness from 1 cm to several tens of centimeters. Layers thicker than about 5 cm have sharp lower contacts, burrowed or gradational upper contacts, and show normally graded bedding. Dropstones range in size from coarse sand to well-rounded pebbles and are usually dark, fine-grained pieces of basalt. Lithologic Subunit IA is essentially devoid of calcium carbonate, and organic carbon concentrations are low, averaging 0.2% to 0.3% in this unit.

The boundary between the subunits is reasonably abrupt at Site 882; it is well displayed in the physical-properties measurements and occurs over just 1 or 2 m.

> Lithologic Subunit IB, 105-398.3 mbsf, is a reddish-brown to greenish-gray bioturbated diatom ooze. Calcium carbonate in the form of nannofossils and micrite particles is an important minor component of much of this subunit, especially between about 105 and 230 mbsf. Below 230 mbsf, calcium carbonate is again very low in abundance although present in many samples. Organic carbon concentrations in Subunit IB are about 0.2%. Sponge spicules make up more than 10% of the sediment at 120-150 and 260-310 mbsf. A few ash layers occur, at depths of 210-230 and 340-398 mbsf. Three dropstones occur in this subunit, the deepest at 359 mbsf.

Shipboard analyses of the physical properties of Site 882 sediments reveal a marked change at 105 mbsf. At that level there is a distinct downward decrease in both wet and dry bulk density and a downward increase in porosity and water content. Throughout the core these properties can be related directly to diatom content, the pure oozes having the highest porosities and lowest bulk densities.

Biostratigraphic zonations based on siliceous microfossils provide the basic stratigraphy at Site 882, with nannofossils providing some stratigraphic information in lower Pliocene sediments. Magnetic-reversal stratigraphy is clear in the upper, more clayey, portion of the core. Reversals related to the Brunhes/Matuyama boundary; to the Jaramillo, Olduvai, and Réunion events; and to the Matuyama/Gauss boundary are clear. The Matuyama/Gauss reversal boundary occurs at the same position in the core as the boundary between lithologic Subunits IA and IB. Sedimentation rates based on biostratigraphic zonations and magnetic-reversal stratigraphy are 40 to 50 m/m.y. in sediments younger than 4.2 Ma, perhaps 200 m/m.y. in sediments between 4.2 and 4.8 Ma, and 38 m/m.y. in lower Pliocene and upper Miocene sediments.

Sediment mass-accumulation rates range from a little more than 2 $g(cm^2 \cdot k.y.)^{-1}$ through most of the section to more than 9 $g(cm^2 \cdot k.y.)^{-1}$ during the time of extreme sedimentation rates in the early Pliocene (Fig. 4). Fluxes of the individual sedimentary components reflect the influx of terrigenous material in Subunit IA and the extreme diatom flux in the upper portion of Subunit IB. Diatoms accumulated at 1.6 to 1.8 $g(cm^2 \cdot k.y.)^{-1}$ throughout the section except for the interval of the early Pliocene between about 4.2 and 4.8 Ma, when they were deposited at extreme rates of 7.5 $g(cm^2 \cdot k.y.)^{-1}$. The other biogenic components also reached flux maxima at this same time, carbonate reached 0.5 $g(cm^2 \cdot k.y.)^{-1}$, a value appropriate to the higher productivity regions of the equatorial oceans, and organic carbon fluxes reached about 0.02 $g(cm^2 \cdot k.y.)^{-1}$. Rapid burial may have acted to preserve these components in this high sedimentation-rate interval. The terrigenous components of the sediment, clay and quartz, accumulated at fairly low rates in the Miocene and Pliocene Subunit IB, but their mass-accumulation rates increased fourfold or more in the younger Subunit IA. The mass accumulation rate of volcanic ash increased by an order of magnitude in sediments younger than the Matuyama/Gauss reversal boundary. At this same time the number of dropstones increases from one in 10 cores in older sediments to an average of two or three per core in the upper Pliocene and Quaternary sediments.

Paleoceanography and Paleoclimatology

The late Miocene of the northwestern Pacific at Site 882 was characterized by ongoing deposition of diatom ooze at rates of 1.6 to 1.8 $g(cm^2 \cdot k.y.)^{-1}$. The deposition of terrigenous clastics was minor, and a small but noticeable amount of volcanic ash accumulated in the sediment. The first/oldest important paleoceanographic event recorded at Site 882 was the enormously rapid deposition of diatoms that occurred during the early Pliocene warm interval, at linear sedimentation rates of 200 m/m.y. and corresponding fluxes of about 7.5 $g(cm^2 \cdot k.y.)^{-1}$. These unusual conditions of extreme silica productivity continued for only 0.5 or 0.6 m.y. The region of this "diatom dump" is limited to the present subarctic North Pacific and the Bering Sea; a similar early Pliocene event may have occurred in the Antarctic. Calcium carbonate and organic carbon fluxes also reached their maxima during this time, probably as a result of the unusual productivity conditions and because rapid burial would have retarded both the dissolution of calcite and the breakdown of organic carbon.

Fluxes returned to more "normal" values at 4.2 Ma. At 2.6 Ma the fluxes of terrigenous materials, clays, and quartz increased several fold, although the overall sedimentation rates changed very little. The late Pliocene and Pleistocene flux of these components was in the range of 300 $mg(cm^2 \cdot k.y.)^{-1}$, values typical for late Cenozoic eolian input to the North Pacific (Janecek and Rea, 1983; Janecek, 1985; Rea et al., 1985), but at Site 882, only a few hundred kilometers from land, it is not possible to differentiate between eolian and hemipelagic materials without considerable further study.

There are at least an order of magnitude fewer dropstones at Site 882 at 50.4°N than there were 360 km to the south at Site 881 at 47.1°N, and examination of the Leg 19 drill sites (Creager, Scholl, et al., 1973) suggests that the northward decline trend may continue. Sites 579 and 580, drilled on DSDP Leg 86, also encountered ice-rafted debris. Cores recovered at Site 580, at 41.6°N, contained considerably more IRD than did those from Site 579 at 38.6°N (Krissek et al., 1985). Site 881, with the largest concentration of IRD of any of the DSDP and ODP drill sites, lies a bit south of the southern tip of the Kamchatka Peninsula and about 300 km seaward of the main opening from the Sea of Okhotsk to the northwest Pacific. Since the abundance of IRD decreases both northward and southward from this point, we conclude that the main source of ice-rafted pebbles in the northwest Pacific is the Okhotsk-Kamchatka region of Siberia. Conolly and Ewing (1970), in a study of the ice-rafting record in Lamont-Doherty Geological Observatory piston cores raised by the *Vema* and *Conrad* in the 1960's, also noticed that the concentration of IRD declined both northward and southward from a location offshore of the southern tip of Kamchatka and suggested a Siberian source for the pebbles. Our work confirms their suggestions and shows that the same IRD depositional pattern has continued for the past 2.6 m.y.

The oldest ice rafting at Site 882 occurred in the latest Miocene, seen as a pebble in sediments of approximately 6 Ma. This compares to the age of the oldest pebble at Site 881 of about 4.3 Ma. A northerly increase in the age of the oldest pebble found exists among the Leg 86 sites to the south (Krissek et al., 1985), where the oldest material is late Pliocene in age, and the two Leg 145 drilling locations. Unfortunately, the Leg 19 sites to the north were spot-cored, so they do not provide a continuous record to determine whether this interesting trend continues northward.

The deposition of volcanogenic material increased by about an order of magnitude at 2.6 Ma. This increase in ash deposition in the latest Pliocene in the North Pacific has been known for many years (Kennett and Thunell, 1975; Kennett et al., 1977), but Sites 881 and 882 provide a much better dated sequence for determining timing of onset of the northwestern Pacific portion of this oceanwide volcanic episode than had been available previously. Examination of the individual ash layers will reveal geochemical trends in Kuril-Kamchatka volcanism.

Site 882, now at a depth of 3255 m, has been at or below the calcite compensation depth (CCD) for most of the time since the late Miocene. The exception is the time of very high sedimentation rates between 4.2 and 4.8 Ma. when the combination of extreme productivity and rapid burial resulted in the preservation of calcite. The late Neogene CCD in the northwestern Pacific of 3250 m or shallower is nearly a kilometer shallower than the nonequatorial Pacific CCD at lower latitudes, which is deeper than 4000 or 4100 m (van Andel et al., 1975; Rea and Leinen, 1985).

Site 883

The Geologic Record

Drilling at Site 883 penetrated about 830 m of uppermost Cretaceous and Cenozoic sediment atop Detroit Seamount and 37.5 m into the underlying basalts. The sedimentary section can be divided into six lithologic units (Fig. 5):

> Unit I, 0-86.9 mbsf, is a Quaternary to upper Pliocene dark gray clay with quartz and diatoms. Vitric ash layers are common, and dropstones are more rare as accessory lithologies. The ash layers are usually light brown or gray in color, but a few are black. Thicker ashes have sharp lower boundaries, show size grading, and have burrowed upper

boundaries. The unit is bioturbated and shows the resultant color mottling and burrow fillings. Unit I corresponds in age almost exactly with the Brunhes and Matuyama chrons.

Unit II, 86.9-458 mbsf, is an upper Pliocene to upper Miocene grayish-green diatom ooze. Calcium carbonate is an accessory component in this unit, and clay occurs in minor amounts. Ash layers are present but in much lower abundance than in Unit I; pumice fragments occur at 131.26-131.46 mbsf. Unit II is moderately bioturbated and mottled.

Unit III, 458-655 mbsf, is a biogenic ooze that can be subdivided into an upper, more siliceous portion and a lower, more calcareous portion. Lithologic Subunit IIIA, 458-597 mbsf, is an upper Miocene to middle Miocene light gray calcareous diatom ooze that forms a transitional unit from the more siliceous units above and the more calcareous sequence below. Subunit IIIA displays moderate bioturbation. Lithologic Subunit IIIB, 597-655 mbsf, is a middle Miocene to lower Miocene light greenish-gray diatomaceous chalk. The subunit is characterized by subhorizontal *Zoophycos* burrows, a few of which are rimmed by pyrite crystals.

Unit IV, 655-818 mbsf is a Paleogene chalk that can be divided into two subunits. Lithologic Subunit IVA, 655-740 mbsf, is an upper Oligocene to middle Eocene very light brown nannofossil chalk. The boundary with the overlying ooze is marked by a pronounced color change from greenish grays above to the creamy tans of Unit IV below and a lacuna of several million years. Some dark-colored vitric ash occurs in Subunit IVA. The entire subunit is extensively bioturbated. Subunit IVB, 740-818 mbsf, is a middle to lower Eocene or perhaps Paleocene nannofossil chalk with ash that becomes more abundant downhole so that the lower part of the unit becomes a nannofossil ash. The unit is bioturbated in the upper portion and displays mottling and *Zoophycos* traces. Current-related sedimentary structures are common, such as lenticular microlamination, small-scale cross lamination, load casts, convolute laminations, scoured surfaces, and burrowed hardgrounds. Micro-faulting and soft-sediment deformation, including centimeter-scale to decimeter-scale recumbent folding, are observed. Subunit IVB in both Hole 883B and Hole 883E displays considerable evidence for downslope displacement of sedimentary material, a process that is more important lower in the section. Debris flows seen as matrix-supported diamictites having very angular clasts of brown altered ash in a light tan chalk matrix are common, and carbonate turbidites occur.

Unit V, 818-830 mbsf in Hole 883B but much thinner in Holes 883E and 883F, consists of Paleocene to Campanian (?) yellow-green to yellow-brown altered ashes that are speckled with iron and manganese oxides. These palagonite clays are now converted to smectites with minor amounts of illite, chlorite, quartz, and feldspar.

Unit VI, 819-856.5 mbsf in Hole 883E and 823-849.4 mbsf in Hole 883F, consists of a series of pillow basalts. The basalts contain 10% to 15% plagioclase microphenocrysts and iddingsite pseudomorph after olivine in a fine-grained groundmass. Rare clinopyroxene occurs. The bulk chemistry of the basalts puts them in the ocean-island basalt (OIB) category. Numerous lithologic or flow units can be recognized, commonly on the basis of the glassy margins of the pillows, now altered to a brown color. Vesicles and small fractures are common and are usually filled with calcite. Calcite, limestone, and palagonite sediment fill the inter-pillow voids.

Shipboard measurements of the physical properties show changes in accord with the major lithologies. Unit I is characterized by dry bulk densities (DBD) of 0.59 g/cm^3 and porosities of 76%. Diatom-rich Unit II is more porous and correspondingly less dense; DBD values average 0.49 g/cm^3. Porosity decreases slightly in Unit III, where DBD values rise to 0.61 g/cm^3 in Subunit IIIA and increase sharply in the chalks of Subunit IIIB to 1.10 g/cm^3 with a corresponding decrease in porosity to 59%. Bulk densities are slightly higher in Unit IV.

Biostratigraphic control was provided by siliceous microfossils in Units I, II, and III, with some assistance from nannofossils in Quaternary sediments. Nannofossil zonation provides the age control in the Paleogene sediments of Units IV and V. Magnetic-reversal stratigraphy is well constrained in the upper clay-rich portion of the core. Reversals related to the Brunhes/Matuyama boundary; to the Jaramillo, Olduvai, and Réunion events; and to the Matuyama/Gauss boundary are clear. The Matuyama/Gauss reversal boundary occurs at essentially the same position in the core as the boundary between lithologic Units I and II. Overall sedimentation rates for the various lithologic units show moderate deposition rates (for the northwest Pacific) for Unit I, approximately 47 m/m.y. for the past m.y. and lower rates of 23 m/m.y. for the interval between about 1.0 and 2.6 Ma. The phenomenon of enhanced sedimentation rates during the past 1 m.y. is seen in all four of the Leg 145 northwest Pacific drill sites. Unit II accumulated the most rapidly, with an overall rate in excess of 90 m/m.y. Rates are slower deeper in the section, 23 m/m.y. in Subunit IIIA, 10 m/m.y. in Subunit IIIB, and about the same down through Subunit IVA. We did not determine meaningful pelagic sedimentation rates for the lower portion of Unit IV, which was subjugated to extensive downslope redepositional processes.

Fluxes of the sedimentary components within the various units can be determined by combining the lithology, sedimentation rate and dry bulk density information for the intervals of interest (Fig. 6). In late Pliocene and Quaternary Unit I, diatoms had mass-accumulation rates (MAR) of 0.6 to 0.7 $g(cm^2{\cdot}k.y.)^{-1}$, and terrigenous materials, clay and quartz, accumulated at higher rates, a total of approximately 1.0 $g(cm^2{\cdot}k.y.)^{-1}$. In Lithologic Unit II, clays and quartz accumulated at somewhat lower rates, about 0.3 $g(cm^2{\cdot}k.y.)^{-1}$, but the rate of silica accumulation increased fivefold to values greater than 3.0 $g(cm^2{\cdot}k.y.)^{-1}$. In the upper portion of Unit III, silica accumulated at a rate similar to that of Unit I, about 0.6 $g(cm^2{\cdot}k.y.)^{-1}$. This opal flux rate declines further in older sediments. The mass-accumulation rate of calcium carbonate is 0.3 to 0.4 $g(cm^2{\cdot}k.y.)^{-1}$ in Units II and III; the calcite MAR doubles in the upper nannofossil chalks of Unit IV to 0.7 $g(cm^2{\cdot}k.y.)^{-1}$.

Paleoceanography and Paleoclimatology

The basalts of Detroit Seamount were erupted in latest Cretaceous time, presumably at the Hawaiian hot spot in the subtropical North Pacific Ocean. The seafloor at the location of Site 883 apparently never reached sea level, as suggested by the complete lack of shallow water or reefal materials in the lowest portion of the sedimentary section. Presumably nearby volcanic eruptions provided volcanic ash to the region, ash now seen as the altered palagonites and smectites of lithologic Unit V. Carbonate and ash deposits on the slopes of Detroit Seamount occasionally reached positions of instability during the lower Eocene and probably Paleocene and moved rapidly downslope as turbidites, slumps, or debris flows. Physical indications of bottom-water activity remain in the sediment column as sedimentary structures. Significant amounts of Paleocene and

Eocene reworking and downslope sediment redistribution have been documented elsewhere in the central and northern Pacific (Schlanger and Premoli Silva, 1981; Rea and Thiede, 1981; Vallier et al., 1983), and the information from Detroit Seamount significantly broadens the known region of that activity. During the Eocene the influx of ash declined, and the more normal nannofossil chalk of middle Eocene to early Oligocene age in Subunit IVA was deposited at rates between 0.5 and 1.0 $g(cm^2 \cdot k.y.)^{-1}$, rates that fall into the low to normal range for carbonate deposition beneath oligotrophic subtropical gyres (Rea et al., 1990).

Above the late Oligocene to early Miocene hiatus, the siliceous component of the sediment becomes important. The MAR of calcite declines to 0.3 to 0.4 $g(cm^2 \cdot k.y.)^{-1}$ in the chalk and oozes of Units III and II, and the flux of silica increases from 0.2 $g(cm^2 \cdot k.y.)^{-1}$ in the more carbonate-rich lower portion of Unit III to 0.6 $g(cm^2 \cdot k.y.)^{-1}$ in the upper, middle and late Miocene, portion of the unit. The diatom ooze of Unit II defines the time of extreme silica deposition in the northwestern Pacific Ocean. Silica flux averages 3.0 $g(cm^2 \cdot k.y.)^{-1}$ during the time between 2.6 and 6.8 Ma, and may have been much higher than that during the early Pliocene. This latest Miocene and early Pliocene episode of silica deposition was observed at the other Leg 145 drill sites in the northwest Pacific and represents a short period of extreme productivity in high latitudes associated with the warm interval of the same age.

Important changes in sediment accumulation occurred in conjunction with the onset of Northern Hemisphere glaciation at 2.6 Ma. The flux of terrigenous clays and quartz to the sediments at Site 883 more than tripled to values of 1.0 $g(cm^2 \cdot k.y.)^{-1}$ and the flux of opal returned to its latest Miocene levels of approximately 0.6 $g(cm^2 \cdot k.y.)^{-1}$. This same enhanced input of terrigenous materials was found at Site 881, where the increase was greater than an order of magnitude and was associated with the onset of bottom-current activity, and at Site 882, where the increase in the flux of terrigenous material was by a factor of 4. Enhanced flux of hemipelagic materials at the time of onset of significant continental glaciation is recorded commonly in the North Atlantic and North Pacific oceans.

At Site 883 dropstones occur in Unit I in slightly lower abundance than that encountered at Site 882, 90 km to the south, and in much lower abundance than at Site 881, about 455 km to the south, again emphasizing the northward decline in ice-rafted debris. Taken together, the Leg 145 drill sites and the Leg 86 drill sites (Krissek et al., 1985; Heath, Burckle, et al., 1985) neatly define the source of the northwest Pacific dropstones to be the Sea of Okhotsk, or possibly the Kamchatka Peninsula, a fact first suspected by Conolly and Ewing (1970). Dropstones appeared in the section at the time of the Matuyama/Gauss reversal boundary at 2.6 Ma and thus herald the onset of major glaciation in the Northern Hemisphere (Rea and Schrader, 1985). In contrast to more southerly locations, no dropstones were found in Site 883 sediments older than late Pliocene.

Ash layers are common to abundant in sediments younger than 2.6 Ma, and occur again in the Eocene portion of the section. At 2.6 Ma the deposition of volcanogenic material increased by more than an order of magnitude. This increase in ash deposition, beginning in the latest Pliocene in the North Pacific, has been known for many years (Kennett and Thunell, 1975; Kennett et al., 1977), but the Leg 145 sites provide much better dated sequences for determining timing of onset of the northwestern Pacific portion of this oceanwide volcanic episode than has been available previously. Examination of the individual ash layers will reveal geochemical trends in Kuril Kamchatka volcanism. The lower occurrence of ash layers provides one of the first good definitions of a period of Eocene volcanism that has been suggested by various data from scattered locations such as Hess Rise (Vallier et al., 1983) and the central Pacific basins (Rea and Thiede, 1981).

The upper Unit I, the gray clay with quartz and diatoms, contains up to 5% percent calcium carbonate, and most samples contain a few foraminifers; nannofossil zonations are possible in the Pleistocene but not below. From these bits of evidence we conclude that Site 883, at its depth of 2385 m, lies very close to the present northwest Pacific calcite compensation depth (CCD). The nearest drill sites, Site 192 at 3014 m depth and Site 882 at 3244 m depth, are clearly below the CCD (Creager, Scholl, et al., 1973). This observation means that the CCD is significantly shallower in the far northwestern Pacific than it is in the central gyre region. Shatsky Rise Site 306 at 3399 m and Hess Rise Site 310 at 3516 m both are characterized by silica-bearing nannofossil ooze of 60% to 70% $CaCO_3$ (Larson, Moberly, et al., 1975). The northernmost site on Hess Rise, Site 464 at 39.9°N and a water depth of 4670 m, contains 11% $CaCO_3$ in its uppermost siliceous ooze unit (Thiede, Vallier, et al., 1981; Dean, 1981), twice as much as occurs at Site 883 at 51.2°N and almost 2300 m shallower.

Shoaling of the CCD toward highly productive polar regions and coastal upwelling zones such as those off the west coasts of South America and Africa is a well-known phenomenon in the modern ocean (Berger, 1974, 1989). It occurs because much of the biological productivity in these regions is in siliceous material which results in the biogeneration of opal and organic carbon. The ensuing breakdown of the organic carbon enhances the rate of dissolution of whatever calcite is produced in these regions, serving to raise the CCD to quite shallow depths. The northward shoaling of the CCD by more than 2 km observed in the North Pacific between about 40°N to 50°N appears to be a classic example of this productivity/dissolution control of carbonate preservation on the seafloor.

Site 884

The Geologic Record

Drilling at Site 884 penetrated 854 m of Cenozoic sediment on the lower flank of Detroit Seamount, including the Meiji Drift, and 87 m into the underlying basalt. The sedimentary section can be divided into two major units, each with subunits (Fig. 5):

> Unit I, 0-604.8 mbsf, is characterized by clay and diatom ooze in changing relative abundances. Subunit IA, 0-128 mbsf, is a Quaternary to upper Pliocene diatom clay and clay. Dropstones and spicule-enriched zones occur as minor lithologies, and fresh ash layers up to 2.5 m thick are common. Some of the thicker ash layers record multiple eruptions. Subunit IB, 128-440.2 mbsf, is an upper Pliocene to upper Miocene clayey diatom ooze grading down to a clayey diatomite. This subunit has a few ash layers, and rare parallel and lenticular laminae. A dolomite concretion occurs at about 172 mbsf, and a piece of wood was found in lower Pliocene sediments at 214 mbsf. Subunit IC, 440.2-545.6 mbsf, is an upper to middle Miocene gray clay. *Zoophycos* trace fossils occur in the lower portion of the unit. Native copper in the form of small bladed and twinned crystals and small veinlets was noted at sub-bottom depths of 507 to 526 mbsf. Subunit ID, 545.6-604.8 mbsf, is a middle to lower Miocene diatomite with clay and a few with spicules. Diatom chalks occur in the lower portion of the unit, and *Zoophycos* trace fossils are present.
>
> Unit II, 604.8-854 mbsf, is dominated by chalk and claystone and displays evidence of minor to total downslope redeposition. Subunit IIA, 604.8-694.7 mbsf, is a lower Miocene to uppermost Eocene claystone with some chalk in the lower portion of the unit. This

subunit displays modest evidence for reworking in the form of sharp contacts, parallel laminae, and thin turbidites. Small bluish-green mottles at 623 to 632 mbsf rarely have grains of native copper at their centers. Subunit IIB, 694.7-771 mbsf, is an upper Eocene to lower-middle Eocene chalk and claystone. Ash is a minor component of this unit; the claystones are interpreted to be altered ashes on the basis of their relatively high smectite content. Little of this unit appears undisturbed. Soft-sediment deformation including recumbent folding is common, and large-scale slump features such as conglomerates with angular clasts occur. Subunit IIC, 771-854 mbsf, is a middle-lower to lower Eocene (Paleocene nannofossils occur in the reworked materials of Subunit IIB) claystone with clayey ash and ash. The claystones are interpreted to represent altered ashes on the basis of smectite content. Minor amounts of chalk occur in this subunit. Evidence for redeposition is less widespread than in the overlying subunit, but turbidites and sharp contacts are common. Streaks of native copper were observed at 806 mbsf.

X-ray-diffraction analyses of the minerals in the sediments of Site 884 show a remarkably constant composition of the terrigenous component from the sediment surface down to about 685 mbsf, near the Eocene/Oligocene boundary and near the lower boundary of Subunit IIA. This component is characterized by a relatively low smectite-to-quartz-plus-illite ratio and a modest plagioclase-to-quartz-plus-illite ratio. The mineral fraction chlorite-plus-kaolinite, dominated by chlorite in the North Pacific, is of lesser relative abundance in these sediments but increases gradually in importance upcore beginning at about 700 mbsf. Below approximately 685 mbsf, both smectite and plagioclase are of much greater relative importance in the clays of Subunits IIB and IIC. These clays are, therefore, interpreted to be altered ashes.

Unit III, 854-941 mbsf, is basalt that occurs in 13 units. Ten units are flows, and three are pillow lavas. The flows are thick (one is 30 m) and usually have chilled or baked margins, but no glassy margins were recovered. Weakly zoned, large (to 25 mm) plagioclase crystals occur in several of the flows, and fresh olivine is common in the lower 50 m, so the basalt is only slightly altered.

A complete sequence of all North Pacific diatom zones ranging in age from late Quaternary to late Oligocene occurs at Site 884. The intervals between 12.0 and 13.5 Ma and approximately 17.5 to

20 Ma are characterized by condensed sections or diastems. Nannofossil biostratigraphy allows definition of the Miocene/Oligocene boundary at 640 mbsf, and the Oligocene/Eocene boundary between 680 and 693 mbsf, within and at the base of lithologic Subunit IIA. The diatom assemblage at Site 884 includes one component which is an arctic-boreal group that has characterized portions of the Bering Sea since it evolved in the late Miocene. Additionally, a benthic form that lives only in the shallow waters of the Aleutian-Bering region occurs consistently, although in low abundance, throughout lithologic Unit I and Subunit IIA. These unusual diatom occurrences indicate relatively long-distance, generally southerly transport of the containing sediments.

The rapidly accumulating clay-rich sediments of Site 884 permitted the development of a magnetic-reversal stratigraphy that is coherent back into the middle Miocene at about 13.5 Ma. This stratigraphy is a singular achievement and, for instance, allows the direct correlation of the North Pacific diatom zonations to the magnetic-reversal time scale in sediments older than latest Miocene for the first time. Further, the depositional history of much of the Meiji Drift can now be constrained, with the temporal control provided by the magnetostratigraphy. Initial paleomagnetic results from the basalts of the lower flank of Detroit Seamount indicate that those rocks are reversely magnetized and were erupted at a paleolatitude of approximately 33°N.

Rates of deposition at Site 884 were high during the late Pliocene and Pleistocene, since 2.6 Ma (Fig. 7). The linear sedimentation rate (LSR) for that interval was about 47 m/m.y. The clay-plus-quartz flux is 1.4 $g(cm^2 \cdot k.y.)^{-1}$, and diatoms accumulated at 0.8 $g(cm^2 \cdot k.y.)^{-1}$ during the past 2.6 Ma. In the remainder of the Pliocene and latest Miocene, 2.6 to 6.2 Ma, the LSR averaged 60 m/m.y., and the mass-accumulation rate (MAR) of clay plus quartz is 0.9 $g(cm^2 \cdot k.y.)^{-1}$ and of diatoms is 1.6 $g(cm^2 \cdot k.y.)^{-1}$. In the remainder of the late Miocene and in the latter part of the middle Miocene between 6.2 and 11.9 Ma, the LSR was 34 m/m.y., and the MAR of clay plus quartz was similar to that of the overlying unit, 0.9 $g(cm^2 \cdot k.y.)^{-1}$, but the diatom flux was somewhat lower, about 0.8 $g(cm^2 \cdot k.y.)^{-1}$. Between 13.5 and 17.5 Ma, LSR values were much reduced, averaging only 13 m/m.y. The MAR of the diatomaceous component was 0.4 $g(cm^2 \cdot k.y.)^{-1}$ and that of the terrigenous component, clay plus quartz, was 0.3 $g(cm^2 \cdot k.y.)^{-1}$. For the Oligocene and lower Miocene portion of the section, representing the period between 20.1 and 34.8 Ma, LSR values are rather low, only 6 m/m.y. Diatoms are not a volumetrically important component of the sediment in this unit, and clay-plus-quartz fluxes were moderate, about 0.4 g$(cm^2 \cdot k.y.)^{-1}$. Throughout the entire Oligocene to Quaternary interval the MAR of $CaCO_3$ is quite low, ranging from about 50 to 90 mg$(cm^2 \cdot k.y.)^{-1}$. Site 884 has not been above the CCD since the end of the Eocene. Meaningful pelagic sedimentation rates could not be calculated for lithologic Subunits IIB and IIC; their total of 159 m of sediment accumulated over a span of about 20 m.y. for a bulk LSR of 8 m/m.y.

Paleoceanography and Paleoclimatology

The basalts of Detroit Seamount were erupted in latest Cretaceous time, based on evidence from Site 883, at the Hawaiian hot spot in the subtropical North Pacific Ocean. If the estimate for the age of basement is correct, then as much as 20 m.y. passed before there was any significant accumulation of sediment at Site 884. None of the downslope-transported material of lithologic Unit II, which should be a reliable integrator of upslope lithologies, shows any indication of shallow-water or reefal material. Displaced foraminiferas now found in Subunit IIA indicate an original paleodepth of less than 500 mbsl. This value can be taken as the deeper constraint on seamount depth; the shallower constraint is the 100-to 150 m water depth beyond which no reef growth is possible. We conclude that Detroit Seamount never built up to sea level.

Ash and $CaCO_3$ were deposited on the slopes of Detroit Seamount during early Tertiary time. During the Eocene, and culminating in the middle Eocene, important amounts of sediment reworking and downslope redeposition occurred, resulting in the soft-sediment deformation, intra-formational conglomerates, turbidites, parallel laminae, scour marks, etc. Downslope reworking of this same age has been documented elsewhere in the central and Northern Pacific (Schlanger and Premoli Silva, 1981; Rea and Thiede, 1981; Vallier et al., 1983), and the information from Detroit Seamount significantly broadens the known region of that activity. By the end of Eocene time the early Tertiary ash influx had ended, reworking had essentially ceased, carbonate deposition was reduced to a minor portion of the whole, and the deposition of continentally derived hemipelagic clays and quartz became important.

The flux of the hemipelagic continental component of the Detroit Seamount sediments has increased ever since first becoming important at the time of the Eocene/Oligocene boundary. Oligocene and lower and middle Miocene rates were a few tenths of a $g(cm^2 \cdot k.y.)^{-1}$. Rates increased to 0.9 $g(cm^2 \cdot k.y.)^{-1}$ during the middle Miocene at about 12 Ma, and again to about 1.4 $g(cm^2 \cdot k.y.)^{-1}$ at the time of the onset of Northern Hemisphere glaciation 2.6 Ma. Diatoms became an important contributor to the sediments above the condensed interval in the lower Miocene with flux rates of 0.4 $g(cm^2 \cdot k.y.)^{-1}$ during the period 17.5 to 13 Ma. During the late middle Miocene the diatom flux doubled to 0.8 $g(cm^2 \cdot k.y.)^{-1}$ and then doubled again to 1.6 $g(cm^2 \cdot k.y.)^{-1}$ in the latest Miocene at 6.2 Ma. Evidence of this period of maximum diatom flux in the latest Miocene and early and middle portions of the Pliocene has been seen at all the Leg 145 drill sites and indicates a relatively warm period in the northwest Pacific. During the late Pliocene and Quaternary, diatom fluxes returned to their previously moderate level of 0.8 $g(cm^2 \cdot k.y.)^{-1}$.

At Site 884 dropstones occur in Subunit IA in similar amounts to those at nearby Site 883, in slightly lower abundance than encountered at Site 882, 110 km to the south, and in much lower abundance than at Site 881, about 475 km to the south, again emphasizing the northward decline in ice-rafted debris. Taken together, the Leg 145 drill sites and the Leg 86 drill sites (Krissek et al., 1985; Heath, Burckle, et al., 1985) neatly define the source of the northwest Pacific dropstones to be the Sea of Okhotsk, or possibly the southern Kamchatka Peninsula, a fact first suspected by Conolly and Ewing (1970). Dropstones appeared in the section at the time of the Matuyama/Gauss reversal boundary at 2.6 Ma and thus heralded the onset of major glaciation in the Northern Hemisphere (Rea and Schrader, 1985). In contrast to more southerly locations, no dropstones were found in Site 883 or Site 884 sediments older than late Pliocene.

Ash layers are common to abundant in sediments younger than 2.6 Ma and occur again in the Eocene portion of the section. At 2.6 Ma the deposition of volcanogenic material increased by more than an order of magnitude. This increase in ash deposition beginning in the latest Pliocene in the North Pacific has been known for many years (Kennett and Thunell, 1975; Kennett et al., 1977), but the Leg 145 sites provide much better dated sequences for determining timing of onset of the northwestern Pacific portion of this oceanwide volcanic episode than had been available previously. Examination of the individual ash layers will reveal geochemical trends in Kuril-Kamchatka volcanism. The lower occurrence of ash layers provides, along with Site 883, one of the first good definitions of a period of Eocene volcanism that has been suggested by various data from scattered locations such as Hess Rise (Vallier et al., 1983) and the Central Pacific basins (Rea and Thiede, 1981).

The presence of native copper as crystals and veinlets or streaks in the sediments of Site 884 is an unusual aspect of authigenic activity in this location. Copper in deep-sea sediments is rare but has been reported from the Pacific Ocean (Manihiki Plateau, Jenkyns, 1976), Atlantic Ocean (western Atlantic, Hollister, Ewing, et al., 1972; Angola Basin, Siesser, 1978), and the Caribbean Sea (Donelley and Nalli, 1973). Most occurrences have been related, without significant laboratory investigation, to percolation of hydrothermal fluids through a sedimentary section characterized by the proper geochemical host conditions (cf. Jenkyns, 1976). There is enough copper in the sediments of Site 884 to provide a fruitful basis for a sophisticated geochemical study of this phenomenon.

The Meiji Drift

Deep thermohaline currents, confined to the Coriolis-correct side of a basin or deep-sea ridge, can be responsible for the long-term, long-distance transport of sediment. The resulting deposits are greatly elongate parallel to the flow-constraining bathymetry and can exceed 1 km in thickness. The sediments in these deposits are often some combination of biogenic-pelagic material and land-derived, fine-grained hemipelagic sediment. Drift sediments are almost always homogeneous and bioturbated and rarely display the sedimentary structures commonly associated with deep currents such as parallel laminae, sharp contacts and scour marks, or cross-bedding. Rates of deposition, often several tens of meters per million years, depend on supply and are noticeably higher in the drift deposit than in nearby deposits accumulating under purely pelagic conditions (Kidd and Hill, 1987; Pickering et al., 1989).

DSDP Legs 93 (van Hinte, Wise, et al., 1986) and 94 (Ruddiman, Kidd, et al., 1987) drilled three of the major drift deposits in the North Atlantic. The Hatteras Outer Rise, drilled at Site 603, is a very uniform silt and clay "muddy contourite" composed of silica and nannofossil-bearing clay. At Site 603, 950 m of this deposit has accumulated since the middle Miocene, giving sedimentation rates of over 90 m/m.y. for this time span (Wise and van Hinte, 1986). The Feni Drift, a deposit 600 km long, 100 km wide, and up to 1600 m thick was drilled at Site 610 in the North Atlantic.

This deposit is glacial-aged mud with ooze above 135 mbsf and nannofossil ooze and chalk with very low clay content below that horizon. The deposit is early Miocene in age at a depth of 723 mbsf, giving a sedimentation rate of over 40 m/m.y. (Ruddiman, Kidd, et al., 1986; Kidd and Hill, 1987). Drilling at Site 611 encountered the Gardar Drift, a deposit 1000 km long, 130 km wide, and 1450 km thick. The Gardar Drift is an alternating mud and carbonate ooze of late Pliocene and Quaternary age in the upper 105 mbsf and a structureless, homogeneous pure carbonate ooze and chalk below. The upper 571 m of this deposit was deposited at rather uniform rates of 60 m/m.y. in the Mio-Pliocene to 100 m/m.y. in the Quaternary (Ruddiman, Kidd, et al., 1987; Kidd and Hill, 1987). The resulting overview of drift deposition provided by these and prior drilling legs is that the deposits are fundamentally pelagic, consisting of nannofossils and foraminifers, are without sedimentary structures indicative of current-controlled deposition, and have high and relatively uniform sedimentation rates. Tracing the reflector surfaces underlying the drift deposits to drill holes where they could be dated made it possible to determine that deposition of drift deposits in the North Atlantic began at the time of the Eocene/Oligocene boundary (Kidd and Hill, 1987).

The thick sediment deposit on the northeast side of the Obruchev Swell was first noted by Ewing et al. (1968) in their general review of Pacific sediment thicknesses. DSDP Leg 19 drilled one site, Site 192, on the upper part of the swell, on Meiji Seamount, and encountered thick pelagic and hemipelagic deposits (Creager, Scholl, et al., 1973). Scholl et al. (1977) provided the first detailed description of the Meiji Drift deposit, based upon seismic-reflection profiles and the Leg 19 drilling at Meiji Seamount. The Meiji Drift in the northwest Pacific is a sedimentary deposit on the northeast side of the northernmost Emperor Seamount chain that is over 800 km long and about 350 km wide between 300-m isopachs. The deposit is up to 1800 m thick at its northwestern end at the Kamchatka Strait and thins to the southeast. Scholl et al. (1977) note a clear link of the mineral component in the Miocene and younger deposits of Meiji Seamount to the same material at Site 191 in the Komandorski Basin and to Siberian source regions. They conclude that the Kamchatka current that flows south through the deep Kamchatka Strait transports Siberian terrigenous materials to the northwest Pacific, forming deposits both northeast of the northern Emperor seamounts and the Meiji Drift, and along the base of the Kamchatka-Kuril continental margin.

Mammerickx (1985) presents information that suggests that the Meiji Drift deposit may be traceable as far south along the east flank of the Emperor Seamounts as 35°N, a distance over 2000 km from the Kamchatka Strait. She emphasizes the strong similarity of the Meiji Drift to the North Atlantic drifts and presumes the same depositional process. In support of this thesis she notes several reports of indications of sources of cold, deep water in the far northwest Pacific (Mammerickx, 1985).

Site 884 was positioned on the Meiji Drift at a location where the deposit was expected to be thin enough, less than 800 m thick, so that it could be completely penetrated. The seismic reflection profile taken by the *R/V Farnella* and processed at the U.S. Geological Survey by Scholl and Dadisman (personal communication, 1992) along which Site 884 was chosen shows clear evidence of ongoing sediment transport processes in the form of modern and buried channels, demonstrating that this location has been one of active deep-water flow throughout the history of the deposit. Site 884 is on the southwest side of the main sedimentary axis of the deposit, and the site-survey profiles collected by the *JOIDES Resolution* show that the sedimentary units thicken to the northeast.

The information gathered as a result of drilling at Site 884 includes several important results. First, Leg 145 was able to define a sediment body that contains pelagic-biogenic materials, largely siliceous, and hemipelagic land-derived clays and quartz. Deposition of this feature has continued since the time of the Eocene/Oligocene boundary with the possible exception of one or two brief lacunae in the Miocene. The mineralogy of the terrigenous component has remained invariant throughout the time of deposition, with the exception of a modest increase in the relative abundance of the 7-angstrom clay component which is dominated by chlorite in the North Pacific. Finally, northern-source diatoms occur throughout the deposit. All these indications suggest a constant depositional process supplied by sediment from the same northern or northwesterly source region. The mass-accumulation rates of the sediment components vary as plate motion carries the site toward the continental source, the importance of which varies with climatic regime, and as production of the biogenic component waxes and wanes.

Backtracking the site along the Hawaiian trend for the past 35 m.y. places it in the relative location of about 40°N and 165°W, in the middle of the Oligocene North Pacific (Rea and Duncan, 1986). Mineral fluxes in the Oligocene portion of the section are about 400 mg$(cm^2 \cdot k.y.)^{-1}$,20 to 40 times greater than mid-Cenozoic eolian fluxes to the ocean (Janecek and Rea, 1983; Janecek, 1985), and so are clearly hemipelagic. The question is to discover how such long-distance hemipelagic transport might be accomplished. One possibility is that the northwestward continuation of the Hawaii-Emperor Ridge acted as a flow guide for the North Pacific thermohaline circulation, diverting bottom-water flow coming south from the Bering Sea to the southeast along this proposed Meiji extension. If so, the history of the Hawaii-Emperor-Meiji extension ridge, hence the life of the Hawaiian hotspot, is extended by about 40 m.y.

The assembled data suggest that deposition of the Meiji Drift was occurring by early Oligocene time. Northern-source minerals and diatoms have accumulated at moderate to high rates, generally increasing throughout the middle and late Cenozoic, in an elongate deposit on the northeast flank of the northwest extension of the Emperor Ridge. The supply of terrigenous material increased markedly at times of known climate change in the middle Miocene and late Pliocene and thus may have been related to the enhanced physical erosion of the continents surrounding the North Pacific caused by deterioration of climate in those regions. The (presumably) early Oligocene onset of deposition and continuing deposition of the Meiji Drift entail important consequences for the physical oceanography of the North Pacific. Southerly flow of bottom waters from the Bering Sea into the North Pacific basin has been occurring for as long as 35 m.y. Presumably this flow has been controlled geographically by the location of one or two deep passages through the Aleutian Ridge. At present, and perhaps ever since the last important change in direction and rate of plate convergence in the region at about 43 Ma (Rea and Duncan, 1986), the deep passage is at the western end of the Aleutian chain, the Kamkchatka Strait. The basins of the Bering Sea have served as catchments for the voluminous clastics, mostly turbidites, that derive from Siberia and Alaska, allowing a bypassing of the finer, hemipelagic component to the North Pacific. Without such a large catchment basin, the clastics entering the northeast Pacific directly from North America have formed the vast turbidite abyssal plains of the Gulf of Alaska.

In a broader sense, the onset of drift deposition in the North Pacific at generally the same time as in the North Atlantic suggests a similar oceanographic and probably climatic setting. The paleolatitude and paleodepth of the Bering Sea and the basins between the Iceland-Faeroes Ridge and the Charley Gibbs Fracture Zone are similar. Pelagic sediments in the North Atlantic are more calcareous, but the middle Tertiary supply of clastics appears to have been greater in the North Pacific.

The response of the northern oceans to the onset of Southern Hemisphere glaciation in the earliest Oligocene seems to involve a fundamental change in deep circulation. It remains a fruitful area of research.

Sites 885/886

The Geological Record

Sites 885 and 886, located 2.2 km apart, are characterized by about 70 m of sediments overlying basalt. The sedimentary sequence is similar at both sites but differs in thickness, being 52 m thick at Site 885 and 71.9 m thick at Site 886. Three lithostratigraphic units can be recognized at both sites (Fig. 8):

Unit I, 0-17.3 mbsf, is Quaternary to late Pliocene in age and consists of reddish-brown and brown pelagic clay in concentrations typically ranging from 65% to 95%. Diatoms and sponge spicules constitute the minor lithologies of this unit. Diatom concentrations are relatively constant, comprising 4%-15% of the section. Spicule concentrations are low (1%-15%) in the upper half of the unit and increase up to 25%-30% in the lower part. Volcanic ash and pyrite are present as accessory lithologies. Two thin (1 and 3 cm) but distinct ash layers with sharp lower and gradational upper boundaries occur in the middle of the unit at Site 885 but were not observed at Site 886, probably being obscured by bioturbation. Pyrite is scattered throughout the upper portion of the unit either in the form of concretions about 2 cm in diameter with limonite surface staining, aggregated clots, or intergranular cement in ash-filled burrows. The sediment is bioturbated throughout and exhibits dark-colored burrows and mottles, and light-colored pockets filled with ash and spicule oozes.

Unit II, 17.3-50.3 mbsf, is of late Pliocene to late Miocene age and consists of light brown to yellowish-brown diatom ooze with diatom concentrations ranging from 54% to 95% and averaging 81%. A dark yellowish-brown clayey diatom ooze from approximately 49 mbsf to the base of the unit at 50.3 mbsf forms a transition between the diatom ooze and the underlying clayey unit. Ash, pumice clasts, limonite, and ferromanganese nodules and nodule fragments constitute minor lithologies, particularly in the lower portion. Ashes form a single distinct layer in the middle of the unit and also occur scattered throughout the section as burrow fillings. The ferromanganese nodules are black or dark brown and botryoidal in shape; the largest are 6-8 cm along the major axis and typically have a distinct concentric internal structure with volcanic (?) clasts as cores. Sediments display slight bioturbation as indicated by burrows, mottles, and pockets.

Unit III, 50.3-71.9 mbsf, is late Miocene in age in the uppermost part and undated down throughout the most of the sequence, being barren of any fossils except for fish teeth in the deeper portion. This unit is composed predominantly of brown to dark brown pelagic clay, grading down to dark reddish-brown hematitic clay at the base of the unit. The uppermost part contains up to 20% diatoms. The characteristic feature of this unit is a high concentration (10%-30%) of authigenic and/or diagenetic minerals including zeolite, hematite and ferromanganese nodules scattered throughout the section. Co-mingled chert and ferromanganese oxide concretions (<1 cm in diameter) occur in separate thin (3-5 cm) layers. The color, shape, and internal structure of the ferromanganese nodules are similar to those observed in overlying unit.

Unit IV, 52.1-58.8 mbsf (but poorly recovered) in Hole 885A and 68.5-68.9 mbsf in Hole 886B, consists of angular fragments of aphyric basalt. The basalts are highly altered and have surficial coatings of yellowish, orange, and black alteration products. Some relatively fresh pieces contain extremely rare microphenocrysts of moderately altered plagioclase and olivine completely altered to iddingsite in a microcrystalline groundmass. Two lithologic units can be tentatively recognized, based on an altered glassy margin at the top of a lower flow in Hole 885A. Due to poor recovery and the extent of alteration, the nature, sill or basement, of these basalts remains unknown.

Shipboard measurements of the physical properties agree well with major lithologies. The clay of Unit I is characterized by relatively high dry bulk density (DBD) values varying from 0.4 to 0.55 g/cm3 (average 0.45 g/cm3) and by porosities averaging 80%. The diatom ooze of Unit II is more porous (83%), and, accordingly, DBD values decrease to a value of 0.41 g/cm3. Dry bulk densities increase to average values of 0.5 g/cm^3, and porosity correspondingly decreases again to 80% in pelagic clays of Unit III.

Units I and II contain abundant to common diatoms of good to moderate preservation, providing continuous zonation ranging from the Miocene *Thalassionema schraderi* Zone through the late Pleistocene *Neodenticula seminae* Zone. The assemblage at Sites 885/886, along with diatom zonation from latitudinally close DSDP Leg 86 sites (Koizumi and Tanimura, 1985), provide a link between the equatorial and subarctic North Pacific. Radiolarians are present throughout these units, but zonation is possible only for the Pleistocene interval. Ichthyoliths are the only fossils present in the pelagic "red" clays of Unit III. Despite the relatively slow sedimentation rates, good paleomagnetic reversal stratigraphy down to Anomaly 3 was obtained both at Sites 885 and 886, providing reliable age control for biostratigraphic zonations. The Matuyama/Gauss reversal boundary is close to the boundary between lithostratigraphic Units I and II, marking as it does in other Leg 145 sites a distinct transition between two different lithologies.

Linear sedimentation rates (LSR) within the stratigraphically well-constrained portion of the sequence (Units I and II) averaged 5.7 m/m.y (Fig. 9). The LSR did not vary significantly from the late Miocene through the Quaternary. Fluxes of clay and diatoms were 0.03 and about 0.2 $g(cm^2 \cdot k.y.)^{-1}$, respectively, for upper Miocene-upper Pliocene Unit II. Clay flux increased up to 0.18 $g(cm^2 \cdot k.y.)^{-1}$ for the uppermost Pliocene through Quaternary interval, while diatom flux decreased to 0.02 $g(cm^2 \cdot k.y.)^{-1}$.

Paleoceanography and Paleoclimatology

Basalt was recovered at both Sites 885 and 886 (52 and 71 mbsf, respectively) at much shallower depths than expected. The seismic record across the sites shows sedimentary cover above acoustic basement having a thickness of about 75 m, but this acoustic basement was not expected to be basalt. The nature and age of these basalts remain unknown, but their presence at this depth in the section emphasizes an unusual history of the seafloor in this area. If the basalt is considered "true" oceanic seafloor, then the thin carbonate cover which generally overlies oceanic basement is lacking here, denoting a time of unusually shallow calcite compensation depth. If the basalts are a sill within the sedimentary sequence (note that a baked contact is not observed, then volcanic activity has occurred in the region at least several tens of millions of years after formation of oceanfloor.

The oldest reliably dated sediments at both sites are late Miocene in age. Before that time pelagic clay deposition dominated the region. The sediment is typical "red" or "brown" clay recovered elsewhere in the North Pacific (McManus, Burns, et al., 1970; Thiede, Vallier, et al, 1981; Heath, Burckle, et al., 1985; Leinen, 1989). These clays accumulated very slowly at abyssal depths beneath oligotrophic waters and consist of terrigenous, hydrogenous, and hydrothermal minerals (Kadko, 1985; Leinen, 1987, 1989). Linear sedimentation rates calculated for the Late Cretaceous through Paleogene clay section at DSDP Site 576 averaged about 0.4-0.5 m/m.y. (Heath et al., 1985; Janecek, 1985). If we assume that the red clays at Sites 885/886 accumulated continuously and with similar average linear sedimentation rates as at Site 576, then the 20-m-thick sequence recovered at these sites represents 30-40 m.y. of deposition, and the underlying basalts are Eocene or older in age.

Since the late Miocene, pelagic clays and biogenic silica have accumulated in the region. Diatoms appeared in sediments of Sites 885 and 886 at approximately 9.5 Ma and greatly increased in abundance at about 7.5 Ma, distinctly marking the boundary between pre-upper Miocene brown clays and upper Miocene-upper Pliocene yellowish-brown clayey diatom ooze. Sedimentation rates increased to average values of 5.7 m/m.y. This well-defined interval of increased diatom flux (to about 190 $mg(cm^2 \cdot k.y.)^{-1}$ coincides with a period of enhanced biogenic silica supply in the North Pacific observed at all other Leg 145 sites. However, owing to the location of Sites 885/886 under low-productivity oligotrophic waters, mass-accumulation rates of silica are lower here as compared to the more northerly drill sites. Diatom supply decreased in the late Pliocene to an average of 20 $mg(cm^2 \cdot k.y.)^{-1}$.

Upper Miocene-Quaternary clays at Sites 885/886 differ from older the older clays at these sites and are more similar to clays that compose the upper part of abyssal pelagic sequences throughout the central North Pacific (McManus, Burns, et al., 1970; Thiede, Vallier, et al., 1981; Heath, Burckle, et al., 1985). These younger clays generally contain relatively more quartz and other eolian terrigenous material (Leinen, 1989).

Clay fluxes at Sites 885 and 886 in the late Miocene through late Pliocene remained low, averaging about 30 $mg(cm^2 \cdot k.y.)^{-1}$ but increased to approximately 180 $mg(cm^2 \cdot k.y.)^{-1}$ near the Matuyama/ Gauss boundary at 2.6 Ma. These mass-accumulation rates are comparable to those obtained for eolian material from late Cenozoic sequences elsewhere in the central North Pacific (Rea and Janecek, 1982; Janecek, 1985; Rea et al., 1985) with the large increase in Pliocene mass-accumulation rates having resulted from increased eolian input from Asia with the onset of Northern Hemisphere glaciation.

The occurrence of small ferromanganese nodules in red clays in the lower part of the Sites 885/886 sequence is consistent with low sedimentation rates and low organic carbon content (< 0.1%) determined for these sediments. At the same time, the occurrence of relatively large ferromanganese nodules in Miocene diatom ooze suggests an influx of chemical elements from hydrothermal sources also occurred then. The nature of these nodules awaits more detailed shore-based study, but several factors suggest that diagenetic processes did not contribute much to their formation, including the rounded or botryoidal shape of the nodules, the low organic carbon concentration, and the presence of other oxidized forms of iron in the sediments. The relatively large dimensions of the nodules also favor a hydrothermal source for their formation. At the seafloor, under the influence of a hydrogenous source, nodules form very slowly, with growth rates averaging 2 mm/m.y (Bogdanov et al., 1990). At these rates, formation of the large nodules that are observed in upper Miocene-Pliocene sediments of Sites 885/886 would require at least 30 m.y.

Site 887

The Geologic Record

Three sedimentary units with a total thickness of 289 m and basalt were recovered at ODP Site 887 in the Gulf of Alaska. The sedimentary section, early Miocene to Quaternary in age, can be divided into three lithologic units (Fig. 8):

> Lithologic Unit I, 0-90 mbsf, consists of two subunits. Subunit IA, 0-45 mbsf, is a greenish-gray siliceous silty clay of Pleistocene age. Diatom layers averaging roughly 30 cm in thickness occur on a 1-m spacing in the silty clays. Ash layers are common, and dropstones are abundant in this unit. Subunit IB, 45-90 mbsf, is a Pleistocene to upper Pliocene clay with a few diatomaceous layers. Dropstones and ash layers are common, and calcareous zones occur intermittently in this subunit.

Lithologic Unit II, 90-270 mbsf, can be divided into three subunits. Subunit IIA, 90-174 mbsf, is an upper Pliocene to upper Miocene gray to brown homogeneous diatom ooze. A few ash layers and one dropstone zone, at approximately 130 mbsf, occur in this subunit. Subunit IIB, 174-235 mbsf, is an upper to middle Miocene gray calcareous diatom ooze. A few ash layers occur in the lower part of the subunit. Subunit IIC, 235-270 mbsf, is a middle to lower Miocene clayey siliceous ooze dominated by poorly preserved diatoms and radiolarians. Ash layers occur throughout the subunit.

Lithologic Unit III, 270-289 mbsf, is a lower Miocene brown clay that occurs just above the basalt in Hole 887D. In Hole 887A several meters of basaltic pea gravel in a clay slurry was encountered at the bottom of the hole, resting on basalt, a testimony to the local variability of basement cover on this seamount platform.

Lithologic Unit IV, 289-376.3 mbsf, is represented by the 16.3 m of basalt recovered from drilling 87.3 m into basement. The basalts range from highly clinopyroxene-plagioclase phyric basalt in the upper portion to moderately plagioclase phyric basalt to sparsely plagioclase phyric basalt near the bottom of the hole. The logging runs into basement defined a compound edifice that consists of at least three and possibly four flows or sills with intervening sediment layers. The upper intra-basalt sediment layer is an Oligocene nannofossil chalk. Hole 887D provides an intriguing glimpse into the geology of these kinds of volcanic constructions.

Calcareous fossils are present in the Miocene and lower Pliocene parts of the section, but Pleistocene sediments are present only in discrete, apparently cyclic, zones; most of the Pleistocene is barren. Diatoms are abundant and provide the basic biostratigraphic zonations, as they have for the other Leg 145 drill sites. Radiolarians are common throughout the section. Reworked middle Miocene forms of these fossils occur in the upper Miocene and lower Pliocene sediments.

In addition to the biostratigraphy provided by the siliceous microfossils, a magnetic reversal stratigraphy complete to 18 Ma has been constructed for essentially the entire section of APC Hole 887C, 0-270 mbsf. This stratigraphy provides a framework for calibration of microfossil zonations and allows the determination of well-constrained sedimentation rates (Fig. 10). Subunit IA, the siliceous clays, has a linear sedimentation rate of about 61 m/m.y. that pertains from 0 to 0.74 Ma. Sedimentation rates decline more or less continuously downcore, and were about 25 m/m.y. for the Pliocene and lower Pleistocene portion of the section, 0.74 to 5.8 m.y. in age, and 10 m/m.y. for the middle and upper Miocene. The lower Miocene clays may have a linear sedimentation rate of perhaps 2 m/m.y. Casting the sedimentation rates as mass-accumulation rates allows differentiation of the input of the major sedimentary components. Terrigenous materials, recorded on board as clay plus quartz, increased in flux by nearly an order of magnitude at the time of the onset of Northern Hemisphere glaciation from 0.10 to 0.15 $g(cm^2 \cdot k.y.)^{-1}$ for the Miocene and lower and middle Pliocene sediments, to about 1.0 $g(cm^2 \cdot k.y.)^{-1}$ for sediments younger than 2.6 Ma. The greatest flux of terrigenous materials occurred in the youngest portion of the section, in materials younger than 0.74 Ma. Diatoms, the other major sedimentary component, reached their flux maxima in the lower and middle Pliocene portion of the section, where they accumulate at over 1.0 $g(cm^2 \cdot k.y.)^{-1}$ in the time interval between 2.6 and 5.7 Ma. The lower Pliocene period of greatly enhanced diatom deposition, observed on Leg 145 throughout the North Pacific, is also present in the Gulf of Alaska.

Paleoceanography and Paleoclimatology

The Patton-Murray Seamount edifice was extruded in the latest Oligocene onto seafloor that was already 10 to 12 m.y. old. Volcanic activity must have continued for at least 1 or 2 m.y. as demonstrated by the series of sills or flows with sedimentary interlayers. Seamount peaks stand as high as 3000 m above the platform level, which is in turn 1500 m above the seafloor. Those peaks must have stood above sea level, and the well-rounded pea gravel in the bottom core of Hole 887A implies shallow-water processes prior to downslope emplacement.

Sediment deposition was initially slow and with little carbonate. Calcite becomes a noticeable contributor to the sediments only within Subunit IIB, which is of late Miocene age. Clearly the CCD was not becoming deeper through the past 10 to 15 m.y. at Patton-Murray, as it does elsewhere in the Pacific (Berger, 1973; van Andel et al., 1975; Rea and Leinen, 1985). In that sense its behavior is similar to that observed for the northwest Pacific, but from a single site it is not possible to discern the extent of any vertical excursions.

Diatom fluxes reflect the pattern observed on Leg 145 throughout the North Pacific, reaching a maximum in the latest Miocene and early Pliocene. At Site 887 that maximum is on the order of 1 $g(cm^2 \cdot k.y.)^{-1}$, approximately a threefold increase in mass-accumulation rate compared to both underlying and overlying sediment.

The onset of Northern Hemisphere glaciation had a strong effect on sedimentation in the Gulf of Alaska. The flux of opal was greatly reduced and the sediments became dominated by terrigenous grains of clay and quartz. The timing of ice rafting in the Gulf of Alaska was first studied by the scientists of DSDP Leg 18 (von Huene et al., 1973, 1976) based on recovery from rotary cores. The Site 887 information demonstrates that ice-rafted debris became significant exactly at the 2.6-Ma magnetic reversal that marks the onset of glaciation. Lower Pliocene dropstone zones that are about 4.5 Ma may represent the marine record of alpine glaciation in southeast Alaska, as indicated by studies of onshore geology (Lagoe et al., 1993). Dropstones are far more abundant in the Gulf of Alaska than in the northwest Pacific and of quite different lithology, confirming the pronounced Alaskan source of ice-rafted debris suggested by Rea and Schrader (1985). The pan-Pacific dropstone record will allow us to compare timing and pulses of glaciation in Siberia and North America.

The terrigenous materials, hemipelagic in the lower portion of the core with increasing contribution from ice-rafting upsection, become coarser and accumulated more rapidly in the upper 45 m of the section in Subunit IA. The age of this change is approximated by the Brunhes/Matuyama reversal boundary at 0.74 Ma and may correspond to the increased amplitude of glacial cycles as recorded in the marine oxygen-isotope signal.

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TABLE 1

Leg 145 Site Locations

Site	Latitude	Longitude	Water Depth (m)
881	47°06.1'N	161°29.5'E	5531
882	50°21.8'N	167°36.0'E	3244
883	51°11.9'N	167°46.1'E	2385
884	51°27.0'N	168°20.2'E	3826
885	44°41.3'N	168°16.0'W	5711
886	44°41.3'N	168°14.3'W	5173
887	54°21.9'N	148°26.8'W	3631

FIGURES

Figure 1. Location of Leg 145 sites.

Figure 2. Lithostratigraphy of Sites 881 and 882.

Figure 3. Composite sedimentation rate plot for Holes 881A to 881C of Site 881 (left side of figure) using magnetostratigraphy above ~210 mbsf (diamonds) and biostratigraphy below 210 mbsf (squares, circles and triangles = diatom, radiolarian, and nannofossil datum levels, respectively). Dashed lines mark significant changes in the linear rate of sedimentation. On the right, histograms show the average flux (mass-accumulation rate, in $g/cm^2 \cdot k.y.$) of sedimentary components for each of the five time-stratigraphic intervals delimited by the dashed lines. It is evident that the major lithological break at this site (at ~164 mbsf) resulted from a dramatic increase in the flux of glass, clay, and quartz, beginning 2.6 m.y. ago.

Figure 4. On the left, a sedimentation rate plot for Hole 882A using magnetostratigraphy (solid symbols) and biostratigraphy (open symbols; squares, circles, and triangles = diatoms, radiolarians and nannofossils, respectively). Below 300 mbsf, where the data do not provide a unique solution, four alternative age models ("A"-"D") are considered in the text. Models "B" and "C" are thought to be the most reasonable, and the former is chosen for determinations of flux (mass-accumulation rate; histograms on right). In the upper two time-stratigraphic intervals, average diatom fluxes do not appear to vary significantly, whereas significant changes occur in the average fluxes of clay and carbonate, which account for the boundary between lithologic Subunits IA and IB. The most significant change at this site is the dramatically increased diatom flux between 4.2 and 4.8 Ma (note scale change for that interval).

Figure 5. Lithostratigraphy of Sites 883 and 884.

Figure 6. On the left, a sedimentation rate plot for Hole 883B using magnetostratigraphy (solid symbols) and biostratigraphy (open symbols; squares, circles, and triangles = diatoms, radiolarians, and nannofossils, respectively). For flux (mass-accumulation rate) calculations the section is divided into five intervals where rates of sedimentation are relatively constant. These intervals are identified by dashed lines tying the stratigraphic column to the flux results (histograms

to right), and their boundaries coincide with lithological boundaries (dashed lines) or condensed intervals or hiatuses (wavy horizontal lines). The flux results quantify the change from Paleogene carbonate sedimentation to Neogene siliceous sedimentation and the late Neogene onset of terrigenous sedimentation associated with glaciation.

Figure 7. On the left, a sedimentation rate plot for Site 884 using magnetostratigraphy from Holes 884A and 884B (solid symbols) and biostratigraphy from Hole 884B (open symbols; squares, circles, and triangles = diatoms, radiolarians, and nannofossils, respectively). For flux (mass- accumulation rate) calculations the section is divided into five intervals where rates of sedimentation, dry bulk density, and sediment composition are relatively constant. These intervals are identified by dashed lines tying the stratigraphic column to the flux results (histograms to right). The flux results quantify the origin of late Paleogene Meiji Drift sedimentation, Neogene siliceous and hemipelagic sedimentation, and late Neogene and Quaternary terrigenous sedimentation associated with glaciation.

Figure 8. Lithostratigraphy of Sites 885/886 and 887.

Figure 9. Sedimentation rate plot for Site 885/886 using magnetostratigraphy. Dashed line shows model sedimentation rate used for flux calculations, shaded pattern shows range of unit boundary locations among these sites, and average unit boundaries are assumed to occur at ~17 and ~52 mbsf (solid lines). Average rates and fluxes (in $g/cm^2 \cdot k.y.$) are calculated for the upper two lithological units, but there is no chronostratigraphic information below Unit II. The major flux change at this site occurs at the lithologic Unit I-Unit II boundary, with a change from dominantly diatomaceous sediments to dominantly clayey sediments. That level in these cores probably marks the onset of Northern Hemisphere glaciation at ~2.6 Ma.

Figure 10. On the left, an age-depth plot for Site 887 using magnetostratigraphy from Hole 887C. For flux (mass-accumulation rate) calculations the section is divided into five intervals where rates of sedimentation, dry bulk density, and sediment composition are relatively constant. These intervals are identified by dashed lines tying the stratigraphic column to the flux results (histograms to right). Solid horizontal lines mark lithostratigraphic unit boundaries. Flux results quantify the late Neogene and Quaternary influence of terrigenous sedimentation associated with glaciation and the latest Miocene-early Pliocene pulse of diatom sedimentation.

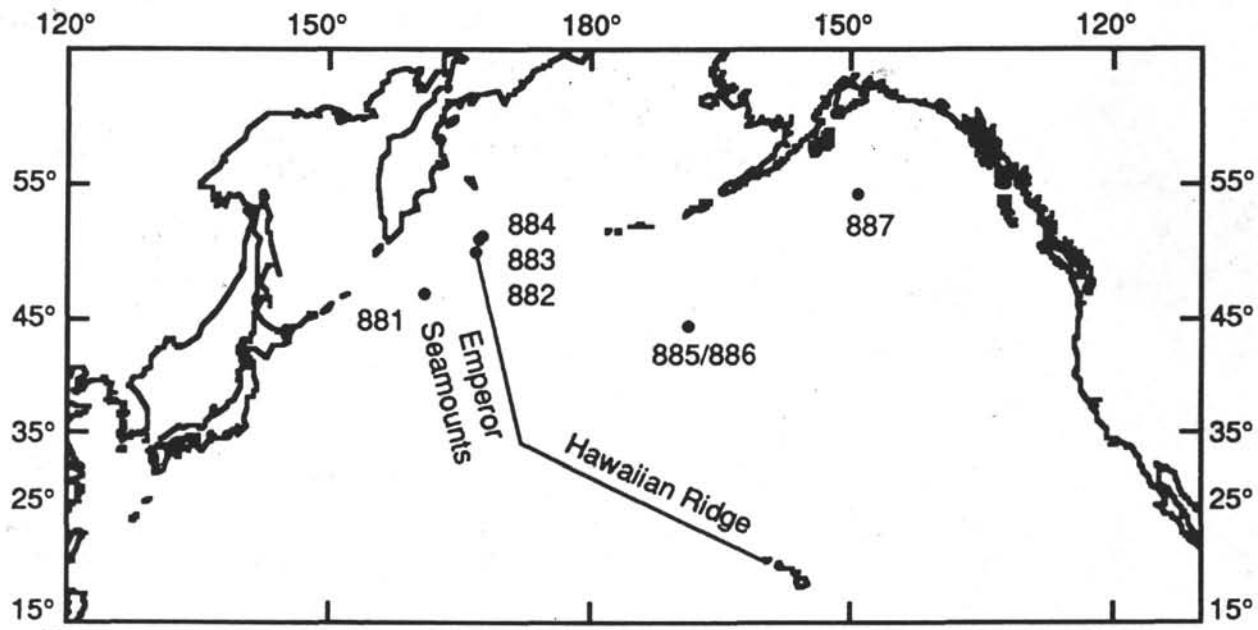

120°
150°
180°
150°
120°
55°
45°
35°
25°
15°
884
883
882
881
887
885/886
Emperor Seamounts
Hawaiian Ridge

Figure 1

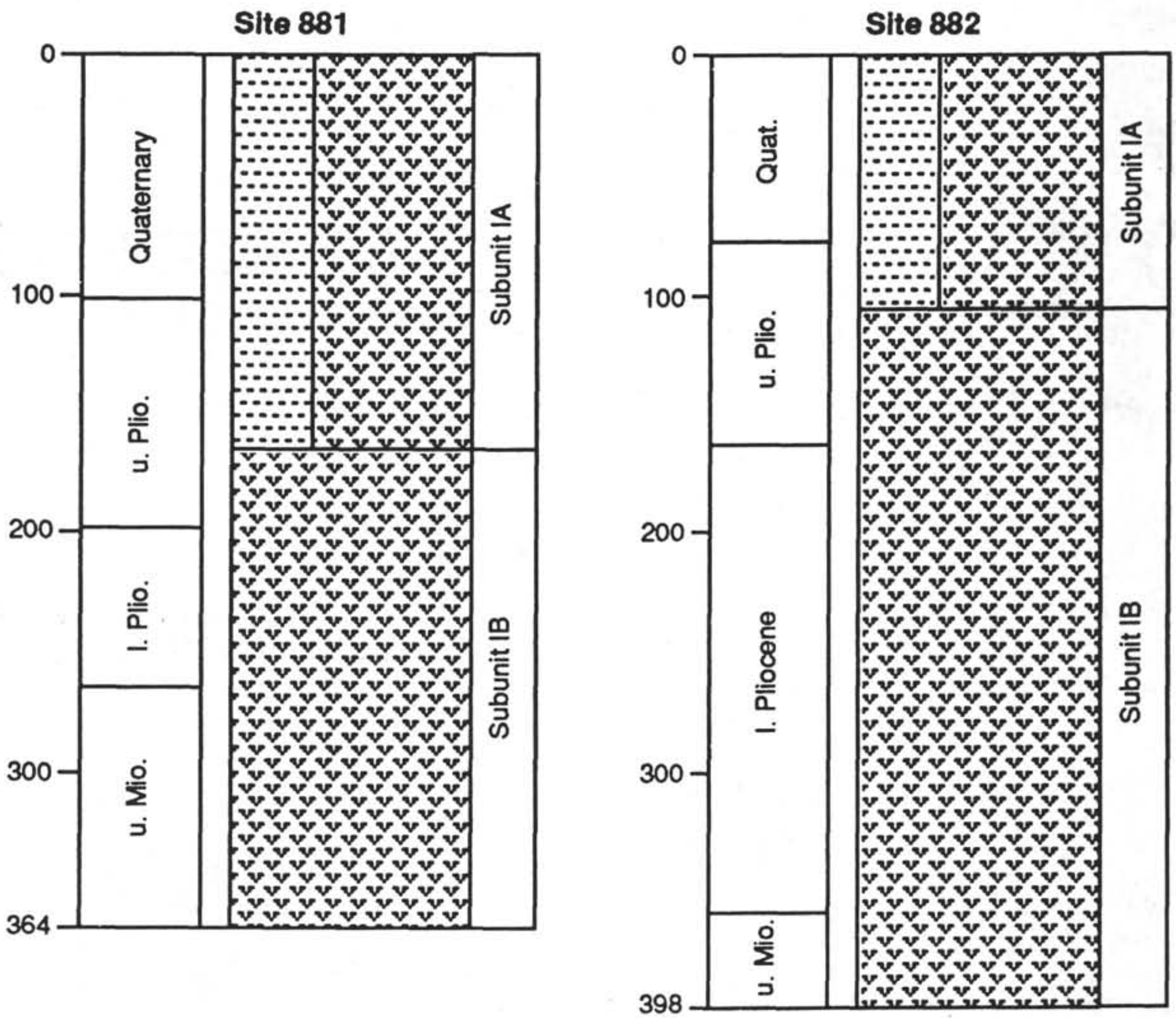

Site 881
0
100
200
300
364
Quaternary
u. Plio.
l. Plio.
u. Mio.
Subunit IA
Subunit IB
Site 882
0
100
200
300
398
Quat.
u. Plio.
l. Pliocene
u. Mio.
Subunit IA
Subunit IB

Figure 2

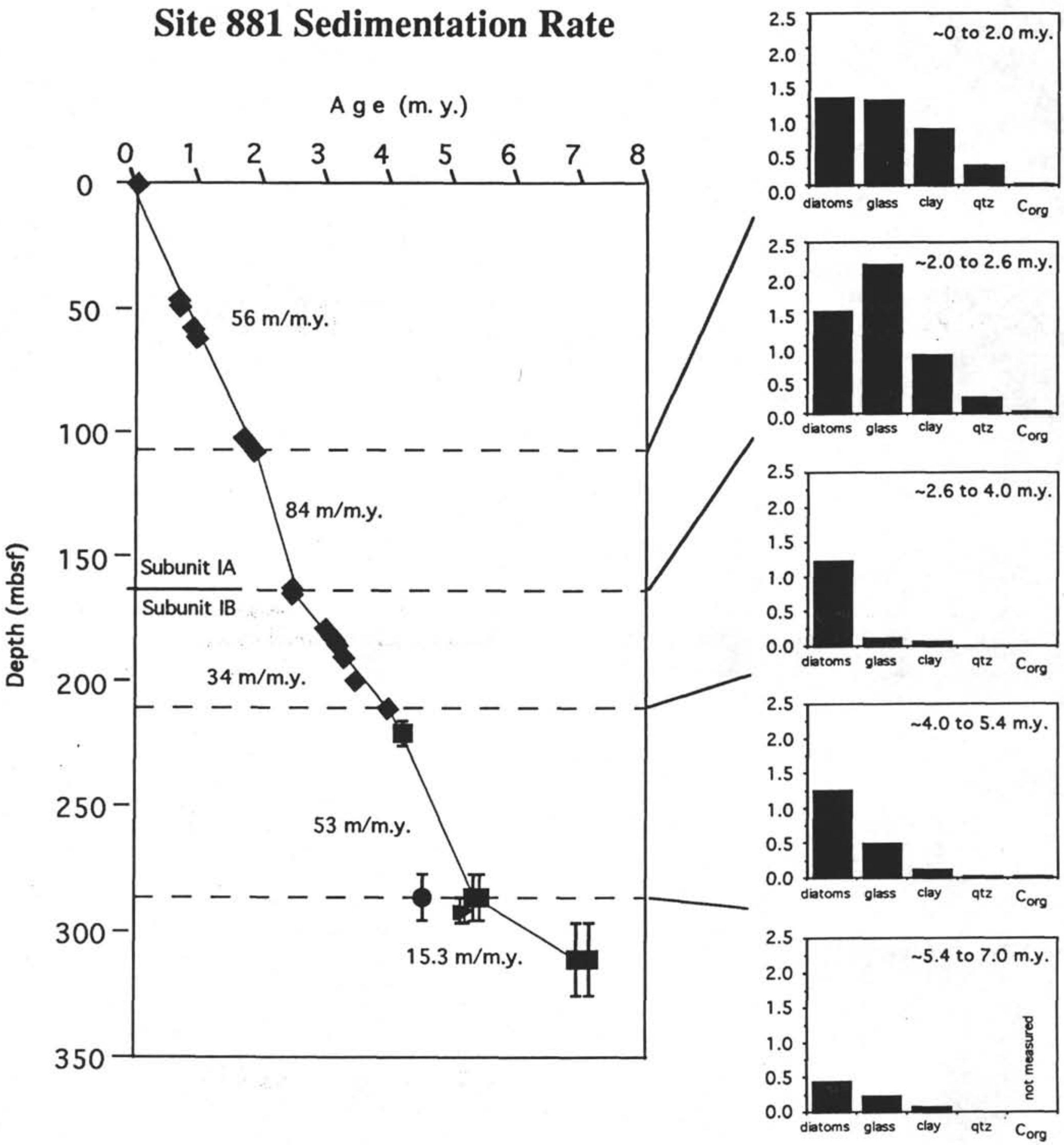

Site 881 Sedimentation Rate
Age (m. y.)
0 1 2 3 4 5 6 7 8
Depth (mbsf)
0
50
100
150
200
250
300
350
56 m/m.y.
84 m/m.y.
Subunit IA
Subunit IB
34 m/m.y.
53 m/m.y.
15.3 m/m.y.
~0 to 2.0 m.y.
~2.0 to 2.6 m.y.
~2.6 to 4.0 m.y.
~4.0 to 5.4 m.y.
~5.4 to 7.0 m.y.
not measured
diatoms glass clay qtz Corg
0.0 0.5 1.0 1.5 2.0 2.5

Figure 3

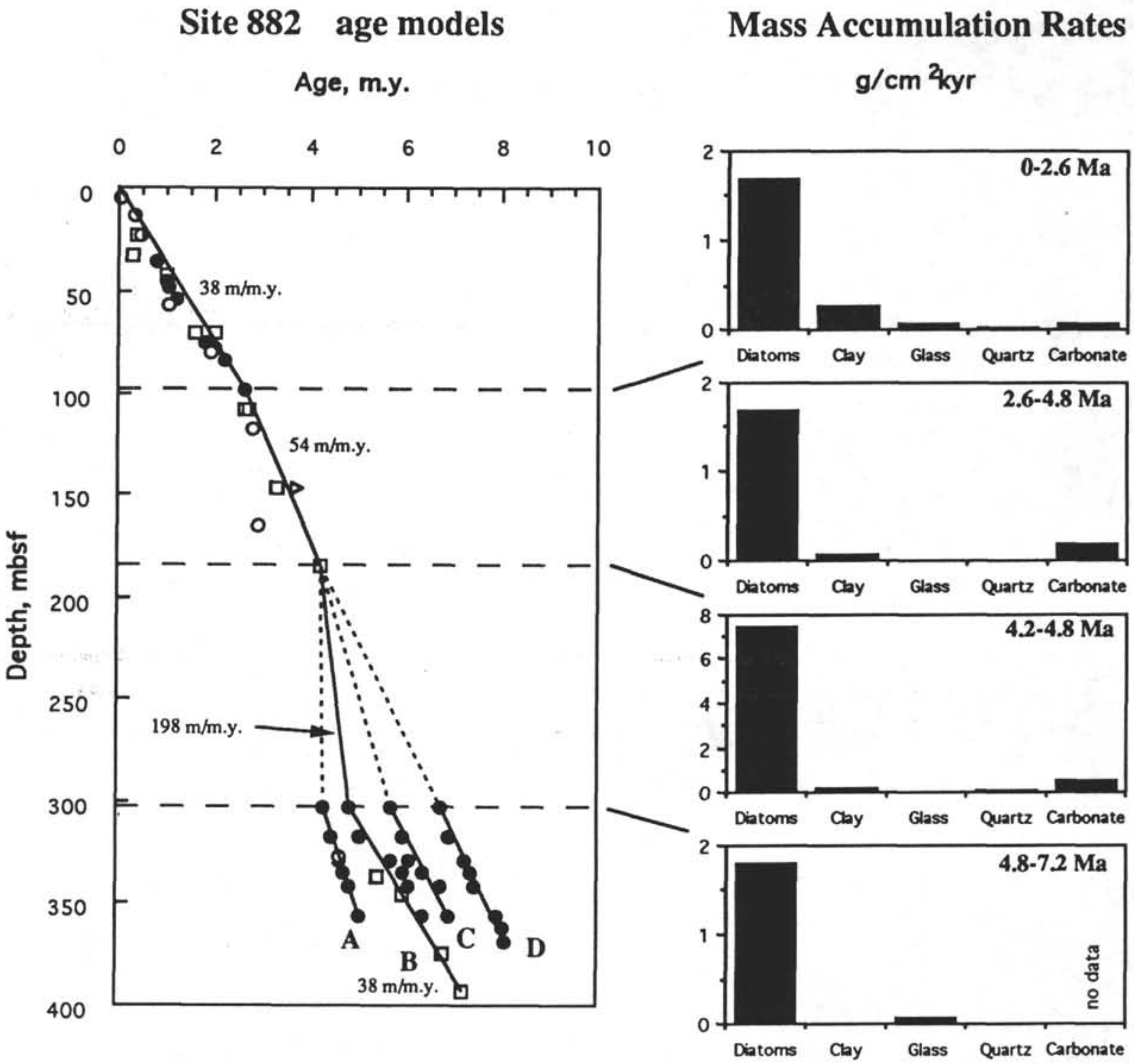

Site 882 age models
Age, m.y.
0
2
4
6
8
10
0
50
100
150
200
250
300
350
400
Depth, mbsf
38 m/m.y.
54 m/m.y.
198 m/m.y.
A
B
C
D
38 m/m.y.
Mass Accumulation Rates
g/cm²kyr
0-2.6 Ma
2.6-4.8 Ma
4.2-4.8 Ma
4.8-7.2 Ma
no data
Diatoms
Clay
Glass
Quartz
Carbonate

Figure 4

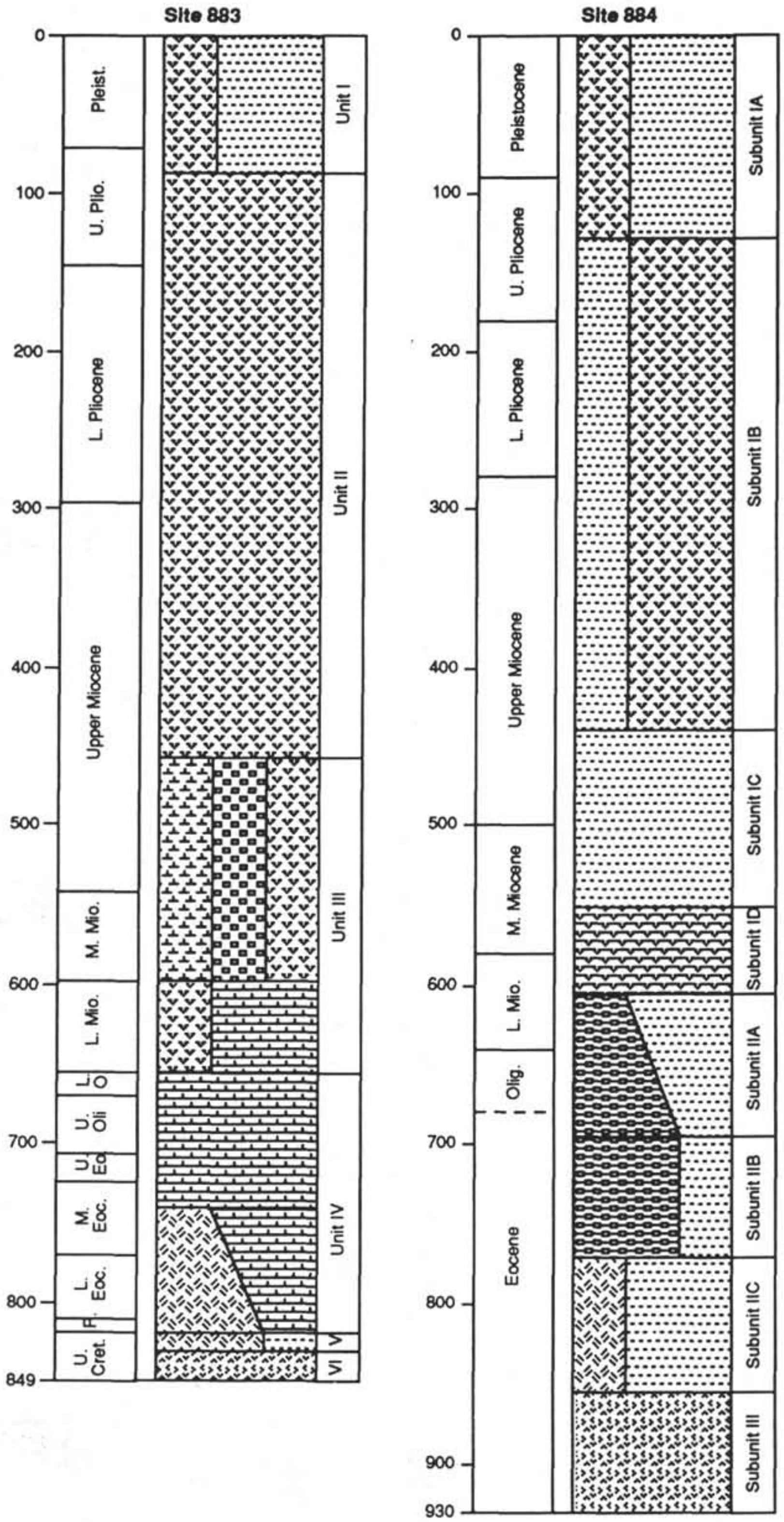

Site 883
0
100
200
300
400
500
600
700
800
849
Pleist.
U. Plio.
L. Pliocene
Upper Miocene
M. Mio.
L. Mio.
L. O
U. Oli
U. Eo
M. Eoc.
L. Eoc.
P.
U. Cret.
Unit I
Unit II
Unit III
Unit IV
V
VI
Site 884
0
100
200
300
400
500
600
700
800
900
930
Pleistocene
U. Pliocene
L. Pliocene
Upper Miocene
M. Miocene
L. Mio.
Olig.
Eocene
Subunit IA
Subunit IB
Subunit IC
Subunit ID
Subunit IIA
Subunit IIB
Subunit IIC
Subunit III

Figure 5

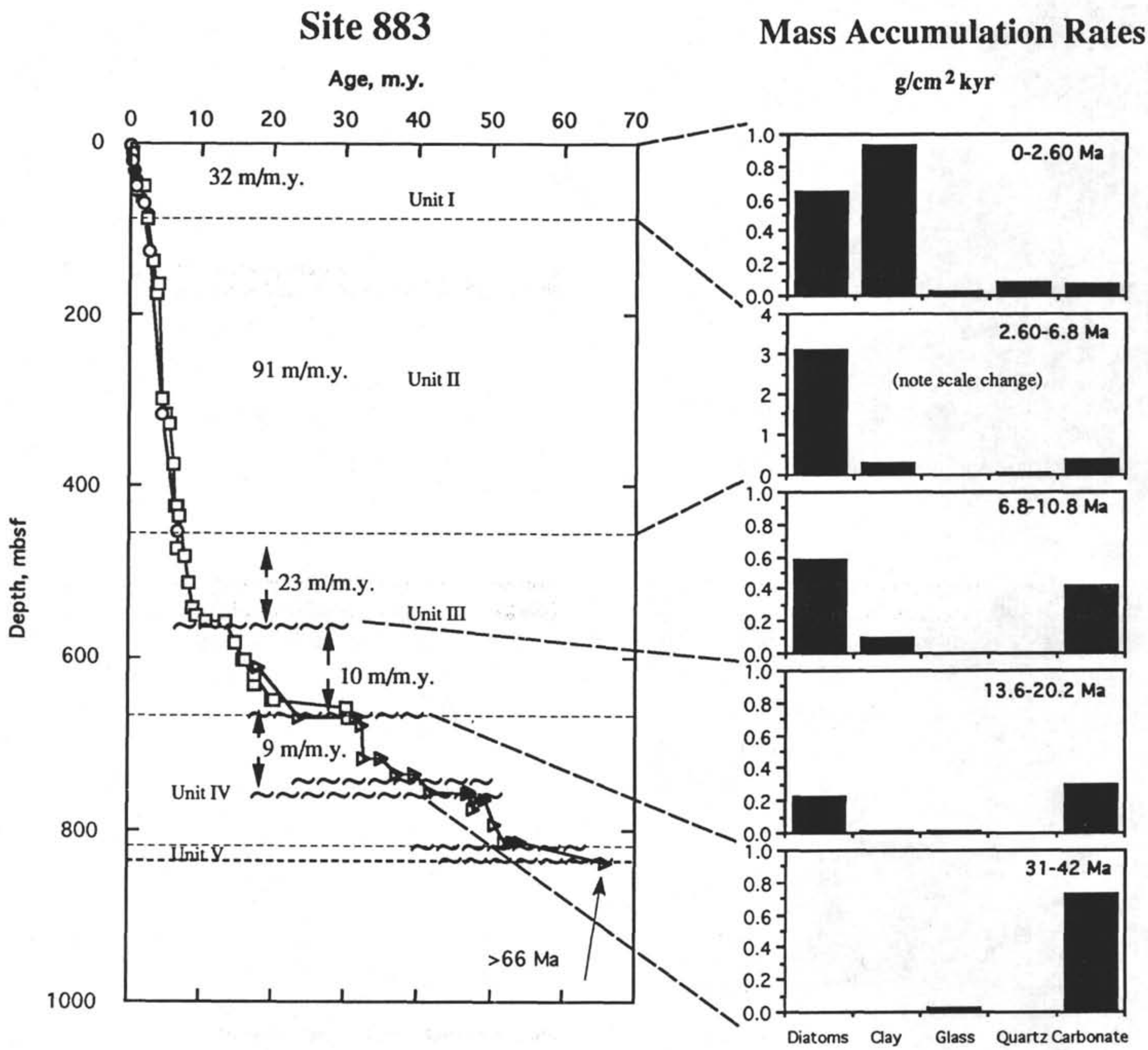

Site 883
Mass Accumulation Rates
Age, m.y.
g/cm 2 kyr
0 10 20 30 40 50 60 70
Depth, mbsf
0
200
400
600
800
1000
32 m/m.y.
Unit I
91 m/m.y.
Unit II
23 m/m.y.
Unit III
10 m/m.y.
9 m/m.y.
Unit IV
Unit V
>66 Ma
0-2.60 Ma
2.60-6.8 Ma
(note scale change)
6.8-10.8 Ma
13.6-20.2 Ma
31-42 Ma
Diatoms
Clay
Glass
Quartz
Carbonate

Figure 6

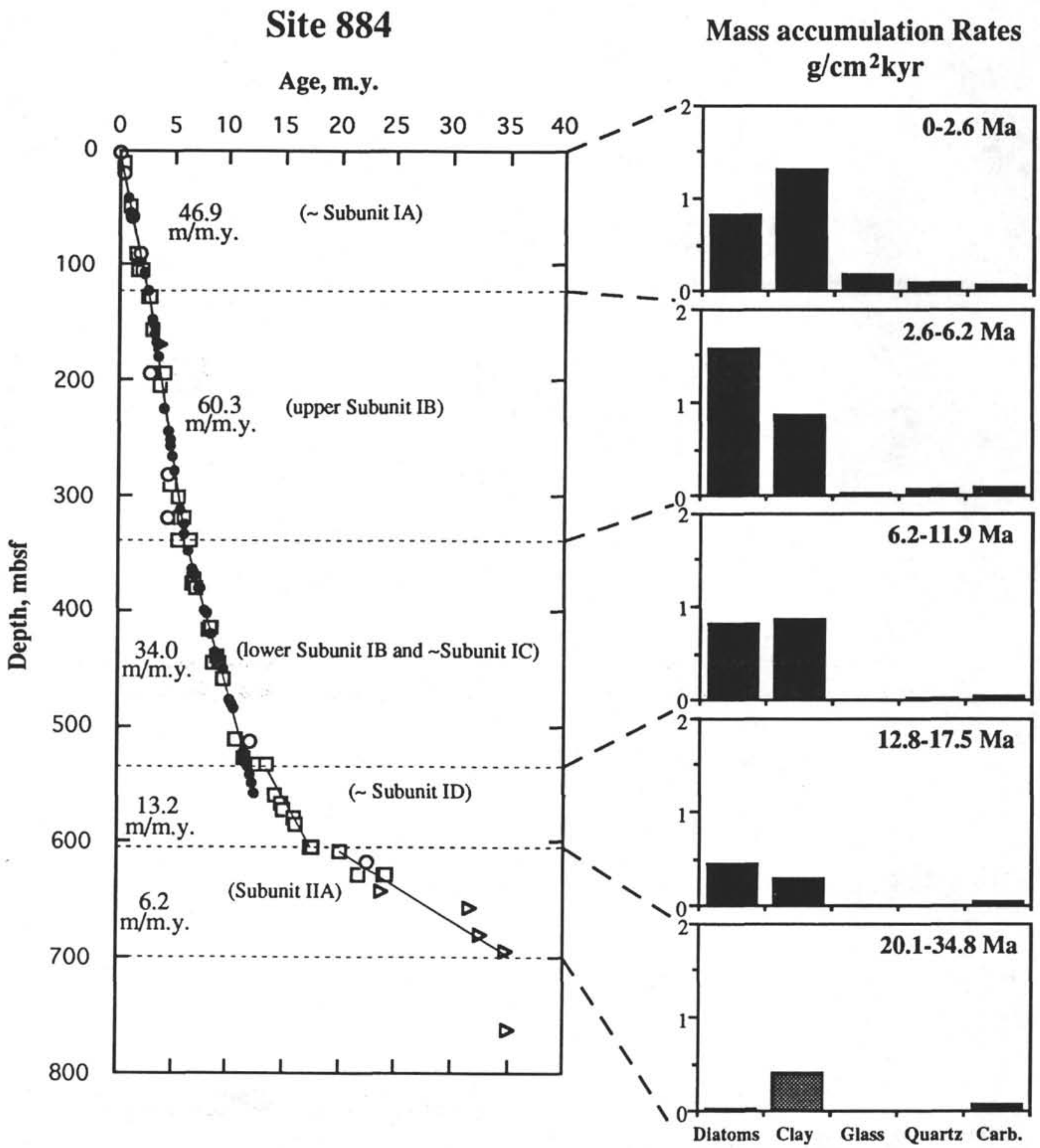

Site 884
Age, m.y.
0 5 10 15 20 25 30 35 40
Depth, mbsf
0
100
200
300
400
500
600
700
800
46.9 m/m.y.
(~ Subunit IA)
60.3 m/m.y.
(upper Subunit IB)
34.0 m/m.y.
(lower Subunit IB and ~Subunit IC)
13.2 m/m.y.
(~ Subunit ID)
6.2 m/m.y.
(Subunit IIA)
Mass accumulation Rates
g/cm2kyr
0-2.6 Ma
2.6-6.2 Ma
6.2-11.9 Ma
12.8-17.5 Ma
20.1-34.8 Ma
Diatoms
Clay
Glass
Quartz
Carb.

Figure 7

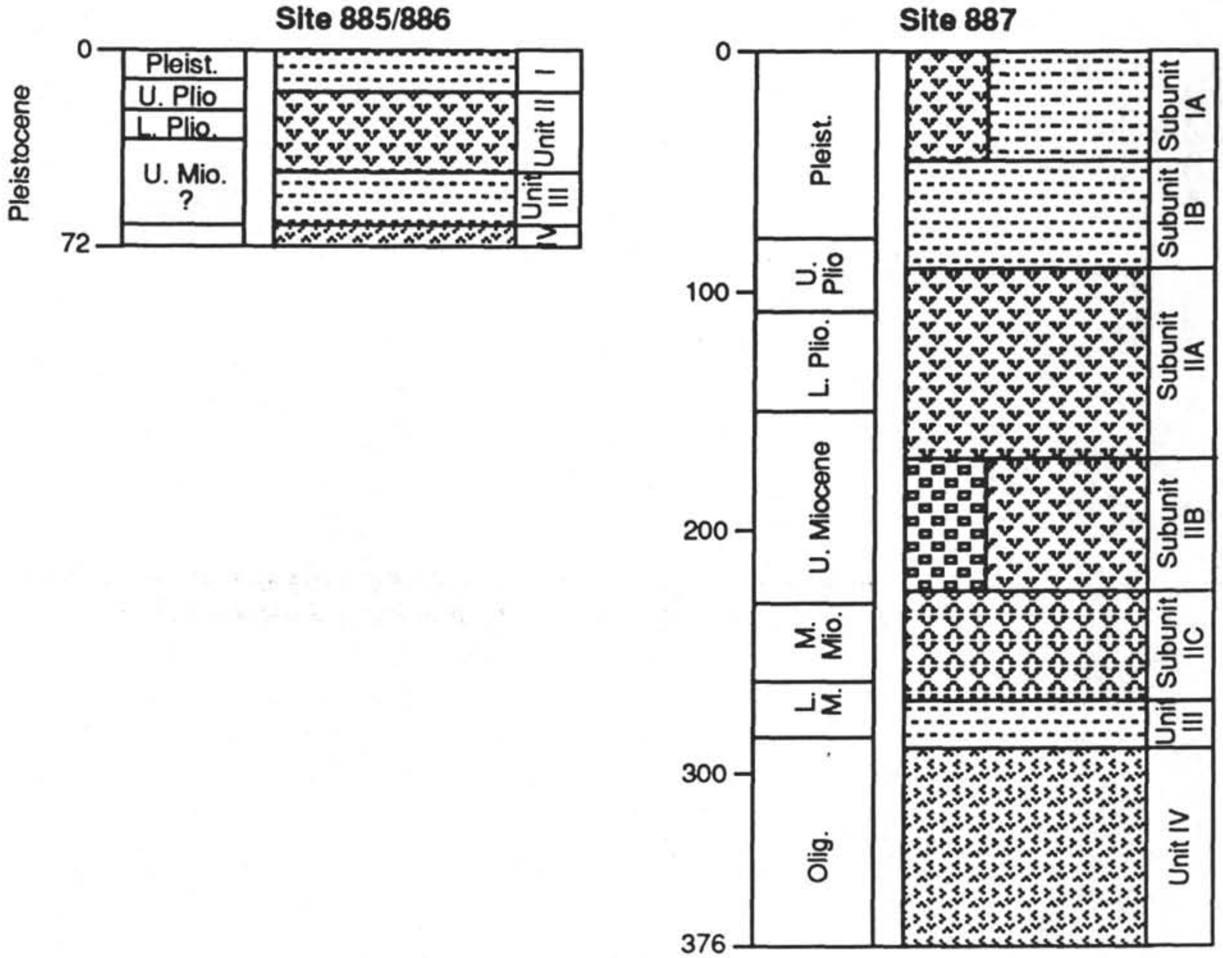

Site 885/886
Pleistocene
0
72
Pleist.
U. Plio
L. Plio.
U. Mio.
?
I
Unit II
Unit III
IV
Site 887
0
100
200
300
376
Pleist.
U. Plio
L. Plio.
U. Miocene
M. Mio.
L. M.
Olig.
Subunit IA
Subunit IB
Subunit IIA
Subunit IIB
Subunit IIC
Unit III
Unit IV

Figure 8

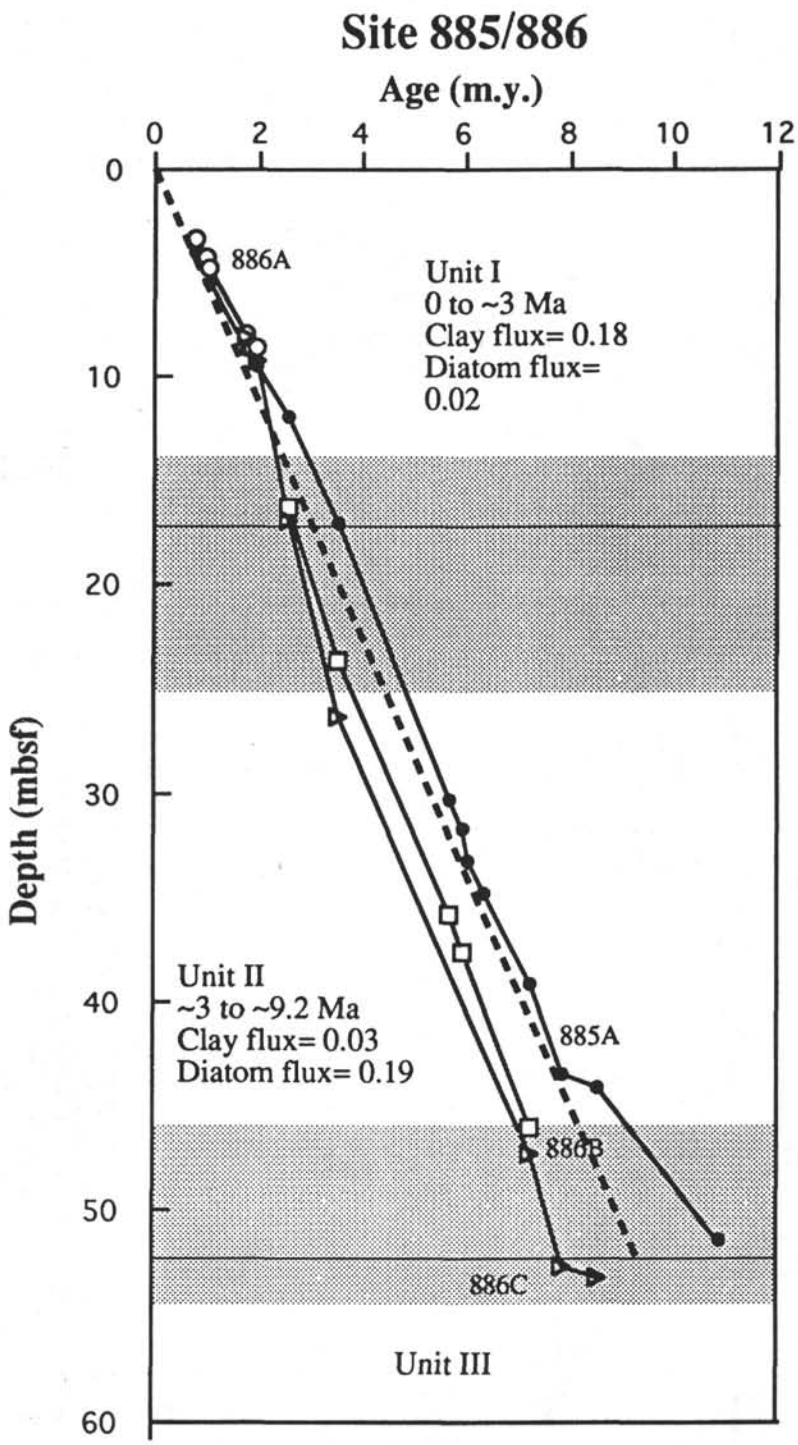

Site 885/886
Age (m.y.)
0
2
4
6
8
10
12
0
10
20
30
40
50
60
Depth (mbsf)
886A
Unit I
0 to ~3 Ma
Clay flux= 0.18
Diatom flux=
0.02
Unit II
~3 to ~9.2 Ma
Clay flux= 0.03
Diatom flux= 0.19
885A
886B
886C
Unit III

Figure 9

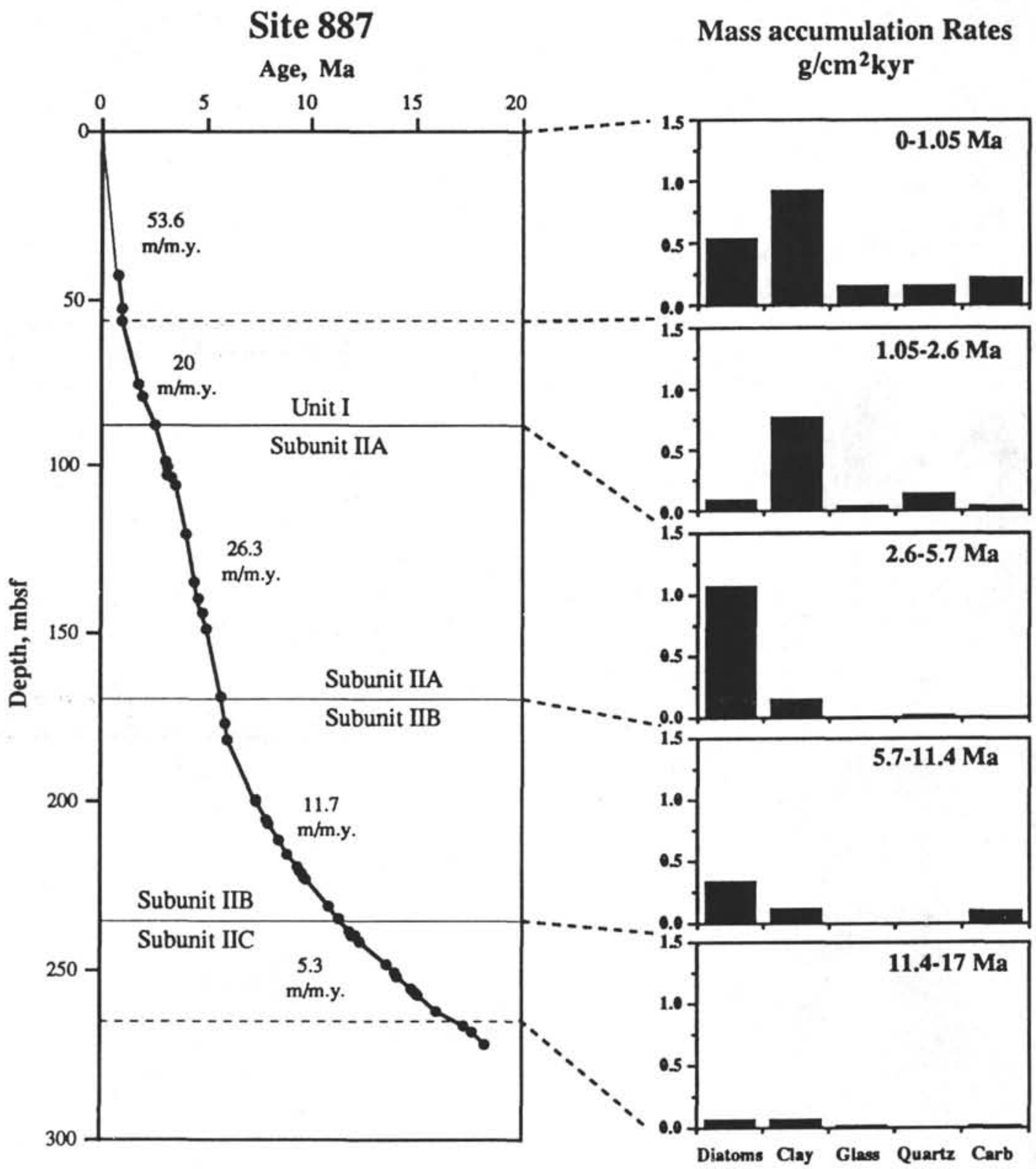

Site 887
Age, Ma
0
5
10
15
20
Depth, mbsf
0
50
100
150
200
250
300
53.6
m/m.y.
20
m/m.y.
Unit I
Subunit IIA
26.3
m/m.y.
Subunit IIA
Subunit IIB
11.7
m/m.y.
Subunit IIB
Subunit IIC
5.3
m/m.y.
Mass accumulation Rates
g/cm²kyr
0-1.05 Ma
1.05-2.6 Ma
2.6-5.7 Ma
5.7-11.4 Ma
11.4-17 Ma
1.5
1.0
0.5
0.0
Diatoms
Clay
Glass
Quartz
Carb

Figure 10

OPERATIONS REPORT

The ODP Operations and Engineering personnel aboard *JOIDES Resolution* for Leg 145 were:

Operations Superintendent:	Ron Grout
Development Engineer:	Mark Robinson
Schlumberger Engineer:	Dave Ritz

TRANSIT TO PROPOSED SITE NW-1A

The ship cast off the last line in Yokohama at 1100 hr on 24 July and headed north through an overcast and heavy fog to the first of six planned drill sites. The vessel traversed the 1305 nmi at an average speed of 11.5 kt and arrived at the first survey point at 2205 hr 28 July. After the seismic equipment was deployed, a 47-nmi survey was conducted in the area of proposed site NW-1A at an average speed of 5.7 kt. A beacon was deployed at 0045 hr 29 July and was tracked by the DP control as it descended while the ship continued with the survey. Upon returning to the site of the beacon deployment at 0520 hr, no signal could be detected. At 0623 hr, a second beacon was deployed at a position approximately 1.5 km south-southwest of the original beacon drop. After the seismic gear was retrieved, the vessel returned to location, the thrusters were lowered, and the drill pipe was run in the hole with the APC/XCB drilling assembly.

HOLE 881A

Just prior to spudding the hole and with the bit approximately 20 m above the mud line, two pipe swabbing pigs were pumped down the drill string to remove any rust buildup within the pipe. The vessel then was offset 20 m south, where the first APC core was spudded at 2030 hr 29 July. This first core was full (9.92 m) and thus could not be used to establish the mud line depth.

HOLE 881B

The second attempt at a mud line core for this location recovered 5.59 m of core and established the seafloor depth at 5542.0 m below rig floor (5531.0 m below sea level). APC coring advanced through Core 145-881B-18H (167 mbsf) at which point 80,000 lb of overpull was required to extract the core barrel. As a result of the high overpull, this depth was considered refusal depth, and the bit was brought to the sediment surface to offset for the next hole, an APC/XCB hole to basement. The recovery for Hole 881B was 170.3 m (102% recovery)

Attempts were made to orient Cores 4H and 5H, but the extra weight of the Multishot and Tensor tools was apparently forcing the landing shoulder of the APC into the Landing Saver Sub in the bottom-hole assembly (BHA), which required high overpulls on the coring line winch to free the core barrel. Orientation of cores was abandoned at this site because of the risk of getting the core barrel stuck in the pipe.

HOLE 881C

After offsetting the vessel 20 m south, a third mud line core attempt retrieved 3.82 m of core, giving a seafloor depth of 5541.7 mbrf. APC coring advanced to Core 145-881B-17H (155.8 mbsf), just above Hole 881B refusal depth. Heat-flow measurements were attempted on Core 145-881B-4H (failure) and Core 145-881B-9H (good run). At 155.8 mbsf, coring resumed with the XCB system. Core 145-881B-18X advanced 6.5 m and recovered 3.9 m while Cores 145-881B-19X and -20X recovered no sediment. At this point, another APC attempt was made. After obtaining a full stroke on the shot, the barrel could not be freed from the formation by overpulls up to 90,000 lb. Rather than increase the overpull, the barrel was washed over. The recovered core contained 9.5 m of sediment. XCB coring then resumed to 363.8 mbsf (Core 145-881B-39X). There was zero recovery on Cores 145-881B-22X, -24X, -26X, -28X, -31X, -33X, -34X, -37X, -38X, and -39X. Coring operations were terminated due to time constraints after Core 145-881B-39X, and preparations for logging were begun after the last core was brought on deck. The XCB recovery for this hole amounted to 61.7 m or 31% of the cored interval. The total recovery for this hole was 62.5%.

At 2315 hr on 1 August, the top drive was set back and the hole wiped from total depth (364 mbsf) to 74 mbsf and back down to the bottom with no evidence of fill. After the hole was flushed with a high viscous mud sweep, the pipe was pulled to logging depth (54.9 mbsf).

Hole 881C Logging Operations

The wireline cable and the Quad combination tool were rigged-up after the wiper trip. Delays were encountered during testing, when it was discovered that one of the conductor pins on the sonic tool was damaged and that the tool needed to be replaced. The Lamont-Doherty temperature tool and an aluminum go-devil were attached to the base of the string. Sea-state conditions were rough, so the wireline heave compensator was used.

The Quad tool string was run into the hole and it was soon discovered that the SFLU resistivity channel had failed and could not be recovered. A down log was recorded at 2300 ft/hr (700 m/hr) from 110 mbsf to total depth at 364 mbsf (5904.7 mbrf). The HLDT caliper was opened and indicated a borehole diameter of 11.5 in. Immediately afterward, however, the caliper began reading anomalously high diameters exceeding 18.5 in. When the tool string was recovered, it was noted that the caliper arm had been bent upward, probably resulting from downward ship heave when the arm was first extended at total depth. The first up log was recorded at 1800 ft/hr (550 m/hr) using the wireline heave compensator from 360 to 80 mbsf. A second up log was recorded from 170 to 70 mbsf. The SFLU log was operative following the second up log, so a third up log was recorded from 360 to 50 mbsf. The third run is considered the most complete and most reliable log for this hole. The HLDT density tool was free to rotate in the borehole due to the damaged caliper arm, so the density log data must be considered suspect over several intervals.

The FMS tool string with the Lamont-Doherty temperature tool and go-devil was run into hole after completion of quad tool logging. We encountered difficulty exiting the base of pipe, and this would prove to be the demise of further logging efforts. Several attempts were made to open the lockable flapper valve at the base of pipe, but the tool string could not pass the obstruction. At 0300 hr on 3 August, the decision was made to conclude logging operations, and the tool was pulled out of hole. At 0515 hr 3 August, the logging equipment was rigged down and the pipe pulled out of the hole. The bit cleared the seafloor at 0545 hr, thereby ending Hole 881C.

HOLE 881D

The vessel was offset 20 m east for Hole 881D coring operations. As the upper sediments were adequately recovered from Hole 881C, the pipe was washed down to 155 mbsf, at which point APC coring resumed. Core 145-881C-1H was shot at 155 mbsf and required 90,000 lb of overpull to release. Core 145-881C-2H was shot at 164.6 mbsf and required 50,000 lb of overpull. Cores 145-881C-3H through -6H covering the interval 174.0 to 212.0 mbsf required washing over after 100,000 lb of overpull would not release the barrels from the formation. After washing over 6 m of the core barrel on Core 145-881C-7H, the barrel became stuck in the pipe. It appeared that the core barrel was bent due to contact with dropstones and could not be drawn into the pipe. While slowly setting weight on bit to free the barrel, the tool parted at the top of the second core barrel. The upper portion of the tool was recovered unharmed, but the remaining core barrel was still in the formation, and the hole had to be abandoned. Coring operations were terminated, and the pipe was pulled out of the hole. The bit was on deck by 0900 hr 4 August at which time the transit to proposed Site DSM-3 began.

TRANSIT TO PROPOSED SITE DSM-3

The transit from Site 881 to proposed Site DSM-3 covered 307.5 nmi at an average speed of 11.0 kt. At 1330 hr 5 August, the vessel slowed to stream seismic gear for a short survey of the proposed site area. The beacon was dropped at the proposed site location at 1500 h, and the vessel continued on with the survey. At 1730 hr, the survey ended, and the ship returned to the site.

HOLE 882A

The first piston core at Hole 882A was retrieved at 0110 hr 6 August and recovered 8.8 m of sediment to establish the mud line as 3254.7 mbrf. APC coring advanced uneventfully to Core 145-882A-11H (94.3-103.8 mbsf), where the first large overpull was encountered (70,000 lb). Overpull then decreased to less than 10,000 lb by Core 145-882A-15H (132.3-141.8 mbsf). Excessive overpull (100, 000 lb) during the retrieval of Core 145-882A-17H (151.3-160.8 mbsf) required the barrel to be washed over before it could be pulled free. The washover coring technique was used to free the core barrel for the remainder of the cores at this hole with the exception of Core 145-882A-20H (179.8-189.3 mbsf), which came free with only 50,000 lb of overpull. The hole was terminated after Core 145-882A-42H due to time constraints but not before setting a new record for APC depth penetration. Cores 145-882A-4H (27.8-37.3 mbsf) to -29H (265.3-274.8 mbsf) were oriented successfully. APC coring in Hole 882A recovered 411.2 m of sediment (103.2% recovery). After Core 145-882A-42H was brought on deck, the bit was pulled out of the hole and cleared the mud line at 1030 hr 7 August, thereby ending Hole 882A.

HOLE 882B

After the vessel was offset 20 m west, the first core of this hole was brought on deck at 1130 hr 7 August with 4.38 m of sediment, establishing the mud line at 3255.1 mbrf. APC coring advanced to Core 145-882B-19H (165.9-175.4 mbsf) before the first overpull of 100,000 lb was required. By Core 145-882B-20H (175.4-184.9 mbsf), it was necessary to wash-over each of the APC core barrels to extract them from the formation. After Core 145-882B-30H was run down the pipe and just before it seated, the assistant driller noticed a drop in weight about 5 m higher than the expected landing depth of the core barrel. The pressure in the pipe would not hold to shoot the next piston core, so the core barrel was retrieved and inspected. When the drill-pipe connection was broken at the rig floor, all that was found of the core barrel assembly was the Inner Shear Pin/Landing Shoulder and the Inside Fishing Neck. The piston rod and core barrel were gone. With the "junking" of the hole, coring operations were terminated at Hole 882B. At this point, the pipe was pulled out of the hole, and by 1730 hr 8 August, the bit was on deck and the vessel under way to proposed site DSM-1. APC coring at Hole 882B recovered 280.9 m of sediment (103.9% recovery). Cores 145-882B-4H through -29H were oriented.

TRANSIT TO PROPOSED SITE DSM-1

The 49.0-nmi transit to Site DSM-1 began at 1830 hr 8 August. At 2330 hr the ship slowed to 6 kt and began a 13.5-nmi survey. The beacon was launched at 0050 hr at the proposed site location. Upon retrieval of the seismic gear after the beacon drop, the ship came about and was on location by 0200 hr 9 August.

HOLE 883A

Hole 883A was spudded at 0715 hr 9 August, and Core 145-883A-1H contained 9.5 m of sediment to establish the mud line depth at 2407.0 mbrf. Three more APC cores were taken in quick succession at this hole, which was dedicated to physical-property studies. The last core (Core 145-883A-4H) was on deck by 0930 hr after which the bit was pulled out of the hole, clearing the seafloor at 0940 hr. The total cored interval was 38.0 m, with 38.49 m recovered (101.3%).

HOLE 883B

The ship was offset 20 m north of Hole 883A, and at 1100 hr 9 August the first piston core was recovered with 7.9 m of sediment to establish the new mud-line depth at 2395.6 mbrf. APC coring then proceeded to 226.4 mbsf (Core 145-883B-24H), where the first core barrel had to be washed-over in order to recover it from the formation. For the remainder of the APC cores on this hole, the procedure was to wash-over half the core barrel and then apply up to 120,000 lb of overpull to release the barrel from the sediment. Cores 145-883B-4H through -31H were oriented.

At 292.9 mbsf, the sediment became too stiff for further APC coring. XCB coring began with Core 145-883B-32X and proceeded to 448.7 mbsf, where Core 145-883B-46X (429.0-438.9 mbsf) and Core -47X (438.9-448.7 mbsf) recovered a total of 0.03 m of sediment. In an attempt to increase core recovery, the next core taken was a piston core (145-883B-48H). After washing over this core barrel for 15 min, 9.34 m of sediment was recovered, but the sediment was deemed to stiff to continue with APC coring.

XCB coring resumed to 840.7 mbsf (145-883B-88X), where basalt chips were recovered in the core barrel and the rate of penetration was reduced to 3 m/hr. This depth was considered to be the beginning of basement, and thus the depth objective for the hole was reached. Overall, 840.5 m of sediment/basement was cored at Hole 883B, and 692.9 m recovered (82.4%). The APC system cored 302.4 m and recovered 306.36 m (101.3% recovery). The XCB system cored 538.1 m and recovered 386.54 m (71.8% recovery).

After Core 145-883B-88X was retrieved the drill string was pulled out of the hole, and the bit cleared the mud line at 0900 hr 12 August. During pipe retrieval the vessel was offset 20 m north of the previous position.

HOLE 883C

Hole 883C was spudded at 1130 hr with an approximately 4-m vertical offset relative to Hole 883B. Core 145-883C-1H contained 3.13 m of sediment, to establish the mud-line depth at 2396.5 mbrf. APC coring advanced to 250.0 mbsf (Core 145-883C-27H), at which point coring operations switched over to the XCB system. Cores 145-883C-4H through -27H were oriented.

XCB coring advanced to 317 mbsf (Core 145-883C-34X), where operations were again switched over to the APC system (Cores 145-883C-35H to -38H) in an attempt to retrieve sediment too soft to be obtained by the XCB on Hole 883B. These last four APC cores all had to be washed-over in order to be retrieved. The depth objective of the hole was reached after Core 145-883C-38H, and the bit was pulled out of the hole, clearing the mud line at 1515 hr, thereby ending Hole 883C. Overall, the APC penetrated 288.0 m of sediment with 102.8% recovery. The XCB cored 67.0 m and recovered 48.16 m (71.9%).

HOLE 883D

After offsetting the vessel 20 m west of Hole 883C, Hole 883D was spudded at 1600 hr. After obtaining two cores (17.0 m cored, 17.3 m recovered) to be used for high-resolution sampling, the bit was pulled up to drill floor in order to switch over to RCB coring operations.

HOLE 883E

Hole 883E was spudded at 0345 hr 14 August and washed down to 300 mbsf, where the first wash barrel was retrieved (empty). After another barrel was run down the pipe, washing continued to 547.0 mbsf, where a second wash barrel was retrieved. Another core barrel was run down in the pipe, and the zone from 547.0 to 556.5 mbsf was cored in an attempt to retrieve an interval not recovered in the other holes at this site. The core contained 6.25 m of sediment but did not recover the interval of interest. The bit was washed down further to 640 mbsf, where continuous rotary coring began. RCB coring advanced into basement at approximately 820 mbsf and continued to 856.5 mbsf (Core 145-883E-23R) at which point the core barrel became stuck in the pipe. After several attempts at retrieving the core barrel failed, a free-fall funnel (FFF) was deployed, and the pipe was pulled out of the hole to retrieve the core barrel .

Upon retrieval of the core barrel the pipe was run back to the seafloor. Meanwhile the weather continued to deteriorate, and by the time the bit reached the top of the FFF, the winds were near 50 kt with seas approaching 5-6 m, and the heave on the order of 2-4 m.

After a 50-min search for the funnel, the bit reentered Hole 883E at 1150 hr 16 August and was run in the hole to a depth of 123 mbsf. At this point the pipe-trip operation was stopped while the television camera was brought to the surface. Approximately 40 min later, pipe was again run in the hole. At 1315 hr, while making a pipe connection, the driller observed a 50,000-lb loss of weight. The camera was run back in the hole, and it was seen that the entire BHA was gone, along with four complete joints and part of a fifth joint of 5-in drill pipe. The FFF was visible and appeared to be completely intact as were the three flotation sonar balls. Most likely, the bit packed off while being run in the hole, and the 2-4 m heave of the vessel caused the pipe to be put into compression, flex, and break at a point 221 m above the bit.

HOLE 883F

The pipe was tripped out of the hole, and a new RCB bottom-hole assembly identical to that for Hole 883E was run to the seafloor. The hole was spudded at 0400 hr 17 August and washed down to basement (820 mbsf). During the wash-down operation, empty wash barrels were retrieved at 599.5 mbsf and at 820 mbsf. Three RCB cores were taken (820.0-849.4 mbsf) before time constraints forced an end to coring operations.

In preparation for logging, the hole was flushed with mud. The top drive was set back, and a wiper trip made to 94.5 mbsf and then back down to the base of the hole, where there was about 3 m of fill. After flushing the hole again with mud, the bit was released on bottom, and pipe was pulled up to logging depth (119.5 mbsf).

Hole 883F Logging Operations

A total of five tool strings were run at Hole 883F: the Schlumberger geochemical, quad combination, and formation microscanner (FMS) tool strings, and the French magnetometer and susceptibility tools. The wireline heave compensator was used on all logging runs.

The geochemical combination tool string, consisting of natural gamma ray (NGT), aluminum activation (AACT), and gamma ray spectrometry (GST) tools, was calibrated at the sea surface and was run to total depth (3242 mbsl; 846 mbsf). An attempt to recalibrate the GST at 690 mbsf indicated that the tool would not attain stable recalibration possibly due to very cool bottom-hole temperatures (~3°C). One main up log was recorded at 167 m/hr from 846 mbsf to the mud line.

The French magnetometer (NRMT) and susceptibility (SUMT) tools were run next to ensure that both tools would measure a borehole environment unaffected by any electromagnetic induction measurements. Two complete passes of the NRMT were conducted at 548 m/hr from total depth (846 mbsf) to base of pipe at 120 mbsf. The total magnetic field measurements of the NRMT were highly reproducible between the two runs. Log quality was seriously compromised above 220 mbsf due to the presence of several stands of drill pipe remaining in adjacent Hole 883E, which was abandoned earlier due to pipe breakage. One main up log of the susceptibility tool (SUMT) was recorded at 1097 m/hr from 856 to 120 mbsf; a shorter repeat up log was recorded from 380 to 120 mbsf.

The FMS tool string was run next and three short up logs were recorded at 548 m/hr from 846-704 mbsf, 846-634 mbsf, and 846-614 mbsf; the main up log was recorded from 846 to 100 mbsf.

The quad combination tool string, with the Lamont-Doherty temperature tool, was the final string run into Hole 883F. A down log was recorded from 150 mbsf to total depth (840 mbsf). The main up log was recorded at 1008 m/hr from 840 mbsf to the mud line. The eccentralizing caliper arm of the lithodensity tool (HLDT) would not open after repeated attempts, so the density and photoelectric effect data recorded during the main up log are unreliable due to excessive tool "stand-off."

TRANSIT TO PROPOSED SITE DSM-4

The 47-nmi transit to proposed site DSM-4 began at 0430 hr 20 August. Seismic gear was deployed throughout the whole transit. After deploying the beacon at the proposed site location at 0830 hr, the ship continued the survey until 1030 hr, at which time the seismic gear was retrieved. The ship then returned to the site location, acquired the beacon at 1100 hr, and was positioned on site with thrusters and hydrophones lowered by 1130 hr 20 August.

HOLE 884A

The first piston core was taken at 1745 hr 20 August at a water depth of 3845.9 mbsl (PDR reading). The core barrel was full with 9.7 m of sediment and therefore could not be used to determine the mud line depth. After Core 145-884A-1H was retrieved, the pipe was pulled above the mud line, and the ship was offset to begin a second hole.

HOLE 884B

The drill pipe was pulled up 5 m relative to Hole 884A, and the first core at Hole 884B was taken at 1830 hr with 6.47 m of recovery to establish the mud line depth at 3899.5 mbrf. Piston coring advanced successfully through Core 145-884B-9H. Core 145-884B-10H (82.5-86.3 mbsf) advanced only 3.8 m, and Core 145-884B-11H (86.3-87.3 mbsf), the last piston core of this hole, was only able to advance 1 m. APC coring operations ended after Core 145-884B-11H, with 87.3 m cored and 89.46 m of sediment recovered (102.5% recovery). Piston cores 145-884B-4H through -11H were oriented.

XCB coring was initiated with Core 145-884B-12X (87.3-93.3 mbsf). Coring advanced routinely to 853.9 mbsf (Core 145-884B-91X). Core 145-884B-91X contained a 40-cm chunk of basalt, confirming that basement had been reached. XCB coring operations recovered 702.30 m over an interval of 766.6 m (91.6% recovery). The total percentage recovery of the hole was an impressive 92.7%.

After coring operations ceased, the top drive was set back and the pipe pulled out of the hole. From 853.9 to 536 mbsf, the hole was sticky, with an overpull of 60,000 lb required to advance the pipe; above 536 mbsf, the resistance disappeared. The bit cleared the mud line at 1100 hr 24 August, and the vessel was offset 20 m north.

HOLE 884C

This hole was spudded at 1130 hr, 24 August, and Core 145-884C-1H contained 2.4 m of sediment, thereby establishing the mud line at 3836.1 mbrf. APC coring advanced to 78.4 mbsf (Core 145-884C-9H) at which point operations were switched over to the XCB coring system. XCB coring advanced to 357.8 mbsf (Core 145-884C-38X), when time expired for this site. Cores 145-884C-4H through -9H were oriented. APC coring penetrated 78.4 m, recovering 74.88 m (95.5%), and XCB coring recovered 219.68 m over a 279.4-m interval (78.6% recovery). Total recovery was 82.3%.

HOLE 884D

After the bit cleared the mud line of Hole 884C at 2000 hr 25 August, the ship was offset 20 m west, and two cores were taken for high-resolution paleomagnetic studies. A total of 14.8 m of sediment was cored, with 13.92 m recovered. At the end of coring operations, the APC/XCB bit and BHA were brought to the drill floor to change over to RCB coring operations.

HOLE 884E

An RCB coring assembly was made up and run to the seafloor. The hole was spudded at 0830 hr 26 August, and the bit washed ahead to 842.8 mbsf by 0530 hr 27 August. Wash barrels were retrieved at 300, 600, and 842.8 mbsf. In addition, a wiper trip was made between 842 and 794 mbsf.

RCB coring began at 0630 hr 27 August and the basement-sediment contact reached with the first core (842.5-852.5 mbsf). Ten RCB cores were taken, penetrating over 80 m into basement. Coring terminated at 0300 hr 29 August due to time constraints. Overall, 87.0 m of sediment/ basement was cored with 66.78 m recovered (76.8% recovery). The rate of penetration (ROP) varied from a low of 1.5 m/hr (Core 145-884E-6R) to a high of 4.5 m/hr (Core 145-884E-1R). The average for the entire cored interval was 2.4 m/hr.

In preparation for logging, a wiper trip was made from total depth (929.8 mbsf) to 111.0 mbsf and back to 912 mbsf at which point 18 m of hard fill was found. The interval from 912 to 930 mbsf was washed and reamed, followed by a 50-bbl mud sweep.

At 0945 hr 29 August, the rotary shifting tool was run in the hole with the wireline and released the bit. The top drive then was set back and the pipe pulled to 82.0 mbsf for logging operations.

Hole 884E Logging Operations

A total of five tools were run at Hole 844E: the Schlumberger quad combination, formation microscanner (FMS), and geochemical tool strings, and the French magnetometer and susceptibility tools. The wireline heave compensator (WHC) was not operational during all logging runs due to electronic failure.

Total penetration in Hole 884E was 930 mbsf; however, due to unstable borehole conditions, logging operations were not possible in the lowermost sediment or igneous basement. The first logging run encountered an impenetrable bridge at 760 mbsf, and due to a combination of further bridge formation and sloughing of unconsolidated sediments into the borehole during the course of logging operations, this depth had decreased to 645 mbsf by the final logging run.

The French CEA-LETI/TOTAL/CNRS-ENS magnetometer (NMRT) and susceptibility (SUMT) tools were run first to ensure that both tools would measure a borehole environment unaffected by any electromagnetic induction measurements. Two passes of the NMRT were conducted at 1800 ft/hr over the intervals 760-770 mbsf and 738-770 mbsf, respectively. One main up log of the SUMT was recorded at 3600 ft/hr from 682-664 mbsf; a shorter repeat up log was recorded from 365 to 359 mbsf.

The quad-combo tool (with the new LDGO temperature tool) was run next. During the down-log run, the sonic tool (SDT) failed at a depth of 614 mbsf, and the tool was pulled out of the hole. After the SDT was replaced, the quad combo was run back in the hole and set down on a bridge at 693 mbsf. The up log was run successfully from 693 to 652 mbsf.

The fourth logging run consisted of the formation microscanner (FMS) tool string. Three passes were made at 1500 ft/hr over the intervals from 654-52 mbsf, 654-414 mbsf, and 428-452 mbsf.

The last logging run consisted of the geochemical tool (GST) with the old LDGO temperature tool. The tool was run from 647 to 652 mbsf at 550 ft/hr. At 310 mbsf, however, the GST calibration failed, and the log yields became highly variable.

At 0600 hr 31 August, the logging equipment was rigged down, and by 0630 hr the pipe was being pulled out of the hole. The bit cleared the seafloor at 0645 hr, and the drilling equipment secured for the transit to Site NW-4A by 1230 hr 31 August. Concurrent with the pulling of the pipe, both beacons were successfully recalled and on deck by 0900 hr.

TRANSIT TO PROPOSED SITE NW-4A

The 1024-nmi transit to NW-4A was marked by the crossing of the International Dateline on 0620 hr 2 September. At 0145 hr 3 September, the ship slowed to 6 kt to deploy the seismic equipment and begin a 22-nmi survey. At 0330 hr, the beacon was launched on site as the ship continued with the survey. At 0630 hr, the seismic equipment was pulled in, and the ship acquired the beacon signal at 0730 hr. By 0800 hr, the ship was on location with hydrophones and thrusters lowered.

HOLE 885A

The first mud line core was attempted at 1715 hr 3 September but was shot too high in the water column. The pipe was lowered until the formation appeared to take 20,000 lb of weight on bit at a depth of 5714 mbrf. The pipe was lifted up to 5711 mbrf, and a second attempt to obtain a mud line resulted in yet another water core. An attempt was made to retag bottom at 5714 mbrf with no success. The bottom was assumed to be hilly and potentially dangerous to the health of the drill string. The vessel was offset 400 m east to what appeared to be much flatter terrain and the drillpipe lowered to what was thought to be 5715.0 mbrf. A third spud-in attempt at 2230 hr also resulted in a water core. This third failed spud-in attempt was the result of a miscount of the number of stands of pipe on the drill string.

At 2330 hr, Hole 885A was finally spudded, and 4.6 m of sediment recovered in Core 145-885A-1H, resulting in a mud-line depth of 5719.9 mbrf . Piston coring advanced to 52.3 mbsf (Core 1454-885A-7H), where a hard contact (basement) prevented full stroke. The last core of this hole was an XCB attempt (Core 145-885A-8X), which advanced 6.5 m and recovered 0.42 m of basalt and baked clay fragments. APC coring penetrated 52.3 m and recovered 53.22 m (91.2% recovery). Total recovery was 53.64 m over 58.8 m of cored interval (91.2% recovery).

Cores 4H-7H were oriented. After Core 145-885A-8H was retrieved, the pipe was pulled out of the hole, with the bit clearing the mud line at 1000 hr 4 September.

HOLE 886A

The ship offset to what appeared to be a deeper sediment pond located about 2200 m east of Site 885. At 1230 hr 4 September, a new beacon was deployed, and consequently the next hole was designated Hole 886A.

At 1500 hr, the first mud-line core was attempted at a depth 5666 mbrf but resulted in yet another water core. After a second mud-line attempt was shot at 5680 mbrf and also resulted in a water core, the PDR settings were examined. The pulse-width setting on the transmitter was found to be set at 25 ms instead of 100 ms, resulting in a depth error reading of about 57 m. The next mud-line core was attempted at a depth of 5725 mbrf. The resulting core barrel was full and unsuitable for assigning a mud-line depth. The core, however, was used for high-resolution interstitial water and physical-property analyses.

HOLE 886B

Hole 886B was spudded with a successful mud-line core at 1900 hr 4 September. The resulting mud-line depth was determined to be 5725.7 mbrf. Piston coring advanced to 58.8 mbsf (Core 145-886B-7H) and recovered 59.28 m (100.8% recovery). In order to avoid a hard impact with basement, coring was switched over to the XCB coring system, and Core 145-886B-8X advanced 9.7 m but recovered only 0.81 m. The next core was only able to advance 0.4 m in 30 min of rotation and recovered 0.41 m of basalt fragments. The pipe was pulled out of the hole after Core 145-886B-9X, and the vessel was offset 20 m east.

HOLE 886C

Hole 886C was spudded at 0645 hr 5 September, and Core 145-886C-1H contained 6.86 m of sediment upon recovery establishing the mud line at 5724.7 mbsf. Piston coring advanced 72.4 m (Core 145-886C-8H) and recovered 67.09 m (92.7% recovery). After Core 145-886C-9H was brought on deck the pipe was pulled out of the hole. While the pipe was being pulled out of the hole, the two beacons on this site were recalled and collected in heavy fog. The vessel then was offset to Site 885, and the remaining beacon recalled and extracted from the fog and dark, thanks to the effectiveness of the flasher on the beacon. By 0030 hr 6 September, the ship was under way to the last site of the leg.

TRANSIT TO PROPOSED SITE PM-1A

At 0930 hr 9 September, near the end of the 955-nmi transit to proposed site PM-1A, the seismic gear was deployed and a 34 nmi site survey was conducted at an average speed of 5.7 kt. The beacon was deployed at the proposed location at 1130 hr, and the survey continued past the site. At 1500 hr the survey ended, the gear was retrieved, and the vessel came about to return to location. Shortly after the beacon signal was acquired at 1530 hr, the hydrophones and thrusters were lowered, and the ship was on location.

HOLE 887A

The first piston core was spudded at 2145 hr 9 September and recovered 6.65 m of sediment, establishing the mud line at 3642.8 mbrf. Piston coring advanced to 130.2 mbsf (Core 145-887A-14H), where an overpull of 130,000 lb required a switch to XCB coring operations. Coring continued with the XCB from 130.2 to 193.4 mbsf (Core 145-887A-26X) where the formation started softening again. Piston coring resumed and continued until 269.7 mbsf (Core 145-887A-29H), where the final switch to the XCB was made in anticipation of basement contact. The last two cores advanced 16.3 m in unstable hole conditions (gravel). With total depth designated as 286 mbsf, the pipe was pulled out of the hole to the surface, and the vessel offset 20 m east. On this hole, piston coring penetrated 196.7 m and retrieved 190.51 m (96.9% recovery). XCB coring penetrated 49.38 m and recovered 89.30 m (55.3% recovery).

HOLE 887B

The objective of this hole was to provide five cores for high-resolution sediment and pore-water chemistry analysis. The APC did not fully stroke out during the first two attempts at mud-line cores, and only a handful of gravel was recovered. It was also noted that the core-catcher flapper was missing on each of the two barrels. In order to determine if the core barrel was being prevented from full stroke by an internal obstruction or by the formation, the pipe was picked up and an intentional water core attempted. The lack of proper bleed-off suggested that the barrel did not stroke out completely in the water column; but when the core barrel was retrieved with the shear pins severed, it was clear that whatever obstruction was being encountered was in the bottom-hole assembly.

The bit was reluctantly pulled out of the hole and was on deck at 1600 hr 11 September. The bit and lockable float valve were replaced, and the APC system tested twice just below the sea surface. After these two successful tests, the pipe was run to the seafloor, where Hole 887B was spudded at 0100 hr 12 September. The first core contained 2.05 m of sediment to establish the mud-line depth at 3647.5 mbsf. After obtaining five cores, which penetrated 40 m (103.5% recovery), the pipe was pulled out of the hole and the mud line cleared at 0515 hr. The vessel was offset 20 m north, and the last piston-cored hole of Leg 145 initiated.

HOLE 887C

The first core was taken at 0600 hr and recovered 4.32 m of sediment to establish the mud-line depth at 3645.2 mbrf. In an attempt to improve recovery over the results of the APC/XCB coring of Hole 887A (83.9%), this hole was piston cored to total depth using wash-over whenever the overpull exceeded 130,000 lb. The total cored interval was 273.8 m, with 269.44 m recovered (98.4% recovery). Cores 145-887C-4H through -16H were oriented. In order to achieve this enhanced recovery, 10 core barrels had to be extracted by washing over. At the conclusion of this hole, the pipe was pulled out of the hole, and the bit and BHA changed to an RCB coring configuration.

HOLE 887D

The final hole of Leg 145 was an RCB excursion into basement. This hole was spudded at 2200 hr 13 September and washed down to 257.4 mbsf, where rotary coring was initiated just above basement. The first three cores advanced effortlessly through the soft sediment overlying basement, with a total recovery of only 0.91 m. The basement contact occurred at approximately 295 mbsf (Core 145-887D-4R), where the rate of penetration slowed to 5.2 m/hr. Rotary coring advanced into alternating layers of sediment (?) and unstable basalt for the next 78 m. The rate of penetration increased markedly with the last five cores to an average of 15.4 m/hr. Finally, at 373.1 mbsf (Core 145-887D-13R), drilling operations were terminated due to deteriorating hole conditions.

Hole 887D Logging Operations

After an extensive wiper trip and hole flushing, the pipe was pulled to the logging depth of 78.8 mbsf. The logging program began at 1100 hr 15 September, when the Schlumberger equipment was rigged up. The logging program for this hole was to include the standard three suites (Quad-Combo, FMS, Geochemical) plus the French susceptibility tool (SUMT). Unfortunately, only the Quad-Combo and FMS tools were run, as the FMS tool became stuck in the pipe, necessitating a pipe trip out of the hole. The logging runs were as follows:

LOG No. 1: (NGT/HLDT/SDT/DITE). On the first pass, the tool string was lowered to 347.8 mbsf (within 25.3 m of total depth), and the bottom 150 m of the hole logged. On the repeat pass, the hole was logged from 347.8 mbsf to the mud line. The tool was out of the hole at 1830 hr 15 September.

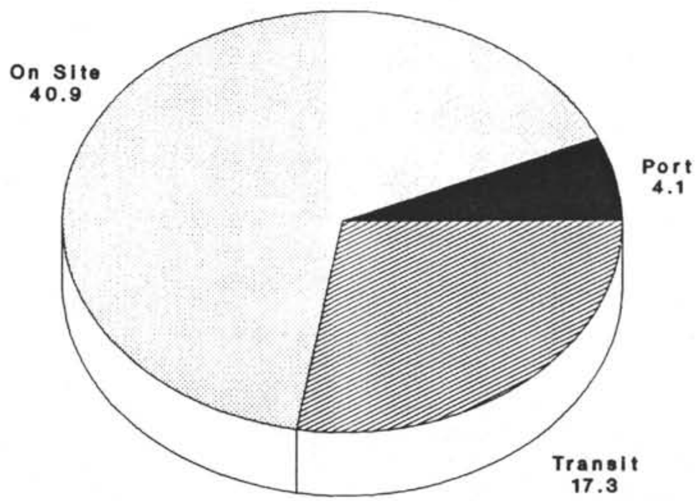
LOG No. 2: (FMS/GPIT/NGT). The first five passes concentrated on logging the bottom 100 m of the hole from 242.8 to 342.8 mbsf; the sixth pass logged from the bottom of the hole up to the base of the pipe.

At the end of the FMS logging run, the logging cable had to be worked rigorously in order to work the FMS tool into the pipe. After succeeding in moving the tool 170 m up the pipe, the FMS tool became permanently stuck. In order to retrieve the tool, the pipe had to be pulled out of the hole, and logging operations terminated. Once the tool was on deck, the drilling assembly was secured for transit, and the vessel turned on a southeasterly heading toward Victoria.

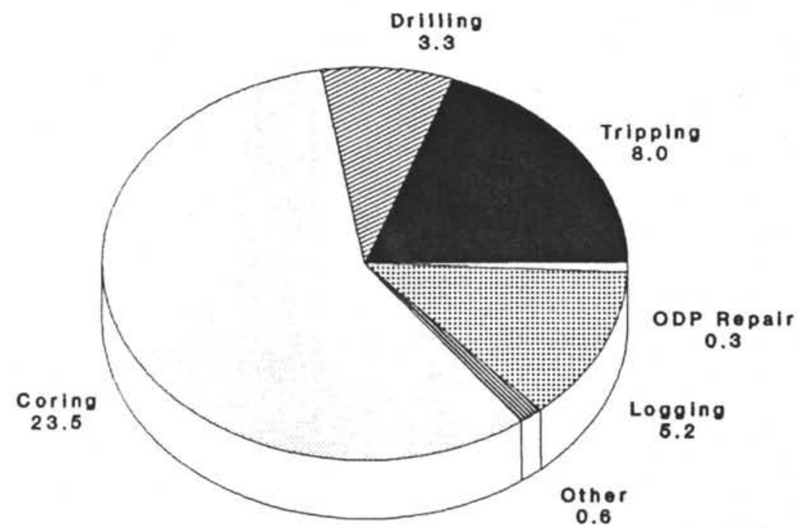
Leg 145 Operations Summary

Total Days (20 July-20 September 1992)		62.4
Total Days in Port		4.1
Total Days Underway		17.3
Total Days on Site		40.9
Tripping	8.0	
Drilling	3.3	
Coring	23.5	
Logging/Downhole Science	5.2	
Reentry	0.0	
Casing and Cementing	0.0	
Stuck Pipe/Downhole Trouble	0.0	
Fish & Remedial	0.0	
Devel. Engineering	0.0	
Repair Time (Contractor)	0.0	
Repair Time (ODP)	0.3	
W.O.W.	0.0	
Other	0.6	
Total Miles Transited		4823.0
Average Speed Transit (knots)		11.4
Number of Sites		7
Number of Holes		25
Total Interval Cored (m)		5015.1
Total Core Recovery (m)		4321.7
% Core Recovery		86.2
Total Interval Drilled (m)		2705.7
Total Penetration (m)		7720.8
Maximum Penetration (m)		929.8
Maximum Water Depth (m from drilling datum)		5725.7
Minimum Water Depth (m from drilling datum)		2395.6

Leg 145
Time Distribution-In Days



Leg Totals



On Site

OCEAN DRILLING PROGRAM
SITE SUMMARY
LEG 145

HOLE	LATITUDE	LONGITUDE	WATER DEPTH (meters)	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)
881A	47 6.136N	161 29.492E	5542.0	1	9.50	9.92	104.4%	0.00	9.50	14.00	
881B	47 6.136N	161 29.492E	5542.0	18	167.00	170.33	102.0%	0.00	167.00	21.70	
881C	47 6.133N	161 29.490E	5541.7	39	363.80	227.20	62.5%	0.00	363.80	83.50	
881D	47 6.135N	161 29.522E	5542.0	6	57.00	57.91	101.6%	155.00	212.00	27.25	
		SITE TOTALS:		64	597.30	465.36	77.9%	155.00	752.30	146.45	6.10
882A	50 21.797N	167 35.996E	3254.7	42	398.30	411.20	103.2%	0.00	398.30	43.50	
882B	50 21.798N	167 35.976E	3255.1	29	270.40	280.90	103.9%	0.00	270.40	31.00	
		SITE TOTALS:		71	668.70	692.10	103.5%	0.00	668.70	74.50	3.10
883A	51 11.898N	167 46:128E	2407.0	4	38.00	38.49	101.3%	0.00	38.00	8.67	
883B	51 11.908N	167 46.128E	2395.6	88	840.70	695.41	82.7%	0.00	840.70	71.33	
883C	51 11.919N	167 46.123E	2396.5	38	355.00	344.30	97.0%	0.00	355.00	30.25	
883D	51 11.919N	167 46.108E	2396.5	2	17.00	17.31	101.8%	0.00	17.00	6.25	
883E	51 11.917N	167 46.098E	2396.5	23	226.00	116.60	51.6%	630.50	856.50	69.25	
883F	51 11.906N	167 46.085E	2396.5	3	29.40	13.58	46.2%	820.00	849.40	81.75	
		SITE TOTALS:		158	1506.10	1225.69	81.4%	1450.50	2956.60	267.50	11.15
884A	51 27.026N	168 20.228E	3837.8	1	9.70	9.72	100.2%	0.00	9.70	9.25	
884B	51 27.026N	168 20.228E	3836.0	91	853.90	791.76	92.7%	0.00	853.90	89.25	
884C	51 27.038N	168 20.217E	3836.1	38	357.80	294.56	82.3%	0.00	357.80	30.50	
884D	51 27.038N	168 20.196E	3837.1	2	14.80	13.92	94.1%	0.00	14.80	8.00	
884E	51 27.034N	168 20.216E	3836.0	10	87.00	66.78	76.8%	842.80	929.80	131.00	
		SITE TOTALS:		142	1323.20	1176.74	88.9%	842.80	2166.00	268.00	11.17
885A	44 41.296N	168 16.319W	5719.9	8	58.80	53.64	91.2%	0.00	58.80	26.50	
		SITE TOTALS:		8	58.80	53.64	91.2%	0.00	58.80	26.50	1.10
886A	44 41.384N	168 14.416W	5724.8	1	9.70	9.70	100.0%	0.00	9.70	5.25	
886B	44 41.384N	168 14.416W	5725.7	9	68.90	60.50	87.8%	0.00	68.90	12.50	
886C	44 41.384N	168 14.400W	5724.7	8	72.40	67.09	92.7%	0.00	72.40	18.25	
		SITE TOTALS:		18	151.00	137.29	90.9%	0.00	151.00	36.00	1.50
887A	54 21.921N	148 26.765W	3642.8	31	286.00	239.84	83.9%	0.00	286.00	48.50	
887B	54 21.921N	148 26.778W	3647.5	5	40.00	41.38	103.5%	0.00	40.00	13.25	
887C	54 21.934N	148 26.778W	3645.2	30	273.80	269.44	98.4%	0.00	273.80	35.75	
887D	54 21.935N	148 26.788W	3645.2	13	115.70	19.92	17.2%	257.40	373.10	70.00	
		SITE TOTALS:		79	715.50	570.58	79.7%	257.40	972.90	167.50	6.98
		LEG TOTALS:		540	5020.60	4321.40	86.1%	2705.70	7726.30	986.45	41.10

TECHNICAL REPORT

The ODP Technical and Logistics personnel aboard *JOIDES Resolution* for Leg 145 were:

Laboratory Officer:	Randy Current
Assistant Laboratory Officer:	Don Sims
Marine Laboratory Specialist/Yeoperson:	Michiko Hitchcox
Marine Laboratory Specialist/Curatorial Representative:	Lorraine Southey
Marine Computer Specialists/System Managers:	Edwin Garrett
	Barry Weber
Marine Electronics Specialist:	Roger Ball
Marine Laboratory Specialist/Photography:	Shan Pehlman
Marine Laboratory Specialists/Chemistry:	Chieh Peng
	Philip Rumford
Marine Laboratory Specialist/X-ray:	MaryAnn Cusimano
Marine Laboratory Specialist/Thin Section:	"Gus" Gustafson
Marine Laboratory Specialist/Underway Geophysics:	Robert Kemp
Marine Laboratory Specialist/Physical Properties:	Jean Mahoney
Marine Laboratory Specialist/Storekeeper:	Jeff Millard
Marine Laboratory Specialist/Paleomagnetics:	Monica Sweitzer
Marine Laboratory Specialist:	Tim Sykes

SCIENTIFIC OBJECTIVES OF LEG 145

Leg 145 was conceived in order to better understand the paleoceanography and paleoclimatology of the North Pacific. The primary objectives of the leg were to determine (1) the high-resolution variations of surface and deep-water circulation and chemistry during the Neogene; (2) the Late Cretaceous and Cenozoic history of atmospheric circulation, ocean chemistry, and continental climate; and (3) the age and nature of the seafloor. To address these objectives, seven sites were drilled in horizontal and vertical transects to record latitudinal changes in ocean fronts and currents, to span changes in deep-water masses, and to place age constraints on plate-motion history.

PORT CALL

Leg 145 commenced at 1000 hr 20 July 1992, when the ship arrived at the dock in Yokohama, Japan. After a minimal delay for customs and immigration, the gangway was opened to the oncoming crew, and crossovers began. Tours were conducted on days 2 through 4. A team of divers were employed to remove and replace the faulty 3.5-kHz transducer in the sonar dome. The operation was a success but required more time than anticipated when one of the divers became ill and was unable to continue. Sensors and instrumentation were brought aboard which eventually will monitor the motion of the ship and drill-string heave compensator. The recorded data are intended to be used to better understand the requirements of the DCS secondary heave compensator. The installation was not completed by sailing time, and the system was not functional. After all freight had been stowed and the laboratories fully stocked, the technical staff were released mid-afternoon of the 23rd to have one last look at people they had never seen before.

LABORATORY OPERATIONS

Underway Operations

The last line was cast off at 1100 24 July 1992, and the ship got under way for proposed site NW-1A, soon to become Site 881. Nearly 4500 mi of bathymetric, magnetic and navigation data were collected in seven lines, as well as 200 mi of seismic survey data. The seismic source for the first five survey lines was one 80-in.^{3} water gun and one 200-in.^{3} water gun. On the last two lines, only the 80-in.^{3} water gun was used. At the request of the geophysicist, the 3.5-kHz echo sounder was digitally recorded. On the first survey, a digital oscilloscope was used to collect the data, which were then transferred to a PC for manipulation. The results were usable but would have required a great deal of time, effort, and programming to correlate and stack the traces. On subsequent survey lines, the receiver output from the echo sounder was attenuated and fed into the MASSCOMP as channel 2. Synchronization was tricky, but the results were well worth the effort, as the data were then in a format which could be easily processed with existing software. No seismic data were collected during the Site 883 pre-site survey due to an electrical problem. The fault was repaired, and a line was surveyed departing the site.

On-Site Laboratory Operations

Aside from the very high recovery, this was a generic leg with only routine laboratory operations being performed. The ship spent 41 days on site and 18 days under way. Core recovery was heavy, with a total of 5015.1 m drilled and 4321.4 m recovered, averaging 86.2%.

Bridge Deck

The new layout of the core laboratory was tested severely this leg, with 25,593 samples logged. Considering the shear volume of core processed through the laboratory, surprisingly few difficulties were encountered. The auxiliary core rack was installed while under way to the first site, and was used extensively throughout the leg.

A 386-PC running with DOS 3.3 was installed on the MST as the controlling computer. It is configured with an 80-MB hard drive and 6 MB of RAM. Drive A is 1.4 MB. Ethernet Mobius was installed to speed transfer of data to the VAX, and the printer output was disabled to reduce the dead time between sections; 3195 sections were processed through the MST. Other than routine maintenance, the only down time encountered was when a section with a severely damaged liner failed to pass cleanly through the susceptibility loop. The core transport boat was damaged and replaced.

One set of new transducers manufactured by Blaytek, Ltd., was installed on the Hamilton Frame for evaluation. They proved to be superior to the old style, with a better signal-to-noise ratio. One unit was damaged early in the leg and was replaced by an old, used transducer.

The cryogenic magnetometer appeared to be functioning well in its new orientation. Only routine calibration and a few loose screws required attention. It was discovered that the helium level gauges read somewhat high when measured with the master control box. To obtain a truly accurate reading, it is necessary to directly read the gauges with a digital voltmeter.

Orientation was done on APC holes at every site. The Tensor tool was run in conjunction with the multishot tool for evaluation purposes. Correlation was good between the two instruments when both worked. The Tensor tool appears to have suffered damage to the firmware, and has been returned for repair. Another new puzzle was the few liners which rotated at some point during the run. Several theories have been put forward, all equally believable.

Fo'csle Deck

Routine shipboard analyses were performed for both inorganic and organic components during this leg. Interstitial-water samples were analyzed to determine:

NO_2/NO_3, NH_4, and $Si(OH)_4$	Spectroscopic
SO_4	Dionex (IC)
Alk/pH, Ca, Mg, Cl	Titration
K, Li, Mn, and Sr	AAS
Salinity	Refractometer
Na	Calculated

This leg, rather than taking samples from the physical-properties split, dedicated carbonate samples were taken. These samples were freeze dried prior to analysis. TOC values were calculated by subtracting inorganic carbon values (coulometer) from total carbon (NCHS). Neither the Rock Eval nor the GHM instrument was used during this leg.

With only one petrologist on board, thin section requests were minimal. Rock types included dropstones of igneous origin, basalts, chert, and concretions of manganese. A 6-port vacuum impregnation jig was fabricated.

X-ray diffraction was used to analyze more than 200 samples from 10 holes for bulk-mineralogy identification. Estimates of peak area were used as a quantitative estimate of diatoms/clay proportions. The chemistry of both sediments and crystalline rocks was determined by XRF analyses. Fewer samples than anticipated were analyzed due to numerous minor problems with the instrument and frequent interruption of the chill-water supply.

Main Deck

There were no major VAX software or hardware upgrades this leg, although several configuration changes were implemented. To speed up the MST data transfer, Serial Mobius was replaced with Ethernet Mobius. Also, a SCSI DAT tape drive was successfully tested with the VAX. In preparation for the future removal of the VAX 11/750, several pieces of hardware connected to JAXVAX were reconfigured to work through the DECSERVERS on the Microvax 3500. Most of the key hardware and software worked well this leg, with the exception of one VAX hard drive which failed.

The following publications were received:

ODP Proceedings: Volume A of Leg 135, parts 1 and 2
Volume B of Leg 124.

Minerals and Mineraloids in Marine Sediments.

All computer-related publications have been relocated from Cabinet 1 in the library to the bookcase in the Conference Room. The extra set of the ODP volumes is now in Cabinet No. 1, and Cabinet No. 2 holds more ODP Bound Reprints. An inventory was done of ODP/DSDP volumes currently on the ship. P-Mail traffic was very light on this leg, due to the increased use of E-mail. E-Mail instructions have been installed on Scratch-A, and a printout of these instructions has been added to the "Yeop's Goodies" Notebook. It was discovered that some documents which have been saved as WordPerfect files in WP5.0/5.1 (PC) format, such as large tables, cannot be reopened as a Mac document for further editing. This is overcome by saving documents in both Mac and PC formats.

Excel files can be directly imported. A Microsoft Excel file of coring summaries for each site was made available to the scientific party on Scratch-A, which reduced the amount of unnecessary photocopying.

Upper 'Tween Deck

A new cabinet was installed in an effort to consolidate and organize the microscope parts. All drawers, and most individual parts, were labeled. This cabinet has been kept locked. All MATMAN photo items have had their location code changed to UTP (photo laboratory), although most perishables are still kept in the hold stores reefer. The Kreonite processor began leaving black marks on the prints again. After all the usual checks, the developer rack was drained, and a hard gray residue was discovered. Removing this residue cured the problem.

This leg sailed with only one Electronics Specialist, who was hard pressed to keep up with the demand on his time. Although equipment problems were minimal, there was always something with a relatively high priority which needed to be done. The X-ray laboratory, underway laboratory, chem laboratory, and entertainment system were the major areas of effort.

Downhole Tools

The ADARA temperature recorder was used two times. No data were collected on the first run due to operator error. The second run was successful. The WSTP was not deployed. On a time-available basis many but not all of the WSTP spare parts were organized and put into new storage bins. They have been assigned sequential numbers, which for the most part follow the spare parts list in the manual. Essential spares which should inventoried on a regular basis are marked with an asterisk (*) on the spare-parts list. The WSTP temperature probes were changed from the high-temperature, 2-thermistor configuration to a single thermistor probe with a flexible signal lead running from the probe to the lower bulkhead, where it connects to an E/O bulkhead connector.

FMS data were collected and processed from two holes, Holes 883F and 884E. Data were collected from Hole 887D but were not processed due to time limitations. The usual problems were encountered. Disk space, software, and hardware appear to be inadequate to the task.

Stores

The offgoing freight was organized well and was relatively small, as was the inbound shipment. Offloading and onloading were handled quickly and efficiently. A new MATMAN shipboard location was created for the drafting supplies (LTDS). These items have been taken off the LTS checkout sheet and are still in the Lower 'Tween storeroom. The gas bottles in storage on the Upper 'Tween deck were each dated according to the leg in which they were sent to the ship. Key locks were installed on the Hold, Lower 'Tween, and the Ships Stores storerooms. The keys are to be issued to the Laboratory Officer, Storekeeper, Assistant Laboratory Officer, and one other Marine Specialist in an attempt to more carefully control access to the storerooms. The hold decking is in need of replacement. Years of heavy loads have taken a toll on the plywood covering, and it is now very difficult to move large items with the palate jack.

An embarrassing problem surfaced this leg with the MATMAN system. It seems that once an item falls below the reorder point, it will never show up on the LASTREO report again until the item has been restocked to a level ABOVE the reorder point. Because a complete physical count each leg is impractical, these items are very often not discovered until the supply is exhausted, as was the case this leg with D-tube tape.