OCEAN DRILLING PROGRAM

LEG 144 PRELIMINARY REPORT

NORTHWEST PACIFIC ATOLLS AND GUYOTS

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ABSTRACT

Five guyots were drilled in the Western Pacific Ocean during ODP Leg 144 (including 20 holes drilled at 10 sites) to investigate the formation of these volcanic edifices, the evolutionary development and demise of carbonate platforms on these features, and the subsequent accumulation of pelagic sediments overlying the drowned platforms. In addition, Hole 801C (drilled during ODP Leg 129) was reentered and logged during Leg 144 and a downhole packer experiment was conducted.

The drilling results of Leg 144 indicate that the formation of carbonate platforms on these guyots, and specifically their termination, is not a simple matter of a mid-Cretaceous drowning event. At least three major episodes of carbonate platform drowning were observed from the guyots drilled; specifically: Albian, late Maastrichtian, and middle Eocene. Most of the carbonate platforms contain paleoecologic assemblages and sedimentary facies that indicate multiple relative sealevel fluctuations during their growth. The Cretaceous and Eocene carbonate systems, in contrast to modern atolls having a coral-algal reef framework surrounding a lagoon, may have produced vast quantities of loose carbonate sediment in large shoal deposits with rudist-algal-coral boundstones forming relatively thin bioherms on the exterior ridges near the margins of the guyot.

In summary, drilling of guyots during ODP Leg 144 revealed that the development and termination of these former carbonate platforms is a complex function of sealevel fluctuations and environmental change, and that modern Pacific atoll reef systems are an inadequate analog for the Cretaceous and lower Tertiary cabonate platforms of the ancient Pacific.

INTRODUCTION

The ocean floor of the Western Pacific Ocean is covered by numerous scattered seamounts and atolls, which cluster together to form larger complexes or are roughly organized along a preferential direction to form a chain. Most of the seamounts are guyots that have a flat top and are considered old, drowned atolls. The Marshall Islands constitute one of the chains departing from near the equator in a northwest direction (Fig. 1). Several authors explain such alignments, like the Hawaiian Chain, as having originated by the progression of a hotspot. Another alignment is illustrated by the Mid Pacific Mountains, which exhibit a roughly east-west orientation. Other guyots or clusters of guyots may not show any apparent preferred orientation, or they may be isolated features. This is the case of MIT Guyot and the poorly defined Japanese Seamounts located close to the Japan trench.

Over wide areas of the Pacific Basin, drowned atolls now lie at depths between 1 and 2 km. Consideration of the normally rapid upward growth of reefs coupled with relatively slow subsidence rates and sea level changes led Schlager (1981) to propose that reef drowning is a paradox. Because many of the drowned reefs north of the Marshall Islands apparently drowned in mid-Cretaceous time (see Winterer et al., submitted; Matthews et al., 1974) it was recently proposed that these Cretaceous reefs were drowned as a result of a global oceanic anoxic event in Aptian-Albian or Cenomanian-Turnian time (Schlanger and Jenkyns, 1976), or by a series of paleolatitudinal changes (Winterer et al., submitted).

Periods of emergence of an atoll, resulting from a sea-level lowering that is faster than the regional subsidence, cause the exposed limestones to undergo intensive diagenesis and karstification, as shown by drilling on Anewetak (Schlanger, 1963; Emery et al., 1954). Solution unconformities mark these periods of emergence. The timing of sea-level changes can be calibrated by analyzing the stratigraphic distribution of these solution unconformities, deciphering the diagenetic history of the previously emergent limestones and tracking the stratigraphic section along a subsidence path (which will be refined by the drilling to clarify the thermal rejuvenation and subsidence history of these guyots).

From Darwin's early observations through Menard's (1964) concept of the Darwin Rise, and Hamilton's (1956) work on the "Sunken Islands of the Mid-Pacific Mountains" to modern studies of uplift caused by thermal rejuvenescence related to mid-plate volcanism (Detrick and Crough, 1978; Crough, 1978), it has become obvious that the central Pacific Basin did not follow a straightforward Parsons-Sclater (Parsons and Sclater, 1977) type of subsidence path (see also McNutt and Menard, 1978). The abnormally fast subsidence of Anewetak and Pikinni since early Eocene time was used by Detrick and Crough (1978) to argue that the seafloor in the Marshalls region had undergone thermally induced uplift of as much as 1.6 km prior to Eocene time, but well after the formation of the underlying plate.McNutt and Fischer (1987) proposed that the Marshall Islands swell can be traced back to the South Pacific Superswell. If episodes of regional uplift and subsidence are related to the passage of the Marshall Islands over thermal anomalies, then the multiple volcanic episodes known to have occurred in the Marshalls region (see regional setting) would argue for the fact that the region has undergone multiple episodes of thermal rejuvenation (Schlanger and Moberly, 1986). Further, the apparent intense and widespread volcanism seen in the Pacific during Cretaceous time was the cause of major uplift. This volcanism may have been a factor in causing the major Cretaceous global sea-level rise from ~110 to ~70 Ma (Schlanger et al., 1981).

Drilling Objectives

Drilling on Leg 144 had the following objectives:

- To recover pelagic sediments for high-resolution stratigraphy and for reconstructing the paleoceanography in this sector of the Pacific;

- To relate the acoustic stratigraphy of the pelagic cap to its depositional and diagenetic history and correlate seismic reflectors with those seen in other guyots;
- To date the interface between the pelagic cap and the underlying platform, and infer the age and cause of platform drowning;
- To establish the stratigraphy, and examine the faunas, floras, and growth of the carbonate platform and facies changes with time;
- To reconstruct migration routes of benthic organisms (rudists and benthic foraminifers) and paleoceanographic implications;
- To examine the diagenesis of the shallow-water limestones and compare the diagenesis of the older guyots with the younger guyots drilled in the Marshall Islands;
- To investigate the nature and variability of the perimeter ridges on Wodejebato Guyot, and Takuyo-Daisan Guyot;

- To determine the age and causes of platform drowning, possible emergence, and subsidence history of the platform limestone relative to sea level;
- To determine the genesis of the rough surface topography of MIT Guyot and Takuyo-Daisan Guyot in relation to the hypothesis of emergence and karsting of the shallow-water limestone cap before the final drowning;
- To establish the age and paleolatitude of the volcanic edifices, and subsequent paleolatitudinal changes;
- To obtain geochemical data from the volcanic edifices for comparison with other sites and the DUPAL/SOPITA anomaly; and finally
- To compare the geological history of drilled guyots with that of other Western Pacific guyots drilled during Legs 143 and 144.

RESULTS

Site 871

Site 871 (proposed site Har-2) is located at 5°33.43'N, 172°20.66'E, in 1255 m water depth, in the south central portion of Limalok (Harrie) Guyot in the southern Marshall Islands (Figs. 2 and 3). This site is the southernmost of the north-south transect of sites drilled by Leg 144, and on the basis of previous work in this region, Limalok Guyot is considered the youngest of the guyots in the Marshall Islands region. As the existing seismic coverage across Limalok Guyot was minimal and existed only as analog records, we allotted time for a complete north-south transect over the summit prior to selecting a site in order to acquire a better understanding of the guyot's subsurface structure (Fig. 4).

JOIDES Resolution launched a beacon at Site 871 at 0857 hr (2057UTC) on 24 May 1992, officially beginning site operations for Leg 144. Coring began at 1530 hr on 24 May 1992 and was completed at 1845 hr on 28 May 1992 after 4.1 days of drilling three holes (Holes 871A, 871B, and 871C). After obtaining our drilling objectives and logging Hole 871C, we departed Site 871 at 0700 hr on 31 May 1992.

Three holes were drilled at Site 871; Hole 871B is located 10 m east of Hole 871A, while Hole 871C is located 10 m to the west of Hole 871A. Holes 871A and 871B were APC (advanced hydraulic piston corer) cored to 139.5 and 133.2 mbsf, respectively, where refusal occurred at the boundary between lower Miocene and middle Eocene sediments. These holes were continued by XCB coring to 151.9 mbsf with a total of 83% recovery (Hole 871A), and 152.4 mbsf with a total of 68.2% recovery (Hole 871B). The APC cores are poor candidates for high-resolution stratigraphic studies because the recovered sediments are winnowed and very soupy. A third hole, Hole 871C, was spudded using the RCB. After washing through the pelagic cap, cores were recovered from 133.7 to 500 mbsf (TD). The recovered material includes shallow-water limestones from 133.7 to 422.9 mbsf, clay from 422.9 to 451.5 mbsf, and altered basalt from 451.5 mbsf to 500 mbsf. Recovery in Hole 871C averaged 14.6% with only 3.5% recovery in the sedimentary section.

A free-fall reentry funnel was deployed through the moonpool at 0145 hr on 29 May 1992 in order to undertake an extensive logging program in Hole 871C. Two attempts were made with the Japanese lightweight, slim-hole magnetometer to log the basement rocks. Although the drill pipe was kept deep in the hole to avoid running the magnetometer past potential bridges in the limestone section of the hole, a bridge had formed in the deeper section of the hole, and a subsequent obstruction of the drill pipe with clay prevented successful logging. A successive series of problems with the clay section resulted in the decision not to log the lowermost portion of the hole, but successful logging was conducted across the entire limestone section. Standard Schlumberger geophysical and geochemical logs were run, as well as two runs with the formation microscanner. Logging was completed at about 0030 hr on 31 May 1992.

Lithostratigraphy

Four lithologic units were identified at Site 871 using a combination of visual core descriptions, augmented with smear-slide and thin-section data, and downhole-logging data (Fig. 5). Age identification of these units was based on calcareous plankton (pelagic cap) and larger benthic foraminifers (shallow-water limestones). The identified units are, from top to bottom:

> Unit I (0-133.7 mbsf). Nannofossil foraminifer ooze and foraminifer ooze of Pleistocene to early Miocene age. Sediment composition allowed the subdivision of Unit I into two subunits. Subunit IA (0-26.5 mbsf) is composed of light gray nannofossil foraminifer ooze of Pleistocene to latest Miocene age; Subunit IB (26.5-133.7 mbsf) is composed of

white homogeneous foraminifer ooze with a medium sand texture, well-sorted and winnowed, of middle to early Miocene age. The transition between the two subunits is marked by a hiatus which spans the late middle to latest Miocene.

Unit II (133.7-422.9 mbsf). Sequence of white to very pale brown platform carbonates of middle Eocene to early late Paleocene age. Unit II is subdivided into six subunits on the basis of fossil content and lithology. The carbonate rock types in Unit II include packstone, grainstone, and wackestone with abundant benthic foraminifers (mostly miliolids with agglutinated foraminifers, Nummulites, alveolinids, and Asterocyclina), common red and green algae (corallinaceans, squamariaceans, solenoporaceans, and udotaceans), and common mollusk molds of bivalves and gastropods. The porosity of these rocks is estimated at 5%-10%, and is predominantly moldic, solution-enlarged interparticle, and/or microvuggy. Porosity is moderately reduced by passively precipitated pore-lining carbonate cement; however, most of the secondary porosity remains open. The contact between the pelagic cap and the underlying platform limestone is marked by an iron-manganese oxide and phosphatic hardground. Borings in the hardground are infilled with pelagic sediment of late early Oligocene age.

Unit III (422.9-451.6 mbsf). Variegated clay of indeterminate age that displays large variations in the texture and content of lithoclasts. Basalt pebbles occur in the lower part of the unit. The unit is composed of three subunits. Subunit IIIA (422.9-423.8 mbsf) is a homogeneous gray clay with patches of dark gray, fine, sand-sized sediment comprised of fragmented shells. Subunit IIIB (423.8-435.9 mbsf) is composed of mottled, variegated clays. Subunit IIIC (435.9-451.6 mbsf) is a heterogeneous subunit of clay, basalt clasts and sandy intervals.

Unit IV (451.5-500 mbsf TD). Interbedded volcanogenic sandstones with basaltic breccias and flows. Except for a thin basaltic lava flow, the uppermost 6 m of recovered basement consists of a series of volcanogenic breccias. These are followed by a sequence of massive flows, from 1 to over 7 m thick. All the flow units appear to have a similar mineralogy with only minor variations; they appear to be nepheline-bearing basalt. The basalt typically has high NRM intensities (up to 18A/m) and negative inclinations. Five or more distinct inclination groups are present, values vary from +2° to -32°, and are compatible with the predicted paleosecular variation.

Geochemistry

Interstitial-water data indicate minimal diagenesis within the foraminifer ooze composing the pelagic cap (Unit I). The pelagic cap (Unit I) and lagoonal limestone (Unit II) at Site 871 have a calcium carbonate content of 95% to 98% with less than 0.3% organic carbon and no sulfur. The top of the clay section (Unit III) is enriched in organic carbon and total sulfur (up to 12% and 13% respectively).

Downhole Logs

The entire carbonate-platform succession was successfully logged (Fig. 6). The Paleocene/Eocene boundary at 319 mbsf is marked by a uranium concentration and cementation surface at the top of coralline grainstones from Unit II. A similar uranium cementation horizon at 138 mbsf coincides with the phosphatic hardground at the top of Unit II, the middle Eocene carbonate platform. Between these two major surfaces, the Eocene platform generally consists of low-resistivity facies containing several smaller uranium anomalies, especially within the upper 80 m of the platform. The underlying rhodolith and coralline grainstone facies contain several dense, high-resistivity, meter-scale beds, which exhibit high uranium concentrations that may be an expression of the algal nature of the material.

Interpretation

Initial interpretations of the cores obtained at Site 871 indicate that the upper portion of the igneous basement of Limalok Guyot was formed by a series of eruptions of highly alkalic basalts, basanites, and nephelinites. These are probably related to the constructional phase of the volcano rather than a short-lived post-erosional phase. The basalt has basement inclinations that appear to represent normal polarity magnetization acquired at a low southern paleolatitude of approximately 10°S.

The angular volcanic breccias and the thick overlying sequence of dense variegated clay record a period of weathering and erosion of the volcanic pile. The weathering and erosion most likely occurred in subaerial conditions, as exhibited by the poor preservation of terrestrial-derived organic matter. The low-diversity pollen assemblage represents the limited floral diversity; the assemblage is dominated by angiosperms and abundant fungal spores. The preservation and assemblage are suggestive of a moist tropical island with limited floral diversity.

Flooding of the island occurred during the early late Paleocene, with the initial stages of inundation characterized by marginal-marine conditions. The color transition near the top of the clay from light gray to an increasingly darker gray reflects an increase in organic matter (TOC up to 10%), and sulfur (TS up to 12%); the sulfur is observed as pyrite and marcasite. This gray clay was deposited in a low-energy environment, under sulfate-reducing conditions that were influenced by seawater. The organic-rich clay was burrowed and infilled with skeletal debris that still preserve their aragonitic composition, and with calcareous nannofossils of early late Paleocene age. This clay zone is interpreted as being a basal transgressive marine deposit.

The overlying carbonate sequence records the development and demise of a Paleocene to Eocene carbonate platform. The lowermost limestones have a well-sorted packstone texture, with coarse-sand-sized grains; the constituent grains exhibit a high biotic diversity. These characteristics suggest a well-oxygenated, turbulent, shallow-marine depositional environment that existed on Limalok Guyot during the early late Paleocene. The presence of pyrite and carbon fragments within these limestones suggests that there was sulfate reduction in this early diagenetic marine environment.

The late Paleocene packstones and grainstones contain a normal marine biota and rhodoliths, denoting deposition on an open shelf or steep ramp. These packstones give way to grainstones, rudstones, and some boundstones, which contain abundant miliolids, scleractinian corals, red and green algae, echinoids, and larger foraminifers (Nummulites, Discocyclinidae). The facies signify the presence of a nearby reef and they represent deposition in a back-reef environment during the late Paleocene.

A period of deposition in a protected lagoon that may have undergone periods of slight restriction during the early Eocene is represented by lower Eocene wackestones that contain low-spired gastropods and miliolids in a low-diversity assemblage. The overlying lower and middle Eocene burrowed skeletal wackestones and packstones contain Alveolina and miliolids; these low-energy facies indicate continued deposition in a protected, shallow-lagoon setting during early to middle Eocene time. The presence of middle Eocene grainstones signifies the return of higher energy conditions. Some of the grainstones exhibit low-angle cross laminations composed of coarse-sand-sized grains and keystone vugs; these grainstones are interpreted as beach or sand-bar deposits. The uppermost limestones are middle Eocene packstone and wackestone containing Nummulites and miliolids that were deposited in a protected, shallow lagoon.

The platform limestones on Limalok Guyot represent a shallowing-upward sequence, with changes in depositional environment from open subtidal to a shallow-lagoonal depositional setting. A peak in faunal diversity, coupled with the presence of planktonic foraminifers, marks at least one period of higher sea level during the early middle Eocene. Benthic foraminifers and rare diatoms in the uppermost part of the sequence are indicative of a central lagoonal environment just prior to platform drowning.

The carbonate platform, Unit II, (Fig. 5) is overlain by an iron-manganese oxide and phosphatic crust containing middle Eocene calcareous plankton. This planktonic assemblage tightly constrains the date of the platform drowning and indicates that oceanic, poorly oxygenated waters covered the relict platform immediately after its demise. Manganese oxide encrustation and phosphatization possibly continued through some part of the late Eocene and early Oligocene.

The carbonate platform subsided into the pelagic realm by the early Oligocene as demonstrated by the presence of planktonic foraminifers and nannofossils that infill borings in the marine hardground. The accumulation of pelagic sediments did not commence until the early Miocene. Lower and middle Miocene sediments were strongly winnowed by subsurface currents, although sediment preservation was relatively continuous with accumulation rates of 5-20 m/m.y.
A prominent disconformity, spanning the late middle Miocene through most of the late Miocene (approximately 6 m.y.), resulted in appreciable reworking of calcareous microplankton of Oligocene and early/middle Miocene age. Sediment accumulation during the latest Miocene and Pliocene was slow (2-3 m/m.y.) and discontinuous. The relatively complete, albeit thin,

uppermost Pliocene and Pleistocene sequence suggests a change in oceanographic conditions. This change was accompanied by higher sediment-accumulation rates (11-12 m/m.y.) and a decrease in sediment winnowing.

Site 872

Site 872 is located at 10°05.85'N, 162°51.96'E, at 1084 m water depth, on the central part of Lo-En Guyot, approximately 148.2 km from Anewetak Atoll in the northern Marshall Islands (Figs. 1, 2, and 7). The guyots in the Marshall Islands region have pelagic caps that range in thickness from virtually 0 to 150 m. The thickness of an individual pelagic cap appears to be strongly correlated with both the depth of the guyot (related to length of the depositional history) and the size of the guyot (less erosion near the perimeter of the summit). Of the guyots surveyed on the 1988 cruise of the *R/V Moana Wave* (MW8805), the pelagic cap atop Lo-En Guyot appears to be the most complete in the region, and therefore was a key objective of drilling on this guyot. On the basis of the 3.5-kHz echo-sounder records, the position of Site 872 is in the thickest part of the pelagic cap on Lo-En Guyot (Fig. 8).

JOIDES Resolution deployed a beacon for Site 872 (proposed site Pel-3) at 1352 hr (0252UTC) on 2 June 1992. Coring began at 1730 hr on 2 June 1992 and was completed at 0400 hr, 6 June 1992, after 3.55 days of drilling three holes (Holes 872A, 872B, 872C) and the unsuccessful logging of Hole 872B. We departed at 0800 hr on 6 June 1992.

Three holes were drilled at Site 872. Hole 872A is located 150 m northwest of Hole 872B, and Hole 872C is located 106 m north of Hole 872B; all three holes were offset 75 m from the acoustic beacon deployed at this site. The unusual distance between the three holes was chosen in order to prevent or diminish the chance that drilling disturbance in the vicinity of one drill hole would disrupt the physical properties of the ooze within another drill hole in the pelagic cap. Experience with the exceptionally soupy, winnowed foraminifer ooze from Site 871 on Limalok Guyot guided this decision.

Holes 872A and 872C were APC cored to 143.7 and 139.5 mbsf, respectively, where refusal occurred at the boundary between upper Oligocene and middle Eocene sediments. These holes were continued by XCB coring to 144 mbsf with a total recovery of 85.9% (Hole 872A);

Hole 872C was cored to 148 mbsf with a total recovery of 98.5%. Hole 872B was spudded using the RCB system. After spot coring the pelagic cap, cores were recovered from 135.2 to 192.5 mbsf (TD) with a total recovery of 30.1% in Hole 872B.

The APC cores recovered from Hole 872A were winnowed and very soupy, similar to the material recovered from the pelagic cap at Limalok Guyot (Site 871). The lack of cohesion in these sediments when they are drilled, and the subsequent handling of these water-laden cores on deck, result in cores that are poor candidates for high-resolution stratigraphy. In order to salvage Site 872 for the high-resolution stratigraphy objective, we implemented a different method of handling cores upon arrival on the rig floor when drilling Hole 872C. Excess water at the top of a core was removed with a device named a piglet that was inserted into the core liner while the core was upright within the core barrel on the rig floor. Additional excess water was removed after the core was cut into sections. Each section was turned upright to permit water to rise to the top for removal, and the core liner was then trimmed at the top of the ooze. In this manner we were able to recover cores in which the details of mottling, sharp changes in color and lithology, and sedimentary structures could be observed.

Lithostratigraphy

Four lithologic units were recognized at Site 872 using a combination of visual core descriptions, augmented with smear-slide and thin-section data (Fig. 9). Age identification of these units is based on calcareous nannofossils and planktonic foraminifers studied in smear slides, washed residues, and thin-section samples. The identified units are, from top to bottom:

> Unit I (0-143.6 mbsf, 872A; 0-141.7 mbsf, 872C). White to pale brown nannofossil foraminifer ooze intercalated with foraminifer ooze of Pleistocene to late Oligocene age. Sediment composition allowed the subdivision of Unit I into two subunits. The calcium carbonate content of Unit I is almost 100%, and interstitial-water analysis indicates minimal diagenesis. Subunit IA (0-30.2 mbsf, 872A; 0-32.9 mbsf, 872C) is composed of white to very pale brown nannofossil foraminifer ooze and intercalated foraminifer ooze of Pleistocene to late Miocene age. Subunit IB (30.2-143.6 mbsf, 872A; 32.9-141.7 mbsf, 872C) is composed of very pale brown homogeneous foraminifer ooze with a medium sand texture that is well sorted, winnowed, and of late Miocene to late Oligocene age. The

transition between the two subunits is marked by an interval of sediment characterized by a mixture of nannofloras and faunas of different zones followed by a disconformity. This mixed and incomplete interval spans the late middle to early late Miocene. Within the lower Miocene, another disconformity, representing a hiatus of approximately 5 m.y., was observed in Subunit IB at about 100 mbsf in both holes. The sedimentary succession across the Oligocene/Miocene boundary appears to be complete.

Unit II (143.6-143.7 mbsf, 872A; 135.2-135.36 mbsf, 872B) includes three subunits. Subunit IIA is composed of phosphatized middle Eocene chalk containing pebbles of basalt, conglomerates, and volcaniclastics (143.6-143.7 mbsf; Hole 872A). Subunit IIB consists of phosphatized volcaniclastic sandstone of indeterminate age (135.2-135.3 mbsf; Hole 872B). Subunit IIC is comprised of a conglomerate, coated by a shiny dark brown to black veneer, and encloses phosphatized lithoclasts <1 to 3 cm in diameter (135.3-135.36 mbsf; Hole 872B). The phosphatized lithoclasts contain volcaniclastic debris set in a pelagic limestone matrix of latest Santonian to early Campanian age. The lithoclasts are redeposited in pelagic sediment of late Paleocene age.

Unit III (135.36-135.41 mbsf, 872B). Subangular basalt clasts, 0.5 to 4 cm in size, in a pelagic limestone matrix of late early Santonian age in contact with slightly altered basalt.

Unit IV (143.7-144.0 mbsf, 872A; 135.41-192.5 mbsf, 872B; 146.0-148.0 mbsf, 872C). Differentiated alkali olivine basalt as massive flows and flow-top breccias. The uppermost 71 cm of Unit IV in Hole 872B has a few fractures infilled with pelagic sediments of early Santonian age. These pelagic sediments are increasingly phosphatized with depth, and contain some reworked planktonic foraminifers of late Turonian age. A sparsely olivine-phyric basalt identifies the uppermost flow in both Holes 872A and 872B; in Hole 872C, the upper volcanic flow is a highly altered olivine basalt (142.75-143.10 mbsf) which belongs to a different flow. The brecciated flow-tops in several flow units in Hole 872B suggest that these flows were erupted subaerially in a short time, which precluded soil development on top of the flows. In Hole 872C, the basalt unit is overlain by a 10-cm-thick dark gray clay that appears to be an alteration product of the basalt. Basalt samples display NRM intensities of less than 10A/m and usually have a nearly univectorial magnetization. Inclinations of the characteristic remanent magnetization are negative and range from -41° to -61°.

Downhole Logs

Logging in Hole 872B was initially planned to gain definitive information about the presence or absence of additional sediment intervals in the basalt, and to obtain a clearer understanding of the unconformity between the upper Oligocene foraminifer ooze and the underlying hardground. The condition of the hole was less than favorable, but with difficulty it was cleaned to total depth in preparation for logging. However, logging proved to be unsuccessful, as both of the geochemical tools on board the ship would not properly calibrate during in-pipe checks, and a tool run encountered a bridge only 4 m beneath the pipe. The prospects of obtaining any logging results did not justify additional logging time.

Interpretation

Initial interpretation of the cores obtained at Site 872 indicates that a series of subaerial eruptions of differentiated alkali olivine basalt, possibly hawaiites and mugearite, form the upper part of the igneous basement at Lo-En Guyot. They appear to represent the very latest shield stage or the alkalic-cap stage of hotspot volcanism. Magnetic measurements demonstrate that the basalt is normally magnetized, with the magnetization probably acquired at a paleolatitude of about 30°S.

Planktonic foraminifers and possibly calcareous nannofossils of late Turonian age are reworked into lower Santonian sediments filling the fractures in the basalt. On the basis of the biostratigraphic age of these organisms and other benthic organisms; volcanism occurred prior to the late Turonian. Moreover, the association of middle neritic benthic foraminifers with planktonic organisms demonstrates that by early Santonian time a relatively shallow pelagic environment was present on Lo-En Guyot, or, alternatively, transport of shallow-water material into a deeper site of deposition occurred at that time. The hypothesis that the Lo-En volcanic edifice existed and was submerged prior to late Turonian time is further supported by the occurrence of nearshore marine organisms of early Albian age recovered in dredges along the southern slope of this guyot. The backtracked location of Lo-En and other volcanic edifices that erupted during the Middle

Cretaceous (Lincoln et al., in press) agrees with the interpretation that Lo-En existed prior to the late Turonian and was located at a paleolatitude of 30°S.

The overall paucity of pelagic sediments, and the occurrence of highly phosphatized, manganese oxide encrusted lithoclasts of different origin and age (late Santonian, early Campanian, and late Paleocene) above the basalt in Holes 872A and 872B, suggest that for several millions of years the guyot experienced prevailing nondepositional conditions in an active current regime. A somewhat higher energy environment may have existed at the location of Hole 872C where only the youngest, slightly phosphatized chalk of middle Eocene age and one pebble with a Santonian matrix were recovered; alternatively, this may be a function of poor core recovery.

Continuous pelagic sedimentation was established on Lo-En Guyot only by late Oligocene time. The middle Eocene sediment thinly blanketing the conglomeratic chalk is overlain by a 140-m-thick sequence of upper Oligocene and Neogene pelagic carbonates. The hiatus associated with this middle Eocene to late Oligocene disconformity suggests that the seafloor may have been exposed for as long as 15 m.y. Calcareous microplankton stratigraphy indicates that sedimentation was relatively continuous from the late Oligocene through the Pleistocene with only minor periods of nondeposition and/or erosion during the Miocene and possibly during the early Pliocene. The abnormally high ratio of planktonic foraminifers to nannofossils throughout most of the Oligocene and Miocene pelagic sequence signifies significant winnowing of the sediment. This current activity apparently waned during the Pliocene and Pleistocene, as indicated by the relative increase in the volume of nannofossils in the uppermost oozes.

An indirect relationship with Anewetak Atoll is confined to a few volcanic glass shards in a single pebble with a Campanian pelagic matrix from Hole 872B. These shards may be interpreted as evidence of the Campanian volcanic event that was responsible for the eruption of the basalts recovered by drilling in Anewetak Atoll.

Site 873

Site 873 (proposed site Syl-2A) is situated on the south-central summit of Wodejebato (Sylvania) Guyot, in the northern Marshall Islands (Figs. 1, 2, and 10). After completing the transit from Lo-En Guyot, a seismic line was shot using a 200-cubic-inch water gun, along a north-south transect over the guyot. The line was shot across the positions of proposed sites Syl-2A, Syl-1, and Syl-4. An expendable sonobuoy was deployed over the northern edge of the guyot, and a seismic experiment was conducted simultaneously with the seismic profiling. The location of Site 873 was selected from a migrated 6-channel seismic profile showing a local high in the deep reflector representing a change in the character of the basement (Fig. 11).

Coring began at Site 873 at 1200 hr on 7 June 1992 and was completed at 2100 hr, 11 June, after 4.4 days. Two holes were drilled at Site 873; Hole 873B was located 100 m northeast of Hole 873A. Hole 873A was spudded using the RCB. After washing through the pelagic cap, cores were recovered from 54.3 to 232.3 mbsf (TD). The recovered material includes a manganese crust and a manganese phosphatized limestone conglomerate from 54.3 to 59.8 mbsf, shallow-water limestones from about 69.3 to 155.9 mbsf, clay from 155.9 to 174 mbsf, altered basalt from 175.1 to 204.3 mbsf, and volcanic breccia from 204.3 to 232.2 mbsf. Recovery in Hole 873A averaged 20.1% with only 2.4% recovery in the uppermost 34 m of the sedimentary section. This hole was logged with the aid of the conical-side entry sub. The FMS, geophysical, and geochemical tools produced good data, with the exception of the sonic velocity log, which was marginal as the result of hole rugosity.

The second hole, Hole 873B, was APC cored through the pelagic cap to 58 mbsf, where refusal occurred at the boundary between early Miocene and middle Eocene sediments. This hole was continued using the motor-driven core barrel (MDCB) to 69 mbsf. Recovery in Hole 873B averaged 78%. The sediments (Nannofossil Foraminifers and Foraminifer ooze) in the APC cores were winnowed and very soupy, similar to the sediments recovered from the pelagic cap at Limalok and Lo-En guyots, Sites 871 and 872 respectively. Excess water at the top of the cores was removed with a "piglet" that was inserted into the core liner while the core was upright within the core barrel on the rig floor.

Lithostratigraphy

Six lithologic units were recognized at Site 873 (Fig. 12):

Unit I: (0-54.3 mbsf). Nannofossil Foraminifer ooze and Foraminifer ooze of Pleistocene to early Miocene age. Sediment composition allowed the subdivision of Unit I into two subunits. Subunit IA (0-29 mbsf) is composed of light gray nannofossil foraminifer ooze of Pleistocene to latest Miocene age; Subunit IB (29-54.3 mbsf) is composed of very pale brown, mainly homogeneous foraminifer ooze with medium sand texture of middle to early Miocene age; it is well sorted and winnowed. The transition between the two subunits is marked by a disconformity spanning most of the late and late middle Miocene. Minor disconformities occur within the remainder of the middle Miocene and in the early Miocene. Two palynofacies were identified for Unit I, based on taphynomic differences between organic remains.

Unit II: (54.3-54.9 mbsf). Manganese oxide encrusted, phosphatized limestone conglomerate of middle Eocene to late Paleocene age.

Unit III: (54.9-155.9 mbsf). A sequence of very pale brown to gray platform carbonates of mainly Maastrichtian to possibly late Campanian age. Unit III is subdivided into two subunits on the basis of depositional texture, variations in skeletal constituents, color, and organic carbon and pyrite content. The carbonate-rock types in Unit III include predominantly skeletal packstone and grainstone, but also mudstone, wackestone, floatstone, and rudstone. Components include common to abundant radiolitid rudists, abundant larger foraminifers, common red algae and mollusk molds, and rare caprinid rudists. The porosity is predominantly moldic, interparticle, and vuggy, and estimated to reach 25%-30%, rarely <10%. The lower subunit contains woody material (TOC up to 2.4%) and pyrite.

Unit IV: (155.9-175.1 mbsf). Dark red ferruginous clay to olive claystone of indeterminate age. The upper part of the interval has red to pinkish gray mottles, followed downward by dusky red claystone containing white veins and patches of zeolites that mimic the shape of vesicles.

Unit V: (175.1-204.3 mbsf). Altered basalt of indeterminate age. Differentiated, olivine-poor alkali basalt and hawaiite in at least eight flow units.

Unit VI: (204.3- 232.3 mbsf). Olive gray volcanic breccia of indeterminate age. The volcanic breccia is poorly sorted, with angular to subangular clasts in a dusky red to dark gray green matrix of fine sand and clay. The matrix was originally composed of glass shards and broken fragments of glassy basalt, which are now extensively altered to clay. The volcanic breccia exhibits rare low-angle cross laminations and numerous intervals that fine upward.

Interpretation

Site 873 records two volcanic events associated with the late-stage development of Wodejebato Guyot. Hyaloclastites were formed during phreatomagmatic, nearshore or submarine basaltic eruption; these subsequently underwent deep oxidative weathering. After an unknown period of time, the second event recorded at Site 873 was the eruption of differentiated alkali basalt and hawaiite flows. After volcanism ceased, a second deep oxidative weathering profile developed and was preserved through apparently rapid submergence in a low-energy (lagoonal) environment or by rapid burial.

In the late Campanian, a transgression of the sea occurred over this complete or partially eroded weathering profile, and a shallow-water platform with open-marine circulation developed. Progressive and periodic floodings of the former island are documented as alternating phases of open-marine to more restricted conditions within a shallow lagoon. Planktonic foraminifers are present in the middle of the lower carbonate platform subunit and record the period of maximum flooding. Evidence of restricted environments, such as a decrease in faunal and floral diversity, and the frequency of probable emergence surfaces increase upsection. The sequence ends under normal-marine conditions with algal rudstone as the only evidence of bioherm proximity recovered at Site 873.

The carbonate platform subsided into the pelagic realm before the late Paleocene, as indicated by the presence of upper Paleocene pelagic limestone and lithoclasts of Maastrichtian neritic limestone which are reworked into the hardground. From the late Paleocene to middle Eocene, a manganese oxide encrusted and phosphatized hardground continued to develop. The accumulation of pelagic sediments did not commence until the early Miocene. The pelagic deposition was never continuous, but rather was interrupted by a number of hiatuses of varying length during the Miocene (the most conspicuous) and early Pliocene (Fig. 13). A comparison of sedimentation rates for the pelagic caps at Sites 871-873 illustrates the similarities and differences in accumulation at these sites (Fig. 14). A summary of the calcareous plankton biostratigraphy for these sites and Site 878 is presented in Figure 15.

Site 874

Drilling at Site 873, located in the central part of Wodejebato Guyot, recovered an Upper Cretaceous platform sequence composed of skeletal packstone, grainstone, and wackestone, composed of reefal debris. Reef limestone was not recovered, and logging results did not reveal any evidence that a reef had been encountered. In an attempt to acquire reefal limestones with a more pronounced signature for calibrating sea-level change, the drilling objective was focused on investigating the perimeter ridges that encircle the summit area of Wodejebato platform. On seismic profiles and SeaMARC imagery of this guyot, there are two perimeter ridges along the north and east rims, and only the inner perimeter ridge is consistently present around the west rim of the guyot (Fig. 16). These ridges appear as constructional features in the seismic profiles. The inner perimeter ridge was chosen as a first objective for the thickest carbonate sequence and the distinct "basement" reflector.

Site 874 was located on the inner perimeter ridge near proposed site Syl-4. Seven parallel seismic lines, spaced about 0.25 nmi apart and 1.6 nmi in length were shot along a west-southwest - east-northeast transect over the north-eastern part of the guyot and perpendicular to the axis of the ridges and guyot flank in order to characterize the detailed features of these ridges (Fig. 17). Figure 18 illustrates the locations of Sites 874, 876, and 877 with respect to these seafloor features.

Coring began at Site 874 at 1315 hr on 12 June and was completed at 0330 hr on 15 June, after 2.7 days. Two holes, Holes 874A and 874B, were drilled at Site 874 on the seaward side of the inner ridge crest. A reconnaissance of the seafloor was conducted with the VIT; Hole 874A was spudded in a depression, less than a meter deep, on bare rock with the RCB. After coring 10 mbsf, this first attempt failed. After another seafloor survey with the VIT, Hole 874B was successfully spudded on bare rock and RCB cored to 193.5 msbf (TD). The typical recovery was 19.7%, with poor recovery (0 to 1.6%) in skeletal packstone, thereby decreasing the overall average recovery for the hole to 16.7%. Hole 874B was successfully logged with the geophysical and geochemical strings, as well as with the FMS.

Lithostratigraphy

Core and log data were combined, and four lithologic units were recognized at Site 874 (Fig. 19):

Unit I: (0.0-0.11 mbsf). Manganese oxide encrusted and phosphatized limestone conglomerate of late middle Eocene age. The conglomerate was cemented by phosphatized pelagic sediments of late middle Eocene, early Eocene, and late Paleocene age. Clasts of Maastrichtian foraminifer rudist grainstone are embedded in the crust.

Unit II: (0.11-162.82 mbsf). A sequence of white to light brown bioherms and associated facies of Maastrichtian to possibly late Campanian age. Lithologies are predominantly grainstone, but boundstone, packstone, rudstone, and wackestone were also recovered. Major components include rudists (caprinids and radiolitids), red algae (corallinaceans, squamariaceans), foraminifers (Sulcoperculina, Asterorbis, miliolids), mollusk molds, corals, stromatoporoids, and echinoids. Unit II is subdivided into six subunits on the basis of depositional texture, skeletal constituents, and color. The porosity is mostly moldic, interparticle, or vuggy with a few solution-enlarged interparticle pores; estimated porosity typically ranges from 2% to 20%. Irregular solution cavities are partially filled with banded isopachous crusts of calcite cement and geopetal internal sediments. Cavities in the upper part of the sequence are filled with pelagic sediments of Maastrichtian to late Paleocene age.

Unit III: (162.82-177.7 mbsf). Ferruginous clay and claystone of Campanian age to an older indeterminate age. The main lithologies include black clay, rich in woody material (TOC >5%) and pyrite (30% sulfur) with a thin basal bed rich in larger foraminifers; bluish-gray to dusky red clay with relict structures of vesicular, plagioclase-phyric basalt.

Unit IV: (177.7-193.5 mbsf). A single flow of altered ankaramitic basalt. The groundmass is alkali olivine basalt similar to those recovered at the other sites on Wodejebato Guyot.

Interpretation

A single basaltic lava flow is overlain by a claystone weathering profile. The transition to marine conditions occurred in a low-energy environment and sulfate-reducing conditions. The first marine influx is recorded by the black clay, which yielded marine organisms, including calcareous nannofossils of Campanian age, and abundant woody material from vegetation on the exposed edifice. The absence of reworked clay in the overlying shallow-water limestones may be interpreted as the result of rapid burial, preservation in a low-energy environment, or partial erosion and redeposition elsewhere. The carbonate succession started with grainstone and packstone, rich in larger foraminifers, rudists, corals, red algae (including rhodoliths), indicative of a shallow-marine environment with open-marine circulation and moderate to high energy. After a small episode of a slight decrease in wave energy as inferred from the absence of rhodoliths, a decrease in abundance of radiolitids, and an increase in abundance of larger foraminifers, higher energy conditions resumed, as indicated by poorly sorted algal rudist grainstone/rudstone. A bioherm grew at this time as boundstone with encrusting red algae, tabular coral colonies, and a few clusters of radiolitids. This short episode of "reef" growth was followed by deposition in a shallow lagoon periodically affected by storms, changes in current patterns or short-term sea-level fluctuations, and possible emersion. A return to a more agitated shallow-marine environment is associated with the second and last episode of bioherm development.

The first pelagic sediments recorded at Site 874 are Maastrichtian in age and infill cavities within the upper part of the shallow-carbonate sequence. Site 874 drowned before the end of the Cretaceous, preceded by an emersion episode that generated the cavities, or else the cavities were produced by submarine dissolution, implying only a single drowning event. The overall lack of pelagic ooze, and the presence of manganese-encrusted phosphatized lithoclasts of varying origins and ages overlying the cavities containing pelagic infilling, suggest that Site 874 was and is still a site of prevailing nondeposition.

Sites 875 and 876

Sites 875 and 876 are located on the northeastern rim of Wodejebato Guyot in the northern Marshall Islands. On seismic profiles and SeaMARC imagery of Wodejebato Guyot, there are two bathymetric ridges that partly encircle the summit area of the platform. The inner perimeter ridge is consistently present around the west, north, and east rims of the guyot, whereas the outer perimeter ridge is discontinuous but persistently present along the north and east rim of the guyot. Both sites are located atop the outer perimeter ridge, 1.67 km apart along the seaward crest

(Fig. 17). Because of the proximity of the sites, their location on the same bathymetric feature, and similar scientific objectives, the site discussions are joined.

Three holes were drilled at Site 875, and one hole was drilled at Site 876. Coring began at Site 875 at 0330 hr on 16 June and was complete at 1730 hr on 17 June, after 1.6 days. Prior to spudding Hole 875A with the RCB, a seafloor survey was conducted using the VIT. The relatively flat sandy area had 1-meter-high outcrops coated with a manganese crust. The first 11-m core from Hole 875A recovered 36 cm of poorly cemented, coarse skeletal sands of Maastrichtian age. Hole 875A immediately showed indications of caving and was abandoned. After another TV survey, Hole 875B was spudded 10 m northwest of Hole 875A and RCB cored as a bare-rock spud-in. After 40 m of coring the coarse, poorly cemented skeletal sand (4.9 % recovery), Hole 875B was abandoned because of poor hole conditions. About 16 m north-northwest from Hole 875A, Hole 875C was successfully drilled as a bare-rock spud-in, utilizing a DCB-Geoset bit, and cored to 133 msbf (TD). Recovery in Hole 875C averaged 13.2% (Fig. 20).

Coring began at Site 876 at 0430 hr on 18 June and was completed at 0100 hr on 19 June, after 0.9 day. No TV survey was conducted prior to spudding Hole 876A because the 3.5-kHz records indicated a thin pelagic sediment cover. Hole 876A was rotary cored using an anti-whorl polycrystalline-diamond-compact bit to 154 msbf (TD). The average recovery was 9.6% (Fig. 21). Poor hole conditions prevented logging in Holes 875C and 876A.

Lithostratigraphy

Three lithologic units were recognized at Sites 875 and 876 (Fig. 22):

> Unit I: (0-0.14 mbsf, Hole 875C; 0-0.08 mbsf, Hole 876A). Manganese oxide dendrites penetrating an upper middle Eocene foraminifer limestone encrusting phosphatized Maastrichtian skeletal packstone. The packstone contains cavities infilled with phosphatized pelagic sediments of late middle Eocene, early Eocene, and late Paleocene age.
> In Hole 876A, packstone matrix contains early Eocene pelagic sediment that has filtered into the limestone.

Unit II: (0-0.36 mbsf, Hole 875A; 0-30.83 mbsf, Hole 875B; 0.14-126 mbsf, Hole 875C; 0.08-145.5 mbsf, Hole 876A). Skeletal grainstone and packstone of middle to possibly late Maastrichtian age. White to pale brown, lightly cemented, solution etched, coarse-grained skeletal grainstone contains abundant larger foraminifers (Sulcoperculina and Asterorbis), red algae (corallinaceans and squamariaceans), and rudist (mainly radiolitids with a few caprinids) debris. Planktonic foraminifers are common and widely disseminated. Minor components are corals, green algae (dasycladaceans), echinoderms, and bryozoans. Unit II is subdivided in three subunits, of which the middle one is composed of skeletal packstone with lenses of wackestone. The porosity is intergranular and moldic. Average grainstone porosity is 10%-30%; porosity in the packstone is about 16%. A few small basalt fragments are incorporated at the bottom of Unit II. A cavity at least 30 cm in length extends into the upper surface of Unit II at Site 876. The cavity is lined by manganese oxide and infilled with pelagic sediment of middle Eocene age.

Unit III: (126-133 mbsf, Hole 875C; 145.5-154.0 mbsf, Hole 876A). Highly vesicular basalt, possibly alkali olivine basalt, with 1%-2% pyrite in the uppermost part of the unit in Hole 875C. Hole 876A recovered highly altered alkali basalt and intercalated volcanic breccia. Three massive basalt flow units, less than a few meters thick, and one basaltic breccia were identified from Hole 876A. The uppermost basalt flows are brownish in color and appear to have undergone a relatively brief period of oxidative weathering. The volcanic breccia is composed of subangular to subrounded basalt fragments similar in texture to the underlying alkali basalt flow, suggesting that the breccia formed as the top of the lava flow.

Interpretation

Holes 875C and 876A both terminated in alkalic basalt flows. All the lavas recovered at both sites, including the flow-top breccia, share the dominant mineralogical characteristic of all the Wodejebato flows. The mineralogy of the flows is consistent with a slight to moderate degree of undersaturation, similar to the alkalic cap stage of Hawaiian volcanism. They most likely represent a subaerial sequence, although both outer perimeter ridge sites do not record significant weathering intervals prior to the onset of marine conditions. However, the uppermost basalt at Site 875 was subject to reducing conditions as inferred by the presence of pyrite. Some oxidative weathering affected the uppermost basalt at Site 876.

In the Maastrichtian, a transgression of the sea occurred over the basalt flow in moderately high-energy conditions as demonstrated by the presence of basalt pebbles reworked at the base of the skeletal sands at both sites. The pile of sand encountered at Sites 875 and 876 contains abundant fragments of Late Cretaceous organisms with larger foraminifers as a dominant constituent. Planktonic foraminifers occur throughout, except near the top of the sequence. The sands are well winnowed, moderately sorted, and abraded. No blocks of boundstone or other reef lithology were encountered. These characteristics suggest that the sands underwent considerable reworking before deposition. The reworking of these sands in conjunction with the persistent occurrence of planktonic foraminifers suggests that the depositional setting for these units was a forereef apron, seaward of the reef tract located along the inner perimeter ridge, drilled at Sites 874 and 877.

A shoaling episode interrupted this monotonous sedimentation and is represented by cemented skeletal packstone with lenses of muddier wackestone interbedded in the poorly cemented grainstone, and a layer of mudstone. Although the major skeletal components of the packstone and wackestone remain nearly identical to those from the overlying and underlying grainstones, the mudstone contained only small gastropod molds, ostracodes and small benthic foraminifers. This assemblage indicates a restricted environment. The absence of planktonic foraminifers in the uppermost part of the grainstone sequence possibly indicates a shallow-water environment until the end of sand deposition. Exposure of this shoal may have been extensive, as indicated by the occurrence of cavities at least 30 cm deep and by infiltration of pelagic ooze into the sands to become the matrix of the grainstone at least 70 cm deep in the section. Relief of about a meter on unconnected depressions in the manganese-encrusted surface of the limestone was seen during the VIT survey at these outer perimeter ridge sites. This suggests formation of a microkarstic surface between middle to late(?) Maastrichtian and late Paleocene, before submergence into the pelagic realm.

Site 877

Site 877 is located on the northeastern rim of Wodejebato Guyot in the northern Marshall Islands. Site 877 is 0.7 km north of Site 874; both sites are located on the inner bathymetric ridge.

A single hole was drilled at Site 877; coring began at 1000 hr on 19 June and was terminated at 1905 msbf (TD) at 0600 hr on 21 June, after 1.84 days. The recovery was 13.2%, including one core with zero recovery. A thin manganese crust and a manganese phosphatized limestone conglomerate from 0 to 0.03 mbsf, shallow-water limestone from 0.03 to 183 mbsf, clay from 183 to 186 mbsf, and weathered basalt from 186 to 190.5 msbf were recovered.

Lithostratigraphy

Four lithologic units were recognized at Site 877 (Fig. 23):

Unit I: (0-0.03 mbsf). Manganese oxide encrusted and phosphatized limestone of middle Eocene age. The host substrate is composed of Maastrichtian shallow-water packstone with cavities infilled with partially phosphatized pelagic sediments of late middle Eocene, early Eocene, and late Paleocene age.

Unit II: (0.03-182.9 mbsf). White to light brown and pinkish white Maastrichtian grainstones predominate. Also present are Maastrichtian boundstone, packstone, wackestone and floatstone. Major components include rudists (caprinids and radiolitids), red algae (corallinaceans, squamariaceans), benthic foraminifers (mostly larger foraminifers and miliolids), common mollusk molds, corals, stromatoporoids, and a few echinoids. Unit II is subdivided into five subunits on the basis of depositional texture, variations in skeletal constituents, and color. The estimated porosity ranges mainly from 2% to 25% and is mostly moldic (after caprinid shells, other bivalves, or gastropods) and interparticle to vuggy with a few solution enlarged interparticle pores. Solution cavities in the upper 10 cm of the sequence enclose pelagic geopetal sediments of Maastrichtian, late Paleocene, and early Eocene age; also, in the upper 20 m of the sequence are cavities containing pelagic sediment of late Paleocene and early Eocene age. Lithoclasts containing larger foraminifers occur at the base of the shallow-water sequence and indicate reworking in moderately high- energy conditions. The basal part of Site 877 correlates with that of Site 874. Unit II is thicker at Site 877 than at Site 874; more reef development is present at Site 877 (Fig. 24).

Unit III: (182.9-190.2 mbsf). Black clay, argillaceous limestone, peat, reddish-brown clay, and claystone breccia of indeterminate age. Argillaceous limestone contains thin-shelled mollusk fragments, benthic foraminifers, and calcareous nannofossils of late Campanian age associated with reworked Cenomanian species. Black clay is rich in plant remains and common pyrite; TOC averages 1.48%, and sulfur 8.72%. Total organic carbon averages 12.45% in the peat layer, whereas the sulfur content averages 23.55%. Root molds are present in the clays beneath the peat. Downhole, the organic carbon and sulfur content of the clay and claystone decreases; as the features of a volcanic breccia become progressively more preserved. A clast of basalt is present in the lower part of the unit.

Unit IV: (190.2-190.5 msbf). Basaltic breccia with clasts of vesicular, plagioclase-clinopyroxene basalt. Clasts contain irregular vesicles filled with green clay and have a clay and calcite matrix. Thin, anastomosing subhorizontal calcite veins replace almost 50% of the breccia.

Interpretation

At Site 877, a volcanic breccia was recovered below a thick subaerial, in-situ, weathering profile. The presence of root molds, plant remains, and pyrite indicates that the transition from subaerial to marine conditions took place in a low-energy, sulfate-reducing, marine environment. The occurrence of calcareous nannofossils, restricted to the Cenomanian and reworked in the argillaceous limestone, indicates that only the most recent part of the geological history of Wodejebato Guyot was recovered at Sites 873-877 (Fig. 25).

Sedimentation history at Site 877 mirrors that described from Site 874, the twin site farther to the southeast on the inner perimeter ridge. The difference between these two sites is a function of the limestone sequence being 20 m thicker at Site 877 than at Site 874.

At Site 877, the lower, or older, bioherm began with a rudist assemblage dominated by small erect radiolitids. The rudist framework developed from a scattered community of individuals and evolved into clusters of a few individuals. Radiolitids, in life position, are locally encrusted by red algae. Upsection, the rudists become more abundant and form the bulk of the organic framework, while red algae diminishes in abundance. The assemblage becomes dominated by loosely packed large caprinids, which were typically recumbent and barely acquired a gregarious habit. These caprinids formed an open framework that may easily have been smothered by increased sedimentation. This development differs from that recorded at Site 874, where in addition to rudists, algae and coral form boundstone. The differences between the assemblages at Sites 874 and 877 suggest a lateral zonation of the frameworks as a response to their slightly different positions along the axis of the ridge. The second, more recent episode of bioherm construction resulted in a strong similarity between the two sites. In both locations the boundstone is composed of stromatoporoids, coral, and caprinid rudists that are heavily encrusted by red algae without any lateral zonation.

Site 801

The *JOIDES Resolution* arrived at Site 801 at 1500 hr on 23 June 1992. Hole 801C, already cored and cased into middle Jurassic oceanic crust on Leg 129, was reentered to conduct downhole measurements of the basement section, since they were not accomplished during Leg 129. The reentry was easily made, as the cone was visible at the seafloor, and the casing appeared to be in good shape.

Downhole Logs and Packer Experiments

The first logging run with the geophysical string and LDGO temperature tool went to 7 m above hole TD. Uniformly high velocities and high but variable resistivities were measured throughout. The exception to this was within the hydrothermal zone located halfway down the hole, which separates the upper alkalic basalts from the lower tholeiitic basalts, where both velocities and resistivity values were erratic (Fig. 26). Temperature data tentatively indicate no significant underpressure and water downflow into the hole. The next FMS run also penetrated to 7 m above hole TD, but the following FMS runs and the geochemical run bottomed 40 m above hole TD, due to a bridge that developed during the first FMS run. These various high-quality data provide an extraordinary amount of detail on the geochemical and physical characteristics of the alkalic basalts, tholeiitic basalts, and the intervening hydrothermal zone. Results at a previous site indicate that we may be able to recover information about the magnetic polarity of the basalts from the FMS magnetometer data.

The packer work was less successful, but we tentatively conclude that the hydrothermal unit halfway down the hole, and possibly the lower alkali basalt section, are extremely permeable; the tholeiitic basalts below are relatively impermeable. Our first packer sets were just below the bottom of casing. The pressure records at the rig floor for this first set all indicate an extremely permeable zone somewhere below the packer. However, no downhole pressure data were recorded due to a clock malfunction. Our second set was attempted just below the hydrothermal unit and was not successful due to a ruptured packer element. When we attempted to inflate the packer, the 6200-m-long drill string was lifted several meters uphole instead. This indicated to us that we were pumping through the ruptured packer element into the bottom of an impermeable hole, and the result was to jack up the drill string. When we attempted to inflate the packer again, at the original packer set level just below casing on the way out of the hole, the drill string remained immobile, thus, indicating that we were pumping through the ruptured packer element and into the permeable hydrothermal unit, now located below the BHA.

Site 878

Site 878 (near proposed site MIT-1(E)) is located at 27°19.143'N, 151°53.028'E in 1323 m water depth, on the northeastern part of MIT Guyot near its southern edge (Figs. 1, 27, and 28). The MIT Guyot is an isolated feature close to the Wake Group in the 18°-28°N guyot band. A local pre-site seismic survey of MIT Guyot was conducted on 28 June 1992 from 1330 hr to 1830 hr. This survey was used to determine the location of Site 878. The *JOIDES Resolution* deployed a beacon at Site 878 at 1815 hr on 28 June 1992, officially beginning site operation on MIT Guyot. A VIT survey was conducted prior to setting the mini-hard-rock guide base (HRB) on the seafloor in preparation for a bare-rock spud. Coring at Site 878 began at 1300 hr on 29 June 1992 and was completed at 2300 hr on 10 July 1992, after 11.4 days. Upon completion of the drilling, a logging program, including the geophysical and geochemical tool strings, and FMS, was undertaken. After obtaining our drilling objectives and logging Hole 878A, we departed Site 878 at 2130 hr on 12 July 1992. When departing Site 878 we deployed the 200-cubic-inch water gun to obtain a southeast-northwest seismic profile over MIT Guyot and through Site 878.

Three holes were drilled at Site 878. Hole 878A was a multiple reentry hole; Holes 878B and 878C were single-core holes, used for the purpose of recovering the surficial hardground and pelagic sediment overlying the carbonate platform. Hole 878A was primarily cored with the RCB to 910 m mbsf (TD); a Syndax diamond coring bit (DCB) was utilized from about 200 to 400 mbsf rather than the conventional roller-cone bit. In the upper 202 m, the average core recovery was 3.9%; however, if the first core that contains some pelagic ooze is excluded, the average recovery drops to 2.29%. When coring with the DCB, recovery of the carbonate platform remained low, averaging 2.26%. RCB coring of polymictic breccia yielded a core recovery of nearly 100%. Beneath the polymictic breccia, RCB coring was continued. Recovery of the lower platform limestone unit was about 6.5%, whereas recovery in the basalt averaged 54.7%. The recovered material included foraminifer nannofossil ooze to nannofossil ooze with manganese nodules, from 0 to 3.2 mbsf; shallow-water limestone, from 3.2 to 399.7 mbsf; bluish gray clay and breccias with basalt and limestone clasts, from 399.5 to 604 mbsf; shallow-water carbonates, from 604 to 722.5 mbsf; and basalt, from 722.5 to 910 mbsf (Fig. 29).

Lithostratigraphy

Six lithologic units were recognized at Site 878, using a combination of visual core descriptions, smear-slide and thin section data, and downhole-logging data. The age of these units was based mainly on the identification of calcareous nannofossils and planktonic foraminifers in the pelagic cap, and on larger benthic foraminifers and calcareous plankton in the shallow-water limestone. The recognized units are, from top to bottom (Fig. 29):

Unit I (0-3.2 mbsf). Yellowish brown foraminifer nannofossil ooze and nannofossil ooze with manganese nodules of early Pleistocene to late Miocene age. The average carbonate content in Unit I is 70.6%. This unit is divided into three subunits on the basis of the paucity of planktonic foraminifers, the presence of chalk fragments in the intermediate subunit, and the abundance of manganese nodules and crusts in the lowermost subunit. These nodules range from sub-millimeter to 5 cm in size. The manganese nodules and crust fragments contain phosphatized pelagic limestone fragments of latest Albian, Santonian-Campanian, late Paleocene, and early Eocene age. In addition to the abundance of manganese nodules, the insoluble residue yielded zeolites, sand-sized quartz grains, volcanic ash, goethite and hematite, and rare marcasite. The pelagic sediment was highly disturbed; however, a disconformity spanning the early Pliocene was detected.

Unit II (3.2-236 mbsf). White micritized, gastropod-rich wackestone, packstone, and mudstone; peloidal packstone with fenestral fabric; peloid-algal wackestone; and minor grainstone and rudstone of Albian to Aptian(?) age. Skeletal components in the unit include nerineid gastropods and oysters, benthic foraminifers (agglutinants, miliolids, and a few encrusting forms), and rare corals and sponge spicules. The carbonate content of Unit II is virtually 100%. Porosity varies between 7% and 15%, and is mainly moldic and intergranular in the wackestone. Grains are cemented by bladed, fine- to medium-crystalline calcite. Some fossil molds are lined by similar calcite crusts or contain geopetal sediment. Porosity increases to 25% and becomes interparticle in the grainstones.

Unit II is divided into four subunits on the basis of depositional texture and variations in skeletal constituents. Subunit IIA is wackestone with molds of nerineids, and peloidal packstone. Subunit IIB is characterized by the presence of peloids and fenestral fabrics. Subunit IIC contains gastropod-rich upper zones and oyster-rich lower zones. Subunit IID is characterized by mudstone coarsening upward to medium-sand-sized grainstone.

Unit III (236-399.7 mbsf). Primarily consists of very pale brown grainstone of fine to medium grain size, wackestone, and mudstone of late Aptian age. The carbonate content is nearly 100%. Unit III is divided into three subunits on the basis of depositional texture and variations in skeletal constituents. Subordinate lithologies of this unit include skeletal rudstone containing rudist, coral, and calcisponge fragments in Subunit IIIA; Orbitolina-rich skeletal grainstone of coarse grain size at the base of Subunit IIIB; and well-lithified skeletal foraminifer wackestone and mudstone in Subunit IIIC. These subunits display a subtle overall trend of decreasing density and increasing porosity with depth; the highest porosity (up to 40%) of this unit is in the grainstone.

Unit IV (399.7-604.3 mbsf). Primarily consists of polymictic breccia with both basalt and shallow-water limestone clasts in a white to grayish-green matrix of late to possibly early Aptian age. This unit is normally magnetized with a mean inclination probably acquired at 20°S during the Aptian.

Unit IV is divided into three subunits. Subunit IVA is a thin bed of bluish-gray clay (maximum 1.5% $CaCO_3$); Subunit IVB is polymictic breccia with an ash tuff bed at the top; and Subunit IVC is a polymictic breccia with steeply inclined beds as well as slump and fluid-escape structures. Each of the two lower subunits grades from a carbonate-rich (lithoclasts and matrix), matrix-supported breccia at the bottom to basalt-rich, clast-supported breccia at the top. In both Subunits IVB and IVC, the carbonate content varies from 80% at the bottom to less than 40% at the top. In each breccia subunit, there is a linear increase in porosity from about 20% at the bottom to 36% at the top; there is an equivalent decrease in sonic velocity from 4.0 to 2.5 km/s over the same interval in each subunit.

The most common carbonate lithoclasts in this unit are mudstone and wackestone with miliolids. Less common lithoclasts are skeletal-peloidal wackestone and packstone, oolitic grainstone, mollusk-peloid wackestone, peloid grainstone, fenestral wackestone and packstone, and mudstone with sponge spicules. Nerineids are the most abundant macrofossils in the limestone clasts, along with rudist debris, corals, and algal-bacterial thrombolites as less common components.

Volcanic clasts, with the exception of the large basalt ones, are replaced by clay minerals; however, they retain well-preserved relict igneous textures. There are three major types of basalt clasts: (1) scoriaceous basalt; (2) much less vesicular, microcrystalline basalt, or some olivine microphyric basalt; and (3) non-vesicular basalt. Other volcanic clast types are altered, highly vesicular fragments of basalt with elongate vesicles, and altered clasts of basalt with pumice-like texture; both types are abundant at the top of the breccia. Finally, four minute clasts of black, organic-rich material were found in the breccia.

Unit V (604.3-722.5 mbsf). Very pale brown skeletal grainstone, packstone, and wackestone with minor rudstone, rich in nerineids, oysters, and corals of early Aptian age. This unit is mainly normally magnetized, but a reversal interval is apparently present and may correlate with Chron M0 of early Aptian age. The carbonate content is nearly 100%. Measured porosity values vary between 16% and 38%, and sonic velocity ranges from 2.2 to 4.4 km/s.

Unit V is subdivided into two subunits on the basis of texture and composition. Subunit VA consists of peloid foraminifer wackestone to grainstone with intervals of gastropod, oyster, and coral rudstone and some stromatoporoid bindstone. Subunit VB is composed of coarse-grained skeletal grainstone with subordinate mollusk and coral rudstone. A few highly altered basalt fragments occur near the base of this subunit; the lowermost grainstone is poorly sorted and stained reddish-yellow.

The upper subunit contains peloids, miliolids, mollusks, small gastropod molds, red algae, calcisponge fragments, a few ooid grains, and lithoclasts; some fenestral fabric is present in the wackestones. Within Subunit VA, there appears to be two coarsening-upward cycles. The grainstone has up to 35% porosity, predominantly interparticle and some moldic porosity; the packstone has 5% to 15% porosity as interparticle, moldic, and vuggy.

The majority of grains in Subunit VB are rounded and coated by micrite up to 200 microns thick. Skeletal constituents include red algae, codiaceans, calcisponges, corals, and stromatoporoids; molds of small gastropods are also present. Planktonic foraminifers and nannofossils occur in the lowermost part of the unit. Cement in the grainstone is patchily distributed, and porosity ranges between 20% and 35%, mostly as primary interparticle porosity.

Unit VI (722.5-908.7 mbsf). Alkalic basalt flows and flow-top breccias of older than early Aptian age. Thirty-four igneous units were recognized, including 24 distinct lava flows, 3 volcaniclastic units, and 2 weathering horizons. The remaining units are basalt breccias or intervals of undifferentiated, fragmented, and altered material. At least one reversed-polarity interval and one normal-polarity interval are recorded in Unit VI. The lower reversed-polarity interval is at least as old as Chron M1, but it may represent an earlier reversed-polarity interval of the Lower Cretaceous. The mean inclination of the basalt unit indicates that basement rocks acquired their magnetization at about 10°S during the Barremian.

Almost all the lava flows have well-defined vesicular and/or brecciated flow tops which grade downward into massive basalt. The flow tops are reddish or purplish in color, and are altered to clay. The majority of vesicles are filled by white or pale to dark green clay. Preliminary petrographic examination suggests that all the lavas are of alkalic affinity, including basanite, alkali olivine basalt, and hawaiite. Several volcaniclastic units occur among the basalt flows. Of these, Units 4 and 9 are altered tuffs that appear to have been composed of a poorly sorted variety of vesicular and non-vesicular basalts in a finer matrix of uncertain composition. Volcanic unit 31 is a thick (15.5 m recovered), highly altered vitric tuff, originally composed of angular, irregular, highly vesicular glassy clasts in a matrix of more finely divided glassy material. The upper 7.5 m of Volcanic unit 31 has been severely altered (bleached) to light beige clay, and the remainder is brick red in color and more lithified.

Interpretation

Initial interpretation of the cores obtained at Site 878 indicates that the upper part of the igneous basement of MIT Guyot was formed by numerous lava flows of alkalic affinity, more likely associated with the constructional phase of volcanism rather than with a later rejuvenated phase. The presence of well-defined vesicular and/or brecciated flow tops suggests they are probably subaerial in origin, although indications of significant weathering are missing. Some of the tuffs appear to have been subaqueously deposited.

The overlying sequence records the development of a carbonate platform in the early Aptian. The contact between the carbonate platform and the basement rocks was not recovered; however, a few fragments of highly altered basalt are present within the lowermost coarse-grained skeletal grainstone. The combination of the basalt fragments and the fossil evidence suggests that marine deposition was initiated in a fully oxygenated high-energy environment, such as an open-marine shoal. This was followed by at least one episode of pelagic influence, and then by a period of slightly less oxygenated, marine conditions. Sedimentation evolved toward coarsening-upward cycles as the environment fluctuated from open-marine to more restricted lagoonal conditions.

The development of the carbonate platform was abruptly interrupted during the late early Aptian, by a volcanic eruption through the carbonate platform, which resulted in a 200-m-thick sequence of polymictic breccia. The breccia contains clasts of shallow-water platform deposits whose origins are still uncertain and whose ages are poorly constrained. There is no apparent depositional trend related to the carbonate lithoclasts. The rare fragments of woody plant material in the breccia are of sub-bituminous rank, implying the presence of a nearby island at some point in the development of the ancient carbonate platform. The maturity level of the organic matter cannot be explained from burial depth alone.

Two distinct cycles are observed within the volcaniclastic succession. Each of these cycles most likely represents a short-lived eruptive episode from a single vent. It is suggested that, at the beginning of each cycle, the eruptive products were dominated by lithoclasts from pre-existing volcanic flows and the carbonate platform. As the vent became established, progressively more material derived from new lava was incorporated into the eruptive products. The breccias, recovered at Site 878, may represent the evidence for short-lived, very late-stage, phreatomagmatic eruptions through a carbonate platform. The resulting mixed basalt/limestone debris was likely redeposited by slumping and gravity flows down the flank of the platform. The perimeter of the platform may have been constructional or down-faulted along the margin. This difference may be resolvable if the relative ages of the limestones above, below, and within the breccia sequence can be established.

The topmost part of the breccia unit is rich in euhedral pyrite, which may indicate that reducing conditions characterized the final deposition of the breccia. Carbonate-platform deposition resumed by late Aptian in a low-energy, restricted and poorly oxygenated lagoonal environment. The lagoonal environment rapidly changed to an oxygenated and open-marine environment with pelagic influence at the beginning of this open-marine well-oxygenated phase. Later in the late Aptian, this open-marine platform gave way to the growth of one or more bioherms near Site 878 and terminated by another flooding event inferred from planktonic foraminifers.

A significant change occurred in the late Aptian, with the onset of alternating poorly oxygenated marine and restricted environmental conditions. These alternating conditions evolved into a low-energy, fully restricted environment that was occasionally interrupted by storm deposits possibly during the Albian. The recovery at Site 878 indicates that the platform was dominantly a restricted environment prior to its demise. Iron oxide staining associated with some vugs may indicate that the top of the platform was very briefly subaerially exposed before drowning. It is uncertain if any of the uppermost carbonate-platform sequence was removed by erosion or dissolution.

Manganese nodules within and below the ooze sequence contain nuclei that record several episodes of calcareous pelagic sedimentation. The oldest material consists of phosphatized pelagic limestone with planktonic foraminifers of latest Albian age. This assemblage establishes a minimum age for the drowning of the underlying carbonate platform. Other intervals represented in the manganese nodules are late Santonian to early Campanian, latest Paleocene, and middle early Eocene age, based on calcareous microplankton. The age distribution of these microfossils suggests that, for several millions of years, the guyot experienced prevailing nondepositional conditions in an active current regime.

A thin (3 m) manganese-bearing nannofossil ooze of latest Miocene, late Pliocene, and early Pleistocene age was recorded at the upper surface of Site 878. The upper Miocene ooze contains well-preserved nannofossils but severely dissolved planktonic foraminifers. In addition, it contains manganese nodules and micronodules, echinoderm fragments, fish otoliths, and benthic foraminifers including common Uvigerina. This indicates deposition in a low-oxygen environment at, or near, the late Miocene oxygen minimum. The Pliocene-Pleistocene ooze contains well-preserved diatoms, radiolarians, and dinoflagellates in addition to calcareous microplankton, implying a relatively high local productivity during its deposition.

Site 879

Site 879 is located at 34°10.46'N, 144°18.56'E in 1501 m water depth atop the southern ridge of the guyot, at the crosspoint between the east-west and south-north seismic lines (Figs. 1 and 30). Takuyo-Daisan Guyot is the easternmost guyot of the Seiko cluster of seamounts, in the 30°-35°N guyot band in the northwestern Pacific.

A local pre-site seismic survey was conducted from about 2300 hr on 14 July to 0400 hr on 15 July across Takuyo-Daisan Guyot, in the Seiko cluster of seamounts, of the Japanese Seamount province. The D/V *JOIDES Resolution* approached the guyot from east, and a seismic profile was shot parallel to an east-west-trending ridge along the southern rim of the guyot. Seismic profiling continued as the ship passed south to north across the proposed site Seiko-1, eastward across proposed site Seiko-2, and finally in a southwest direction leading to the southern margin. Takuyo-Daisan Guyot was the last of five guyots drilled on Leg 144. As a consequence of time constraints, a new site on the southern perimeter ridge was selected from these seismic profiles, where a suitable acoustic target was identified (Figs. 31 and 32).

JOIDES Resolution launched a beacon at Site 879 at 0339 hr on 15 July 1992, beginning site operations for Site 879. Coring began at about 1200 hr on 15 July 1992 and was completed by 1950 hr on 17 July, after 2.3 days of drilling Hole 879A. Upon completion of the drilling, Hole 879 was logged using the geophysical tool string and FMS. After obtaining our drilling and logging objectives at Hole 879A, we departed Site 879 at 1500 hr on 18 July 1992.

One hole was drilled at Site 879. A reconnaissance of the seafloor was conducted with the VIT, then Hole 879A was spudded on bare rock using the RCB. Hole 879A was successfully cored to 226.5 mbsf. The average core recovery was 17.4%, with poor recovery (5.1%) of the shallow-water sequence (four cores with zero recovery) (Fig. 33). The recovered material included shallow-water limestone from 0 to 150.6 mbsf; argillaceous sandy limestone, calcareous claystone, volcanic conglomerate, calcareous sandstone, and rudstone from 150.6 to 169.7 mbsf; claystone with relict volcanic texture and minor conglomerate from 169.7 to 190.2 mbsf; and basalt breccia from 190.2 to 226.5 mbsf (TD).

Lithostratigraphy

A preliminary evaluation of the recovered material at Site 879 yielded three lithologic units. These are based upon a combination of data, including visual core descriptions, smear slides, and downhole logging. The age of these units was based mainly on the identification of larger benthic foraminifers and calcareous plankton. The recognized units, from top to bottom, are:

> Unit I (0-169.7 mbsf). White, pale brown to brown, sometimes stained, carbonate-platform sequence of Albian(?) to late Aptian age. Unit I was divided into five subunits on the basis of depositional texture, variations in the skeletal components, and degree of influx of terrestrial and volcanic materials. Components include gastropods (nerineids and cerithids), bivalves (thin-shelled forms, large oysters, and rudists), corals, benthic foraminifers (orbitolinids, cuneolinids, miliolids), Ortonella, dasycladacean algae, oncoids, and peloids; calcisponges and echinoids are minor components. A few intervals in this unit yielded calcareous nannofossils and planktonic foraminifers. Micritization is

common. Subunit IA consists of coral-mollusk rudstone and floatstone with a skeletal grainstone to packstone matrix. Subunit IB consists of skeletal packstone and wackestone with rare intervals of grainstone. Intervals with pelagic components are also contained within this subunit. Subunit IC consists of skeletal wackestone with intercalated skeletal packstone; both rock types contain altered basalt lithoclasts of medium-sized sand. Intervals with planktonic foraminifers and nannofossils are also found in this subunit. Subunit ID consists of bioturbated argillaceous limestone, calcareous sandstone, and calcareous claystone intercalated with organic-rich and clay-rich intervals. A several-centimeter-thick interval of brown coal, a piece of wood, and fragments of coal incorporated into the calcareous sandstone are contained in this subunit. This subunit also contains a volcanic component of altered glass and lithoclasts of basalt; many of the skeletal components are pyritized. Underlying Subunit IE consists of calcareous sandstone, volcanic conglomerate, and gastropod rudstone.

Porosity in Unit I of the rudstone ranges from 1% to 18%, mostly moldic, locally intergranular and shelter porosity. The floatstone has 10% to 16%, mostly moldic, solution-enlarged interparticle and intraparticle porosity. The grainstone is 2% to 15% porosity, of which about 50% is moldic porosity and 50% is intergranular porosity. The packstone has 12% to 16% porosity, which includes moldic, solution-enlarged intergranular and possible fenestral porosity. The skeletal packstone, especially in the lower part, has 1% to 5% porosity, commonly moldic and vuggy with some intergranular porosity. Porosity is negligible in Subunits ID and IE.

Micronodules, dendrites, and pore linings of manganese are scattered throughout the unit, whereas varicolored grains of altered basalt occur in the lower portion. Only a small fragment of the surficial phosphatic crust (which may have been manganese coated, as noted during the VIT survey) was recovered. The resistivity log registered four plurimetric zones enriched in thorium, which are interpreted to represent clay-rich zones within the host facies of Subunit ID.

Unit II (169.7-191.0 mbsf). Consists of clay, claystone with relict volcanic-breccia texture, and a minor conglomerate interval of late Aptian or older in age. Clasts in the breccia are (1) pale yellow, highly vesicular basalt with vesicles filled by zeolite, and

(2) dusky red to dark gray basalt with <10% vesicles. The claystone is dark red, dusky red, and reddish black, displaying a relict volcanic-breccia texture. The dusky red and reddish black clasts are basalt altered to clay; the matrix is dark red. The dark brown conglomerate is matrix supported and consists of isolated, well-rounded pebbles in a coarse sandy volcanic matrix. Pebbles are orange to yellow brown, highly vesicular aphyric basalt; the pebbles increase in size downward from 0.5-1 to 1-1.5 cm. There is a zonation in the color of some clasts, probably the result of weathering.

Unit III (191.0-226.5 mbsf). Consists of 19.5 m of plagioclase phyric basalt intercalated in a complex fashion with volcanic breccia of indeterminate age. This complex intermixture can best be described as a peperite, formed by the intrusion of the basaltic lava into soft, wet sediment. The basalt occurs as irregularly shaped, sub-spherical, pillow-like bodies, commonly with relict glassy selvages, ranging in size from less than a centimeter to a meter or more. The basalt is highly plagioclase phyric with approximately 20% plagioclase (often very fresh in appearance) and minor olivine phenocrysts in a microcrystalline groundmass. The original wet sediment that the basalt "pillows" intruded into is now represented by irregular bodies of volcanic breccia. The breccia is completely altered to clay and/or zeolite minerals, but still retains the primary textural features in great detail. About 60% of the original clasts are of fragile, angular, highly vesicular, glassy basalt. The remaining clasts are also angular and composed of a variety of non-vesicular basalts, very little of which can be attributed to fragmentation of the associated plagioclase phyric lava. The matrix of the breccia consists of sand-sized shards of the same glassy vesicular basalt as the larger clasts, cemented by bluish-green clay or zeolite.

This breccia is very similar in texture to the polymictic breccia of Hole 878A, although it lacks the included limestone clasts. The vesicular clasts were formed from new magma during the eruption, whereas the remainder are fragments of pre-existing basalt.

Interpretation

A very preliminary interpretation of the cores obtained at Site 879 suggests that the upper part of the volcanic edifice shows evidence of basaltic intrusion into wet sediments as documented by the peperite. This is overlain by a thin layer of yellowish volcanic breccia that appears to have undergone intense weathering. A high-energy, marine and/or nonmarine environment (beach and/or stream) eroded and rounded the pebbles of the basalt to form the conglomerate. These highly vesicular, aphyric basalt pebbles are weathered to orange and yellowish brown. Another breccia containing basalt clasts with a red clay and volcanic-sand matrix has undergone extensive oxidation probably as the result of subaerial weathering. By the late Aptian, flooding of the weathered volcanic edifice by marine waters is documented by the calcareous nature and the presence of biotic contents in the rudstone, calcareous sandstone, and argillaceous limestone. Progressive and periodic floodings of this former island are documented by lagoonal deposits with nerineids to more open-marine deposits containing planktonic organisms. The presence of coal and wood associated with beginning of the shallow-water marine deposition as well as the basaltic lithoclasts attests to the terrestrial influence at this site. This implies that a vegetated, exposed volcanic edifice was close to Site 879. Moreover, the presence of coal contained within the sandstone, as well as well-rounded basalt pebbles and molds of mollusks in the matrix of the volcanic conglomerate, is consistent with deposition in a nearshore marine environment. The argillaceous limestone is heavily bioturbated, potentially indicating oxygenated bottom-water conditions. The upward decrease of terrestrial influence, as suggested by a progressive decrease in abundance of plant remains and volcanic grains until they are absent, parallels the establishment of more open-marine conditions. Planktonic foraminifers are present in the middle of the carbonate sequence and record periods of maximum flooding. These pelagic deposits are heavily bioturbated, indicating oxygenated bottom-water conditions. A low-energy, shallow-marine environment follows at this location as shown by the presence of lime mud in the packstone and wackestone, with rare grainstone intervals, as well as on the basis of the biotic contents of oysters, and nerineids. This low-energy environment gradually evolved into a more open-marine, higher energy setting documented by an oncolite-rich interval and then the presence of coral-mollusk rudstone and floatstone. The carbonate platform subsided into the pelagic realm after Albian(?) to late Aptian time.

Site 880

Site 880 is located at 34°12.53'N, 144°18.74'E at 1525 m water depth, on the center of Takuyo-Daisan Guyot, about 2 nmi north of Site 879 (Fig. 1). The beacon for Site 880 was deployed at

1627 hr (0727UTC) on 18 July 1992. Coring began at Site 880 at 2330 hr on 18 July 1992 and was completed at 0050 hr on 19 July 1992.

Lithostratigraphy

A preliminary evaluation of the recovered material at Site 880 yielded one lithologic unit. This is based upon a combination of data: visual core descriptions and smear-slide. The age of this unit is based on the identification of calcareous nannofossils and planktonic foraminifers, and diatoms in the uppermost layers. One lithologic unit was recognized:

> Unit I (0-18.4 mbsf). Consists of a sequence of interlayered volcaniclastic sand and foraminifer sand with nannofossil foraminifer ooze and volcanic ash of late Pleistocene to late Pliocene age. Unit I ranges in color from shades of yellow green and grayish brown to very dark gray. Increasing darkness is related to the increasing percentage of volcanic material. Noncalcareous components include feldspars, opaques (possibly manganese nodules), vesicular lava fragments, volcanic lapilli, scoriaceous basalt grains, and pyrite. Diatoms, sponge spicules, and silicoflagellates are common in the uppermost layers.

A preliminary evaluation of the cores obtained at Site 880 indicates that the recovered sediment sequence displays variations of two end members, volcaniclastic sand and nannofossil foraminifer ooze. These pelagic sediments were deposited under the varying influence of volcanic eruptions from the nearby convergent-margin setting, and the degree of winnowing that would remove nannofossils.

The recovered sequence contains a condensed but apparently complete section spanning the entire Pleistocene and the Pleistocene/Pliocene boundary. At first sight, these sediments exhibit an apparent cyclic depositional pattern.

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FIGURES

Figure 1. Location of ODP Leg 144 sites. Also shown are the position of Mesozoic magnetic anomaly lineations, fracture zones, and major topographic features as modified from the chart by Nakanishi et al. (1992).

Figure 2. Bathymetry around the Marshall Islands and location of drillsites from Leg 144; contour interval is 1000 m. Ages shown in parentheses are radiometric dates of basalts collected over a number of different surveys.

Figure 3. Contoured bathymetry of Limalok Guyot showing the location of Site 871. Contour interval is 250 m. Profiles A-A' and B-B' were collected during Leg 144; profiles C-C' and D-D' are from the 1981 R/V *Kana Keoki* cruise (Schlanger et al., 1987).

Figure 4. Single-channel seismic profile across Limalok Guyot. Acoustic basement deepens to the south (toward A') with a concomitant thickening of platform sediments. The orientation of profile A-A' is shown in Figure 3.

Figure 5. Lithostratigraphic summary of Site 871.

Figure 6. Stratigraphy of Hole 871C from selected geophysical logs compared to cored intervals, biostratigraphic age, and lithology within Hole 871C. Resistivity is from the medium-penetration resistivity tool; total natural gamma is from the geochemistry run. Caliper, or apparent hole diameter, does not record values greater than 16 inches (40.6 cm); drillbit diameter is 9.9 inches (25 cm). Peaks in natural gamma are marked by shaded lines; these events are mainly due to concentrations of radioactive uranium and may be associated with hiatuses in sedimentation or exposure surfaces.

Figure 7. Contoured SeaMARC II bathymetry over Lo-En Guyot. Contour interval is 200 m. The ship tracks shown in this figure represent the seismic coverage across this guyot. Profiles A-A' and B-B' were collected during a 1988 R/V *Moana Wave* cruise (MW8805); profile C-C' was collected during Leg 144.

Figure 8. Single-channel seismic profile A-A' collected during MW8805. This profile shows the presumed volcanic cone which crops out from the pelagic sediments near A'. An arrow marks the location of Site 872, directly above the thickest sequence of pelagic sediment.

Figure 9. Summary of lithologic units and calcareous-plankton biostratigraphy of Site 872.

Figure 10. Contoured SeaMARC II bathymetry over Wodejebato Guyot. Contour interval is 200 m. The ship tracks in this figure represent the seismic coverage across the guyot. Profile A-A' was collected during a 1990 R/V *Moana Wave* cruise (MW9009); profiles B-B' and C-C' were collected during Leg 144.

Figure 11. Migrated 6-channel seismic profile A-A' showing the location of Site 873. The shallower basement reflector marked on this profile represents the bottom of the carbonate complex. The site is located directly above a local high in the deep reflector; this reflector suggests a change in the character of the basement.

Figure 12. Summary of Site 873, including core recovery, lithologic units, biostratigraphic interpretation, and selected geophysical logs.

Figure 13. Sediment-accumulation rates for the pelagic cap in Hole 873B. Bars represent the upper and lower limits of a biohorizon as constrained by sampling. Foraminifer biohorizons are indicated by filled bars; calcareous nannofossils by open bars.

Figure 14. Summary of sediment accumulation rates for the pelagic caps recovered at Sites 871, 872, and 873.

Figure 15. Summary of interpreted calcareous-plankton biostratigraphy for upper Oligocene to Pleistocene sediment intervals recovered in Sites 871, 872, 873 and 878.

Figure 16. Contoured SeaMARC II and SeaBeam bathymetry over Wodejebato Guyot showing inner and outer perimeter ridges. Contour interval is 200 m and 10 m, respectively.

Figure 17. Contoured bathymetry over Wodejebato Guyot. Contour interval is 10 m. The ship tracks in this figure represent the seven WSW-ENE lines of seismic coverage across this guyot.

Figure 18. Seismic profiles across Wodejebato Guyot showing the location of Sites 874, 876 and 877 with respect to the perimeter ridges. The orientation of profiles a-a' and g-g' is shown in Figure 17.

Figure 19. Lithostratigraphic summary of Site 874 and selected geophysical logs.

Figure 20. Summary of lithologic units and calcareous plankton biostratigraphy of Hole 875C.

Figure 21. Summary of lithologic units and calcareous plankton biostratigraphy of Hole 876A.

Figure 22. Lithostratigraphic correlation between Hole 875C and Hole 876A.

Figure 23. Lithostratigraphic summary of Site 877.

Figure 24. Lithostratigraphic correlation between Sites 873, 874,, 875, 876, and 877.

Figure 25. Comparison of the geological history of Sites 873, 874, 875, 876, and 877 as interpreted from the lithostratigraphy.

Figure 26. Geophysical logs of Hole 801C, originally cored during Leg 129 and re-entered during Leg 144 to conduct downhole measurements.

Figure 27. Contoured SeaBeam bathymetry over MIT Guyot, showing the location of Site 878 and proposed site MIT-1(E). Contour interval is 40 m. The ship tracks in this figure represent the seismic coverage across this guyot.

Figure 28. SE-NW seismic profile A'-A over MIT Guyot and through Site 878. The orientation of profile A'-A is shown in Figure 27.

Figure 29 Part A and Part B. Lithostratigraphic summary of Hole 878A.

Figure 30. Contoured SeaBeam bathymetry over Seiko Guyot, showing the location of Site 879 and proposed sites Seiko-1 and Seiko-2. Contour interval is 50 m. The ship tracks in this figure represent the seismic coverage across this guyot.

Figure 31. Single-channel seismic profile A-A' over Seiko Guyot. The orientation of this profile is shown in Figure 30.

Figure 32. Single-channel seismic profile C-C' over Seiko Guyot. The orientation of this profile is shown in Figure 30.

Figure 33. Lithostratigraphic summary of Site 879.

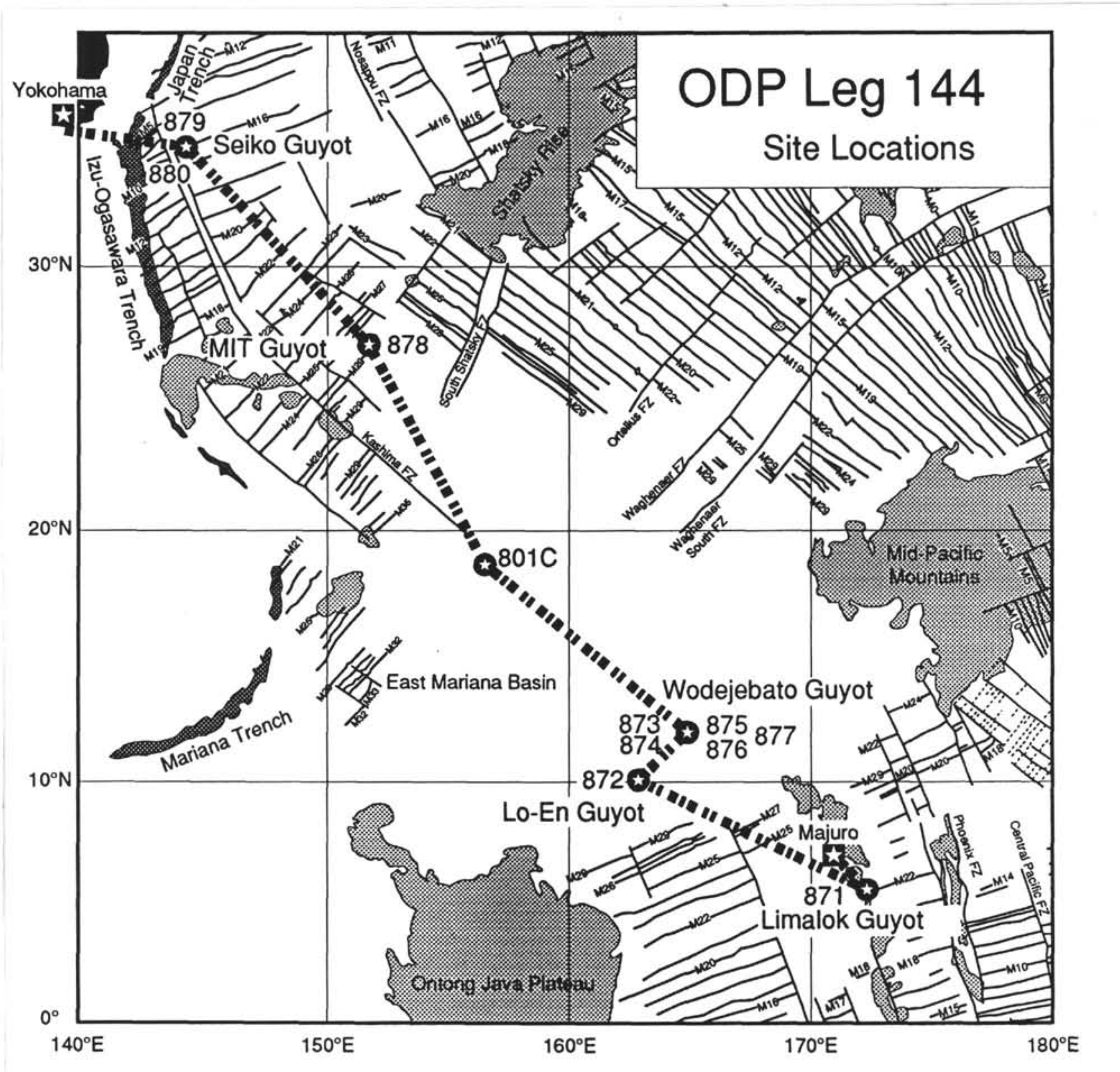

ODP Leg 144
Site Locations
Yokohama
879
880
Seiko Guyot
Japan Trench
Izu-Ogasawara Trench
Shatsky Rise
MIT Guyot
878
South Shatsky
Kashima FZ
801C
Mid-Pacific Mountains
East Mariana Basin
Mariana Trench
Wodejebato Guyot
873
874
875
876
877
872
Lo-En Guyot
Majuro
871
Limalok Guyot
Ontong Java Plateau
Phoenix FZ
Central Pacific FZ
Wagenaer FZ
Wagenaer South FZ
Ortelius FZ
Nosappu FZ
30°N
20°N
10°N
0°
140°E
150°E
160°E
170°E
180°E

Figure 1

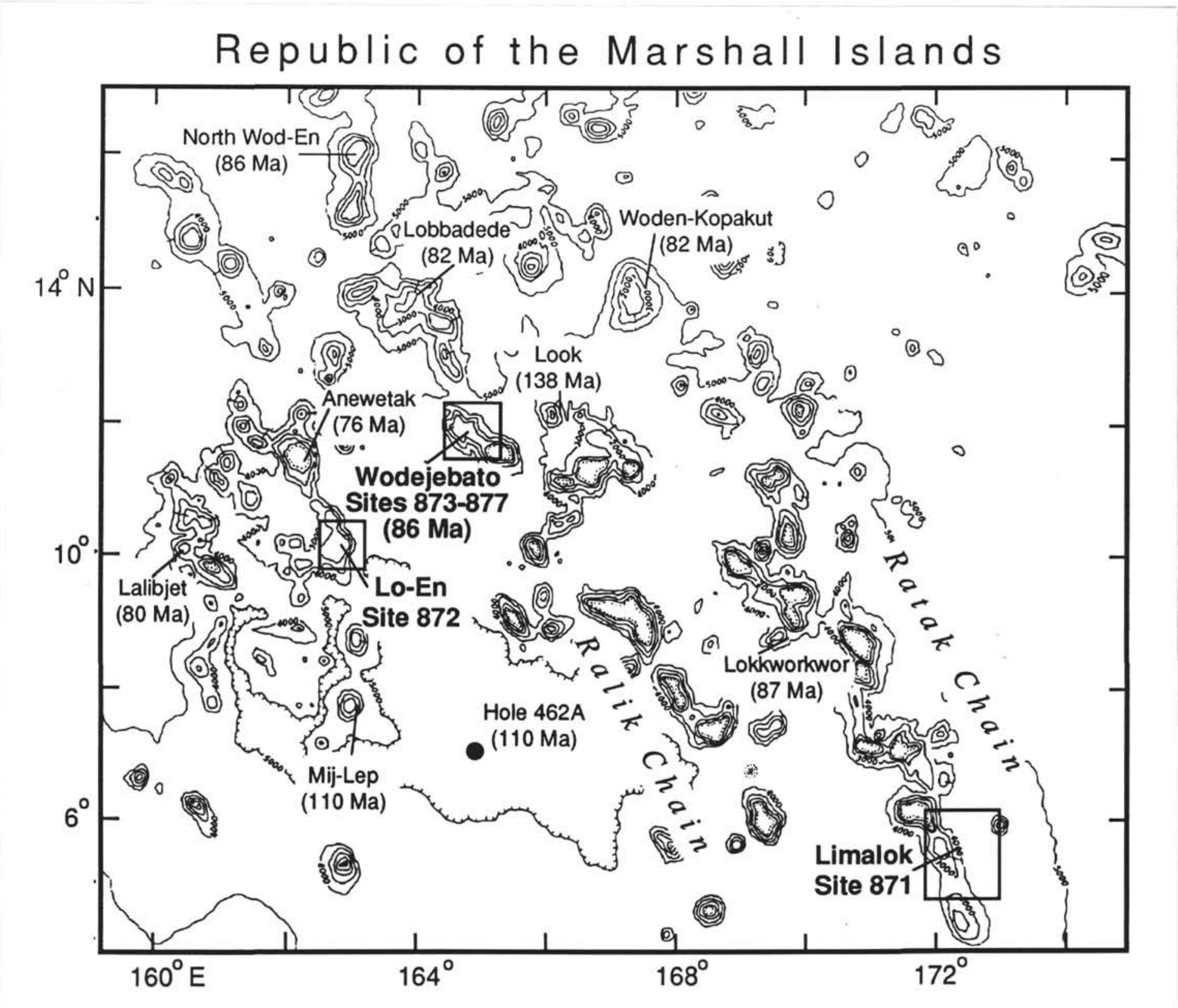

Republic of the Marshall Islands
North Wod-En
(86 Ma)
Lobbadede
(82 Ma)
Woden-Kopakut
(82 Ma)
Look
(138 Ma)
Anewetak
(76 Ma)
Wodejebato
Sites 873-877
(86 Ma)
Lalibjet
(80 Ma)
Lo-En
Site 872
Ralik Chain
Ratak Chain
Lokkworkwor
(87 Ma)
Hole 462A
(110 Ma)
Mij-Lep
(110 Ma)
Limalok
Site 871
14° N
10°
6°
160° E
164°
168°
172°

Figure 2

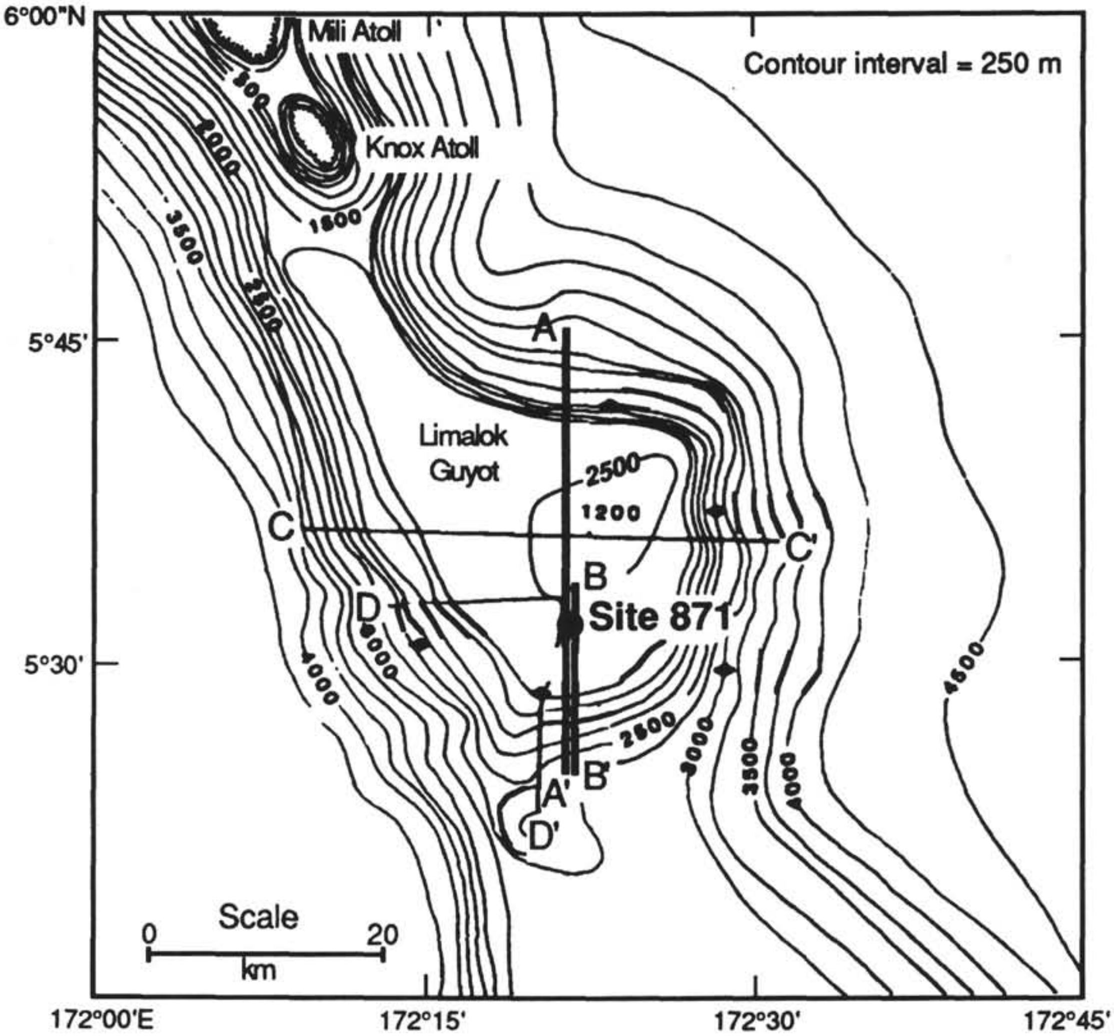

6°00"N
5°45'
5°30'
172°00'E
172°15'
172°30'
172°45'
Mili Atoll
Knox Atoll
Contour interval = 250 m
Limalok
Guyot
Site 871
A
A'
B
B'
C
C'
D
D'
Scale
0
20
km
2500
1200
2000
3500
4000
4500
3000

Figure 3

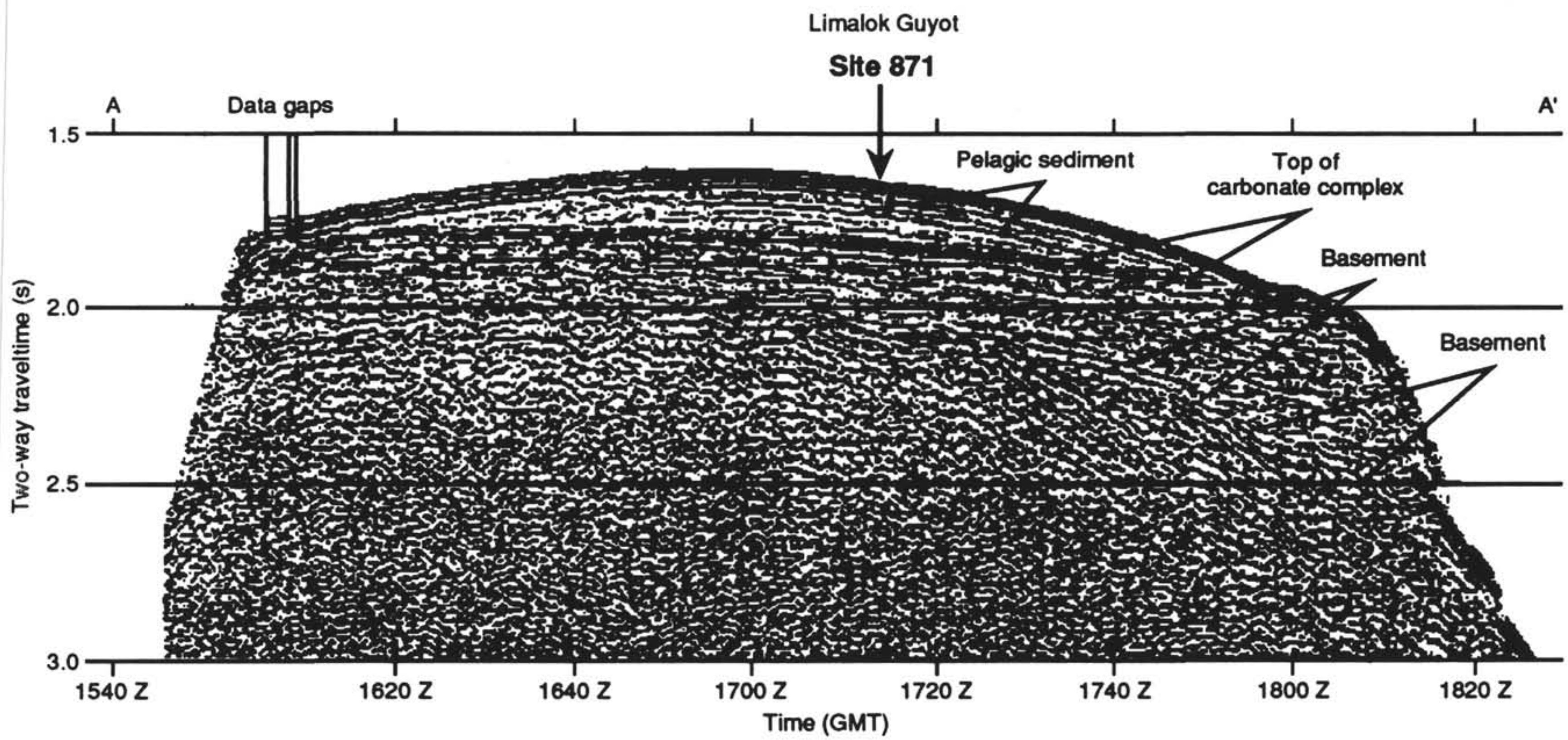

Limalok Guyot
Site 871
A
Data gaps
A'
1.5
2.0
2.5
3.0
Pelagic sediment
Top of
carbonate complex
Basement
Basement
Two-way traveltime (s)
1540 Z
1620 Z
1640 Z
1700 Z
1720 Z
1740 Z
1800 Z
1820 Z
Time (GMT)

Figure 4

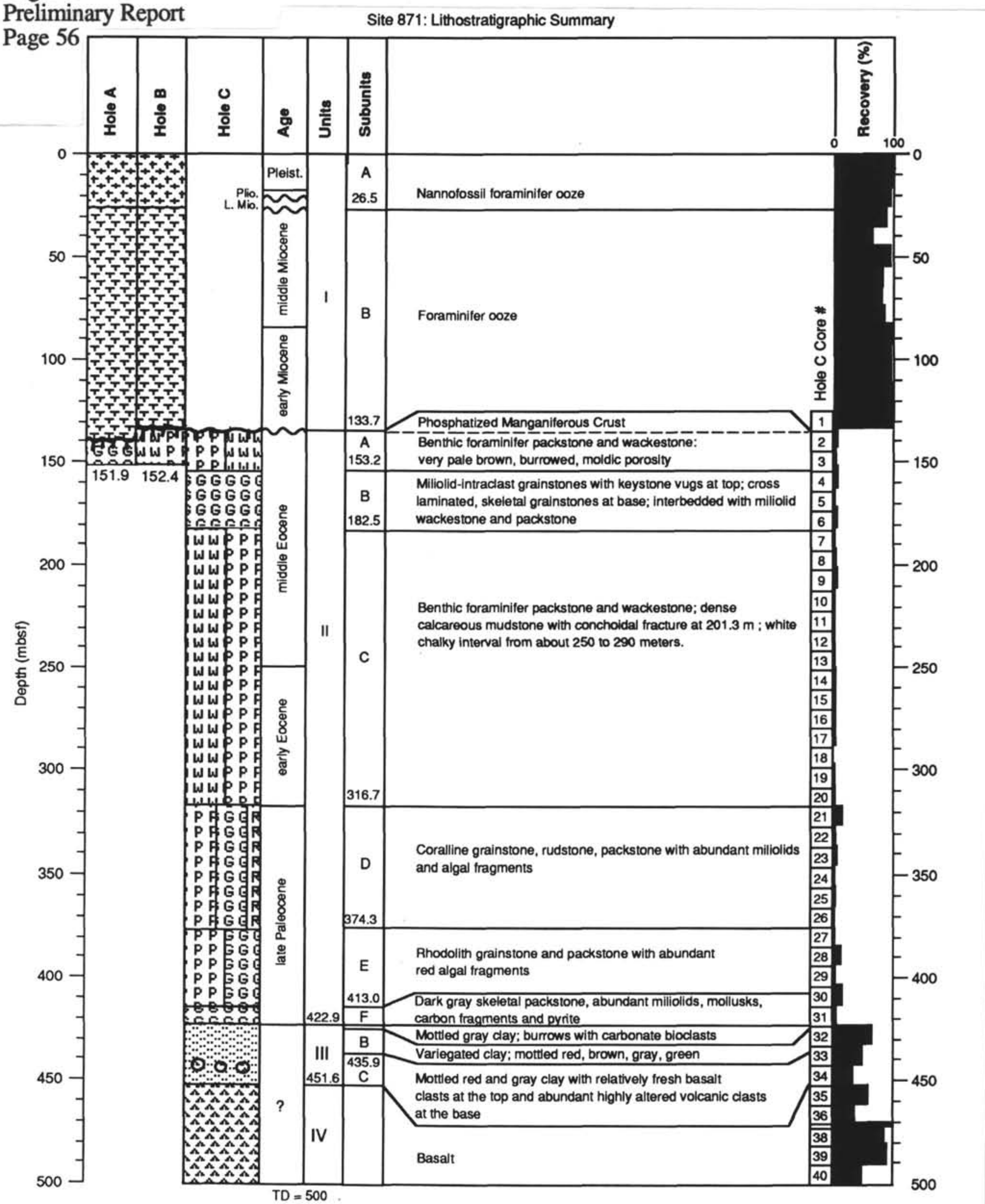

Site 871: Lithostratigraphic Summary
Hole A
Hole B
Hole C
Age
Units
Subunits
Recovery (%)
0
100
Depth (mbsf)
0
50
100
150
200
250
300
350
400
450
500
151.9
152.4
Pleist.
Plio.
L. Mio.
middle Miocene
early Miocene
middle Eocene
early Eocene
late Paleocene
?
I
II
III
IV
A
26.5
B
133.7
A
153.2
B
182.5
C
316.7
D
374.3
E
413.0
422.9
F
B
435.9
451.6
C
Nannofossil foraminifer ooze
Foraminifer ooze
Phosphatized Manganiferous Crust
Benthic foraminifer packstone and wackestone: very pale brown, burrowed, moldic porosity
Miliolid-intraclast grainstones with keystone vugs at top; cross laminated, skeletal grainstones at base; interbedded with miliolid wackestone and packstone
Benthic foraminifer packstone and wackestone; dense calcareous mudstone with conchoidal fracture at 201.3 m ; white chalky interval from about 250 to 290 meters.
Coralline grainstone, rudstone, packstone with abundant miliolids and algal fragments
Rhodolith grainstone and packstone with abundant red algal fragments
Dark gray skeletal packstone, abundant miliolids, mollusks, carbon fragments and pyrite
Mottled gray clay; burrows with carbonate bioclasts
Variegated clay; mottled red, brown, gray, green
Mottled red and gray clay with relatively fresh basalt clasts at the top and abundant highly altered volcanic clasts at the base
Basalt
Hole C Core #
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
38
39
40
TD = 500

Figure 5

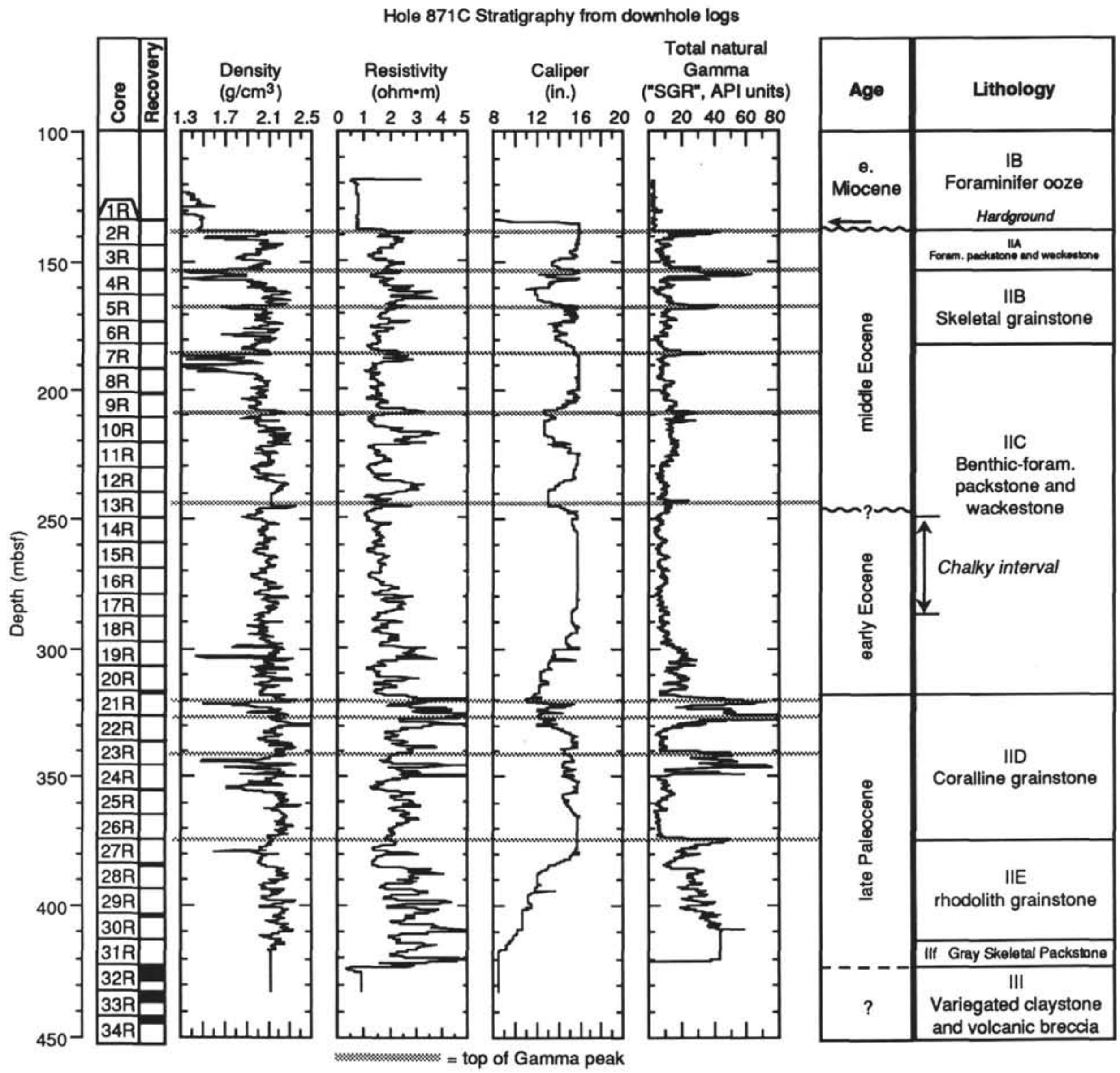

Hole 871C Stratigraphy from downhole logs
Core
Recovery
Density (g/cm3)
1.3 1.7 2.1 2.5
Resistivity (ohm•m)
0 1 2 3 4 5
Caliper (in.)
8 12 16 20
Total natural Gamma ("SGR", API units)
0 20 40 60 80
Age
Lithology
Depth (mbsf)
100
150
200
250
300
350
400
450
1R
2R
3R
4R
5R
6R
7R
8R
9R
10R
11R
12R
13R
14R
15R
16R
17R
18R
19R
20R
21R
22R
23R
24R
25R
26R
27R
28R
29R
30R
31R
32R
33R
34R
e. Miocene
middle Eocene
early Eocene
late Paleocene
?
IB Foraminifer ooze
Hardground
IIA Foram. packstone and wackestone
IIB Skeletal grainstone
IIC Benthic-foram. packstone and wackestone
Chalky interval
IID Coralline grainstone
IIE rhodolith grainstone
IIf Gray Skeletal Packstone
III Variegated claystone and volcanic breccia
= top of Gamma peak

Figure 6

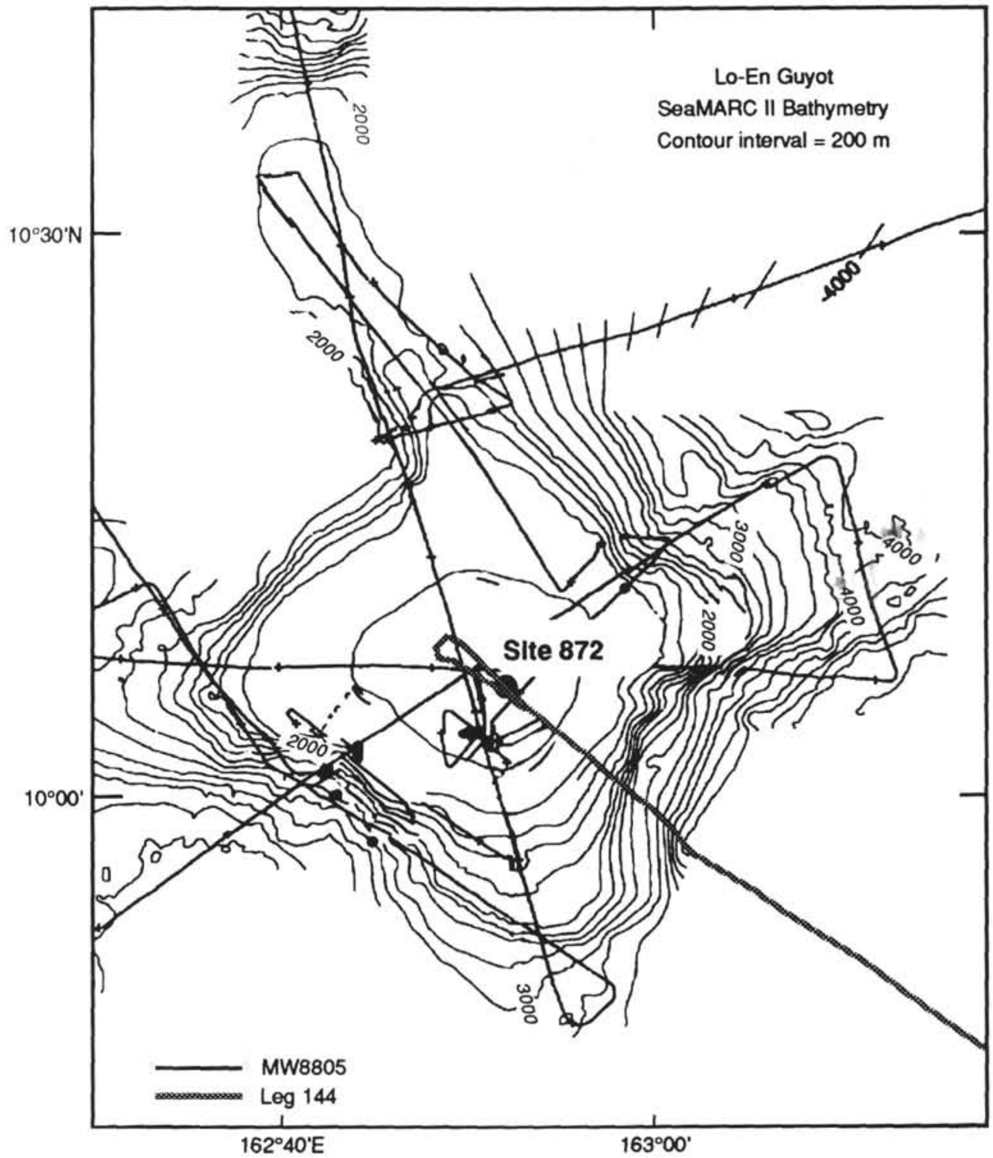

Lo-En Guyot
SeaMARC II Bathymetry
Contour interval = 200 m
Site 872
2000
2000
2000
2000
3000
3000
4000
4000
4000
10°30'N
10°00'
162°40'E
163°00'
MW8805
Leg 144

Figure 7

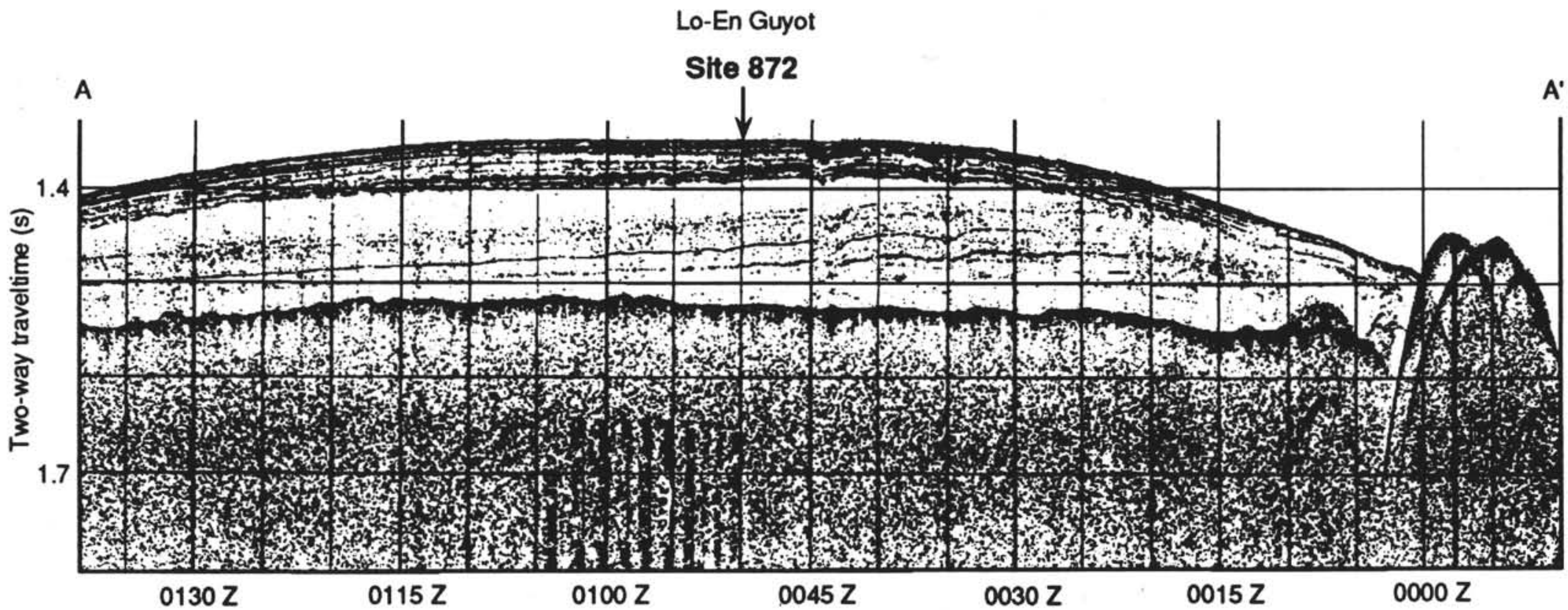

Lo-En Guyot
Site 872
A
A'
Two-way traveltime (s)
1.4
1.7
0130 Z
0115 Z
0100 Z
0045 Z
0030 Z
0015 Z
0000 Z

Figure 8

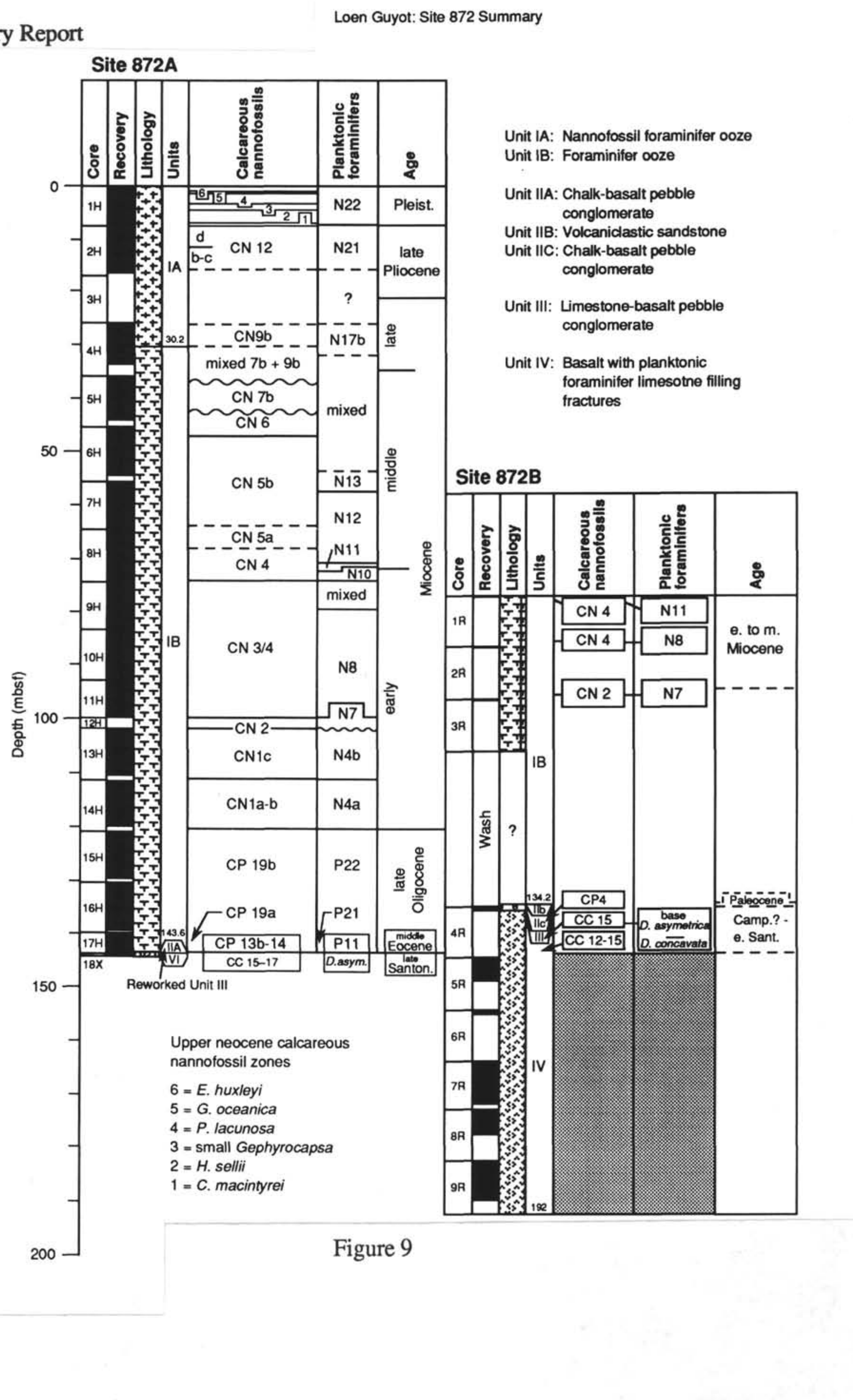

Loen Guyot: Site 872 Summary
Site 872A
Core
Recovery
Lithology
Units
Calcareous nannofossils
Planktonic foraminifers
Age
Depth (mbsf)
0
50
100
150
200
IA
30.2
IB
143.6
IIA
VI
Reworked Unit III
N22
Pleist.
CN 12
N21
late Pliocene
?
CN9b
N17b
late
mixed 7b + 9b
CN 7b
CN 6
mixed
middle
CN 5b
N13
N12
CN 5a
N11
CN 4
N10
Miocene
mixed
CN 3/4
N8
early
N7
CN 2
CN1c
N4b
CN1a-b
N4a
CP 19b
P22
late Oligocene
CP 19a
P21
CP 13b-14
P11
middle Eocene
CC 15-17
D.asym.
late Santon.
Unit IA: Nannofossil foraminifer ooze
Unit IB: Foraminifer ooze
Unit IIA: Chalk-basalt pebble conglomerate
Unit IIB: Volcaniclastic sandstone
Unit IIC: Chalk-basalt pebble conglomerate
Unit III: Limestone-basalt pebble conglomerate
Unit IV: Basalt with planktonic foraminifer limesotne filling fractures
Site 872B
Wash
?
IB
134.2
IIb
IIc
III
IV
192
CN 4
N11
CN 4
N8
e. to m. Miocene
CN 2
N7
CP4
Paleocene
CC 15
base D. asymetrica
Camp.? - e. Sant.
CC 12-15
D. concavata
Upper neocene calcareous nannofossil zones
6 = E. huxleyi
5 = G. oceanica
4 = P. lacunosa
3 = small Gephyrocapsa
2 = H. sellii
1 = C. macintyrei

Figure 9

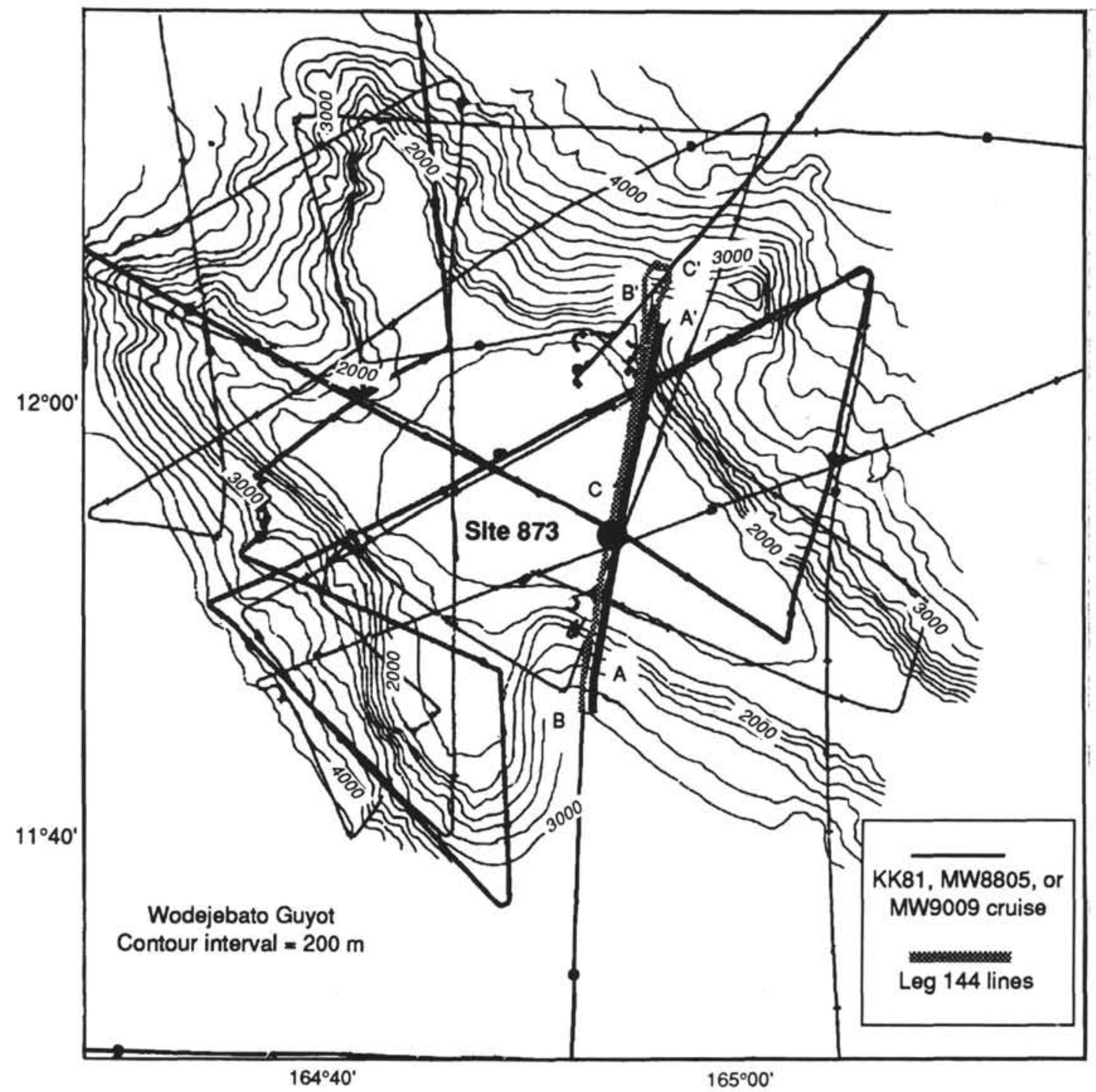

12°00'
11°40'
164°40'
165°00'
3000
2000
4000
3000
2000
3000
2000
3000
2000
2000
4000
3000
A
A'
B
B'
C
C'
Site 873
Wodejebato Guyot
Contour interval = 200 m
KK81, MW8805, or MW9009 cruise
Leg 144 lines

Figure 10

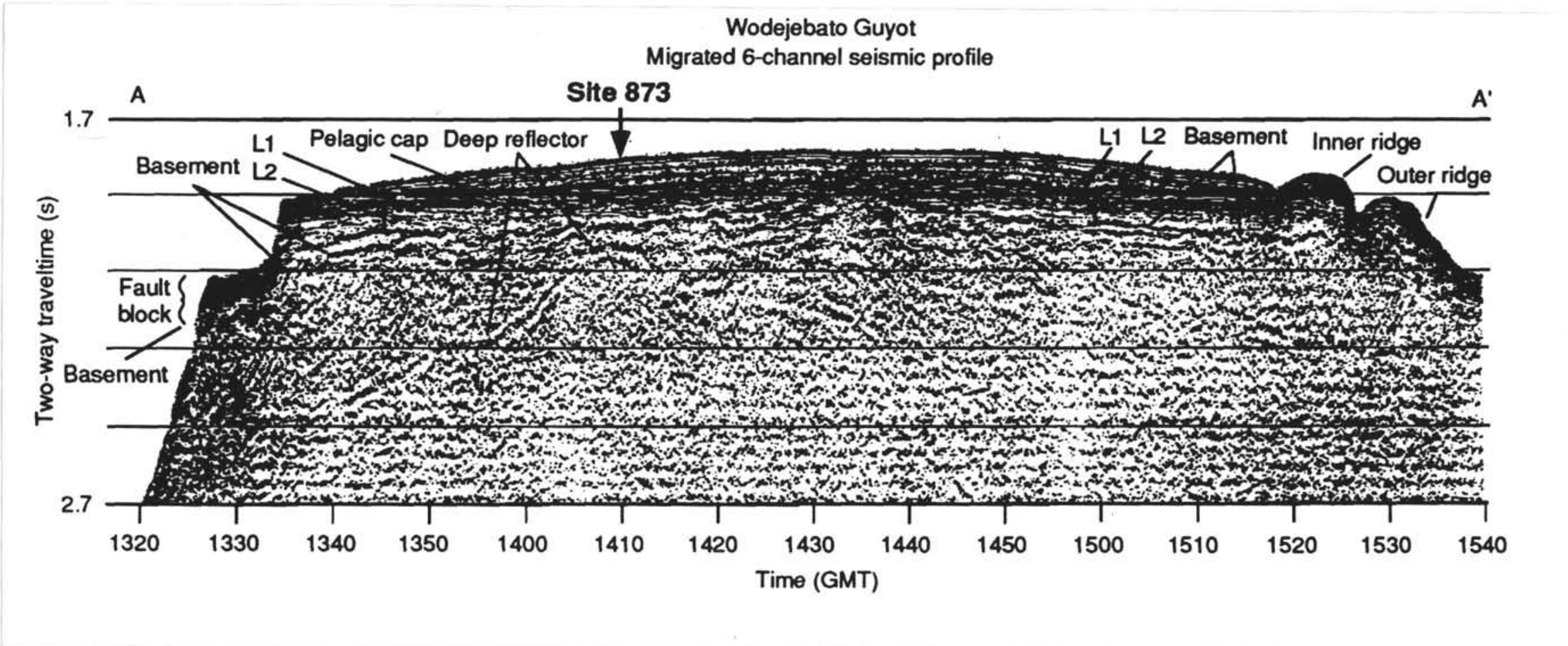

Wodejebato Guyot
Migrated 6-channel seismic profile
A
Site 873
A'
1.7
2.7
L1
L2
Pelagic cap
Deep reflector
Basement
L1
L2
Basement
Inner ridge
Outer ridge
Fault block
Basement
Two-way traveltime (s)
1320
1330
1340
1350
1400
1410
1420
1430
1440
1450
1500
1510
1520
1530
1540
Time (GMT)

Figure 11

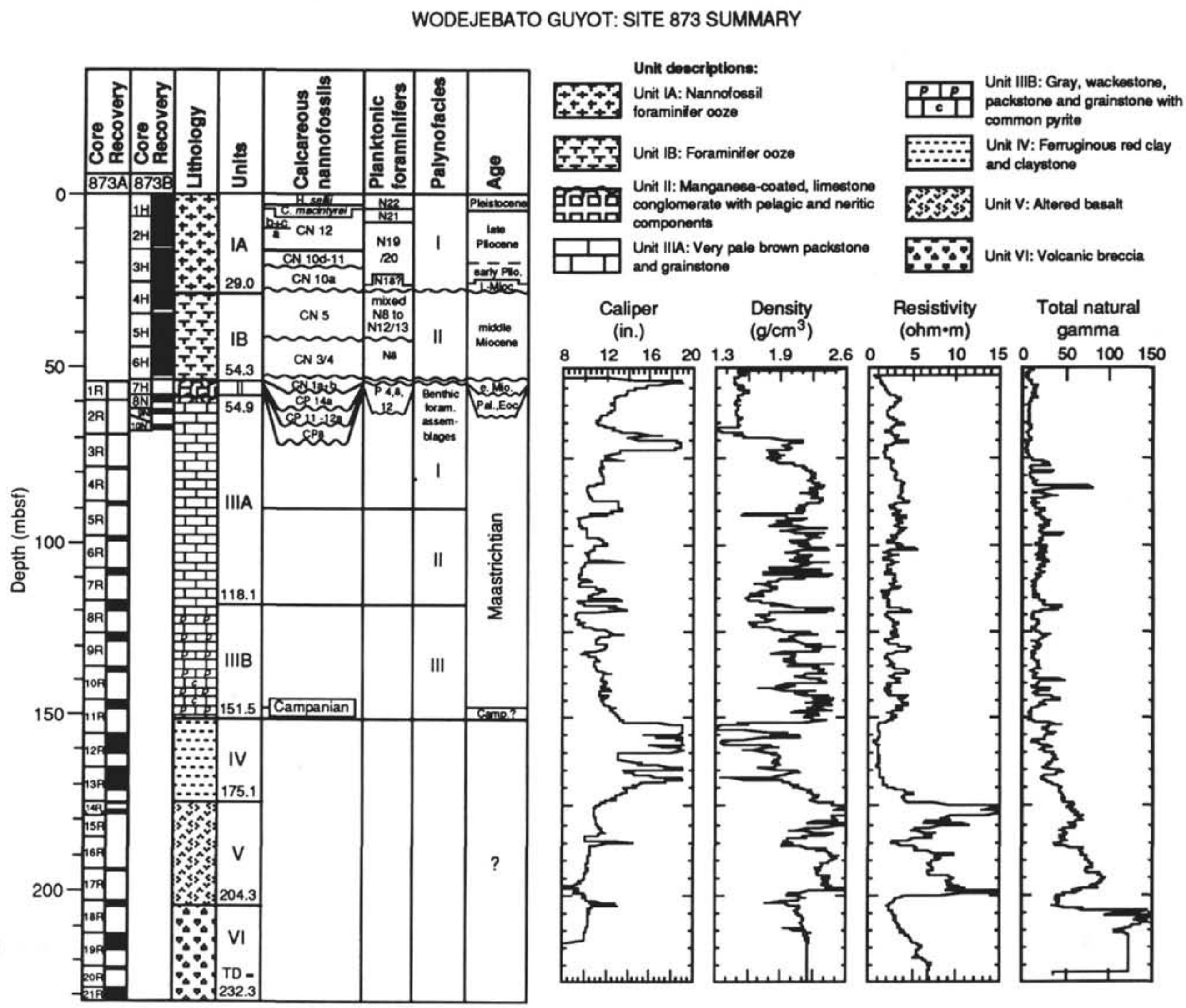

WODEJEBATO GUYOT: SITE 873 SUMMARY
Core Recovery
Core Recovery
Lithology
Units
Calcareous nannofossils
Planktonic foraminifers
Palynofacies
Age
873A
873B
Depth (mbsf)
IA
29.0
IB
54.3
II
54.9
IIIA
118.1
IIIB
151.5
IV
175.1
V
204.3
VI
TD = 232.3
CN 12
CN 10d-11
CN 10a
CN 5
CN 3/4
Campanian
N22
N21
N19 /20
mixed N8 to N12/13
Benthic foram. assem-blages
Pleistocene
late Pliocene
early Plio.
middle Miocene
Pal.,Eoc.
Maastrichtian
Camp.?
?
Unit descriptions:
Unit IA: Nannofossil foraminifer ooze
Unit IB: Foraminifer ooze
Unit II: Manganese-coated, limestone conglomerate with pelagic and neritic components
Unit IIIA: Very pale brown packstone and grainstone
Unit IIIB: Gray, wackestone, packstone and grainstone with common pyrite
Unit IV: Ferruginous red clay and claystone
Unit V: Altered basalt
Unit VI: Volcanic breccia
Caliper (in.)
Density (g/cm3)
Resistivity (ohm•m)
Total natural gamma

Figure 12

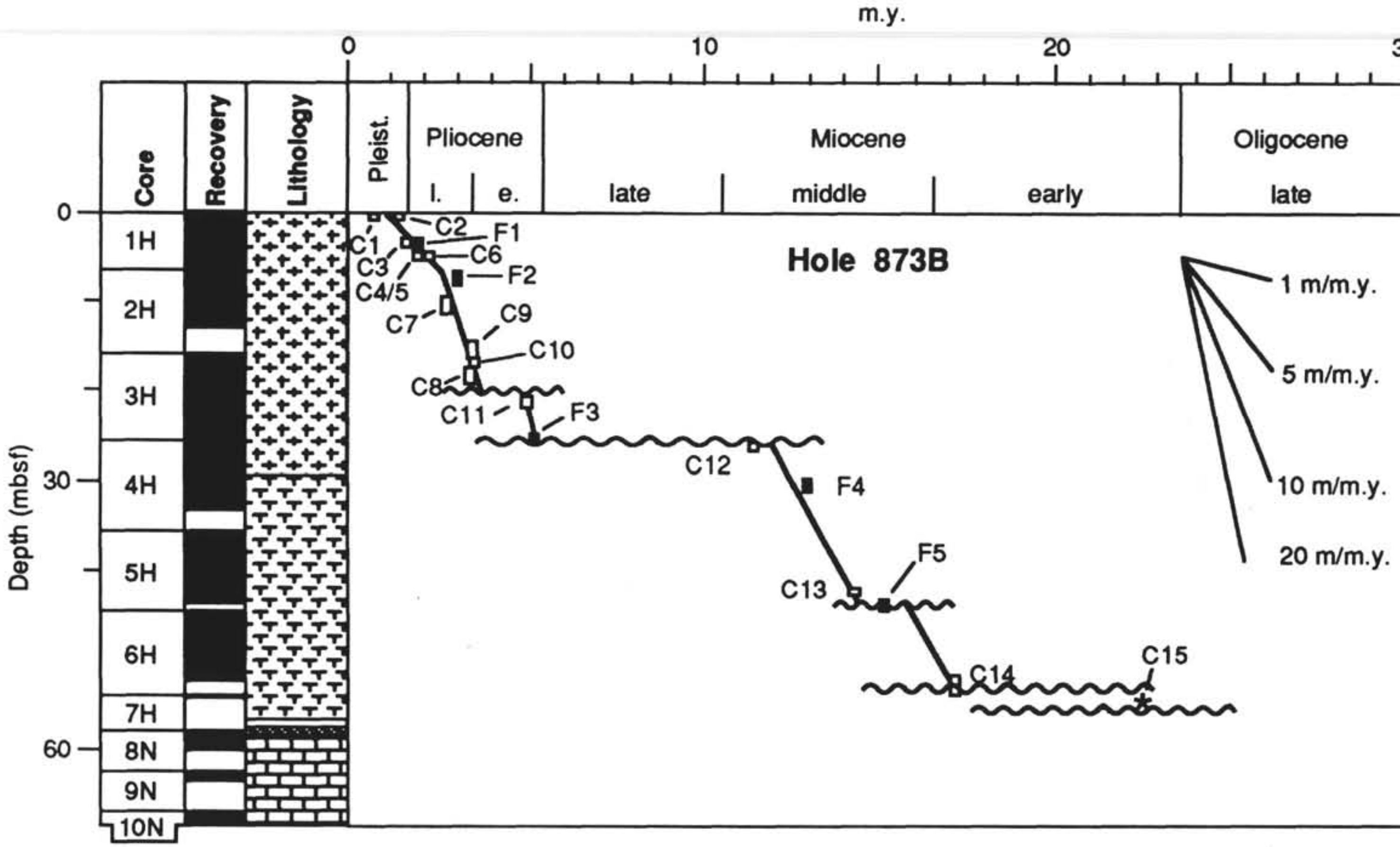

m.y.
0
10
20
30
Core
Recovery
Lithology
Pleist.
Pliocene
l.
e.
Miocene
late
middle
early
Oligocene
late
0
30
60
Depth (mbsf)
1H
2H
3H
4H
5H
6H
7H
8N
9N
10N
Hole 873B
C1
C2
F1
C3
C6
C4/5
F2
C7
C9
C10
C8
C11
F3
C12
F4
F5
C13
C14
C15
1 m/m.y.
5 m/m.y.
10 m/m.y.
20 m/m.y.

Figure 13

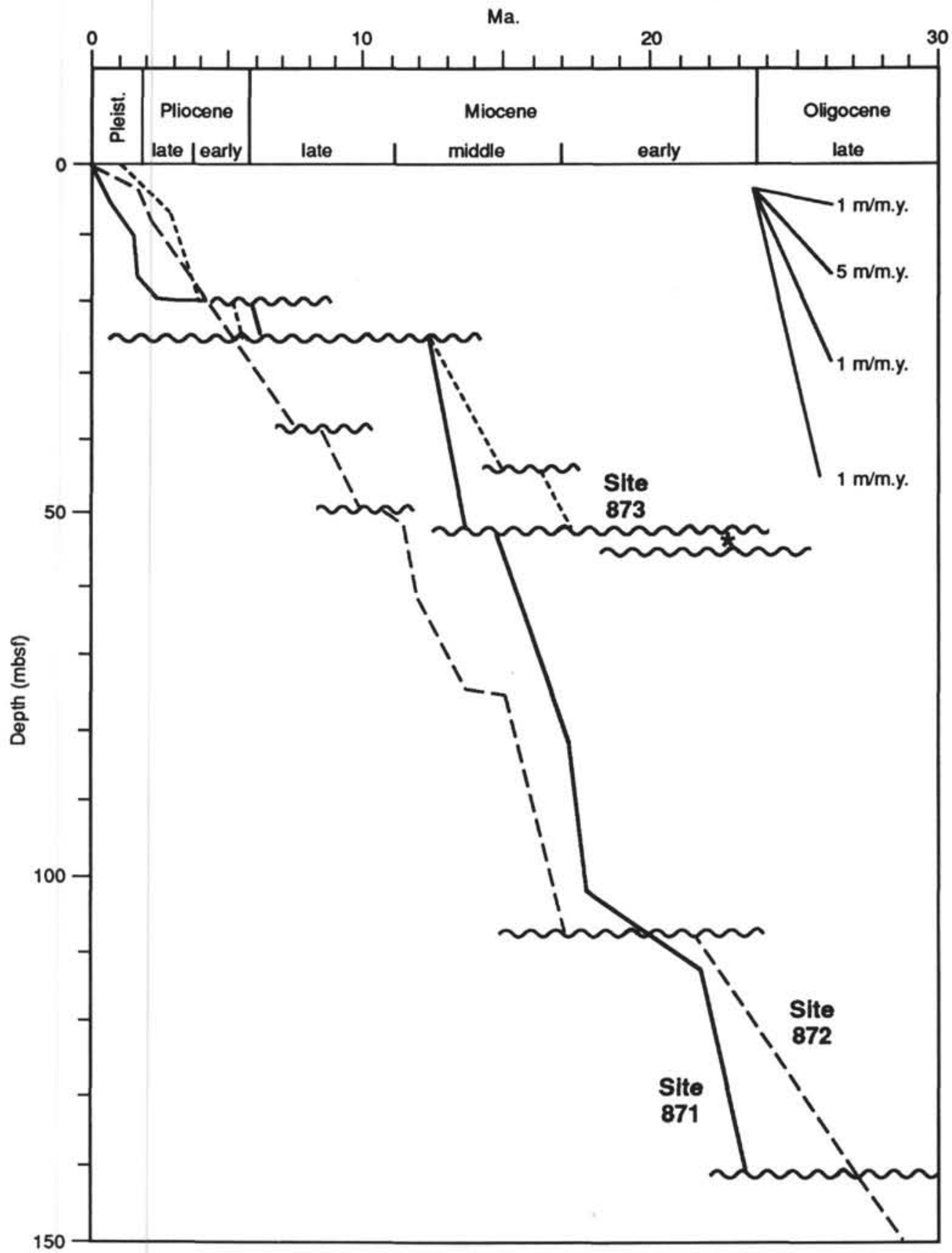
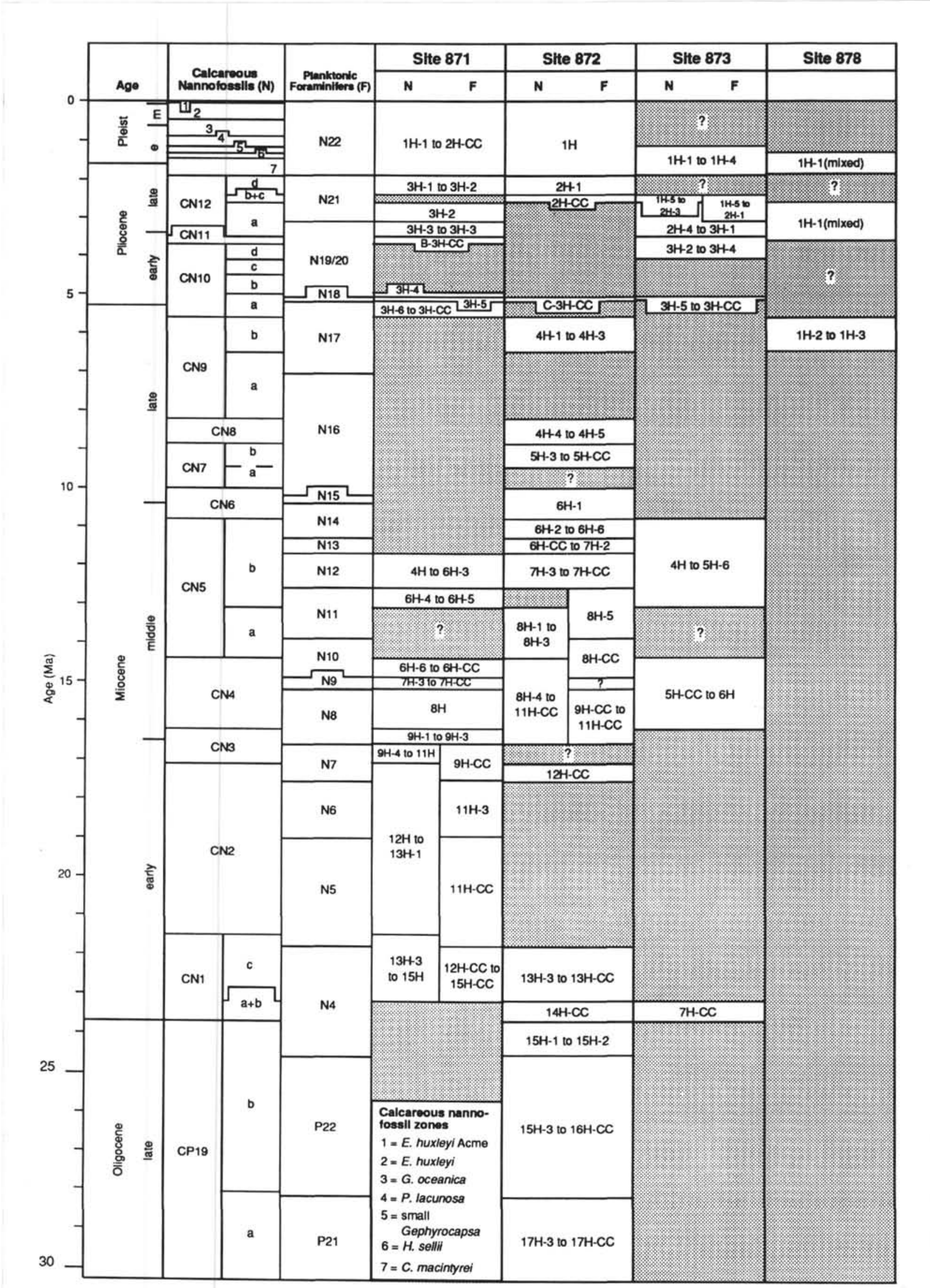

Ma.
0
10
20
30
Pleist.
Pliocene
late
early
Miocene
late
middle
early
Oligocene
late
0
50
100
150
Depth (mbsf)
1 m/m.y.
5 m/m.y.
1 m/m.y.
1 m/m.y.
Site
873
Site
872
Site
871

Figure 14



Age
Calcareous Nannofossils (N)
Planktonic Foraminifers (F)
Site 871
Site 872
Site 873
Site 878
N
F
Age (Ma)
0
5
10
15
20
25
30
Pleist
Pliocene
Miocene
Oligocene
E
e
late
early
middle
CN12
CN11
CN10
CN9
CN8
CN7
CN6
CN5
CN4
CN3
CN2
CN1
CP19
N22
N21
N19/20
N18
N17
N16
N15
N14
N13
N12
N11
N10
N9
N8
N7
N6
N5
N4
P22
P21
1H-1 to 2H-CC
1H
1H-1 to 1H-4
1H-1(mixed)
3H-1 to 3H-2
2H-1
3H-2
2H-CC
3H-3 to 3H-3
B-3H-CC
2H-4 to 3H-1
3H-2 to 3H-4
3H-4
3H-6 to 3H-CC
3H-5
C-3H-CC
3H-5 to 3H-CC
4H-1 to 4H-3
1H-2 to 1H-3
4H-4 to 4H-5
5H-3 to 5H-CC
6H-1
6H-2 to 6H-6
6H-CC to 7H-2
4H to 6H-3
7H-3 to 7H-CC
4H to 5H-6
6H-4 to 6H-5
8H-1 to 8H-3
8H-5
8H-CC
6H-6 to 6H-CC
7H-3 to 7H-CC
8H-4 to 11H-CC
9H-CC to 11H-CC
5H-CC to 6H
8H
9H-1 to 9H-3
9H-4 to 11H
9H-CC
12H-CC
11H-3
12H to 13H-1
11H-CC
13H-3 to 15H
12H-CC to 15H-CC
13H-3 to 13H-CC
14H-CC
7H-CC
15H-1 to 15H-2
15H-3 to 16H-CC
17H-3 to 17H-CC
Calcareous nannofossil zones
1 = E. huxleyi Acme
2 = E. huxleyi
3 = G. oceanica
4 = P. lacunosa
5 = small Gephyrocapsa
6 = H. sellii
7 = C. macintyrei

Figure 15

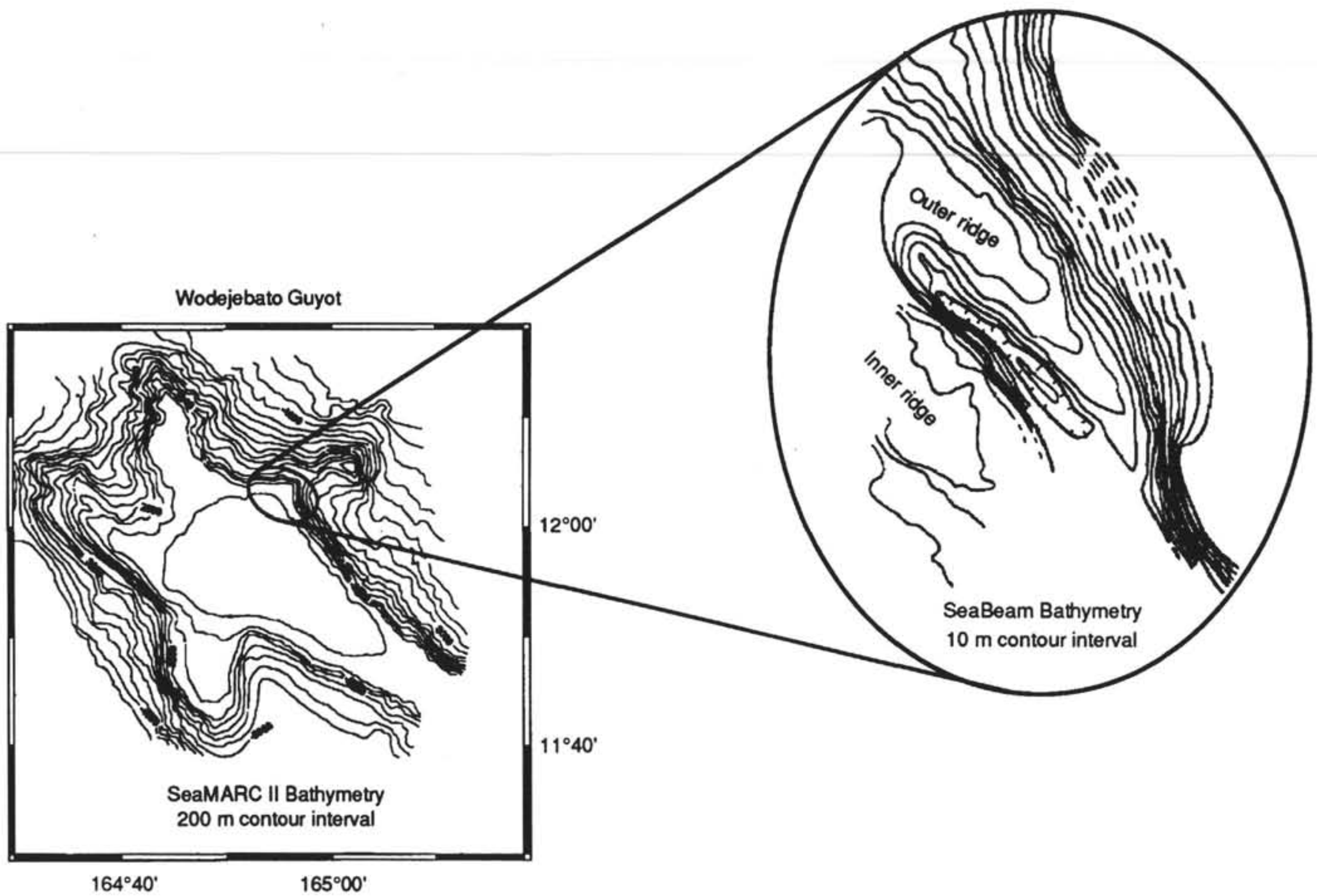

Wodejebato Guyot
12°00'
11°40'
SeaMARC II Bathymetry
200 m contour interval
164°40'
165°00'
Outer ridge
Inner ridge
SeaBeam Bathymetry
10 m contour interval

Figure 16

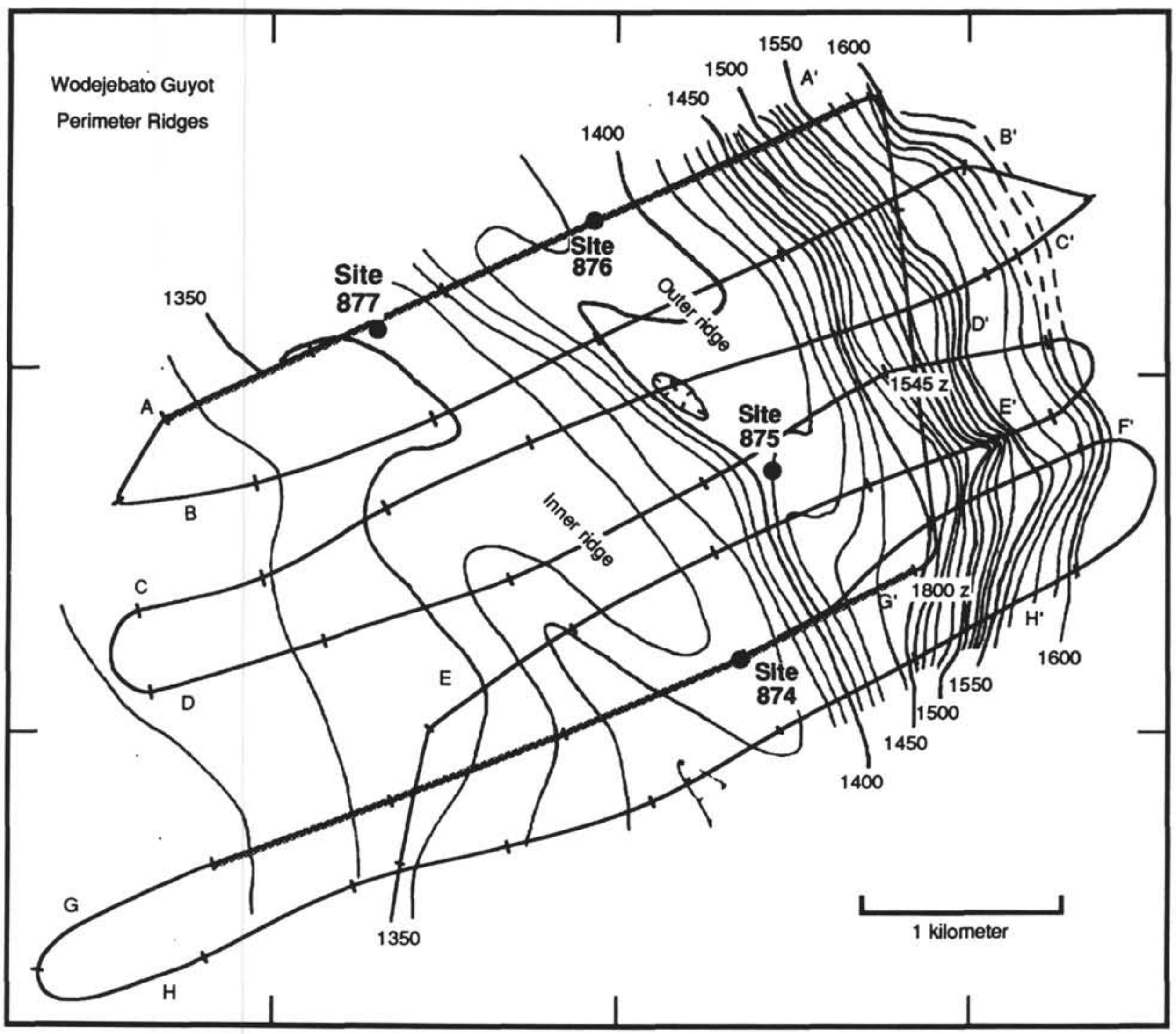
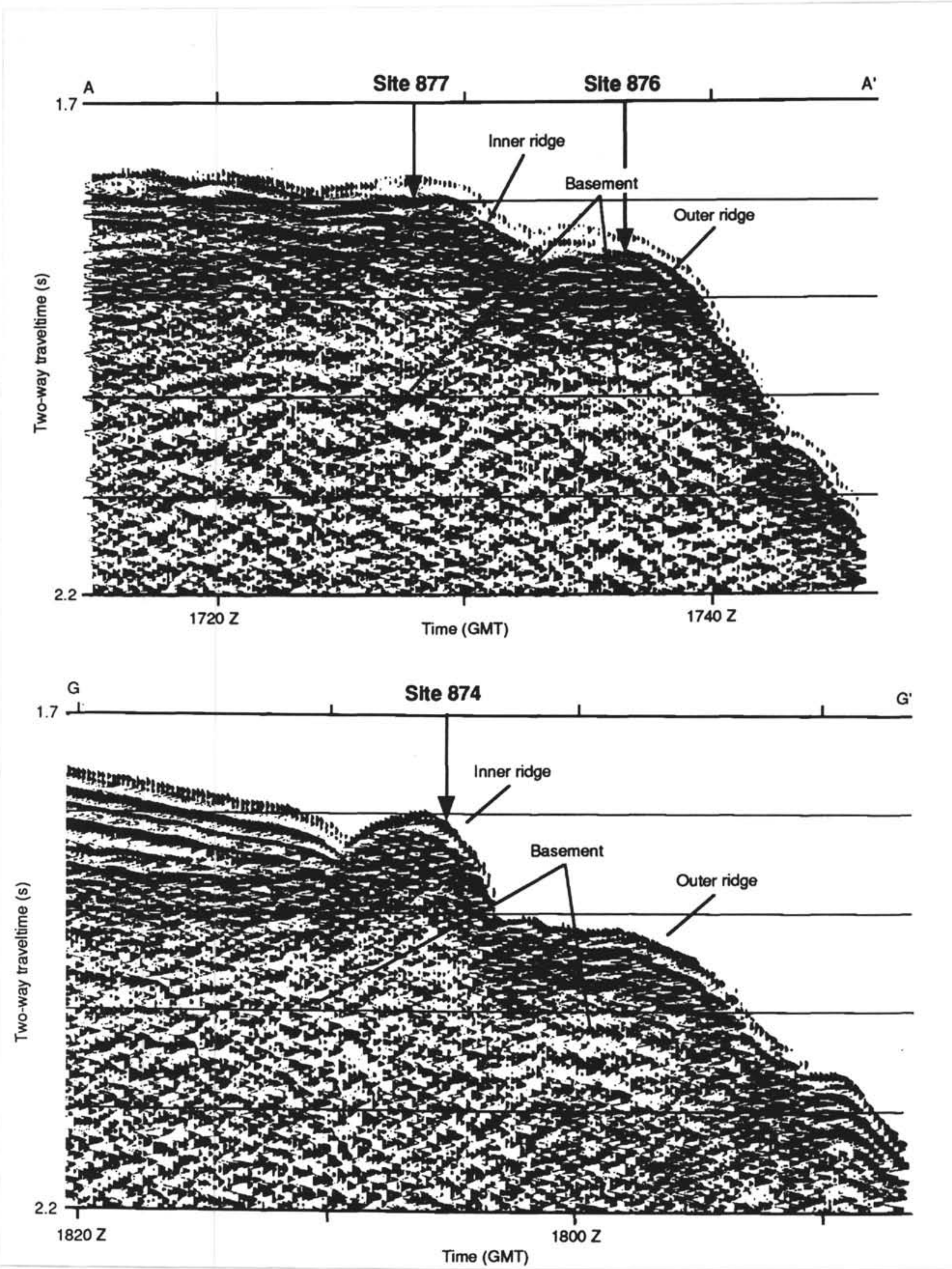

Wodejebato Guyot
Perimeter Ridges
Site 877
Site 876
Site 875
Site 874
Outer ridge
Inner ridge
1350
1400
1450
1500
1550
1600
1545 z
1800 z
A
A'
B
B'
C
C'
D
D'
E
E'
F'
G
G'
H
H'
12°01'N
12°00'
164°55'E
164°56'
164°57
1 kilometer

Figure 17



A
Site 877
Site 876
A'
1.7
Inner ridge
Basement
Outer ridge
Two-way traveltime (s)
2.2
1720 Z
1740 Z
Time (GMT)
G
Site 874
G'
1.7
Inner ridge
Basement
Outer ridge
Two-way traveltime (s)
2.2
1820 Z
1800 Z
Time (GMT)

Figure 18

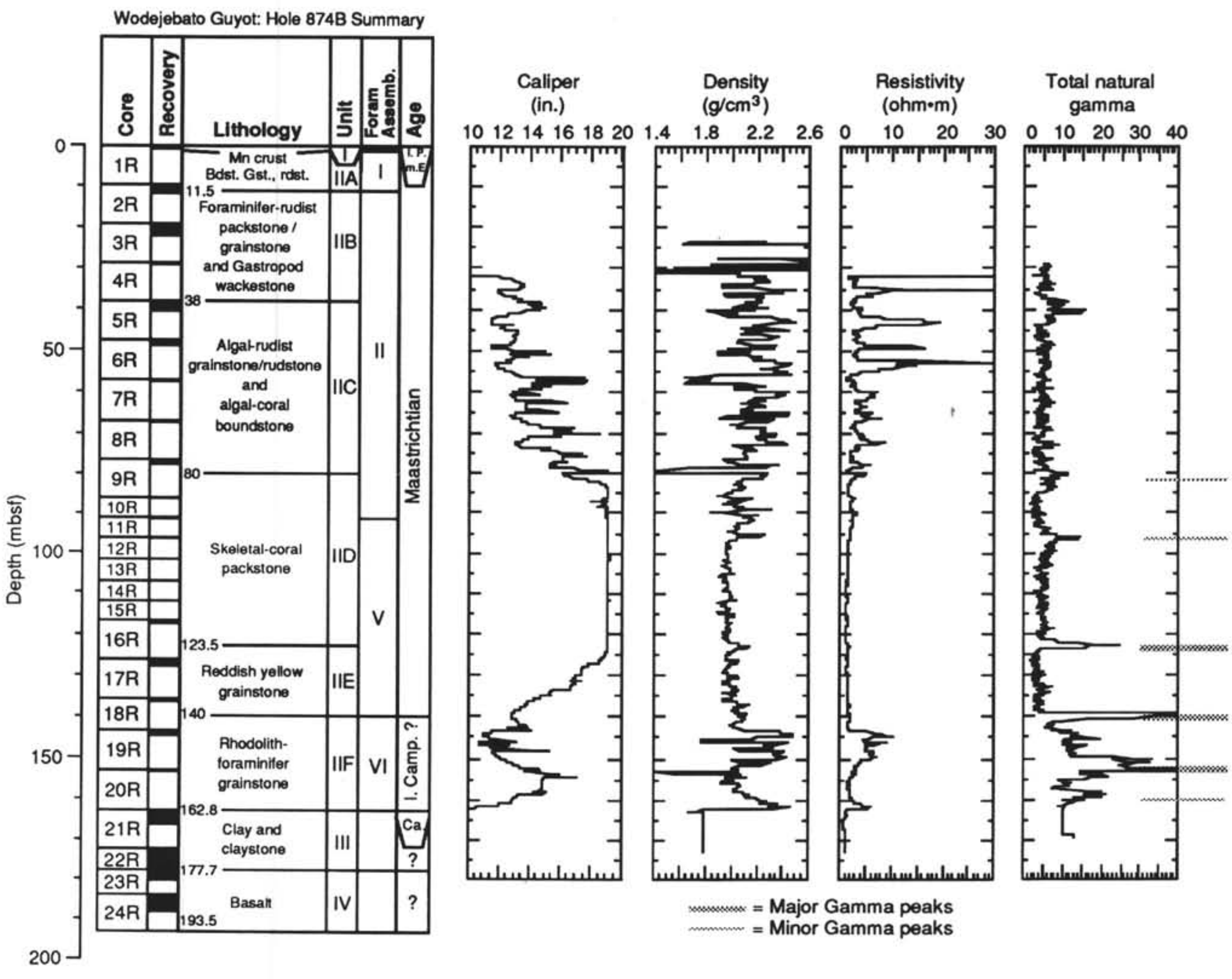

Wodejebato Guyot: Hole 874B Summary
Core
Recovery
Lithology
Unit
Foram Assemb.
Age
Depth (mbsf)
Mn crust
Bdst. Gst., rdst.
Foraminifer-rudist packstone / grainstone and Gastropod wackestone
Algal-rudist grainstone/rudstone and algal-coral boundstone
Skeletal-coral packstone
Reddish yellow grainstone
Rhodolith-foraminifer grainstone
Clay and claystone
Basalt
Maastrichtian
I. Camp. ?
Caliper (in.)
Density (g/cm³)
Resistivity (ohm•m)
Total natural gamma
= Major Gamma peaks
= Minor Gamma peaks

Figure 19

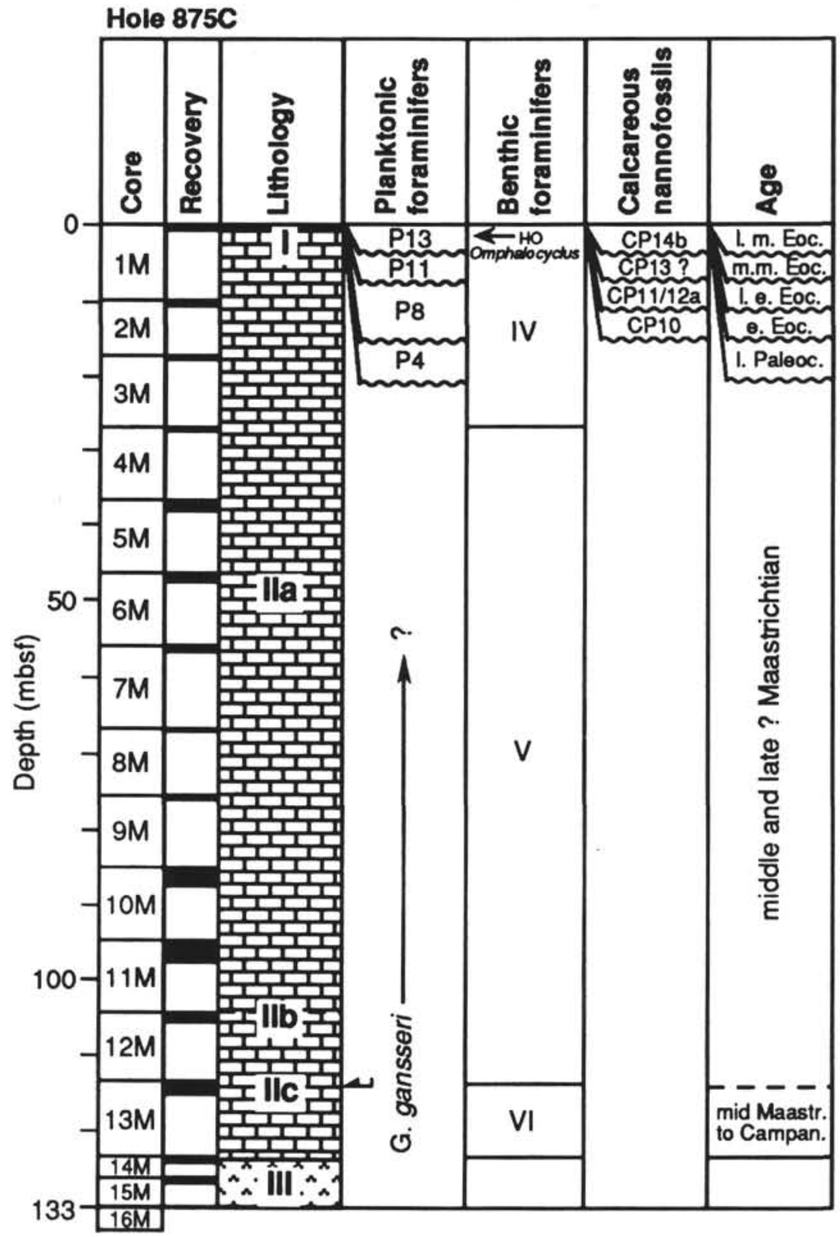

Hole 875C
Core
Recovery
Lithology
Planktonic foraminifers
Benthic foraminifers
Calcareous nannofossils
Age
Depth (mbsf)
0
50
100
133
1M
2M
3M
4M
5M
6M
7M
8M
9M
10M
11M
12M
13M
14M
15M
16M
I
IIa
IIb
IIc
III
P13
P11
P8
P4
G. gansseri
?
HO Omphalocyclus
IV
V
VI
CP14b
CP13 ?
CP11/12a
CP10
l. m. Eoc.
m.m. Eoc.
l. e. Eoc.
e. Eoc.
l. Paleoc.
middle and late ? Maastrichtian
mid Maastr. to Campan.

Figure 20

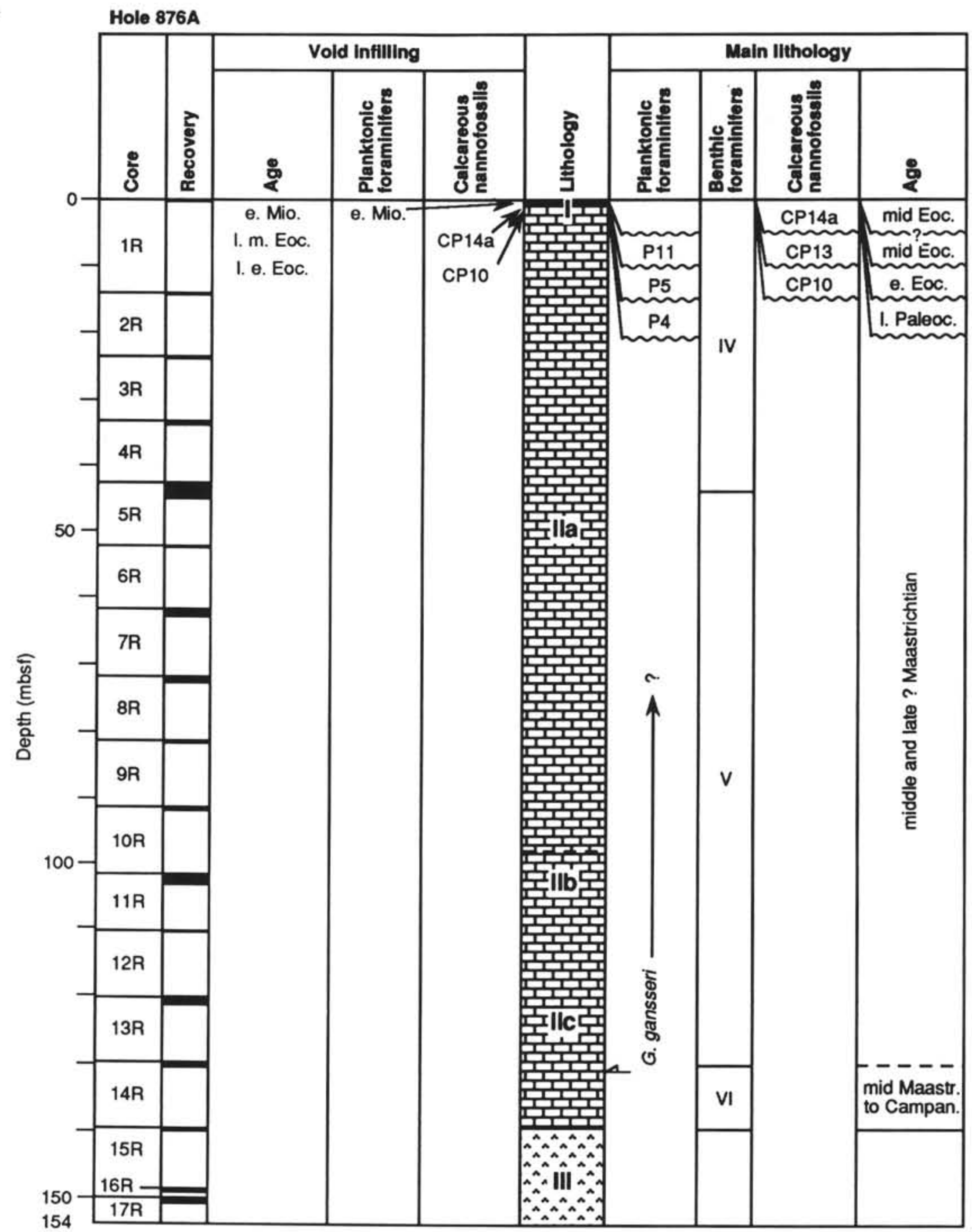

Hole 876A
Core
Recovery
Void infilling
Age
Planktonic foraminifers
Calcareous nannofossils
Lithology
Main lithology
Planktonic foraminifers
Benthic foraminifers
Calcareous nannofossils
Age
Depth (mbsf)
0
50
100
150
154
1R
2R
3R
4R
5R
6R
7R
8R
9R
10R
11R
12R
13R
14R
15R
16R
17R
e. Mio.
l. m. Eoc.
l. e. Eoc.
e. Mio.
CP14a
CP10
I
IIa
IIb
IIc
III
P11
P5
P4
G. gansseri
?
IV
V
VI
CP14a
CP13
CP10
mid Eoc.
?
mid Eoc.
e. Eoc.
l. Paleoc.
middle and late ? Maastrichtian
mid Maastr. to Campan.

Figure 21

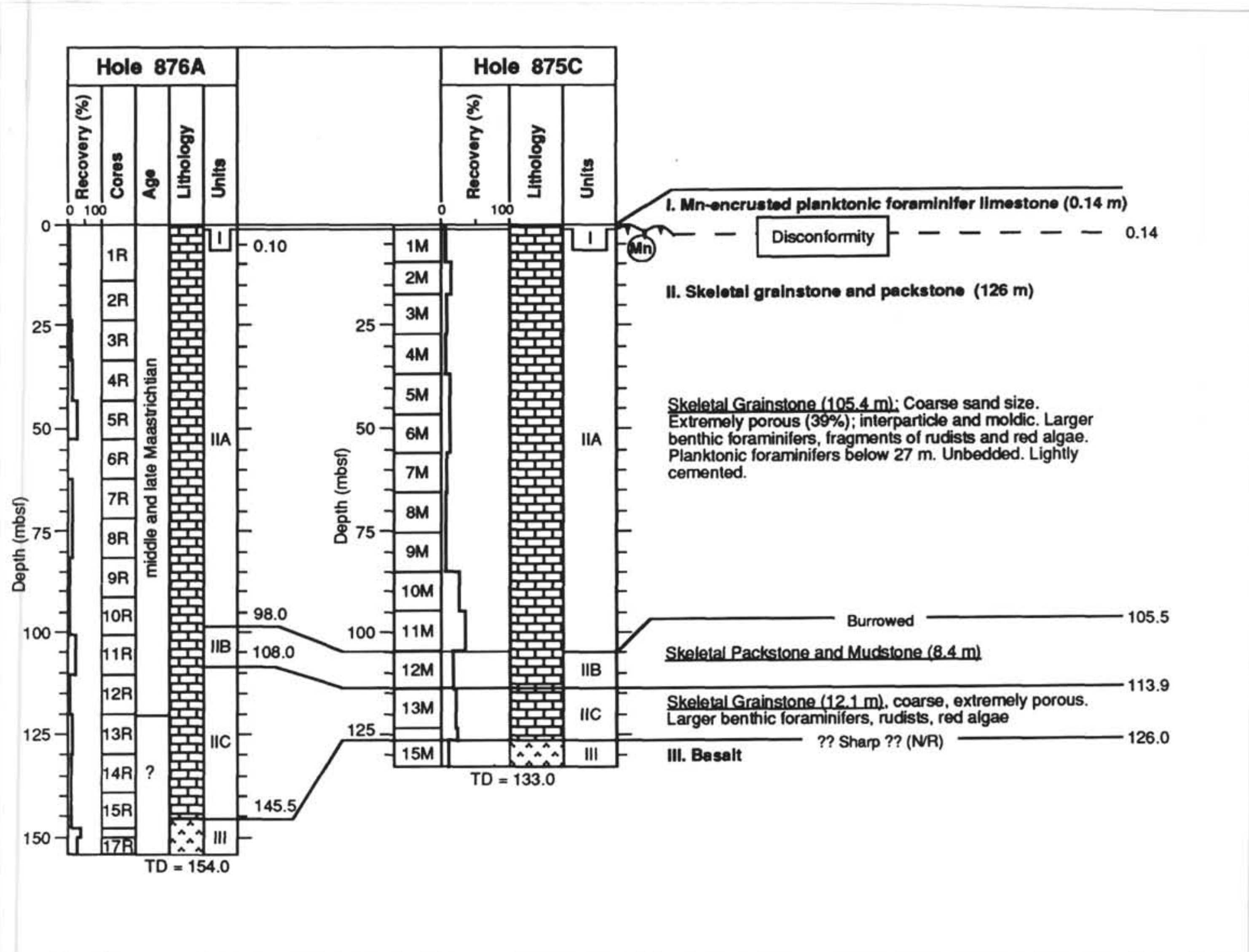

Hole 876A
Recovery (%)
Cores
Age
Lithology
Units
0 100
Depth (mbsf)
1R
2R
3R
4R
5R
6R
7R
8R
9R
10R
11R
12R
13R
14R
15R
17R
middle and late Maastrichtian
?
I
IIA
IIB
IIC
III
0.10
98.0
108.0
145.5
TD = 154.0
Hole 875C
Recovery (%)
Lithology
Units
1M
2M
3M
4M
5M
6M
7M
8M
9M
10M
11M
12M
13M
15M
TD = 133.0
I. Mn-encrusted planktonic foraminifer limestone (0.14 m)
Mn
Disconformity
0.14
II. Skeletal grainstone and packstone (126 m)
Skeletal Grainstone (105.4 m): Coarse sand size. Extremely porous (39%); interparticle and moldic. Larger benthic foraminifers, fragments of rudists and red algae. Planktonic foraminifers below 27 m. Unbedded. Lightly cemented.
Burrowed
105.5
Skeletal Packstone and Mudstone (8.4 m)
113.9
Skeletal Grainstone (12.1 m), coarse, extremely porous. Larger benthic foraminifers, rudists, red algae
?? Sharp ?? (N/R)
126.0
III. Basalt

Figure 22

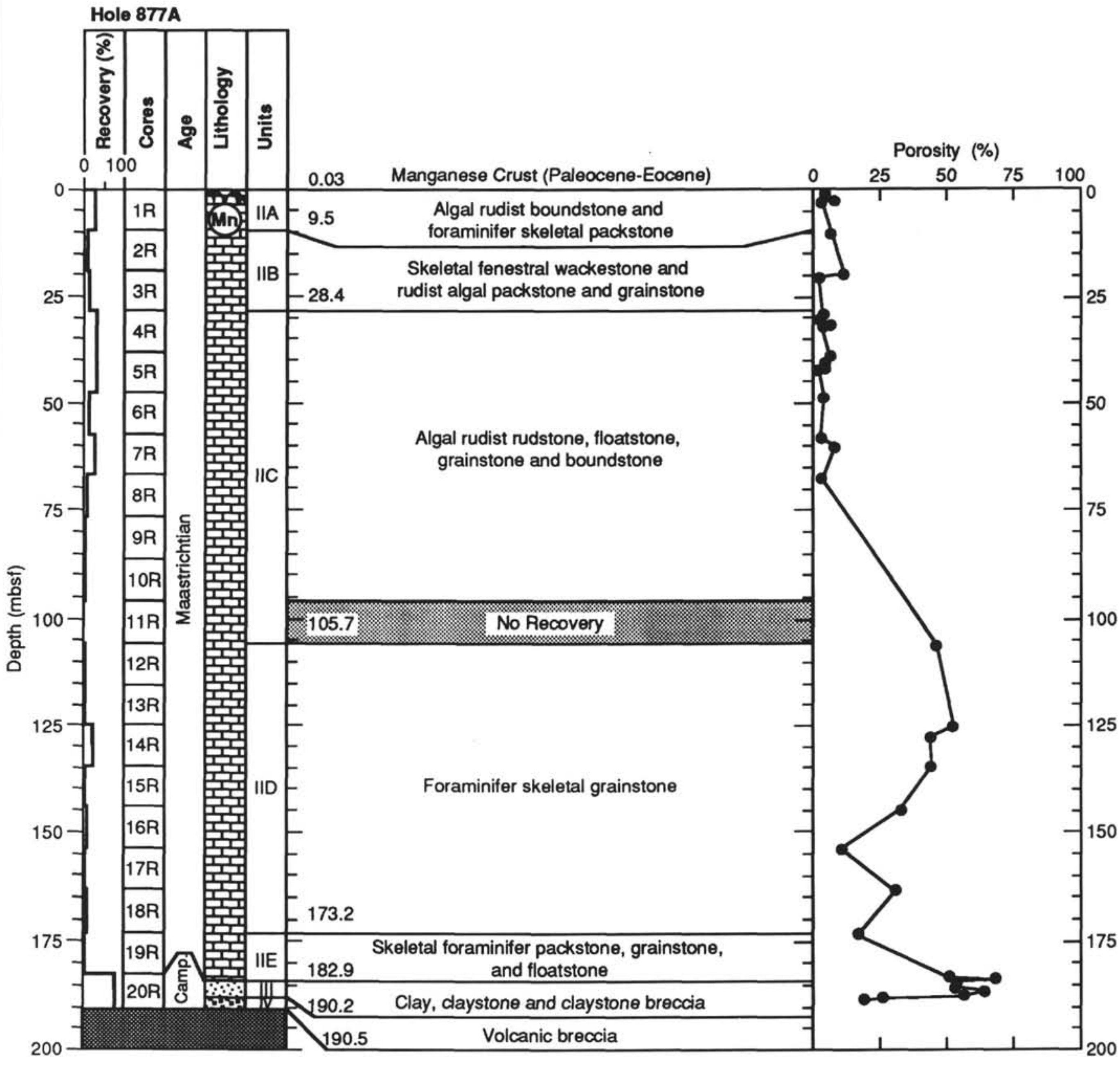
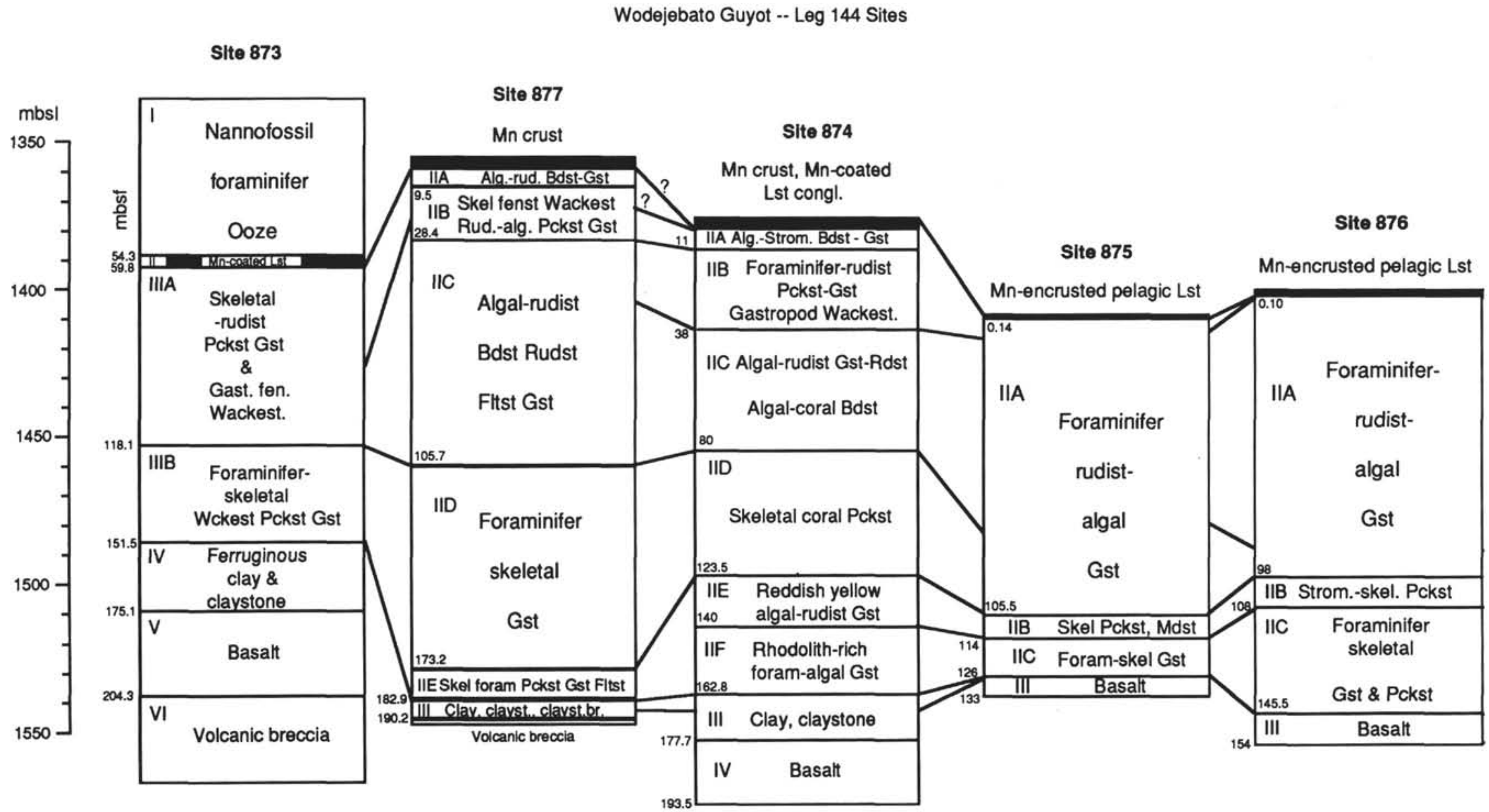

Hole 877A
Recovery (%)
Cores
Age
Lithology
Units
0 100
Depth (mbsf)
0
25
50
75
100
125
150
175
200
1R
2R
3R
4R
5R
6R
7R
8R
9R
10R
11R
12R
13R
14R
15R
16R
17R
18R
19R
20R
Maastrichtian
Camp.
Mn
IIA
IIB
IIC
IID
IIE
III
IV
0.03
Manganese Crust (Paleocene-Eocene)
9.5
Algal rudist boundstone and foraminifer skeletal packstone
Skeletal fenestral wackestone and rudist algal packstone and grainstone
28.4
Algal rudist rudstone, floatstone, grainstone and boundstone
105.7
No Recovery
Foraminifer skeletal grainstone
173.2
Skeletal foraminifer packstone, grainstone, and floatstone
182.9
190.2
Clay, claystone and claystone breccia
190.5
Volcanic breccia
Porosity (%)
0 25 50 75 100

Figure 23



Wodejebato Guyot -- Leg 144 Sites
Site 873
Site 877
Site 874
Site 875
Site 876
mbsl
mbsf
1350
1400
1450
1500
1550
I
Nannofossil
foraminifer
Ooze
Mn-coated Lst
IIIA
Skeletal -rudist Pckst Gst & Gast. fen. Wackest.
IIIB
Foraminifer- skeletal Wckest Pckst Gst
IV
Ferruginous clay & claystone
V
Basalt
VI
Volcanic breccia
Mn crust
IIA Alg.-rud. Bdst-Gst
IIB Skel fenst Wackest Rud.-alg. Pckst Gst
IIC Algal-rudist Bdst Rudst Fltst Gst
IID Foraminifer skeletal Gst
IIE Skel foram Pckst Gst Fltst
III Clay, clayst., clayst.br.
Volcanic breccia
Mn crust, Mn-coated Lst congl.
IIA Alg.-Strom. Bdst - Gst
IIB Foraminifer-rudist Pckst-Gst Gastropod Wackest.
IIC Algal-rudist Gst-Rdst Algal-coral Bdst
IID Skeletal coral Pckst
IIE Reddish yellow algal-rudist Gst
IIF Rhodolith-rich foram-algal Gst
III Clay, claystone
IV Basalt
Mn-encrusted pelagic Lst
IIA Foraminifer rudist- algal Gst
IIB Skel Pckst, Mdst
IIC Foram-skel Gst
III Basalt
Mn-encrusted pelagic Lst
IIA Foraminifer- rudist- algal Gst
IIB Strom.-skel. Pckst
IIC Foraminifer skeletal Gst & Pckst
III Basalt

Figure 24

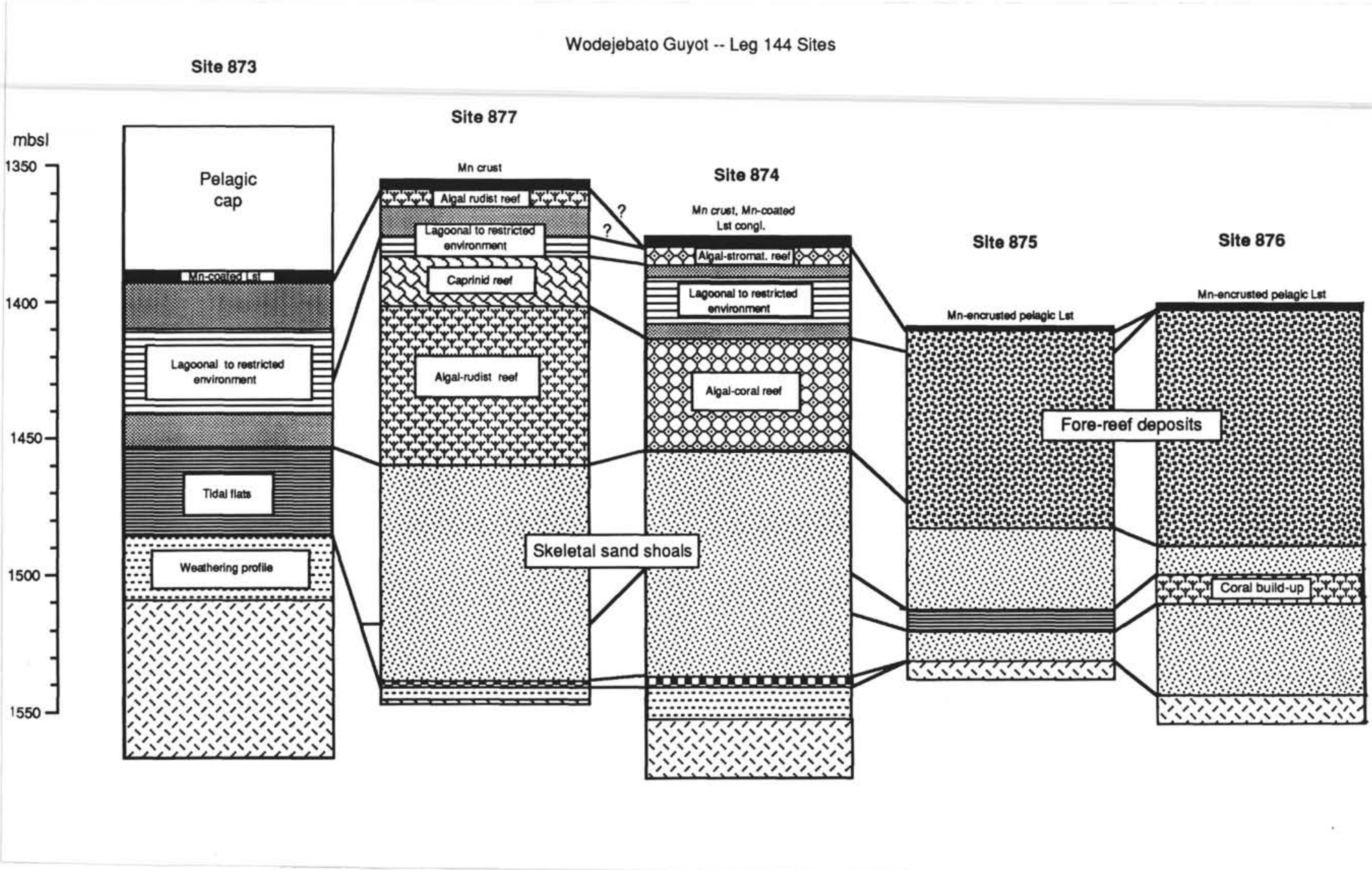

Wodejebato Guyot -- Leg 144 Sites
Site 873
Site 877
Site 874
Site 875
Site 876
mbsl
1350
1400
1450
1500
1550
Pelagic cap
Mn-coated Lst
Lagoonal to restricted environment
Tidal flats
Weathering profile
Mn crust
Algal rudist reef
Lagoonal to restricted environment
Caprinid reef
Algal-rudist reef
Skeletal sand shoals
Mn crust, Mn-coated Lst congl.
Algal-stromat. reef
Lagoonal to restricted environment
Algal-coral reef
Mn-encrusted pelagic Lst
Mn-encrusted pelagic Lst
Fore-reef deposits
Coral build-up
?
?

Figure 25

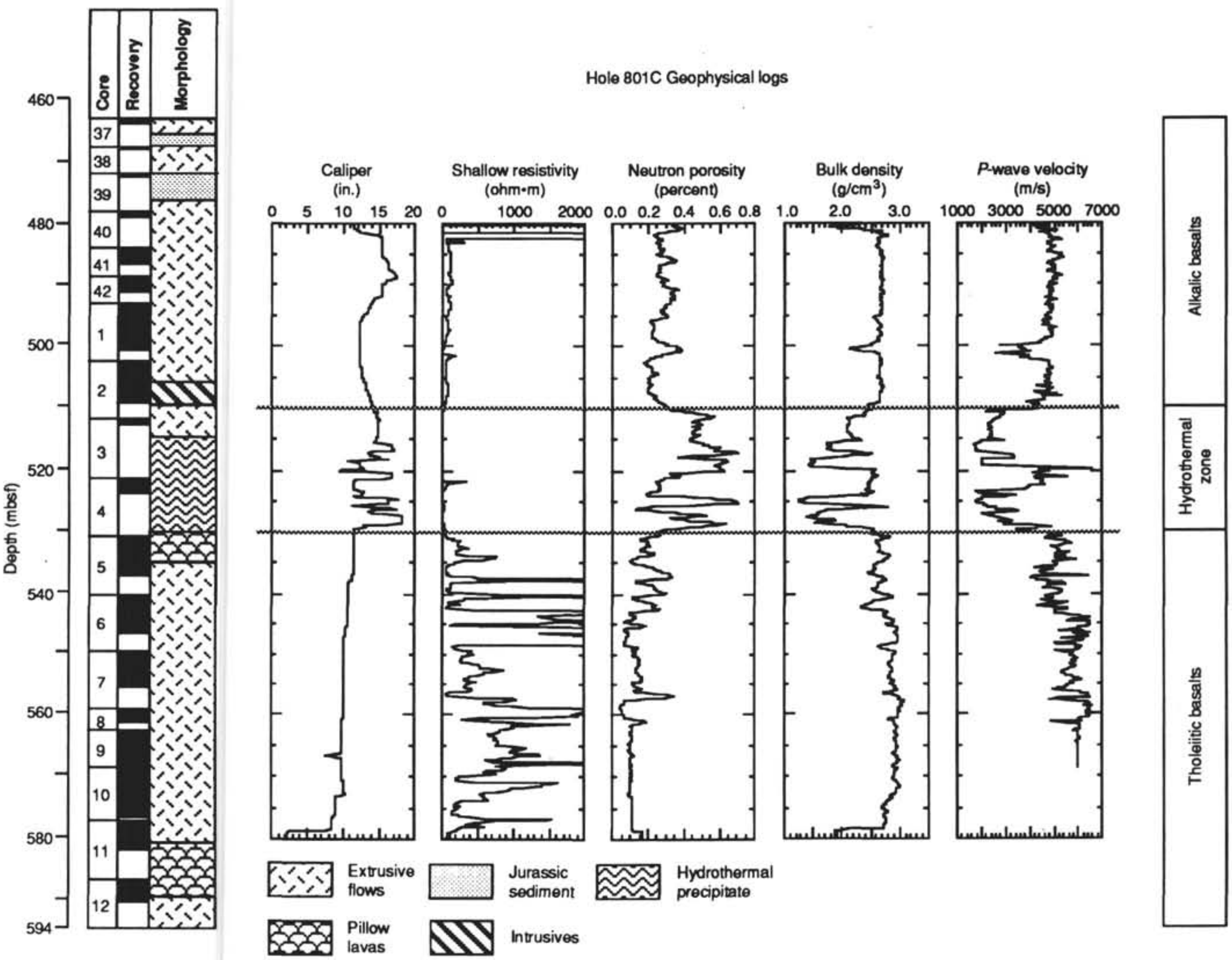

Hole 801C Geophysical logs
Core
Recovery
Morphology
Depth (mbsf)
460
480
500
520
540
560
580
594
37
38
39
40
41
42
1
2
3
4
5
6
7
8
9
10
11
12
Caliper
(in.)
0 5 10 15 20
Shallow resistivity
(ohm-m)
0 1000 2000
Neutron porosity
(percent)
0.0 0.2 0.4 0.6 0.8
Bulk density
(g/cm³)
1.0 2.0 3.0
P-wave velocity
(m/s)
1000 3000 5000 7000
Alkalic basalts
Hydrothermal zone
Tholeiitic basalts
Extrusive flows
Jurassic sediment
Hydrothermal precipitate
Pillow lavas
Intrusives

Figure 26

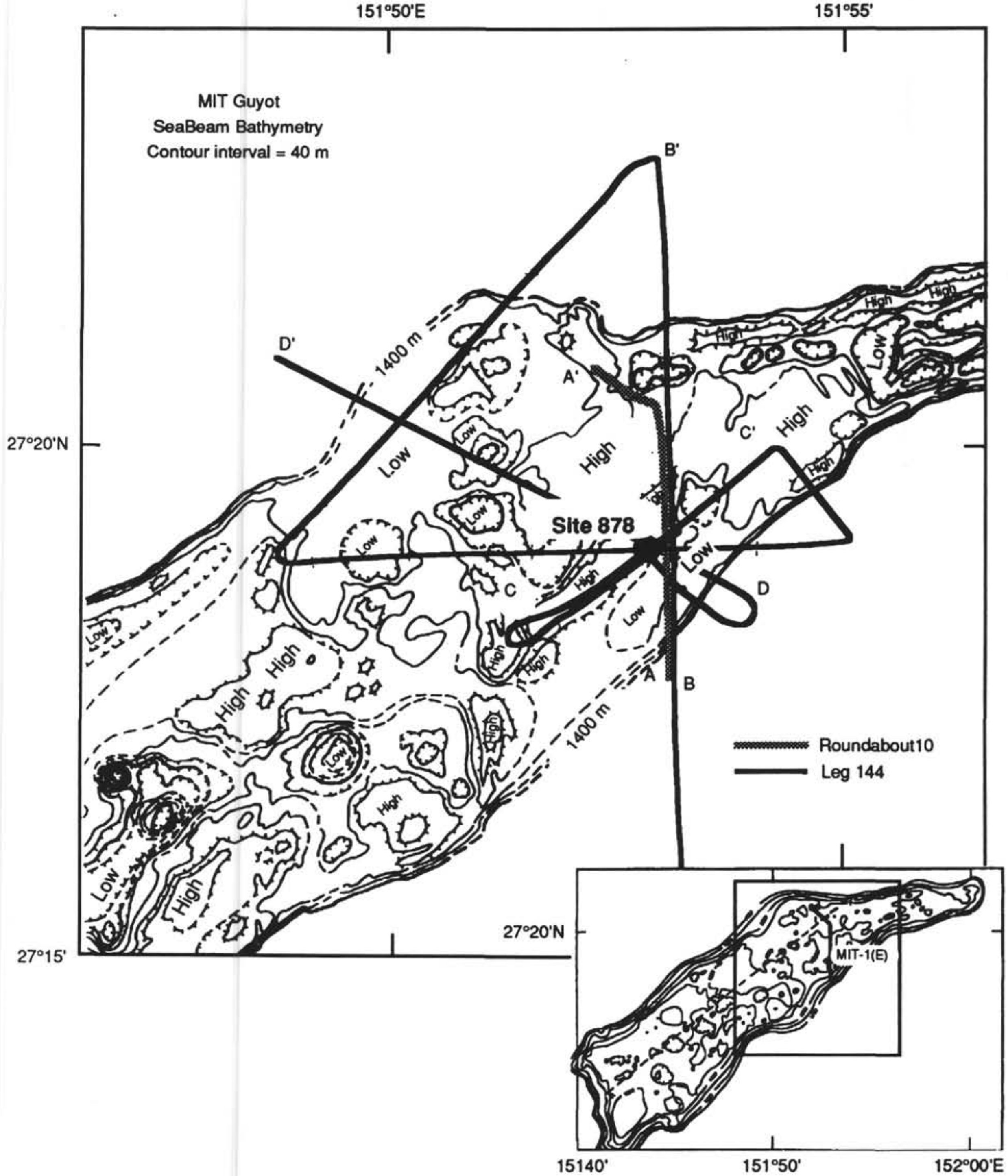

151°50'E
151°55'
MIT Guyot
SeaBeam Bathymetry
Contour interval = 40 m
B'
D'
1400 m
A'
C'
27°20'N
Low
High
Site 878
C
D
A
B
1400 m
Roundabout10
Leg 144
27°15'
27°20'N
MIT-1(E)
15140'
151°50'
152°00'E

Figure 27

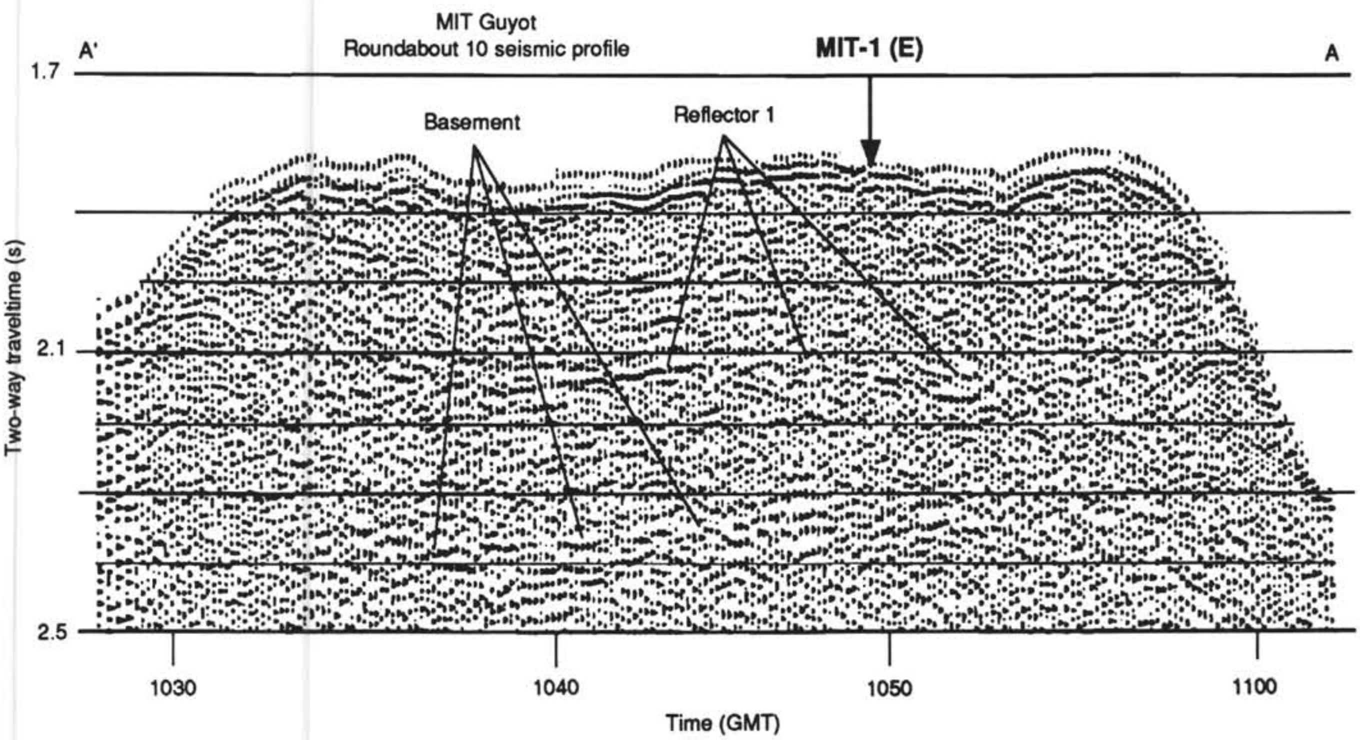

MIT Guyot
Roundabout 10 seismic profile
MIT-1 (E)
A'
A
Basement
Reflector 1
1.7
2.1
2.5
Two-way traveltime (s)
1030
1040
1050
1100
Time (GMT)

Figure 28

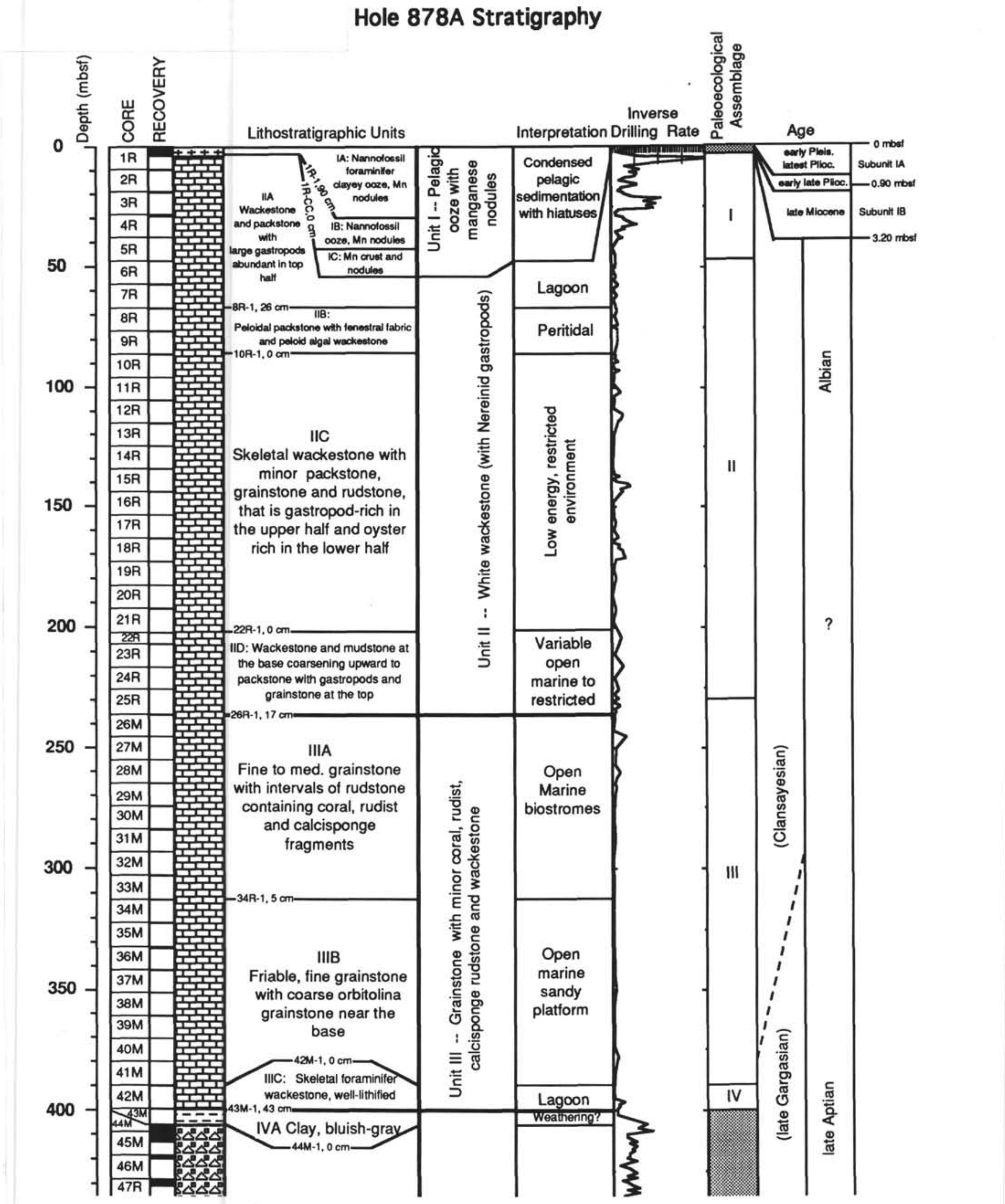


Figure 29 Part A

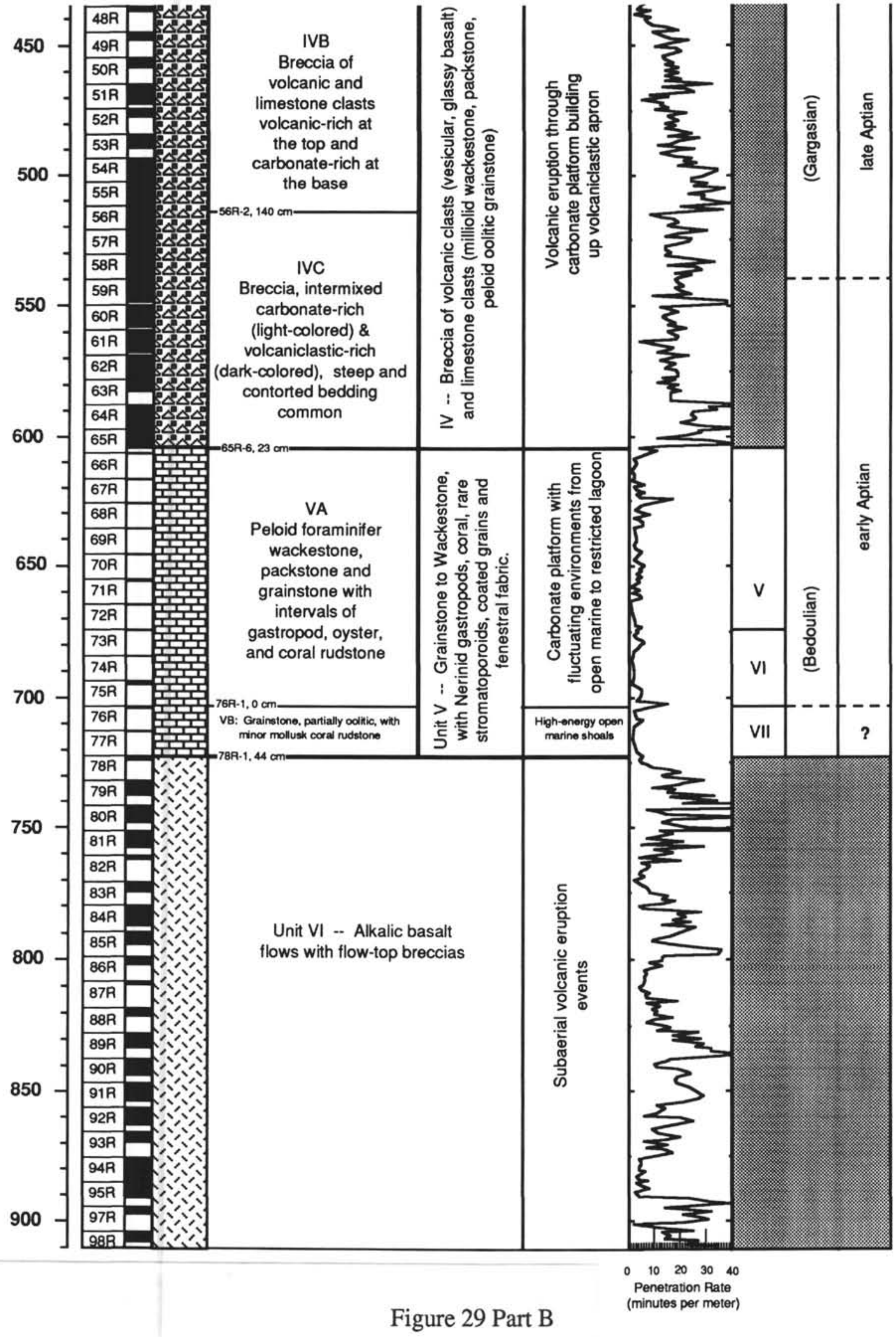


Figure 29 Part B

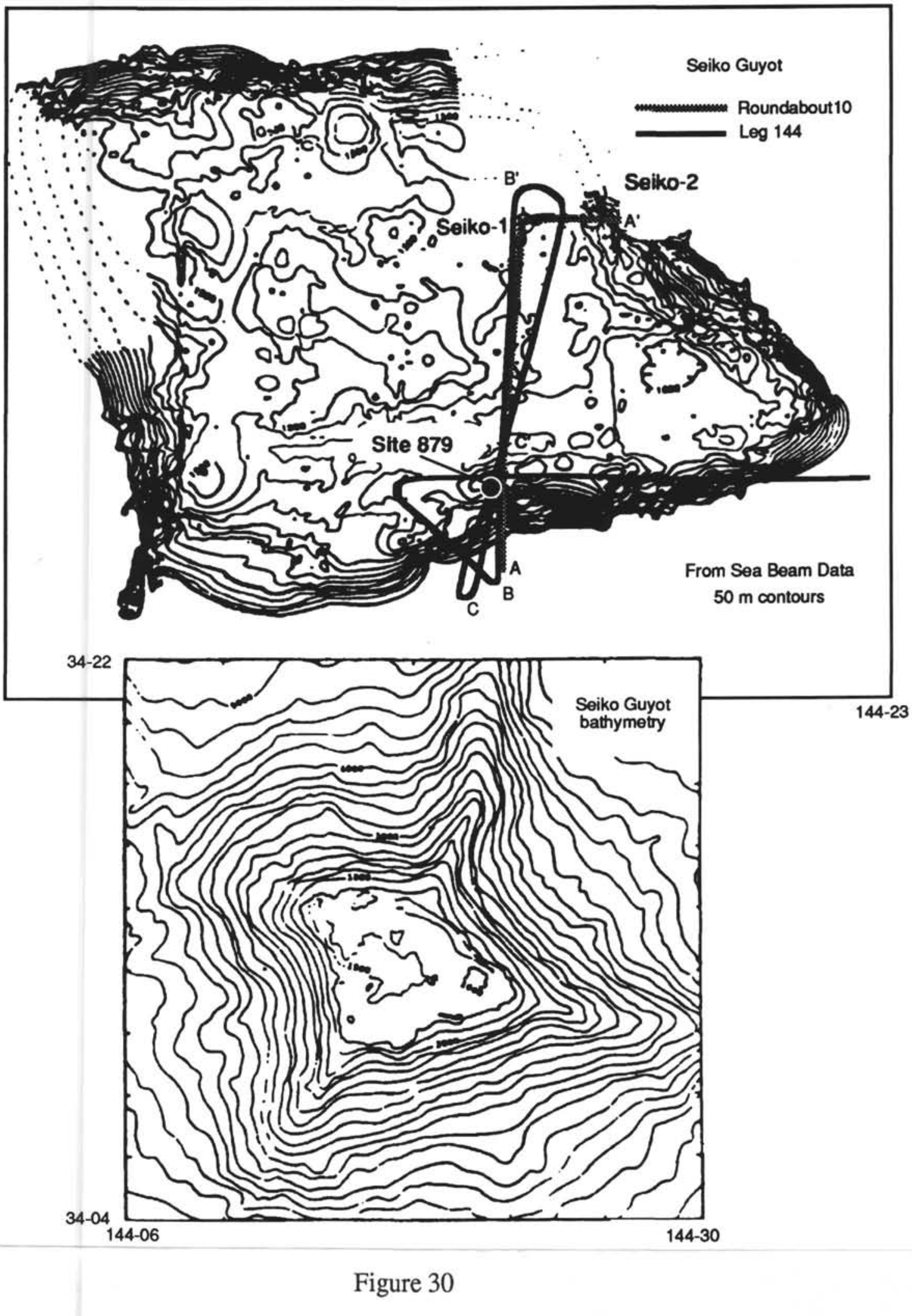

Seiko Guyot
Roundabout10
Leg 144
Seiko-2
Seiko-1
B'
A'
Site 879
A
B
C
From Sea Beam Data
50 m contours
34-22
144-23
Seiko Guyot
bathymetry
34-04
144-06
144-30

Figure 30

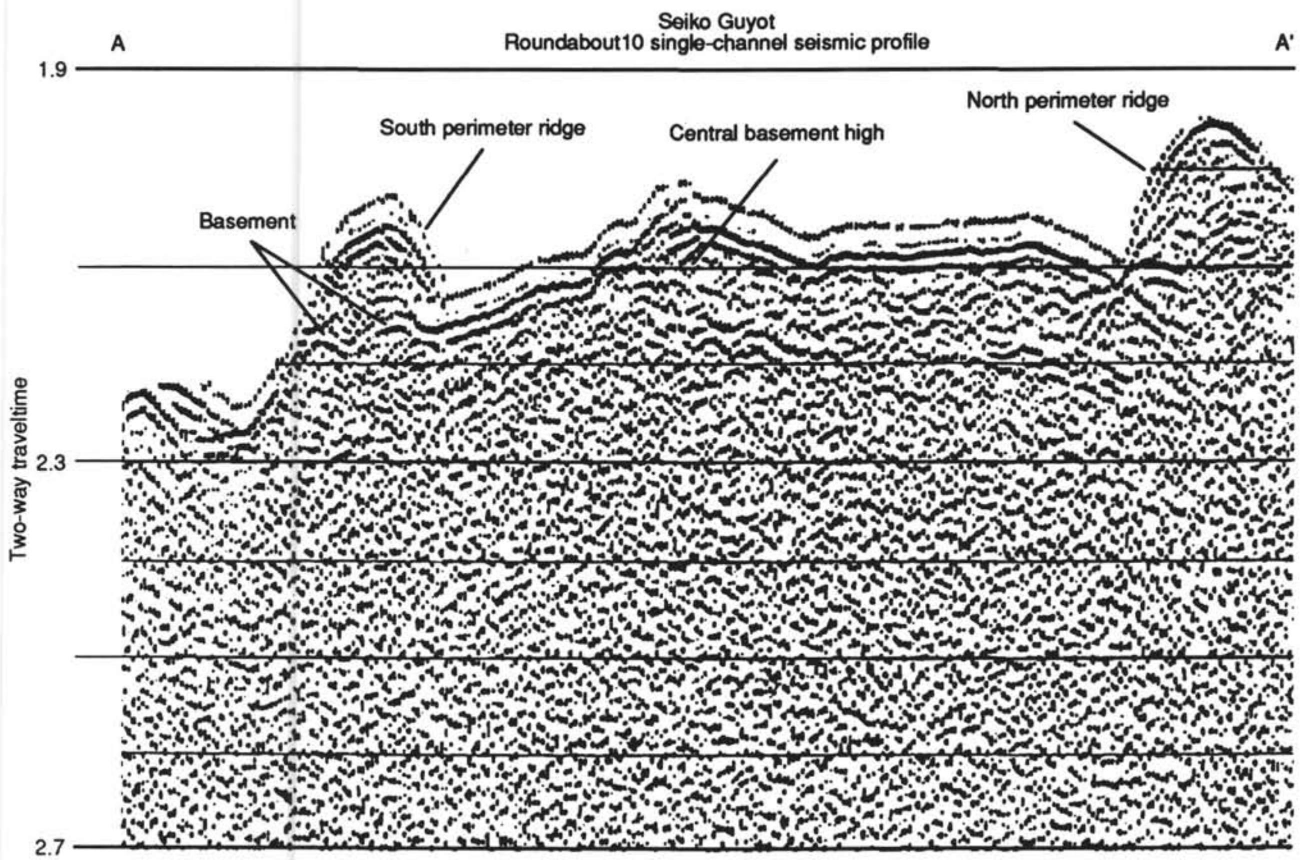

Seiko Guyot
Roundabout10 single-channel seismic profile
A
A'
1.9
2.3
2.7
Two-way traveltime
North perimeter ridge
South perimeter ridge
Central basement high
Basement

Figure 31

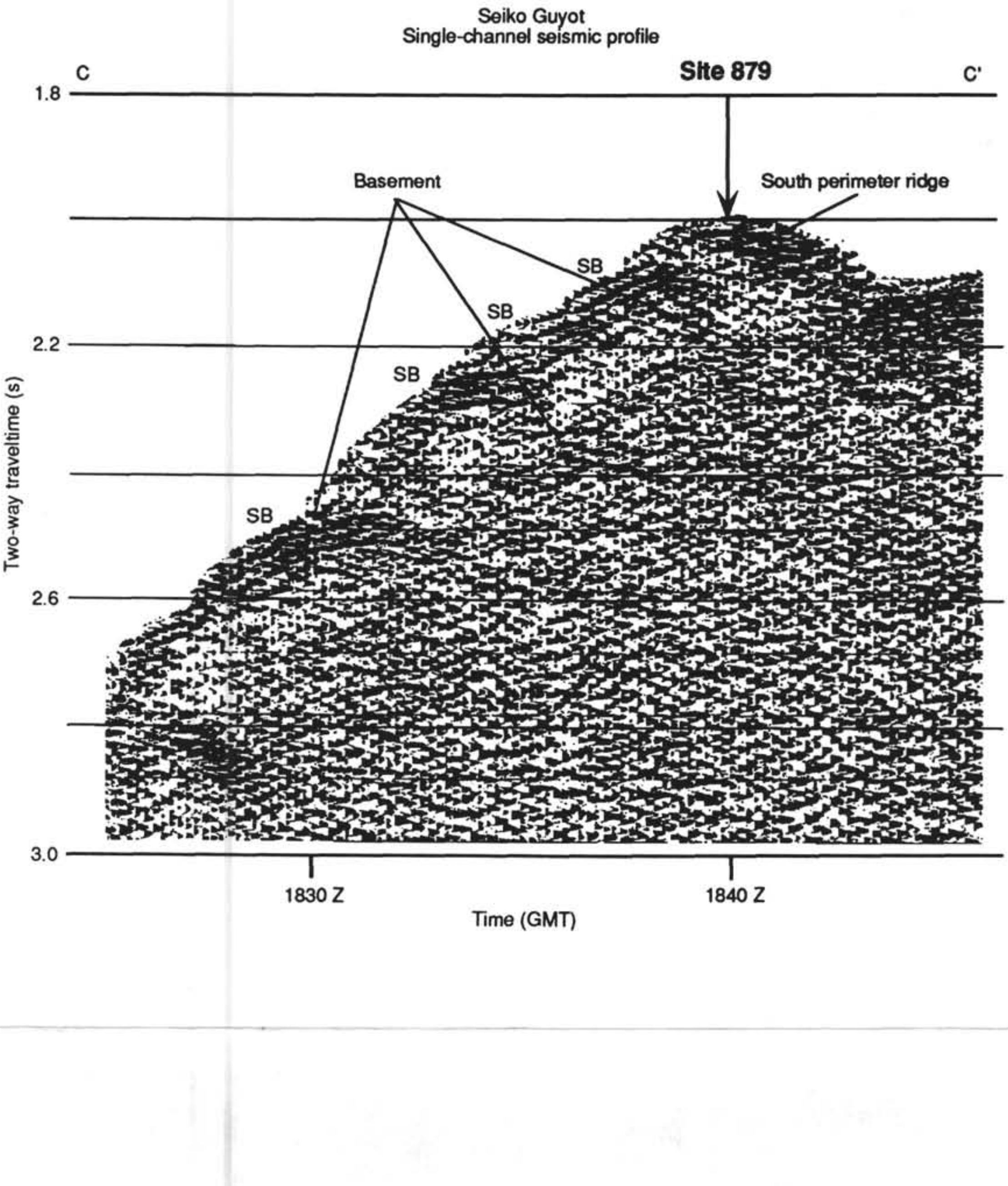

Seiko Guyot
Single-channel seismic profile
C
Site 879
C'
1.8
Basement
South perimeter ridge
SB
SB
2.2
SB
Two-way traveltime (s)
SB
2.6
3.0
1830 Z
1840 Z
Time (GMT)

Figure 32

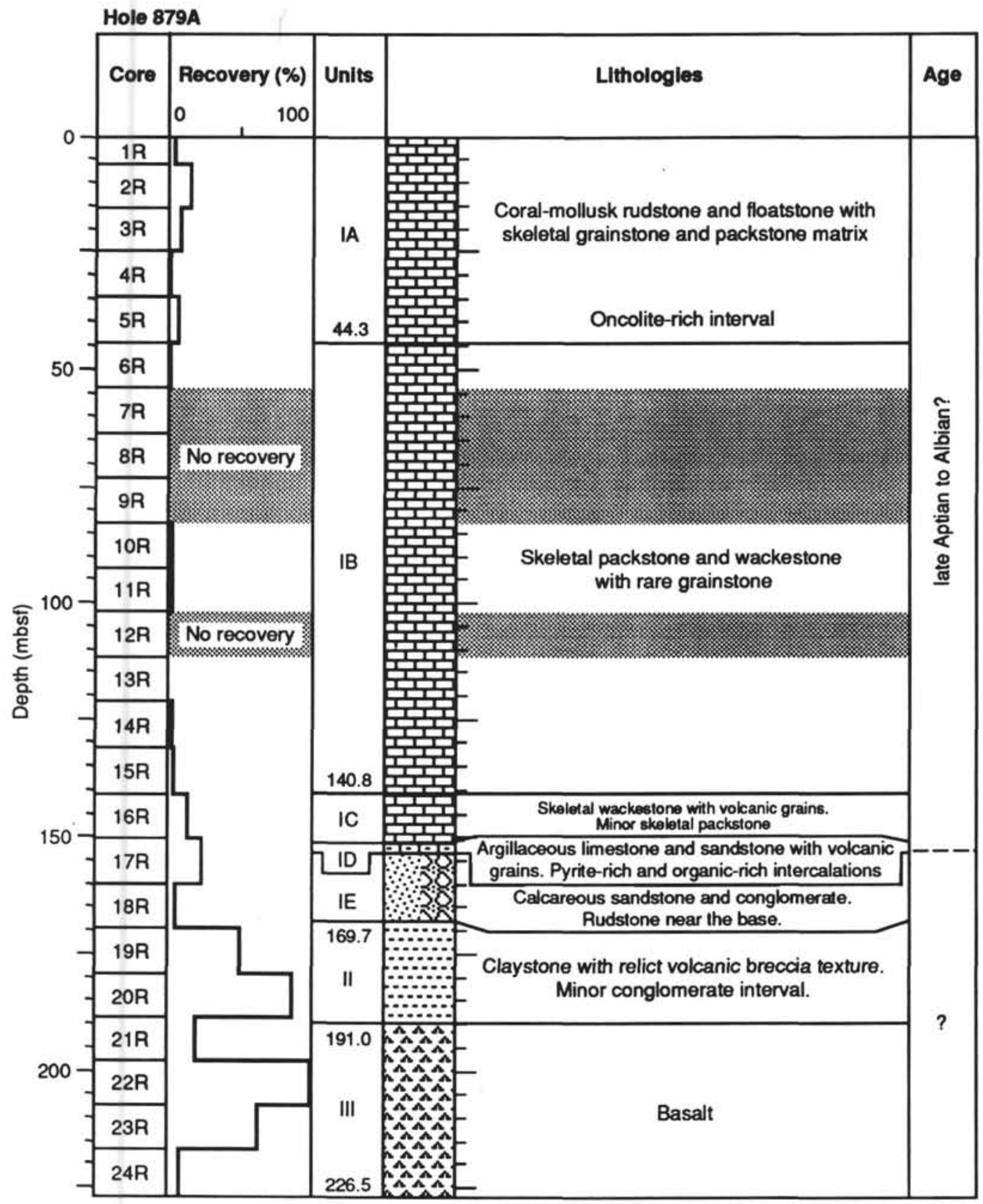

Hole 879A
Core
Recovery (%)
0
100
Units
Lithologies
Age
Depth (mbsf)
0
50
100
150
200
1R
2R
3R
4R
5R
6R
7R
8R
9R
10R
11R
12R
13R
14R
15R
16R
17R
18R
19R
20R
21R
22R
23R
24R
No recovery
No recovery
IA
44.3
IB
140.8
IC
ID
IE
169.7
II
191.0
III
226.5
Coral-mollusk rudstone and floatstone with skeletal grainstone and packstone matrix
Oncolite-rich interval
Skeletal packstone and wackestone with rare grainstone
Skeletal wackestone with volcanic grains. Minor skeletal packstone
Argillaceous limestone and sandstone with volcanic grains. Pyrite-rich and organic-rich intercalations
Calcareous sandstone and conglomerate. Rudstone near the base.
Claystone with relict volcanic breccia texture. Minor conglomerate interval.
Basalt
late Aptian to Albian?
?

Figure 33

OPERATIONS REPORT

The ODP Operations and Engineering personnel aboard *JOIDES Resolution* for Leg 144 were:

Operations Superintendent:	Glen Foss
Development Engineer:	G. Leon Holloway
Schlumberger Engineer:	Steve Kittridge

OVERVIEW

Leg 144 of the Ocean Drilling Program was the second half of a two-part expedition to explore the geology of a number of Western Pacific guyots capped with sediments of Cretaceous age. Cores and logs from the sediments and volcanic rocks were expected to yield information useful in solving problems involving Pacific tectonics, global sea-level history, and the question of carbonate platform "drowning," among others.

The drillship *JOIDES Resolution* departed Majuro in the Marshall Islands on 23 May 1992 and reached port in Yokohama, Japan, on 20 July 1992. Drill sites were investigated on Limalok, Lo-En, and Wodejebato guyots in the Marshall Islands and on MIT and Takuyo-Daisan guyots as the southeast-northwest drilling transect progressed. In addition, ODP Hole 801C in Pigafetta Basin was revisited for the purpose of logging and other downhole measurements. In total, 20 new holes at 10 sites were drilled.

Notable operational highlights and achievements of Leg 144 included:

- The use of alternative coring systems (MDCB and DCB) to improve coring performance in difficult-to-recover lithologies;
- Spudding 10 holes at locations where sediment cover was 0-5 m with minimal loss of BHA hardware;
- The first use of the mini-HRB (hard-rock base) for a deep penetration into sedimentary rocks;
- Successful reentry into a fully-obscured free-fall reentry funnel (FFF) to save logging objectives at Hole 871C; and
- The use of the "anti-whirl" PDC drag-type bit as alternative technology for RCB coring in sedimentary rocks.

MAJURO PORT CALL

Leg 144 began with the first mooring line in the harbor of Majuro Atoll, Republic of the Marshall Islands, at 1200 hr 19 May 1992. The charter flight arrived with most of the oncoming crew and ODP technical staff early on 20 May. The crew change took place the same day, and air freight from the charter was loaded. The work load was relatively light but 207,000 gallons of fuel and

5000 gallons of drill water were loaded in addition to air and surface freight and consumables. Work items for ODL (Overseas Drilling Ltd.) included replacement of rudder stock bolts and repair of an underwater fuel tank leak (by divers), welding repairs to one of the ship's main girders, repair of a high-pressure air compressor, and repair of labstack chill water lines. Divers also made an unsuccessful attempt to repair ODP's dome-mounted 3.5-khz echo sounder. Other work items included replacement of the logging cable with the longer on-board spare, inspection of hoisting equipment, and drawworks maintenance. *JOIDES Resolution* departed Majuro after port-call activities were completed. and the last line was on board at 1315 hr 23 May.

TRANSIT FROM MAJURO TO LIMALOK GUYOT (SITE 871)

Two hours were required to steam across Majuro Lagoon and exit into open ocean. After passing outside the lagoon, the magnetometer was streamed, and soundings were made with the 3.5- and 12-kHz echo sounders. The ship headed southward past Arno Atoll and around Mili Atoll toward Site 871. A seismic profile was shot, using a 200-in.^{3} water gun, along a north-south transect over Limalok (Harrie) Guyot and through the positions of proposed sites Har-1 and Har-2 in order to carefully assess the basement reflector. A positioning beacon was launched at proposed site Har-1. The ship continued on a northward track and launched a beacon at Site 871 (Har-2) at 0900, officially beginning site operations for Leg 144. Total steaming distance, including inside steaming and survey, was only 173 nmi from Majuro.

HOLE 871A

Continuous APC cores were taken in unconsolidated nannofossil foraminifer ooze and foraminifer ooze. The ooze had an extraordinarily high water content, contained only small percentages of nannofossils and/or clay, so that liquefaction occurred when it was disturbed. Core recovery was good (83%), but the liquefaction exhibited by the cores and the sandy texture of the sediment led to unstable hole conditions. Magnetic orientation was attempted on Cores 144-871A-3H to -9H, but these efforts were discontinued because of the fluid nature of the cores, and the tendency of the drill string to stick while it was motionless for multishot exposures. The use of "pills" of drilling mud apparently stabilized the hole after a depth of about 100 mbsf (meters below seafloor) was reached. The contact with the limestone platform was indicated by a change in drilling parameters at 139.5 mbsf. Two XCB cores were taken to a total depth of 151.9 mbsf, with only a few lumps of rubbly limestone recovered in each (0.5% and 4.2% recovery). The bottom-hole assembly (BHA) was raised above the seafloor for a second set of APC cores through the pelagic sediment section.

HOLE 871B

Continuous APC cores were taken to refusal at 133.2 mbsf in easily liquefied foraminifer sand/ooze. The temperature-recording shoe was run on Cores 144-871B-3H, -6H, -9H, and -12H, with three of the four attempts recording usable data. Hole conditions were somewhat better than in Hole 871A, though mud flushes were required. The average core recovery of 68.2% was not as good as the recovery from Hole 871A because two core barrels from Hole 871B were recovered empty. At Hole 871B, two XCB cores were attempted across the limestone platform contact at 133.2 mbsf, but again, only a few pieces were recovered in each core (1.3% and 0.8% recovery). Coring attempts were terminated at 152.4 mbsf.

HOLE 871C

After washing through the pelagic cap to 133.7 mbsf, continuous RCB cores were recovered to 500 mbsf. Annular velocity was kept below 50 m/min during the drilling to minimize hole erosion in the unstable foraminifer ooze, but sticking tendencies and fill on connections signaled the need for occasional mud pills. Continuous RCB cores through the sedimentary section of the platform produced low core recovery (3.5%) despite the utilization of various combinations of drilling parameters. The upper 250 m of the shallow-water limestones were generally friable and drilled at an average penetration rate (ROP) of over 40 m/hr. The average core recovery rate in this upper portion of the limestone was only 2.8%. The next 40 m of limestone was harder, coring at a somewhat lower ROP and a slightly better recovery rate of 5.2%. At 422.9 to 451.5 mbsf, clay was penetrated; core recovery jumped to 47.8% while ROP fell to an average of 9 m/hr. Altered basalt, encountered at 451.5 mbsf, was cored to 500 mbsf. Core recovery in the basalt was about 63.7%, and ROP fell to about 3.5m/hr.

A circulating pressure drop midway through the final core was misinterpreted as a bit seal failure, but this apparently signaled the unseating of the inner barrel after the core liner became jammed. Additional basalt core entered the bit sub cavity and fouled the float valve after the barrel unseated.

As the wiper trip began, an avalanche of cuttings from up-hole flowed back through the open float and filled the lower stand of the BHA, necessitating a round trip for logging. We dropped the free-fall reentry funnel (FFF) before POOH but the sonar/TV found no sign of it in a seafloor crater 8-10 m wide. We made a successful reentry and cleaned the hole easily to TD. There was trouble shifting the mechanical bit release (MBR) sleeve and then getting the bit to fall off. Attempts to log the lower hole with the Japanese magnetometer was no good; this light tool stopped on a bridge in the clay/volcanic section, and then stopped on a clay ball inside the string. We ran standard Schlumberger logs across the limestone section of the hole (did not attempt the lower portion). The logs were good, except that the sonic and FMS suffered from having a large-diameter hole. When the BHA was recovered, the retainer ring and sleeve were missing from the MBR. We easily recovered both beacons at Site 871 and one at proposed site Har-1. After retrieval of the third beacon, an expendable sonobuoy was deployed to obtain wide-angle reflection and refraction data in order to estimate the acoustic velocity structure of the guyot summit. This short seismic experiment was shot over the southwest edge of Limalok Guyot. The seismic gear was retrieved, and transit to proposed site Pel-3 began at approximately 0700 hr on 31 May.

TRANSIT FROM LIMALOK GUYOT TO LO-EN GUYOT (SITE 872)

The ship track to the second drill site led to the northwest between Jaluit and Ailinglapalap Atolls, then passed south of Ujae Atoll, in the Republic of the Marshall Islands. An excellent average transit speed of 11.8 kt was maintained. A 200-in.^{3} water gun was streamed, and the approach survey began about 10 nmi southeast of proposed site Pel-3. The seismic line was shot along a southeast-northwest transect over only the southern part of Lo-En Guyot; a sonobuoy experiment was simultaneously conducted during the seismic profiling. A positioning beacon was dropped at 1345 hr on 2 June to begin operations at Site 872. The total distance traveled, including surveys, was 644 nmi.

HOLE 872A

APC cores were taken to 144 mbsf in very soft foraminifer sand and ooze, and then a 30-cm XCB core was recovered in basalt. Hole conditions were poor from about 60 to 120 mbsf due to foraminifer sand flowing into the hole around the BHA; periodic mud flushes were required. The drill string became stuck while Core 144-872A-11H was being retrieved from 100 mbsf, and an overpull of 130K lb was required to free it. APC coring conditions were fair to poor within the fluidized core material; there were two zero-recovery cores when sediment apparently escaped through a gap in the core catcher flapper valve.

Cores 144-872A-5H to -12H were magnetically oriented; heat-flow data were collected during Cores 144-872A-4H, -7H, and -10H using the Adara shoe. The orientation and heat flow programs had to be discontinued because of adverse hole conditions. Incomplete strokes of the core barrel on Cores 144-872A-11H and -12H appear to have coincided with a reflector on the 3.5-kHz echo-sounder record, but no hard strata were noted in the cores or by drilling parameters. Full stroke then was regained until Core 144-872A-17H (to 143.7 mbsf), when the core barrel struck middle Eocene phosphatized foraminifer limestone that contained fragments of basalt and a reworked, phosphatized Santonian pebbly conglomerate. Coring then switched to XCB mode. Core 144-872A-18X encountered hard drilling with an extremely low ROP. The core barrel was pulled after only 30 cm of penetration and contained 24 cm of basalt core. Plans to attempt MDCB cores of limestone were abandoned because of the unexpected occurrence of basalt.

HOLE 872B

Hole 872B was drilled/washed to 77 mbsf, where RCB coring commenced. After three successive cores, to 106 mbsf, only a few lumps of firm foraminifer ooze were recovered, and hole problems returned. The hole was then drilled ahead from 106 to 135 mbsf, the "wash barrel" was recovered, and continuous coring began. Fragments of a hardground, as well as phosphatized limestone conglomerate in contact with the underlying basalt, were recovered from Hole 872B at 144.8 mbsf; the basalt contact was within a meter of its depth in Hole 872A. Hole conditions had stabilized by the time hard-rock coring began, and operations proceeded smoothly with an average ROP of about 2.8 m/hr with core recovery of over 50%. The drill string became stuck just after the core barrel for Core 144-872B-9R was dropped, apparently the result of loose rocks in the hole beside the BHA. The pipe could not be rotated or moved vertically, so after several minutes of "working" the pipe to free it (as much as 150K lb up and 60K lb down), multiple attempts were made to jar the BHA loose, but the Hydrolex jars could not be cocked. After left-hand torque was applied to the pipe, the pipe came free in the hole, indicating that a connection between the jar body and the lower sub had backed off; however, the string was lowered carefully with slow rotation and moderate circulation, and the connection reengaged successfully. When only moderate right-hand torque was applied, the stuck BHA suddenly broke free, and normal parameters were regained. A mud flush was circulated, and the final core was cut and recovered without incident. A wiper trip was made to prepare the hole for logging. The condition of the hole was found to be less favorable than anticipated, but the hole eventually was cleaned out to total depth. Ultimately, logging proved to be unsuccessful, as both geochemical tools on board the ship would not calibrate properly during in-pipe checks. The drill string was recovered; the BHA was changed to the APC/XCB configuration.

HOLE 872C

In order to salvage Site 872 for the high-resolution stratigraphy objective, we implemented a different method of handling cores upon arrival on the rig floor. Excess water at the top of a core was removed with a device (named a piglet) that was inserted into the core liner while the core was upright within the core barrel on the rig floor. The surficial water flowed through the central portion of the piglet, until the piglet contacted the upper surface of the sediment. The core barrel was then placed horizontally for removal of the core liner and draining of excess water. The piglet inside the core liner prevented the sediment from sloshing during the removal of the liner from the horizontally placed core barrel, and during the transport of the core to the catwalk for subsequent labeling and cutting into sections. After the core was cut into sections, each section was turned upright to permit additional excess water to rise to the top for removal. In this manner, we were able to achieve recovery of cores in which details of mottling, sharp changes in color and lithology, and sedimentary structures could be observed.

We collected continuous APC cores from the seafloor to 139.5 mbsf in watery foraminifer sand/ooze; unstable hole conditions below 60 mbsf required mud pills. Magnetic orientation was attempted for all APC cores starting with Cores 144-872C-4H to -16H. Incomplete stroke was indicated on Core 144-872C-12H from 104 mbsf, but full stroke was regained on Cores 144-872C-13H and -14H. Cores 144-872C-15H and -16H also had incomplete strokes in upper Oligocene foraminifer ooze. The XCB system was used to core from 139.5 mbsf. A hard contact was encountered in Core 144-872C-17X, where upper Oligocene foraminifer ooze was found to overlie clay and basalt; the contact was noted by changes in the drilling parameters at 142.5 mbsf. Core 144-872C-17X became jammed immediately upon encountering the harder material (250 gpm). The ROP through the unrecovered 4.5 m seemed high for the XCB in basalt;

an additional core was attempted in an effort to recover more transitional material from the contact zone. The tungsten carbide cutter shoe was used for both. A higher circulation rate (380 gpm) was used for Core 144-872C-18X, which penetrated 2 m in 1 hr. The core barrel recovered 1.71 m of altered basalt. Since sedimentary strata were not located within the 50 m drilled beneath the basalt contact, achievable objectives of the site were considered fulfilled, and the drill string and beacons were recovered.

TRANSIT FROM LO-EN GUYOT TO WODEJEBATO GUYOT

The ship left Site 872 and sailed northeast to Wodejebato (Sylvania) Guyot in the Republic of the Marshall Islands; the transit speed was only about 10.3 kt as a consequence of opposing winds and currents. Speed was reduced in order to stream the 200-in.^{3} water gun as the vessel approached Wodejebato Guyot from the southwest. A seismic profile, shot across the entire width of the guyot, passed through proposed sites Syl-2A, Syl-1, and Syl-4. Profiling continued past the northeast flank of the guyot, and then the ship reversed direction to survey from the east-northeast to the location of Syl-2A. A sonobuoy experiment was conducted over the eastern edge of the guyot. A positioning beacon was dropped on the second crossing of proposed site Syl-2A at 0545 hr on 7 June. The profile continued for about 2-1/4 nmi before the gear was recovered and the vessel took station on the beacon. Total steaming distance, including the survey, was 193 nmi.

HOLE 873A

The pelagic cap was drilled in about 45 min to 53.4 mbsf, where the first real resistance was encountered by the bit. The "wash" core barrel then was recovered, and continuous RCB coring commenced. The first four cores (to 88.3 mbsf) were cut in poorly cemented limestone that crumbled upon contact with the bit. ROP was approximately 40 m/hr, and average core recovery was 2.5%. The limestone then became better indurated, and recovery increased to about 16% in the denser limestone. Near 156 mbsf, the limestone gave way to 20-25 m of clay and altered volcanic material. There was some hole trouble and bit plugging after penetrating the clay section, but it responded to the deplugger, a wiper trip, and mud flushes. Basalt was encountered in Core 144-873A-14R at 175 mbsf. Circulating pressure was abnormally high following retrieval of Core 144-873A-14R, indicating a partially plugged bit. Coring resumed in basalt and volcanic breccia to TD at 232 mbsf; the ROP occasionally fell below 1 m/hr. Core recovery varied from poor to good; poor recovery was related to jamming of the core catcher with basalt. A full suite of logs was successful for the entire limestone and volcanic section of the hole, but we had to rig the SES and help two of the three tools past ledges with the drill string. No hydrocarbons were encountered. Two beacons failured. The hole was terminated because objectives were reached.

HOLE 873B

Continuous APC cores were taken from the seafloor to 58 mbsf; good recovery but fair-to-poor quality in watery foraminifer sand/ooze material. Excess water at the top of the cores was removed with a piglet that was inserted into the core liner while the core was upright within the core barrel on the rig floor. Core 144-873B-7H from 54 mbsf gave an indication of an incomplete stroke of the core barrel when the APC hit bedrock and shattered the core liner; the impact also sheared the GS pin on the retrieving tool and required two extra wireline trips to replace the pin and retrieve the barrel. The MDCB was used from 58 to 69 mbsf (Cores 144-873B-8N to -10N); this yielded a 39.1% recovery even though all three cores eventually jammed. Material ranged from friable heterogeneous reef rock to poorly cemented carbonate beach sand and was highly unfavorable for coring. The high rate of recovery did have a disadvantage; six times the length of time was needed to core the 11-m interval with the MDCB system than with the RCB. The hole was terminated because the objectives were fulfilled and time was running out.

TRANSIT TO SITE 874

The ship departed Site 873 with the 200-in.^{3} water gun streamed for a seismic survey and soundings being made with the 3.5-kHz echo sounder. At approximately 6 nmi from Site 873, a series of seven crossings over two narrow ($\leq$ 0.5 nmi wide) perimeter ridges along the north-northeast rim of Wodejebato Guyot were made in order to characterize these perimeter ridges and select the location of Site 874. After 5 hr of surveying, the positioning beacon was launched.

HOLE 874A

The VIT was deployed during the initial pipe trip. A reconnaissance of the seafloor was conducted, and a small depression was located that could potentially supply lateral containment of the bit for spudding. The bit was set into the depression and held there by means of the drill string motion compensator while the VIT was recovered to the ship. Irregular torque occurred during the initial spudding of the hole; a minimal weight on bit (WOB) of 6-10K lb and a rotating speed of about 40 rpm were maintained to prevent the bit from skating on the seafloor or stalling. ROP was relatively slow; approximately 2.5 hr were required to cut a 7-m core. The drill string began torquing and sticking in the hole while the first core was being recovered. A 1.5-m core of limestone was recovered, and a second core of 3 m was cut in 1 hr. Hole conditions seemed normal during the coring operation, but severe torquing and sticking occurred as soon as the bit was lifted off bottom for the wireline trip. A viscous mud sweep was circulated while the pipe was "worked" in the hole to free it. The drill string eventually became firmly stuck, apparently by chunks of limestone above the bit wedging it in the bit-sized hole. The connection between the top sub and the outer core barrel (OCB) failed during attempts to free the pipe. Upon recovery of the BHA, it was observed that the drill collar, bit sub, and bit were left in the hole. In addition, the inner-barrel assembly had parted at the connection between the barrel tube and the swivel. The latch and swivel were trapped in the failed and deformed connection, with the swivel extending about 40 cm below the pin. A buckling-type failure of the top sub pin was apparently induced while the pipe was being "worked" and unavoidable cycles of too much down-weight were applied, though actual separation occurred during heavy overpull.

HOLE 874B

The new BHA was given an electromagnetic inspection as it was run through the rotary table, in case other connections were damaged. No other damage was found. As at Hole 874A, the VIT was run, and the string was spaced out for coring. Prior to starting the search for a new site, Hole 874A was videotaped with the OCB extending about 2 m above the seafloor. Following this, the new drilling location was determined by a survey of the seafloor topography that lasted about an hour. About 50 m west of 874A, a sediment chute was located adjacent to an outcrop that stood about 1 m above the sediment surface. By landing the bit on the side opposite the outcrop and then in the chute, the chute was estimated to be about 1.5 m wide and 0.5 m deep. The bit was kept in the middle of the chute with the motion compensator while the VIT was recovered.

The first few meters of limestone were denser than at Hole 874A, with ROP averaging less than 1 m/hr for the uppermost 3.5 m. An 8-m interval of softer limestone then permitted burial of the core barrel before another hard layer was penetrated. Core recovery averaged 14.9% over the first

86.2 m, but a trend toward higher ROP with depth was accompanied by a trend toward reduced recovery. The interval from 86.2-116.8 mbsf cored at up to 100 m/hr, produced a total of 20 cm of skeletal coral packstone in the upper 15.5 m, and no recovery in the lower 15.1 m. The underlying grainstone displayed an increase in recovery, above the contact (162.8 mbsf) with clay. Core recovery was good in the 14.9 m of clay and claystone (162.8 to 177.7 mbsf; 58.3%), and in the 15.8 m of altered basalt (177.7 to 193.5 mbsf: TD; 44.7%). In the basalt, ROP fell to 1 m/hr at times. We terminated coring because objectives were reached, but slightly short of the planned "rathole" because of low ROP in basalt. A wiper trip was made in preparation for logging and a standard suite of Schlumberger logs was run. The geophysical tool string was stopped by an apparent bridge at 176 mbsf (the clay zone). FMS and geochemical logs were recorded successfully; both tools recorded data as deep as 171 and 168 mbsf, respectively. After logging was completed, the backup geochemical tool was picked up and run down the pipe to 100 m for in-pipe calibration checks. The tool was determined to be operational and was recovered.

HOLE 875A

A location approximately 0.5 nmi to the north of Site 874 was chosen for the drill site. The move was accomplished in DP mode after the Site 874 beacons were recovered and while the drill-string round trip was in progress. The VIT was run for a seafloor survey to find a favorable location. The relatively flat sandy area had 1-m-high outcrops coated with a manganese crust. After about 1.25 hr of survey in the outcrop region, a rock-rimmed depression was found that was about 1.2 m deep and 1.5 m across and floored with a thin sediment accumulation. The bit was set into the "natural reentry cone," and the drill string was compensated while the VIT was recovered.

Hole 875A was spudded, and the first core of 11 m was drilled in 13 min. The core barrel recovered 25 cm of coarse, poorly cemented skeletal grainstone. The hole showed indications of caving, and did not yield the anticipated indurated limestone; therefore, the hole was abandoned in the hope that the debris was a localized occurrence.

HOLE 875B

Another VIT reconnaissance was conducted, and a second (slightly broader) sediment-filled depression was located about 10 m northwest of Hole 875A in an area of hummocky outcrops.

Rotation began, and again the bit had the same rapid ROP. Recovery was 36 cm of the Maastrichtian skeletal limestone. Coring then proceeded in the hope that reef rock would be found beneath a veneer of carbonate-sand debris. After drilling Core 144-875B-4R to 40 mbsf with no change in results and an average core recovery of 4.9%, the hole seemed to collapse, and the drill string became temporarily stuck during retrieval of the core. The hole was abandoned because of poor hole conditions and low core recovery and to switch to an alternate coring system.

HOLE 875C

We decided to retrieve the pipe and change the rotary system to a diamond core barrel (DCB) system utilizing a Geoset bit in an effort to improve recovery in the poorly cemented skeletal grainstone. In addition, the irregular but low-relief (≈ 0.5 m) seafloor was considered acceptable for a bare-rock spud without any further VIT survey. Hole 875C was spudded in 1409 m water depth and 16 m north-northwest from Hole 875A. The spud was accomplished with minimum rotation speed (≈ 40 rpm) and just enough WOB to keep the bit from lifting off the bottom. Maximum vessel heave was about 1 m. The first meter required 18 min to penetrate; the ROP increased slightly with depth and 63 min elapsed before the 9.5-m core was cut. When the barrel was recovered, a piece of manganese crust was found at the top of the core with "spin" marks on its lower surface, indicating that it was jammed in the throat of the bit and taking much of the limited bit weight away from the cutting structure; there was about 50 cm of limestone beneath the crust. Coring then continued in poorly cemented skeletal grainstone and rudstone, resulting in increasing ROP and decreasing core recovery. Hole-cleaning problems began after Core 144-875C-4M, and the pipe became firmly stuck while the barrel of Core 144-875C-5M was being retrieved, despite the use of mud sweeps. Apparently, unconsolidated carbonate sand had collapsed around the drill collars and filled the narrow (7-1/4 in. by 6-3/4in.) annulus. After about 45 min, the string was worked free with 120,000 lb overpull and high torque. Additional mud sweeps were successful in cleaning the hole, and coring resumed. A similar, but less serious, sticking incident occurred on Core 144-875C-13M, but again the hole restabilized with mud sweeps. No further hole trouble was encountered. Average core recovery in these poorly cemented limestones was 13.2%, but this was still more than double the recovery obtained using the RCB system in similar material in Holes 875A and 875B. At 126.3 mbsf, the bit contacted basalt. Highly altered and fractured basalt was cored from 126.3 to 133 mbsf; both cores became jammed. Drilling was terminated at 133 mbsf (TD) because objectives were achieved and the drill string was recovered. The positioning beacon was recovered after the bit cleared the seafloor, and the DP/GPS move to Site 876 began while the pipe trip was in progress.

Overall performance of the DCB Geoset bit in the basalt was roughly equivalent to the RCB, but the DCB bit was not designed for drilling igneous rock. Upon recovery, the DCB bit was found to have severe damage to the cutting structure; most of the diamond cutters were sheared off or broken and about 3/4 of the cutting structure was gone. If the bit had not been pulled and we had continued to drill, the outer 1/3 of the face of the bit would have worn out prematurely in comparison to the other cutting surfaces on the bit.

HOLE 876A

An additional effort was made to improve recovery and to evaluate alternative coring hardware; the RCB BHA was fitted with a drag-type "anti-whirl" polycrystalline-diamond-compact (PDC) bit. No VIT survey was conducted prior to spudding Hole 876A because the 3.5-kHz records indicated about 4 m of pelagic cover. This thin pelagic sediment cover was expected to provide enough lateral resistance to prevent the bit from "skating" on the hard manganese-encrusted phosphatized hardground. We punch-cored 3 m of soft pelagic cap before hard resistance was met at 3 mbsf; minimal weight and circulation were applied to begin coring the limestone. Little penetration was made for a few minutes, but then an increase in torque signaled that the PDC cutters had begun to bite into the hardground. After one hard meter, the bit broke through into much softer material, and only 22 min were required to core the initial 14.2-m interval. The hole was "over-drilled" by a few meters to ensure that a connection could be made without pulling out of the hole. Upon recovery, the first core contained none of the soft pelagic material, but the manganese crust and associated phosphatized hardground were recovered. Below the hardground was some poorly cemented grainstone; total recovery was 62 cm.

As coring continued, hole-cleaning problems again appeared at about 40-50 mbsf, and it was necessary to spend about 30 min freeing the pipe and cleaning the hole after Core 144-876A-5R. As before, the hole stabilized, and there were no further hole troubles. Core recovery in the poorly cemented grainstone was somewhat lower than with the DCB, but a 3-m-thick bed of packstone that was not well represented at Site 875 was recovered at Site 876. Basalt was contacted at

145 mbsf and was cored to total depth at 154 mbsf. Bit performance was essentially equivalent to that of the other coring systems, but the condition of the highly altered and fractured basalt made it a poor standard of comparison. Using the anti-whorl PDC, the average recovery was only 9.6%, with a range of 35.4% to less than 1%. Upon recovery of the string, the bit showed considerable wear to the cutting structure, with the diamond cutting edge chipped away on the majority of the PDC's; tungsten carbide studs were apparently drilling the basalt. One jet nozzle was missing, and one was plugged with claylike material, a drilling artifact from the altered basalt. Very little body wear or other damage was noted. The hole was terminated when the majority of scientific objectives were completed and the ROP was too low.

HOLE 877A

After completion of Hole 876A and while the pipe trip was in progress, the transit to Site 877 was accomplished in dynamic-positioning mode. Bathymetry and sediment cover were monitored using the record from the 3.5-kHz echo sounder to ensure that the swale was crossed between the inner and outer perimeter ridges. The positioning beacon was recalled upon departure from Site 876 and was redeployed for Site 877.

The short, light "bare-rock" RCB BHA was assembled, this time with a conventional RBI C-3 roller-cone core bit rather than a C-4 roller-cone core bit. This C-3 bit is designed for medium density formations, and therefore has a slightly softer cutting structure than was used at previous RCB bare-rock spud sites. The change in operational strategy was an attempt to maximize ROP in the uppermost section composed of manganese crust, hardground, and indurated limestone with the very limited available BHA weight in a nearly bare-rock spud-in location. The 3.5-kHz echo sounder records had indicated 5-7 m of soft pelagic cover at the site, but only 1 m was found upon spudding the hole.

The bit rotated for some time on the hard crust before it began to drill; over an hour was required to penetrate the first meter of limestone. Coring continued in hard limestone at a slow rate, with only minimal drill-collar weight and slow rotation. The ROP averaged only about 2-1/2 m/hr for the first 50 m. Core recovery over the interval was about 21% and was consistent with the observed inverse relationship between core recovery and ROP. Below 77 mbsf, boundstone and rudstone gave way to less cemented and more rubbly grainstone. The poorly cemented grainstone cored at rates up to 300 m/hr, and core recovery was predictably minuscule. The grainstones became better cemented below about 150 mbsf, but core recovery remained only about 4%. ROP decreased somewhat at about 184 mbsf in Core 144-877-20R, and hard drilling was encountered at about 189 mbsf. When the bit had reached 190.5 mbsf, the core was recovered to confirm that the basalt objective had been reached. The core barrel contained nearly 5 m of varicolored clay overlying about 1 m of altered basalt. We had 90K lb overpull through the hard-rock section at the top on the trip out. The hole was terminated when the drilling objective was reached.

TRANSIT FROM WODEJEBATO GUYOT TO HOLE 801C

JOIDES Resolution departed Site 877, on Wodejebato Guyot, at 1030 hr on 21 June. The average transit speed of 11.7 kt over the 636 nmi voyage yielded an arrival at Site 801 at 1500 hr on 23 June. Speed was reduced, and the ship was maneuvered to the geographic coordinates of the reentry cone of Hole 801C by GPS navigation. At 1545 the vessel was stopped, and the thrusters and hydrophones were lowered. Once in DP mode, the ship was positioned more precisely, and a positioning beacon was launched at 1630 hr on 23 June.

HOLE 801C

We relocated the hole without difficulty; we had to lengthen the working drill string by eight stands of new 5-in. pipe to reach the second packer setting depth. Reentry maneuvering time was about 1 hr but the cone target was found immediately; a sonar target about 30 m from the cone may have been the VIT lost on Leg 129, but there was no time to investigate. We used a combination of the plastic pig and rubber top plug (twice) in attempts to clean rust from the pipe.

The TSP (TAM straddle packer) go-devil was run on the bottom of the logging BHA, as we reentered the hole and ran only the BHA into the hole for logging. We ran the Quad Combo log (w/ LDGO temp. tool) to within about 7 m of the total depth of Hole 801C as noted during Leg 129. The temperature of the undisturbed water column was logged by the LDGO self-contained temperature recorder as the tool descended. Good logs of all geophysical parameters were recorded from set-down to the casing shoe, an open-hole interval of about 108 m. The second run with the FMS tool reached about the same total depth as the first pass. Abnormal readings on the caliper logs indicated that the arms may have been fouled during the lower part of the first run and apparently dislodged rocks, which formed a bridge about 40 m short of the total depth. As multiple runs were desired for more complete coverage of the borehole wall, the pads were retracted, and the tool was lowered again after reaching the casing. The tool appeared to operate normally, but it would not pass a newly formed bridge in the hole about 65 m below the casing shoe. The second and third FMS runs were made from that depth; excellent-quality data were recorded. The FMS tool was tripped to the surface and exchanged for the geochemical tool string. That tool also was stopped at the bridge, which apparently formed prior to the second run of the FMS tool. With logging operations completed, the sheaves were rigged down, and preparations were made for the scheduled permeability tests.

About 4 hr were spent in pressure-testing the rig's surface equipment and in stopping minor leaks. The packer was lowered into the open hole for the first set at about 22 m below the casing shoe. The TSP (TAM straddle packer) go-devil, with a Kuster downhole pressure recorder, was pumped into place to actuate inflation of the packer. Pressure was held for a short time to establish a hydrostatic baseline pressure on the record and to test pressure integrity of the entire system. The drill string then was pressured up to inflate the packer, with all indications of a normal set. Two pulse tests were attempted after the initial set; pressure bleedoff was very rapid, indicating high permeability. Two constant-rate injection tests followed, with pressure buildup and decay rates indicating good tests and high permeability. To help ensure that the hydraulic seal of the packer would not be doubted, the packer then was unseated and moved up the hole about 2 m. It was reset with the same indications of normal setting (holding 15,000 to 20,000 lb weight). Three pulse tests were accomplished with the same rapid decay as on the first set. A trip was then made with the coring line to retrieve the go-devil and pressure recorder. The record of the Kuster gauge (the only one aboard rated to 15,000 psi) was useless because of a suspected malfunction of the clock; however, usable data were recorded by surface instrumentation. A second go-devil was dressed with a different clock on the same pressure gauge and also with the clock from the first run on a 12,000-psi pressure gauge that would be operating near its maximum limit. While the go-devil was being prepared, the packer was lowered to the depth of the second planned test, about 63 m below the shoe.

After the go-devil was pumped into place at the TSP, inflation was attempted again. This time the system held about 200 psi for several minutes after the go-devil landed, but normal indications of inflation did not appear when more fluid was pumped to raise the pressure in the drill string. Inflation pressures were held only briefly before the drill-string weight indicator dropped. This was interpreted to indicate that the packer element was acting as a sliding piston and "jacking the pipe up the hole." When the element is torn or punctured, it will partially inflate while transmitting fluid into the open hole below it through the rupture. After several attempts to set the packer, it was raised to the position where it had successfully set earlier, to verify that the present difficulty was not in the setting location. Again the packer failed to inflate, but a constant circulating rate was maintained without pushing the pipe up-hole because of the high permeability of the hole immediately below the packer. After confirmation that the element was "blown," the coring line was run to retrieve the go-devil. The go-devil was found to be stuck, and no amount of pulling and/or jarring could dislodge it. The safety shearpin of the pulling tool was sheared, and the coring line was recovered as the crew prepared for a "wet trip." Surprisingly, the drill pipe came dry --indicating that the rupture in the packer element was sufficient to drain the water from the drill string faster than the pipe was pulled. The interior of the deep-water portion of the drill string was coated with anti-corrosion chemical as it was tripped. When the TSP cleared the rig floor, the go-devil was in its proper setting position, extending beyond the reentry/cleanout bit -- and still firmly stuck. The weight of the lower stand of drill collars had to be used to force the seals out of their seats. The packer element showed four or five deep vertical cuts in the outer covering over most of its length with one or two possible punctures at the ends of gashes. Though water continued to leak from one of those holes in the outer covering during disassembly, the breach in the inner bladder could not be located visually. Inspection of the go-devil revealed the seals and landing ring to be in good condition. The presence of rust grit at the seals was blamed for the sticking, although only a small amount was found. The beacon had been recalled during the pipe trip. When the rig floor had been secured and the thrusters and hydrophones raised, the vessel departed for the next site.

TRANSIT FROM HOLE 801C TO MIT GUYOT (SITE 878)

The 568-nmi transit from Hole 801C to the first waypoint for the survey at MIT Guyot was accomplished with an average speed of 11.8 kt. The 200-in.^{3} water gun was streamed, and the guyot was approached from the south. The local pre-site seismic survey included a north-south crossing as well as an east-west crossing over the northeastern portion of the guyot, and an additional crossing over the proposed site before the ship turned to a reciprocal course and launched a beacon. The 3.5-kHz echo sounder profiles showed no acoustically transparent pelagic sediment. The 4.5 hr required for the survey of 31 nmi were used to position the hard-rock guide base (mini-HRB) on the moonpool doors, suspend it from the traveling block by means of a double-jay running tool, complete its construction, and begin filling its ballast tanks with bulk barite. After the beacon drop, the vessel continued on the final leg of the survey for about 1.5 nmi before the seismic gear was retrieved. The ship returned to the drop site, the hydrophones and thrusters were lowered, and ballasting of the HRB continued.

HOLE 878A

The HRB was landed, and the tilt beacon was monitored for any change in angle as the weight of the HRB was applied gradually. The angle of landing remained at about 5° as additional weight was applied. The VIT was lowered for better viewing, the full 72,000-lb weight of the HRB was set down, and the "J" tool was released. The immediate area was exceptionally flat and smooth, except for a rubbly slope a few meters east, which rose 4 or 5 m to another flat bench. The drill string and VIT were recovered to change the BHA. The BHA was similar to those used for earlier bare-rock spuds, except that a stabilized bit sub was installed, along with a stabilizer just above the OCB assembly. During the round trip, about 4.5 hr after the base had been set, the reading of the tilt beacon suddenly increased from about 5° to about 13°.

The HRB was reentered routinely, and while the motion compensator kept the bit in contact with the seafloor, the VIT was recovered to the surface. Even with minimum weight on bit, slow rotation, and a low circulation rate, a fairly rapid penetration rate was achieved from the seafloor to about 3.5 mbsf; a slower penetration rate occurred as the bit encountered harder material for the remaining 6 m of the core interval. Upon recovery, the first core barrel contained nearly 3 m of pelagic ooze and a small amount of limestone, which was jammed in the core catcher. RCB coring then continued through platform limestone with poor core recovery (average 3.9%). Mud sweeps were regularly used in an attempt to keep the hole clean. Below about 40 mbsf, the familiar pattern of increased ROP and decreased core recovery returned. There was no indication that the 9-13/16-in. stabilizers above and below the OCB had any effect, positive or negative, on coring performance, and there were no torquing or sticking tendencies. By 200 mbsf, the average recovery had decreased to about 2.29%. This exceptionally low recovery prompted us to change from a C3 cone-bit to a Syndax diamond coring bit (DCB) in the hope that recovery would be improved. The round trip/reentry for bit change was made when total depth had reached 202.2 mbsf and the RBI C-3 bit had accrued only 11.25 hr of rotation.

The initial DCB core of 4.7 m was cut with minimum weight, circulation, and RPM to "break in" the bit. The core barrel was recovered with 10 cm of grainstone core and nearly an equal amount of graphite cored from the expendable cap that was installed to protect the bit from contact with the HRB. The second core, cut while using more aggressive drilling parameters, also contained two pieces of core from the graphite cap. Core recovery and penetration rate were not significantly different using the DCB than they were using the RCB system in the interval above. Overall progress was slower than with the RCB, because the low coring circulation rates required the use of mud sweeps to clean cuttings from the large upper part of the hole. At 404 mbsf, circulating pressure suddenly increased by about 200 psi and ROP dropped sharply, indicating either a marked change in lithology or bit failure. As the changes were determined to be formation-related, coring continued. The uppermost clay was poorly recovered, but it apparently was no more than 3 m thick. About 22 m of volcaniclastic breccia then were cored with fairly good recovery before coring was interrupted for a pipe trip and change to RCB. Coring with the DCB system did not improve recovery of the platform limestones; recovery averaged 2.26% in 203 m of limestone.

Hole 878A was successfully reentered with the help of the VIT. The 9-7/8-in. RCB bit was run into the hole to just above the point where coring had begun with the 7-1/4-in. DCB bit. Reaming of the interval from 202 to 428 mbsf proceeded smoothly, averaging 41 m/hr. About 9 m of "hard" fill in the bottom of the hole had to be drilled and washed out of the hole with mud. The "wash barrel" then was pulled (empty), and continuous RCB coring resumed. The drilling in the polymictic breccia was much slower but produced the best core recovery and hole conditions of the entire leg. The 159.3 m of the bit run produced an average core recovery of 73.7% at an average ROP of 3.6 m/hr. Total rotating hours, including Holes 878B and 878C and the reamed interval, reached 51 hr after Core 144-878A-63R, and the drill string was tripped for a change of bit. Upon recovery, the bit was found to be in excellent condition, with all bearing seals effective and negligible wear to the cutting structure and body. An identical bit was selected for the ensuing run, and reentry was again made. The hole was clean to about 53 m above total depth, where a minor bridge was knocked out. In Core 144-878A-64R, the same polymictic breccia gave 100% recovery, but the rate of coring was only about 2.2 m/hr. A drilling break near the end of

Core 144-878A-65R was found to represent limestone, and the typical pattern of high ROP/low recovery returned. After about 123 m of carbonate-platform sediments had been penetrated, basaltic rocks were reached at about 727 mbsf. The lower carbonate section produced an average ROP of 21 m/hr and an average core recovery of 6.5%.

Hole problems started shortly after cutting began on the first full basalt core. The basalt flow units were interbedded with zones of altered volcaniclastic rocks and clays. Some of the clayey material was highly indurated and waxy, making it extremely difficult to drill with the tungsten-carbide insert bit. Some of the clays also proved to be unstable and water-sensitive. The basalt was fractured, causing core-jamming problems. A short "wiper trip" was necessary to replace the knobby drilling joints after Core 144-878A-86R. Up to 40,000 lb of drag was encountered as the bit was pulled to the top of the basalt section; it was necessary to ream most of the section back to total depth and to circulate 7 m of fill from the hole with a mud sweep. Drilling parameters returned to normal, and fresher basalt was cored below 800 mbsf. An interval of highly altered volcanic tuff was penetrated from about 875 to 890 mbsf with excellent core recovery.

After Core 144-878A-95R at 894 mbsf, another short trip was made to replace the knobby drilling joints and to "wipe" the hole to the top of the basalt interval. Two additional cores then were taken to 910 mbsf, where coring was discontinued due to expiration of allotted time in order to begin a logging program. The end of the pipe was withdrawn only to 806 mbsf, just below the depth of the lowermost clay ledge, for an attempt to log the lower basement part of the hole. The FMS logging tool was stopped by an obstruction 27 m above total depth, but a good log of a 78-m basement interval was obtained. By the time the FMS had been recovered to the surface, the drill string had begun sticking in the hole. After the logging equipment had been cleared, the pipe was worked to ± 60,000 lb, and a pressure up to 1500 psi was applied to the annular seal, to break the pipe free. Though the pipe came free in the hole, the risk posed to the drill string was considered to be too great for further logging, and the pipe was pulled to the upper logging depth of 46 mbsf. The next logging attempt was with the long, heavy geophysical tool string, which found its way to 2075 m, about 11 m past the uppermost basalt contact. A good log was recorded all the way to drill pipe, but the quality of the sonic log was degraded by the overgauge hole (in excess of 18 in. for much of the interval). The ensuing logs, the FMS and geochemical strings, were stopped by a bridge that had formed at the top of the basalt; however, they produced good logs through the entire sediment section. A delay of about 1-1/2 hr resulted from a mechanical failure of the sensor pad/arm mechanism on the FMS tool. This failure required the FMS to be retrieved and repaired between the two passes in the hole. The logging equipment then was rigged down, and the drill string was recovered. The two positioning beacons were recalled during the pipe trip.

HOLE 878B/C

Two identical single-core attempts were made to recover the highly interesting pelagic ooze found at the top of Hole 878A. Hole 878B was located on offsets 20 m west of Hole 878A and Hole 878C was located 14 m west by offsets (but was seen on subsequent reentry to be only about 4 m west). In both cases, the seafloor was tagged at 1337.2 m water depth, and about 5.0-5.5 m of soft sediment were penetrated before 0.5 m of underlying limestone was cored. In both cases, only core samples of the overlying manganese crust and underlying limestone were recovered, with no ooze at all. Apparently the crust was better developed than at Hole 878A and jammed the liner sufficiently to keep the soft ooze out (many small nodules were mixed with the sediment in Core 878A-1R). Attempts were abandoned due to time limitations.

TRANSIT FROM MIT GUYOT TO TAKUYO-DAISAN GUYOT

Takuyo-Daisan Guyot is the largest and the easternmost guyot of the Seiko cluster of seamounts in the Japanese Seamounts. The guyot lies about 190 nmi southeast of Inubo Saki on the main Japanese island of Honshu. The local pre-site survey required just over 5 hr and covered about 31 nmi.

HOLE 879A

The drill string was made up with an RCB bit and abbreviated "bare-rock" BHA. While the top drive was being picked up, the VIT frame was deployed for a seafloor survey and selection of a spud site. The seafloor in the selected area was fairly smooth, with essentially no observable microrelief; some areas had a thin blanket of pelagic sediment that obscured the underlying topography. After a reconnaissance of about 1.75 hr, the bit was set down in an area where the outcropping surface of the feature was slightly rough. Motion on the drill string was compensated while the VIT was recovered.

Hole 879A was spudded by applying slow rotation and light weight on the core bit. After a few minutes, an increase in torque showed that the bit was "biting," and a falloff in applied weight indicated that penetration had begun. The initial 6-m core required 80 min to cut, but recovered only 24 cm of core. The pipe began torquing and sticking during the recovery of Core 144-879A-1R. The manner of sticking suggested that rocks were falling into the hole from the seafloor and wedging at the bit. At about 25 mbsf the indurated limestone changed drilling character; the ROP increased dramatically as the bit penetrated friable limestone. Core recovery was about 7% over the upper 54 m of Hole 879A, but below this there were three consecutive zero-recovery cores that were taken through an interval where the average ROP was 42 m/hr. Core recovery then averaged about 4% through interbedded poorly cemented and well-cemented limestones to about 150 mbsf, where increasing volcanogenic components altered the properties of the sediment and increased the recovery rate. Below a few meters of interbedded limestone and ash, the sediment was composed of breccia containing volcanic debris which was highly altered, hard, and waxy, therefore reducing its drillability and also the ROP to 2 m/hr in some intervals. Torque began increasing gradually as Core 144-879-21R was being cut until the top drive stalled, and the drill string stuck at 195 mbsf. The pipe was worked free, and the hole interval immediately above was reamed until torque returned to normal. No further coring problems were encountered. Basalt continued to total depth at 226.5 mbsf, with the ROP increasing as the amount of clayey alteration products decreased. Coring was terminated short of the desired 50 m of volcanic penetration because of limited operating time left in the leg.

We released the MBR but had trouble with the RST sticking in the OCB assembly and not passing through the MBR after downshift. When the end of the pipe had been pulled to logging depth at about 41 mbsf, the logging equipment was rigged, and the FMS tool was run into the hole. It reached to within 9 m of total depth and recorded two passes through the hole up to the depth of the pipe. The log showed hole angle to range from 10° to 13° for the entire hole interval and most of the limestone section to be washed out beyond the 16-in. maximum caliper reading. The FMS tool then was exchanged for the geophysical tool string, which found an additional 3 m of hole fill and also logged up to the depth of the pipe. The oversized hole had an adverse effect on the sonic and resistivity logs. Upon completion of logging operations, the drill string was pulled clear of the seafloor, and the beacon was recovered. As the pipe trip continued, the vessel was offset by GPS and PDR navigation to locate a suitable site for recovery of the uppermost (pelagic) sediments. The BHA was given an electromagnetic ("magnaflux") inspection as it was recovered.

HOLE 880A

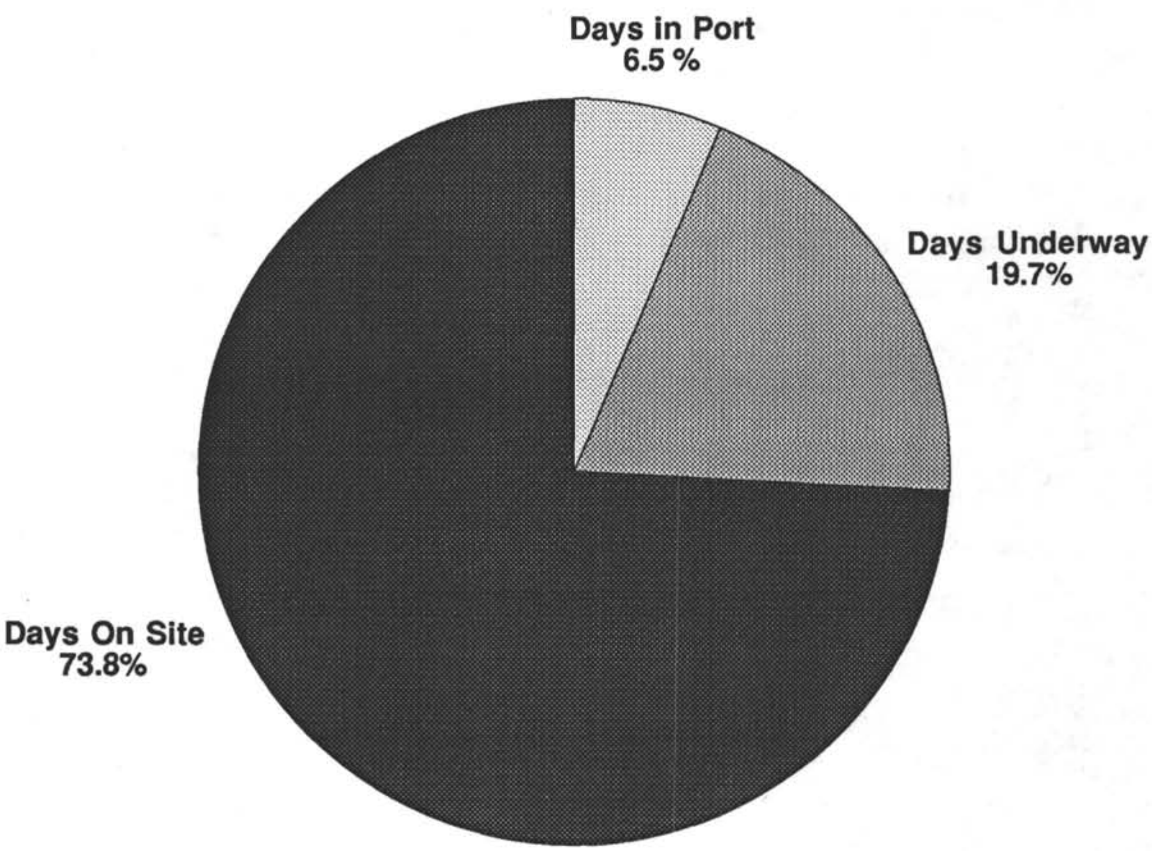
After the drill string was pulled clear of the seafloor and the beacon recovered at Site 879, the vessel began to offset by GPS and PDR navigation to Site 880. Site 879 is located on the southern rim, whereas Site 880 is located on the central summit region of Takuyo-Daisan Guyot. The positioning beacon was redeployed about 2 nmi north of Site 879 as magnaflux inspection of the bottom-hole assembly continued. Hole 880 was APC cored in 1525 m water depth. Two APC cores were recovered at Site 880 with nearly 100% recovery of nannofossil ooze and ash layers. The last core was on deck by 0050 hr 19 July 1992. Drilling operations were terminated in order to prepare for departure to Yokohoma, Japan.

SPECIAL TOOLS REPORT

A discussion of the special tools, bits, and hardware which were used and/or deployed on Leg 144, appear in a separate report. This report is available, upon request, from Barry Harding, Manager of Engineering and Drilling Operations.

LEG 144

TOTAL TIME DISTRIBUTION



Total Days of Leg = 62.8

LEG 144 OPERATIONS SUMMARY

Total Days (19 May-20 July 1992)..	61.8
Total Days in Port	4.0
Total Days Under Way	12.2
Total Days on Site	45.6

Trip Time	8.57
Coring Time	25.73
Drilling Time	0.31
Logging/Downhole Science Time	7.23
Reentry Time	0.60
Repair Time (Contractor)	0.05
Downhole Trouble Time	1.11
Other	2.00

Total Distance Travelled (nautical miles)	3145
Average Speed (knots)	10.6
Number of Sites	11
Number of Holes	21
Number of Reentries	4
Total Interval Cored (m)	3204.6
Total Core Recovery (m)	1087.7
Percent Core Recovered	33.9
Total Interval Drilled (m)	284.5
Total Penetration (m)	3489.1
Maximum Penetration (m)	910.0
Maximum Water depth (m from drilling datum)	5685.0
Minimum Water depth (m from drilling datum)	1093.0

TECHNICAL REPORT

The ODP Technical and Logistics personnel aboard *JOIDES Resolution* for Leg 144 were:

William Mills	Laboratory Officer
Dennis Graham	Chemistry
Erinn McCarty	Curatorial Representative
Matt Mefferd	System Manager
John Eastlund	System Manager
Jo Claesgens	Yeoperson
Brad Cook	Photographer
Eric Meissner	Electronics
Mark Watson	Electronics
Tim Bronk	Thin Sections
Gretchen Hampt	Core Laboratory
"Kuro" Kuroki	Assistant L.O., X-ray
Jon Lloyd	Assistant L.O., Physical Properties
Anne Pimmel	Chemistry
Margaret Hastedt	Paleomagnetics
John Swanson	Student Technician
Jackie Ledbetter	Downhole Tools

SCIENTIFIC OBJECTIVES OF LEG 144

Leg 144 is the second of two legs (Legs 143 and 144) organized to core carbonate-platform-bearing guyots of the Western Pacific. The objective of these legs is to understand Western Pacific tectonics, global sea-level history, carbonate-platform drowning, and the nature of the parent mantle material that produced these volcanic seamounts. To accomplish these objectives, Leg 143 drilled the Limalok (Har sites), Lo-En (Pel sites), Wodejebato (Syl sites), MIT, and Seiko Guyots. In all, we occupied nine sites and cored 19 holes. In addition to the objectives described above, we reentered Hole 801C to complete logging and packer testing left undone from Leg 129.

On 23 May 1992, the *JOIDES Resolution (SEDCO/BP 471)* departed from Majuro Atoll with a crew of 113 (51 scientists and technical staff). Leg 144 ended in Yokohama, Japan on 20 July 1992 after 56 days at sea.

PORT CALL, MAJURO

On 19 May 1992, the *JOIDES Resolution* docked inside the Majuro Atoll, ending Leg 143. On the following morning, most of the technical staff, scientists and drilling crew arrived via a chartered flight from Honolulu and moved immediately aboard. The technical staff completed a hurried but routine crossover so that the offgoing crew could depart on the same chartered flight that day. During the remainder of our 4-day port call, we discharged Leg 143's freight and loaded new supplies. We attempted to repair our 10-kw 3.5 sonar using local divers but were unsuccessful.

LABORATORY OPERATIONS

Underway Operation

Technicians routinely collected bathymetric data on all transits and survey lines and magnetic data on transits only. We used one 200-in.^{3} water gun (with an 80-in.^{3} water gun as backup) as our seismic source for all site surveys. For our navigation, we used GPS.

Sonobouy surveys were attempted on all site surveys with limited success. The poor quality of our current stock of sonobouys limited most surveys to just 1 hr of data before dying. Because of the short transit time and local shipping traffic between the Seiko site and Yokohama, we did not collect any underway data.

SUMMARY OF UNDERWAY GEOPHYSICS DATA (approx.):

Total transit in nautical miles: 3,153
Bathymetry: 2,895
Magnetics: 3,033
Seismics: 258

While on site, we completed several maintenance projects and modifications to the fantail. Technicians completely rebuilt the starboard 200-in.^{3} w/g hose bundle. Gun tow points were moved from the booms to the outboard edge of the helipad. Technicians now handle the tow bundle along the walkways on either side of the SEDCO warehouse and the U/W geophysics laboratory. Line handlers are no longer crowded on the fantail but can now spread out. This gives them room to use their legs instead of their backs while pulling in the tow bundle. Another benefit of this move is that the guns tow outside the ship's wake and won't foul on the winches when the ship makes a tight turn.

On-Site Laboratory Operations

In general, laboratory operations were routine except for the special curation procedures developed for handling watery foraminifer oozes and reefal limestones. All guyots cored had a pelagic cap of a "sandy" foraminifer ooze that would liquefy when piston cored. When the core liner was split into sections, we would lose some of the sediment as the water drained away.

To improve the quality of the cores, a modified piston head from an APC corer was dropped into the top of the core barrel before the drill crew laid it horizontally. This piston head was modified to trap the sediment but yet allow the water to pass through. In addition to using the piston, we would stand the cores up vertically after cutting them into sections. After the sediment had settled to the bottom, the excess water would be drained and the core liner would be cut off and the section recapped.

Recovery of the reefal limestones was very poor, making each piece of rock even more valuable. To properly care for these rocks, the core laboratory specialist curated them with hard-rock procedures (except for numbering each piece). Special care was also taken when cutting and distributing samples. With the abundance of hard rock, numerous thin sections were needed to properly describe them. At the request of the Co-Chiefs, we provided around-the-clock thin-section service. Our thin-section specialists made over 474 thin sections, setting a new record.

NEW AND TECHNICAL HIGHLIGHTS

WSTP/*Origin* Program

A new program was developed by ODP programmers to process temperature data collected with the WSTP's temperature probe. This program replaces the WSTP-FIT program developed on Leg 139. The WSTP data-reduction program is built upon a scientific-analysis package called *Origin* , which runs under Windows.

Because the WSTP/*Origin* program is a major number cruncher and uses extensive interactive graphics, a 486-50MHz PC with all the trimmings was purchased. This PC was set up in the User's Room, where the scientists can reduce their data away from the activity in the Downhole Laboratory. Data collected from the WSTP in the Downhole Laboratory are transferred to the WSTP processing station via the network.

WSTP Data Logger and Data Collection Software

After several years of trying, it looks like the bugs have been worked out of the Dual Channel Data Logger. The new logger has been reduced from a dual to a single channel, and the deck box has been replaced with a National Instruments digital I/O card mounted in a PC. We installed the digital I/O card and data-acquisition software in a 386 PC located in the Downhole Laboratory. The software still has a few flaws but certainly is usable.

Low-Temperature Conversion of WSTP

We removed the high-temperature modifications to the WSTP's thermistor signal cable (made on Leg 139). The tool is now set up for low-temperature data collection.

LabView 2 Programs

LabView 2 was introduced to the ship this leg. This development software is a high-level, icon-based programming language for the Macintosh computer developed by National Instruments. LabView 2 can produce sophisticated user interfaces with little development time. It is especially suited for instrument control, data acquisition/ logging, and data reduction.

Several LabView programs (called Virtual Instruments or VI's) were written this leg:

1) A Balance program that can control any of our shipboard balance systems.
2) A program that calculates hole positions from GPS fixes. This program provides a graphical interface for data editing.
3) A data logger was developed for the uphole pressure gauge used during this leg's packer experiments. This program logs the gauge's voltage along with a time stamp and then writes the data to disk in a "spreadsheet ready," tab-delimited format.

LabView was also used by our electronics specialist as a troubleshooting tool.

Core Laboratory Modifications

During our transit to the MIT Guyot, the technician rearranged storage cabinets and sampling bins into a more efficient layout. We replaced the Felker sampling saw with a new, lighted splash box, and relocated electrical outlets to a safer position away from the water spray.

Subsea Shop

We moved the remainder of our supplies from Lower Sacks to the subsea shop. Miscellaneous gun parts and fantail equipment were stored in drawers and benches. Electrical cables and air hoses were hung in the overhead. We still have use of the forward, inboard corner of Lower Sacks for storage (were the large shelf is). Hydrophone, tow leaders, and miscellaneous cables are stored on the deck with XBT's on top of the shelf.

Acid Cabinets

We reorganized and labeled the cabinets installed on the hold's mezzanine deck during Leg 143. Also, we moved all the hydrofluoric acid to the Paleo Laboratory and labeled the storage areas in this laboratory as well.

Mirror Drive

The System Managers installed a mirror drive in the yeoperson's Macintosh. This will provide added protection against lost files.

INSTRUMENT REPAIRS

Cryomagnetometer

At the start of the leg there appeared to be few problems with this unit with the exception of rollovers on the Y axis. Then about halfway through the leg all three axes were very unstable. Shortly after, they all died. We were able to get the needed parts from the SEDCO ET's, and along with other salvaged parts, repair the three RF amplifiers. After tuning the RF amplifiers to their respective axes, and performing a complete calibration on the 2G boxes, the Cryomagnetometer was brought back on line. It was noticed shortly after that the problem with the rollovers noted at the beginning of this leg was almost nonexistent, so it appears that the rollover problem that we had seen all along might have been caused by bad RF amps.

Rock-Eval

The Rock-Eval instrument continues to consume large quantities of technical time and money while producing little data.

XRF

We spent the first half of the leg troubleshooting a variety of problems on the XRF. A number of bad components were replaced, and goniometer-positioning problems repaired. Even after all of this, we could not get any counts with specific crystal and detector combinations such as the Lif200 crystal and FPC detector. Yet different combinations using either one of the above detectors or crystal pairs would work just fine! This bizarre problem was common to both goniometers and remains unresolved.

Because of the sample backlog, we stopped repair attempts and reconfigured the instrument to use alternate crystal/detector combinations for the affected elements. Using these alternate crystal/detector combinations reduced the overall signal strength of the analyte line but did not appear to affect the precision of our analysis, which was excellent.

PHYSICAL PLANT

Motor Control Panel

Midway through the cruise, we began to have power failures on the Motor Control Circuit (15SP-30). This circuit supplies electrical power to the air conditioning, supply air and exhaust fans. SEDCO's electricians traced the problem to a faulty breaker feeding 15SP-30. A replacement breaker was substituted that was rated for the load but lacked the option of being shut down from the bridge. In an emergency, power to the fans would have to be killed from the ECR. The correct electrical breaker was ordered for delivery to Yokohama..

A/C

When we boarded the ship in Majuro the Lab Stack air conditioner was barely keeping the laboratory spaces comfortable except for the Downhole Laboratory which was uncomfortably hot. Inspection by the SEDCO engineers found that all three lab stack A/Cs had loose fan belts. In the Downhole Laboratory we found the flexible duct feeding the computer room bunched up in the overhead, blocking the air flow. This duct is meant to hang down from the ceiling to the back of the equipment rack.

Photo Laboratory Air Circulation

Several legs ago an additional vent was added to the main air-handler room. While this modification improved the return air flow to the main air handler, it disrupted the proper venting of the photo laboratory. Fumes from photo chemicals began to collect in the darkroom, producing an unsafe working environment for the photographer. This problem was solved by partially blocking the door vent leading to the stairway, which increased the draw from the photo laboratory.

Regulated Power

About the second week of the cruise the Cyberex went off line, but power was smoothly transferred to the motor generator set. SEDCO electricians found several blown circuit cards that had been damaged by a previous repair job. As part of routine maintenance, the batteries were discharged, cleaned, and inspected. Inspection of the batteries found several bad cells and one with a hole burnt through its casing. SEDCO is recommending that we replace all of our Ni Cad batteries with lead acid. These are cheaper and easier to maintain.

Also, the SEDCO electricians wired the regulated power "composite trouble alarm" into their DMS. A new database point was configured, which will notify the engineer on watch in the ECR immediately of certain regulated power-system failures or troubles.