Sager, W.W., Winterer, E.L., Firth, J.V., et al., 1993
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2. SYNTHESIS OF RESULTS, LEG 143[1]

Shipboard Scientific Party[2]

ABSTRACT

Drilling during Leg 143 took place at four localities: the summits of two guyots in the Mid-Pacific Mountains (Sites 865, 866, and 867/868); the archipelagic apron adjacent to a paired atoll-guyot in the Marshall Islands (Site 869); and within the lagoon of a modern Marshall Islands atoll (Site 870). Sites 865 and 866 were situated in the lagoons of two drowned carbonate platforms (Allison and Resolution), principally to examine the history of carbonate platform initiation, growth, and drowning, to test the hypothesis that the guyot summit had been emergent and karstified, and to study the effects, timing, and magnitude of sea level fluctuations. Site 867/868 was drilled on the perimeter mound surrounding the summit of Resolution Guyot, to study the drowning and karstification of what was thought to be a Cretaceous perimeter reef. Site 869, on the archipelagic apron of Pikinni Atoll and Wodejebato Guyot, was drilled to provide a record of volcanism and shallow-water carbonate platform development inferred from turbidites shed from the atoll-guyot pair. Site 870 was an engineering test of shallow-water drilling in the lagoon of a modern atoll, Anewetak.

Deep holes drilled into the ancient lagoons of Allison (Hole 865A) and Resolution (Hole 866A) guyots yielded thick, shallow-water limestone caps that record the history of the guyots from submergence of the volcanic pedestal through the final drowning of the carbonate platform. Though different in detail, both guyots had complex vertical trajectories. The carbonate platform on Resolution formed in the Barremian, on a rapidly subsiding edifice, and accumulated 1620 m of sediments by Albian time. In contrast, the entire 731-m shallow-water limestone section capping Allison Guyot accumulated during its rapid subsidence during the late Albian. Despite the rapid subsidence, the lagoonal facies on both guyots indicate very shallow water throughout most of the carbonate platform histories. In addition, the limestone sections are characterized by meter-scale facies shifts that imply short-period cycles of emergence and submergence. The summits of both guyots show evidence of emergence and karstification at some time after Albian time. Drilling and geophysical data from Resolution Guyot indicate the magnitude of the emergence was at least 160 m. Holes drilled into and next to the perimeter mound surrounding the summit of Resolution Guyot failed to find the expected abundant reefal material, suggesting that these mounds, commonly noted in guyot profiles, are not necessarily reefs like those on Pacific Cenozoic atolls. These results point out important differences between Cenozoic and Cretaceous atolls in this part of the globe; the latter were probably more like open platforms with low relief.

An entirely different history was recorded at Site 869, on the apron adjacent to the atoll-guyot pair, Pikinni and Wodejebato. At this site, surprisingly little shallow-water debris was encountered. Instead, an abundance of volcaniclastics was delivered to the site by turbidity currents, grain flows, and mass flows through late Cenomanian to Maastrichtian time. Especially large influxes of such material during Cenomanian and Campanian time may imply volcanic episodes on the nearby volcanic edifice(s). A few shallow-water fragments and bits of coalified plant remains in Cenomanian layers imply the existence of nearby land and shallow carbonate shoals at that time. During the Cenozoic, volcanism ceased and pelagic sedimentation prevailed, but was interrupted by turbidity currents carrying debris from shallow water.

INTRODUCTION

Across the western Pacific Ocean are scattered scores of Cretaceous seamounts (Menard, 1964; 1984; Matthews et al., 1974). Their origin is uncertain, but may have been related to a large-scale intraplate volcanic episode (Schlanger et al., 1981; Menard, 1984; Winterer and Metzler, 1984) perhaps related to overturn in the mantle (Tarduno et al., 1991; Larson, 1991). Many of these seamounts have flat summits and are called "guyots" (Hess, 1946); still others are surmounted by modern atolls. Though some guyots may have formed by wave planation (e.g., Menard, 1984), many clearly have limestone caps. Because of this and morphologic resemblances to modern atolls (e.g., Ladd et al., 1974), the classic Darwinian model for atoll formation (Darwin, 1842) has often been extended to account for the formation of Cretaceous guyots. The atoll reefs are assumed to have been unable to grow apace with the subsidence of the underlying edifice, and so they drowned.

A corollary of the idea that guyot summits are created by waves or reefs is that they must be sea-level markers. These summits can be thought to be giant "dipsticks" that measure the depth of the ocean at the time they drowned. Indeed, this idea has been used in the western Pacific Ocean to connect guyot summits of the same depth and to infer a large Cretaceous uplift, the "Darwin Rise" (Menard, 1984). However, guyot sedimentation records are far richer than this. Their sediments, almost always deposited near sea level, describe relative rises and falls in sea level caused by their subsidence or uplift, in addition to fluctuations in eustatic sea level. Shifting paleoclimates also leave their imprints on the biota, facies, compositions, and textures of guyot carbonates. Consequently, drilling of guyots offers promise of answering fundamental questions about Cretaceous climate, sea level, biotic assemblages, and tectonics.

Leg 143 was the first of two Ocean Drilling Program (ODP) legs whose purpose was to drill atolls and guyots in the western central Pacific Ocean. Eight atolls and guyots and one site on an archipelagic apron were to be drilled during Legs 143 and 144, spanning nearly 30° of latitude and 35° of longitude. Provinces to be sampled were the Mid-Pacific Mountains, Marshall Islands, Marcus-Wake Guyots, and Japanese Guyots. Two-thirds of the time for Leg 143 was concentrated on two guyots in the Mid-Pacific Mountains, Allison (Site 865) and Resolution (Sites 866 and 867/868). The remainder of the time was spent in the Marshall Islands, where a site (Site 869) was drilled in the basin adjacent to Wodejebato Guyot (formerly Sylvania) and Pikinni Atoll (formerly Bikini), and shallow-water drilling tests were conducted in the lagoon at Anewetak Atoll (formerly Enewetak) (Site 870).

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[1] Sager, W.W., Winterer, E.L., Firth, J.V., et al., 1993. *Proc. ODP, Init. Repts.*, 143: College Station, TX (Ocean Drilling Program).

[2] Shipboard Scientific Party is as given in list of participants preceding the table of contents.

SCIENTIFIC OBJECTIVES

Although Leg 143 scientific goals were multifaceted, the main scientific theme was the origin and evolution of Cretaceous guyots and their relation to sea level. By coring through the pelagic and limestone caps and into the basalt of the underlying volcano, drilling was intended to address the following problems:

1. Determining the age of volcanic construction;
2. Delineating the history of carbonate platform development;
3. Examining the timing, effects, and magnitudes of fluctuations in sea level;
4. Finding the cause(s) and timing of platform drowning;
5. Confirming the existence and magnitude of emergence and karstification; and,
6. Understanding the seismic reflection signatures for comparison to other guyots.

OVERVIEW OF OPERATIONS

After transiting from Honolulu to Allison Guyot in the western Mid-Pacific Mountains (Fig. 1), Hole 865A was drilled between the summit of the pelagic cap and the south rim of the guyot (Fig. 2). The hole penetrated 870.9 mbsf (Table 1) through 140 m of pelagic cap and 698 m of shallow-water limestone before bottoming in 33 m of basaltic sills that had intruded into limestone. Downhole logging runs were conducted in Hole 865A with the following tools: sonic-porosity-density-gamma-temperature, resistivity-gamma-temperature, Japanese downhole magnetometer, formation microscanner (FMS), and geochemical tool.

Hole 865B had the dual purpose of (1) obtaining APC cores from the pelagic cap, which was determined to contain an unusual, expanded Eocene-Paleocene section of paleoceanographic importance, and (2) recoring the upper, shallow-water limestone section with the XCB. Hole 865C was drilled solely with the APC to ensure the completeness of the pelagic sequence. Holes 865B and 865C penetrated 165.5 and 136.6 mbsf, respectively (Table 1).

Resolution Guyot, located in the Mid-Pacific Mountains 387 nmi (716 km) to the northwest of Site 865, was the next target to be drilled. Hole 866A is located approximately 1 km inward from the edge of the guyot summit (Fig. 3), within a trough behind the perimeter mound that contains about 25 m of pelagic sediments. The location was chosen to provide both lagoonal facies limestones and any expected reef washover debris. The hole penetrated 1743.6 mbsf (Table 1) and cored approximately 1620 m of shallow-water limestone overlying about 124 m of basalt. The hole required three reentries, two to change out worn bits and a third to clear a plugged bit. Logging runs were conducted in Hole 866A using the quad tool, FMS, Japanese downhole magnetometer, and geochemical tool. One additional hole (866B) was drilled at this site. The purpose of this

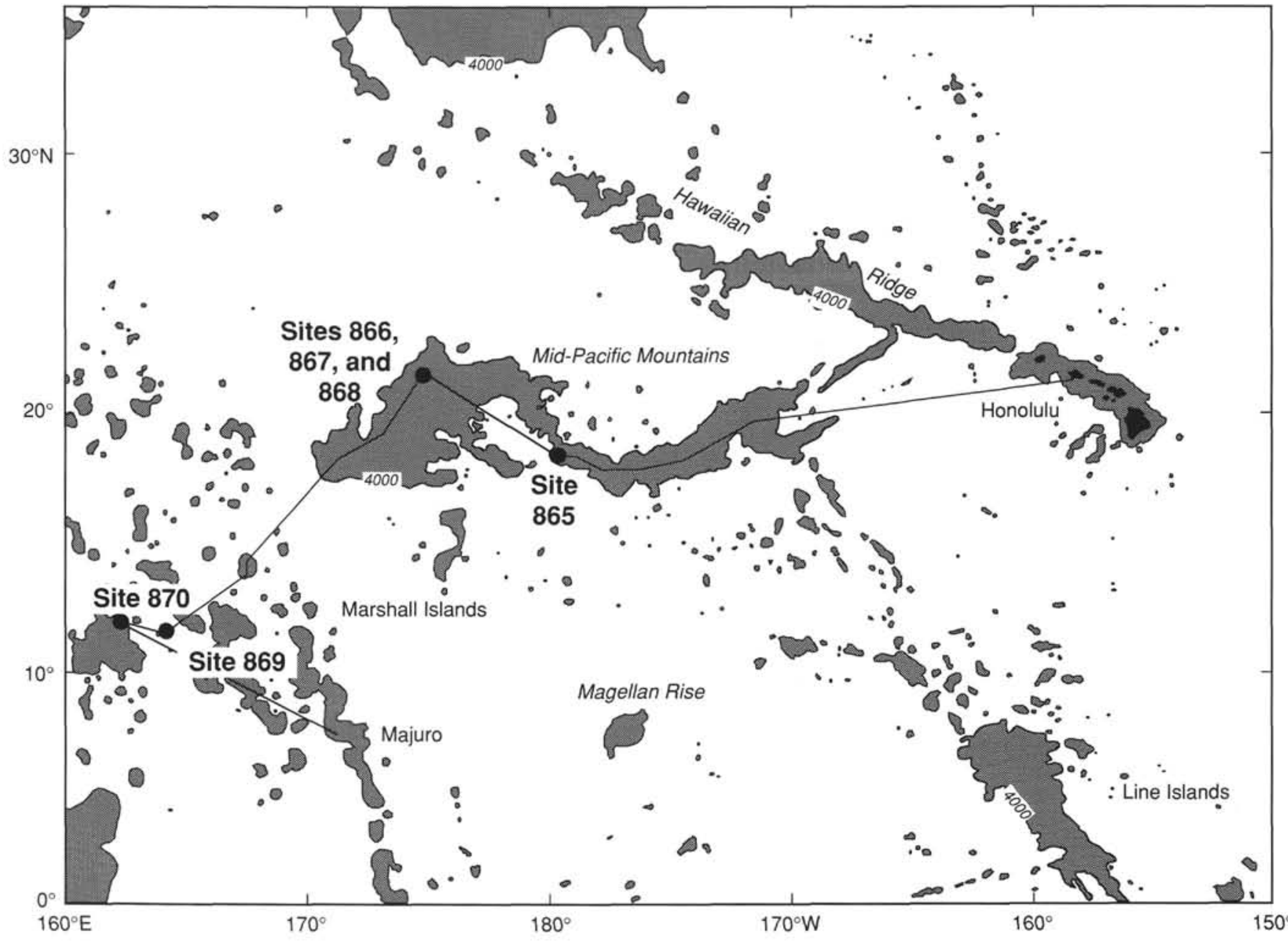

Figure 1. The region visited by *JOIDES Resolution* during Leg 143. Seafloor shallower than 4 km is stippled. The location of Leg 143 drill sites and the track of the drill ship are shown.

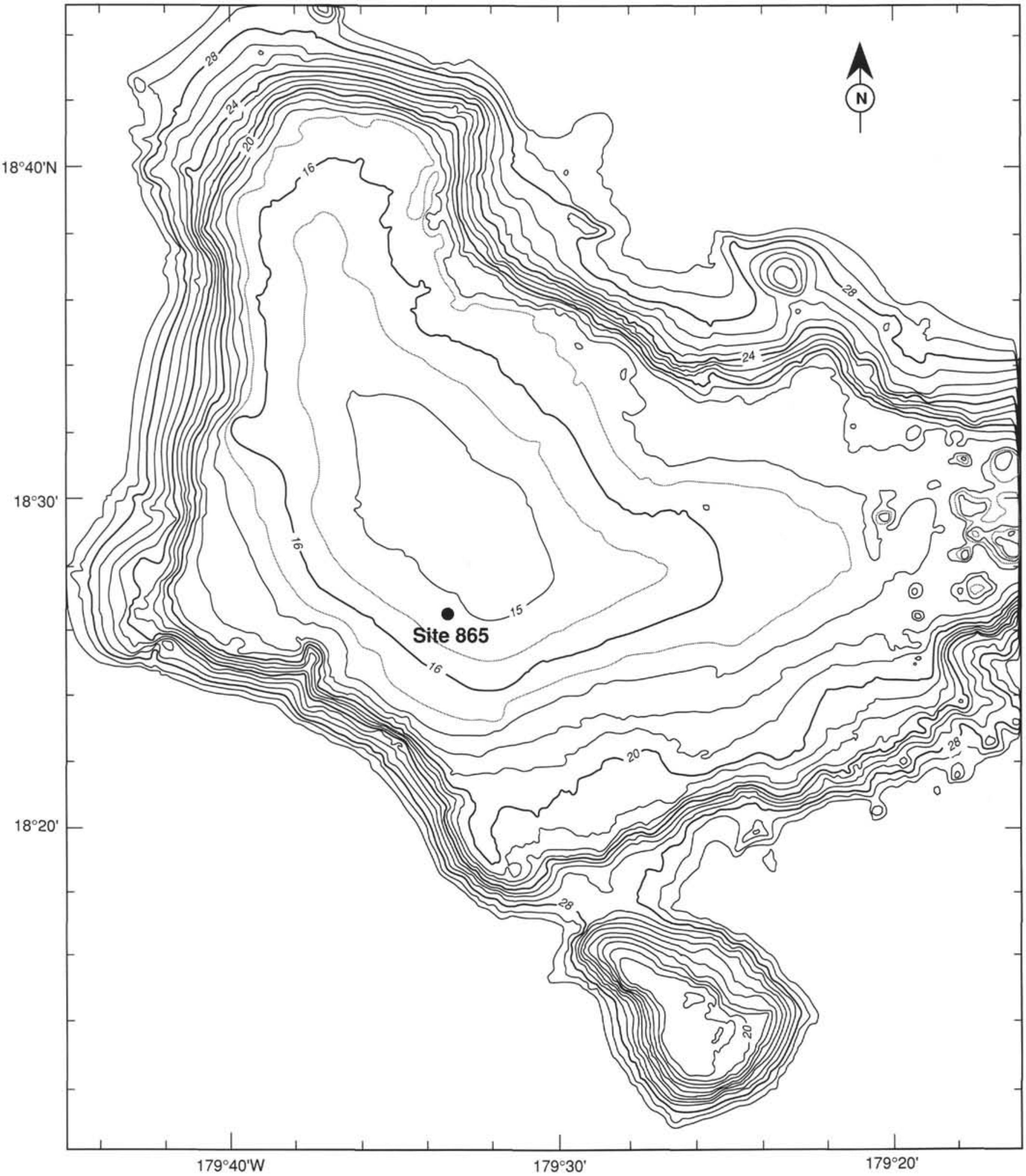

Figure 2. Bathymetry of Allison Guyot summit. Values are shown in kilometers. Bathymetry contours at 100-m intervals above 3000 m are shown; heavy contours at 400-m intervals. Supplementary 50-m contours on the guyot summit are shown in gray. Bathymetry data were obtained with the SeaBeam multibeam echo-sounder in 1988 during Leg 10 of the Roundabout Expedition of the *Thomas Washington* of Scripps Institution of Oceanography.

Table 1. Drill-hole data for Leg 143.

Hole	Latitude	Longitude	Depth (mbsl)	Date occ. (UTC)	Date dep. (UTC)	Time (days)	Penetration (m)	Recovery (m)
Allison Guyot								
865A	18° 26.410′ N	179° 33.339′ W	1518.4	27 Mar	2 Apr	5.63	870.9	132.1
865B	18° 26.415′ N	179° 33.349′ W	1516.2	2 Apr	4 Apr	1.09	165.5	123.7
865C	18° 26.425′ N	179° 33.339′ W	1517.4	4 Apr	4 Apr	0.53	136.3	114.1
Resolution Guyot								
866A	21° 19.953′ N	174° 18.844′ E	1361.8	6 Apr	23 Apr	16.91	1743.6	269.0
866B	21° 19.952′ N	174° 18.870′ E	1346.1	23 Apr	24 Apr	0.73	117.4	23.1
867A	21° 20.963′ N	174° 18.550′ E	1352.2	24 Apr	24 Apr	0.44	10.0	0.1
867B	21° 20.959′ N	174° 18.561′ E	1352.2	25 Apr	27 Apr	2.06	76.8	22.5
868A	21° 21.171′ N	174° 18.564′ E	1384.9	27 Apr	28 Apr	0.67	20.3	9.4
Wodejebato Guyot/Pikinni Atoll								
869A	11° 00.091′ N	164° 44.969′ E	4826.7	3 May	4 May	1.71	166.5	129.3
869B	11° 00.093′ N	164° 45.019′ E	4826.7	4 May	15 May	10.83	796.2	252.0
Anewetak Atoll								
870A	11° 20.829′ N	162° 15.788′ E	38.6	16 May	16 May	0.45	0.2	0.2
870B	11° 20.833′ N	162° 15.775′ E	37.5	16 May	17 May	0.28	31.3	0.4

117.4-m hole was to recore the poorly recovered top section of the shallow-water limestone.

From Site 866, the drill ship moved about 1.2 nmi (2.2 km) northward to the perimeter mound of Resolution Guyot, where Site 867 was drilled (Table 1). Our goal at this site was to core the mound, which was thought to be a Cretaceous reef. No significant pelagic cover was seen at the site, but the drill string was spudded on the hard outcrop without a guidebase. The first hole (867A) penetrated only 10 m before the bottom-hole assembly (BHA) failed. The next hole (867B) was spudded in the same manner using an experimental PDC bit. The bit cored with good recovery, but slowly. At a depth of 76.8 mbsf, the absence of expected reefal material precipitated termination of the hole. Despite the short depth of the hole, a suite of two logging runs was conducted using the quad tool and the FMS.

The ship was moved 400 m farther north to a terrace about 33 m deeper than the perimeter mound. This terrace was drilled because we thought that it might be a lowstand reef or wavecut terrace. Hole 868A was drilled on the terrace with the PDC bit to a depth of 20.3 mbsf (Table 1) before time ran out and it was necessary to begin transit to the next site.

Site 869 is located at a depth of 4827 m on the archipelagic apron of the atoll-guyot pair, 45 nmi (83 km) southwest of Pikinni Atoll and Wodejebato Guyot, in the northern Marshall Islands (Table 1; Fig. 4). Two holes were drilled at Site 869, the first (869A) with the APC/XCB coring system and the second (869B) with the RCB system. Our plan was to drill through soft sediments in the upper 300 to 400 mbsf with the APC/XCB to obtain relatively undisturbed cores and then to switch over to a bit better suited for hard formations. Shallow chert and porcellanite layers forced us to terminate Hole 869A after only 166.5 m of penetration. Drilling in Hole 869B was slower than expected owing to the presence of volcaniclastics in the section. After 796.2 m of penetration, time available for drilling ran out and the hole was terminated. Logging runs were conducted with the quad tool, FMS, Japanese downhole magnetometer, and geochemical tool. The light FMS tool and magnetometer had trouble penetrating through ledges in the chert-rich lower Cenozoic section of the hole, thus the pipe had to be lowered to 235 mbsf, masking the Cenozoic, to get these tools down the hole. Because time ran out for scientific operations, we obtained only a partial geochemical tool run.

SITE SUMMARIES

Site 865

Site 865 is located at 18°26.41′N, 179°33.34′W, at a water depth of 1518 m on the summit of Allison Guyot in the central Mid-Pacific Mountains (Fig. 2). The site is the easternmost of the Leg 143/144 sites and was designed to penetrate lagoonal sediments of the thick, shallow-water limestone cap typical of Mid-Pacific Mountain guyots. Site 865 was drilled with four goals: (1) determining the timing of reef development and demise, (2) identifying subaerial exposure and karst events, (3) developing a model of seismic stratification for comparison with other guyots, and (4) examining the post-drowning sedimentary history of the guyot summit.

Although our pre-cruise plan was to drill only a single hole, three were drilled at Site 865. Hole 865A was the primary, deep hole, that was drilled using a single RCB bit, even in the pelagic cap. APC coring was postponed for Holes 865B and 865C because it was feared that hard, chert layers were present in the pelagics. Hole 865A penetrated 139 m of pelagic sediments that ranged from mid-Paleocene to Quaternary age, but contained an expanded mid-Paleocene to late Eocene section. Recovery through the pelagic section was 55%, but the sediments were pervasively disturbed by rotary coring. Below 139 mbsf, upper Albian, shallow-water limestones were drilled to within a few meters of the bottom of the hole, at 870.9 mbsf. Basalt intrusives interlayered with limestone were recovered in the last four cores, from 831.8 mbsf to the total depth (TD). Recovery in much of the shallow-water limestone section was low (1%–2%), but improved notably (10%–100%) in the clayey limestones and basalts, within the bottom 100 mbsf.

Holes 865B and 865C were APC/XCB holes whose purpose was to double-APC the expanded Paleocene–Eocene pelagic cap sediments for paleoceanographic and biostratigraphic studies. Hole 865B penetrated 165.5 mbsf and ended with five XCB cores that were an attempt to retrieve additional limestone from the mineralized zone near the top of these limestones. Hole 865C extended to 136.3 mbsf and was drilled with the APC only.

Lithology

Four sedimentary units were recognized at Site 865 (Fig. 5). From bottom to top these are as follows:

1. Unit IV (870.9–621.9 mbsf). Upper Albian clayey organic wackestone-packstone with intervals of clay and organic matter. Mudstones are commonly extensively burrowed. Pyrite is common, and dolomite is present locally. Carbonaceous fragments are common lower in the unit and decrease in abundance upward. This unit also contains three layers of moderately to highly altered alkali basalt that are thought to be one or more sills that were intruded into the sediments.

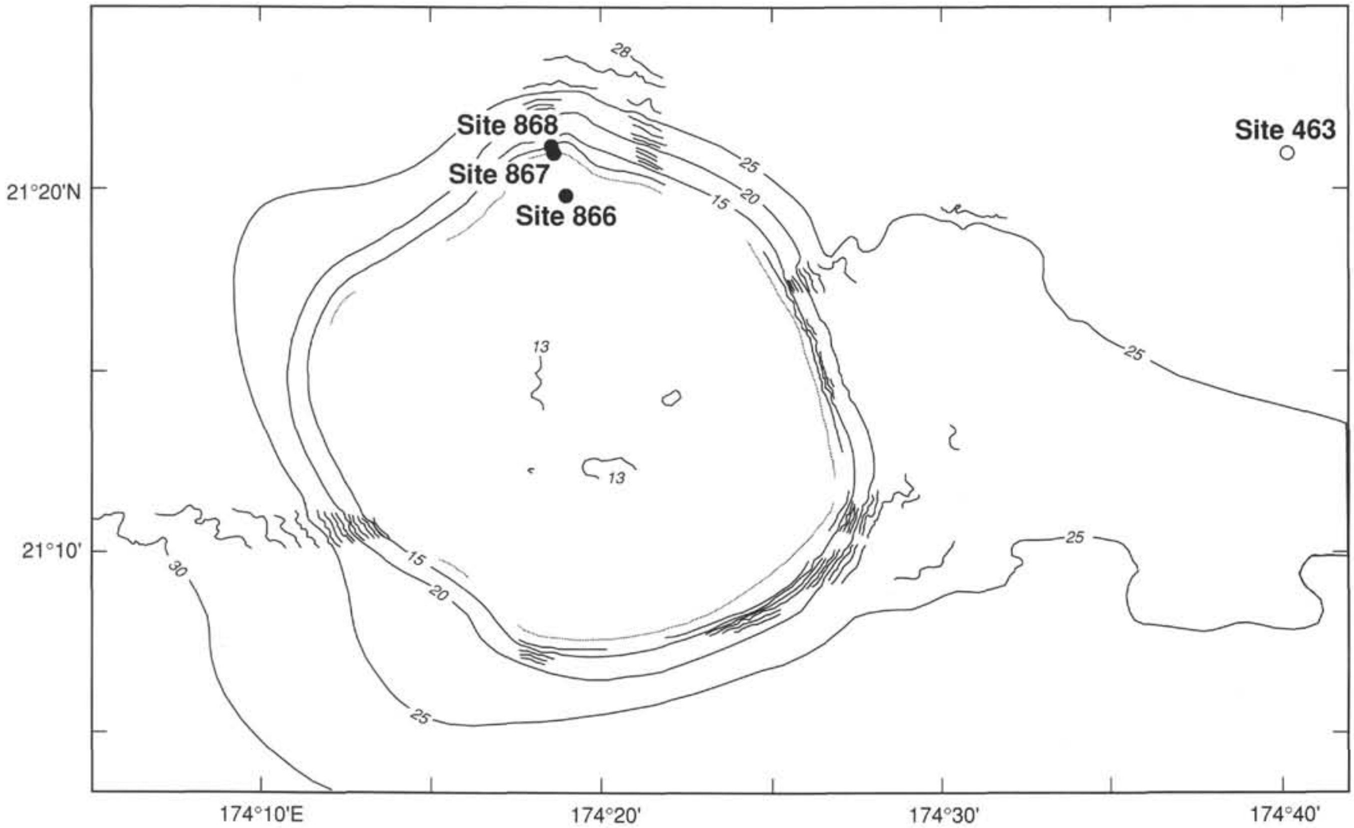

Figure 3. Bathymetry of Resolution Guyot. Bathymetric contours at 100-m intervals where there is SeaBeam multibeam echo-sounder coverage. Heavy contours are at 500-m intervals and include data acquired during pre- and post-drilling surveys aboard the *JOIDES Resolution*. Contour labels in hundreds of meters. Heavy gray line shows the location of the perimeter mound. Sites 866, 867, and 868 are shown by filled circles; Site 463 (DSDP Leg 62; Thiede, Vallier, et al., 1981) denoted by open circle. Site survey data were acquired in 1988, during Leg 10 of the Roundabout Expedition of the *Thomas Washington* of Scripps Institution of Oceanography.

2. Unit III (621.9–207.3 mbsf). Upper Albian dasycladacean/sponge limestone and rudist/gastropod limestone of several facies: peloidal mudstones, wackestones, packstones, and rare grainstones with molds of formerly aragonitic mollusks. High-spired gastropods, small bivalves, sponges, and large sponge spicules are common; benthic foraminifers are relatively abundant; and ostracodes, dasycladacean algae, rudists, and corals are scattered. The interval between 245.9 and 236.3 mbsf may represent a rudist biostrome. Induration is variable, and the limestone ranges from chalky to hard. Dissolution has removed most carbonate fossil skeletons. Episodic subaerial exposure is suggested by the occurrence of erosional surfaces, reddish stains, and brecciated, well-indurated wackestones.

3. Unit II (207.3–139.7 mbsf). Phosphatized upper Albian packstones and wackestones with cavity infillings of mineralized lower-to-middle Turonian and upper Coniacian to upper Campanian pelagic limestone. This unit appears to be partly dissolved, shallow-water limestone that has been phosphatized and filled in with younger pelagic foraminiferal limestone sediments that have been impregnated and phosphatized with manganese oxyhydroxides. The actual thickness of this unit is poorly constrained because only a few small fragments of this material were recovered from five cores and it is possible that some pieces fell down the hole from above. The thickness is partly inferred from high readings in the gamma-ray log in this interval.

4. Unit I (139.7-0.0 mbsf). Lower Paleocene to Quaternary, foraminiferal nannofossil ooze and foraminiferal sand. Approximately 89% of this section is of early Paleocene to late Eocene age and probably formed as the guyot drifted beneath the equatorial high productivity zone. These sediments generally contain a large fraction of sand, which suggests winnowing by currents.

Downhole Logs

An excellent set of logs was obtained from Hole 865A in five runs. The sonic–porosity-density-gamma-ray-temperature, the resistivity-gamma-ray-temperature, FMS, Japanese downhole magnetometer, and geochemical tools were run. The sonic tool showed that the overall acoustic velocities were higher than expected, averaging about 2.9 km/s in the limestones. In addition, the gamma-ray log gave high readings within the upper 100 m of the reefal limestones (Fig. 5), probably because they were once subaerially exposed, as well as at the bottom of the hole, where clays are relatively abundant. The FMS provided a resistivity map of the borehole wall that correlates well with layers recovered in the bottom of the hole (where recovery was good) and that appears to show structure caused by large-scale porosity variations in the shallow-water limestones. The logging operation required 1.8 days.

Seismic Stratigraphy

Seismic-reflection profiles over Allison Guyot show a lens-shaped pelagic cap having a maximum thickness of just over 0.2 s two-way traveltime (twtt). Beneath the cap are two prominent reflectors at 0.167 and 0.633-s twtt beneath the seafloor. These represent the top of the shallow-water limestone at 139 mbsf and the basalt intrusives at about 840 mbsf. One of the surprises from drilling at this site was that the reflectors within the limestone are deeper than expected because seismic velocities are higher. In between the two prominent reflectors are several minor seismic horizons that probably were caused by more cemented layers, perhaps as a result of emergence. Other faint reflec-

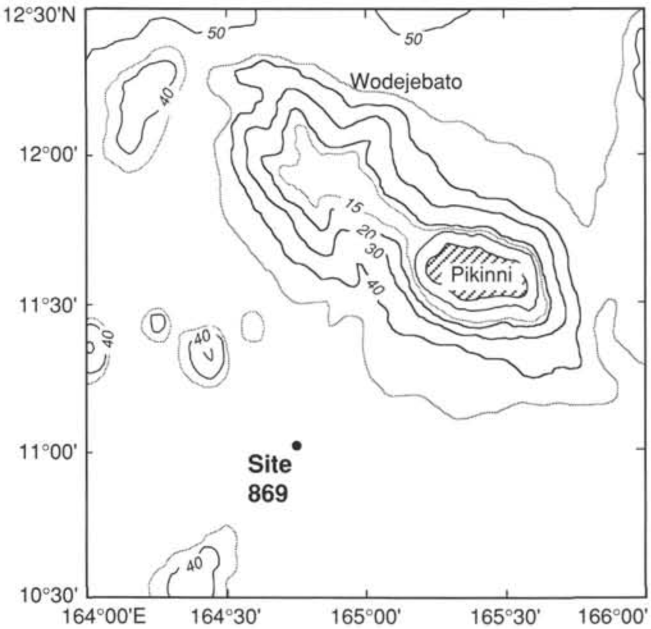

Figure 4. Location map of Site 869. Bathymetric contours at 1000-m intervals are shown as dark lines; auxiliary 500-m contours shown in gray. Values are shown in kilometers.

tors also are seen beneath the basalt reflector, implying that other sediments below may not have been sampled by drilling.

Interpretations

Data from Site 865 give a picture of the evolution of an atoll from its early history to its drowning. The deepest, clayey and carbonaceous sediments of Unit IV imply shallow, restricted, marshy water near land. Possible evaporative periods are suggested by dolomite crystals. Basalts in this unit probably represent either late-stage volcanics or a rejuvenation of the volcano. The cleaner limestones of Unit III show a shift to a more open, normal lagoonal marine environment. Occasional periods of subaerial exposure are suggested by red stains in Unit III, but the pervasive mineralization of Unit II implies a prolonged period of exposure. Upper Cretaceous sediments above the shallow-water Albian limestones are thin or absent, indicating that the period after drowning was nondepositional. During the Paleocene, the guyot passed beneath the equator and received a large pile of pelagic carbonate sediments.

Site 866

Site 866 is located at 21°19.95′N, 174°18.84′E, at a water depth of 1346 m on the northern rim of the summit of Resolution Guyot in the western Mid-Pacific Mountains (Fig. 3). It is located approximately 1.5 km inward from the perimeter mound that fringes the guyot summit platform. Before drilling at Sites 867/868, this mound had been interpreted as a perimeter reef. The purpose of drilling at Site 866 was to obtain a deep hole to sample interfingered lagoonal and reef-washover sediments through the entire limestone cap of the guyot. Goals at this hole were similar to those at Site 865: (1) to determine the timing of reef development and demise, (2) to identify subaerial exposure and karstification, and (3) to develop a model for seismic stratigraphy for comparison with other guyots. Furthermore, drilling was intended to penetrate at least 200 m into the volcanic pedestal beneath the limestone cap, so that a reliable radiometric date and paleolatitude could be calculated for the volcanic edifice.

Site 866 was moved slightly from its proposed location (Site Hue-A). The scarcity of reef debris at lagoonal Site 865 on Allison Guyot suggested that Site 866 should be moved closer to the perimeter reef, so that more reef material would be cored. The proposed location was in a "gutter" behind the perimeter mound, where about 30 m of pelagic sediments was available to support the drill string during spud-in. Using the 3.5-kHz profiler, a short survey over the northeast rim located a spot about 1.2 km east of the proposed site, where the gutter was closer to the rim. The beacon was dropped at 2029 UTC on 6 April, which began 17.6 days of operations at the site.

Originally, one hole to a depth of about 950 m was planned at Site 866, but two actually were drilled. The first (Hole 866A), was drilled using the RCB and reached a total depth of 1743.6 mbsf, then bottomed in basalt. Its great depth is a result of the basalts being far deeper than estimated and the fact that the limestones of the carbonate cap made a stable hole, which permitted deep drilling. The second hole (Hole 866B), was drilled in the upper part of the limestone platform, where recovery was poor in the first hole. This hole was drilled with a diamond core barrel with which we hoped to enhance recovery. A pelagic ooze section (missed in Hole 866A) was cored in Hole 866B, that showed that the mud line had been incorrectly placed in the first hole and that the seafloor actually was 15.5 m shallower than we had assumed. Hole 866B reached 117.4 mbsf, bottoming in limestone.

Hole 866A required 13.4 days to drill. From it, 1620 m of mostly shallow-water limestone and 124 m of subaerial basalt were cored. Three reentries were necessary and these were made using a free-fall minicone. The first and second roundtrips, at 917 and 1569 mbsf, respectively, were to change worn bits. A third trip was required to clear a bit that became plugged with basalt rubble at 1659 mbsf. Deteriorating hole conditions in the basalt section brought an end to drilling. Collapsing rubble stuck the drill string at 1736 mbsf. Although it was freed and the basalt section conditioned, the situation seemed ripe for additional trouble, so drilling was stopped at TD after an additional core. Recovery in the limestone section of Hole 866A was poor at the top (average 1.4% in the top 300 mbsf), but increased downhole (average 34% in the bottom 220 m of limestone). The hole was finished with five logging runs: the quad tool (gamma-ray, caliper, sonic-velocity, neutron-density, resistivity, and temperature), the FMS, the Japanese downhole magnetometer, the borehole televiewer, and the geochemical tool. All except the borehole televiewer and geochemical tool produced good data, although none of the logging tools penetrated very deeply into the basalt because that portion of the hole closed off. Logging operations required 2.6 days.

Hole 866B, located about 30 m away from Hole 866A, took only a short time to drill: 16.5 h. Its average recovery was low, 4.3%, but this was far better than that achieved in the same section of the previous hole.

Age Constraints

Ages for the cores from Site 866 range from Barremian to Pliocene (Fig. 6). Most of the section is Barremian to Albian age shallow-water limestone (dated primarily from benthic foraminifers) and rests upon basalt of uncertain age. Foraminiferal assemblages in the limestones initially indicate a Barremian age from 1620 to 1200 mbsf, Aptian age from 1200 to 270 mbsf, and Albian age from 270 to 13 mbsf. A possible hiatus is suggested at about 1400 mbsf by an abrupt change in the paleodepth, implied by the foraminifers. The basalt below the limestone is reversely polarized and covered with Barremian limestone implying that it formed prior to Chron M0. The shallow-water limestones are capped by a thin veneer of winnowed and reworked pelagic sediments that contain both calcareous nannofossils and planktonic foraminifers ranging in age from Maastrichtian to Pliocene.

Lithology

Core and log data from Holes 866A and 866B were combined, and eight sedimentary units were recognized (Fig. 6):

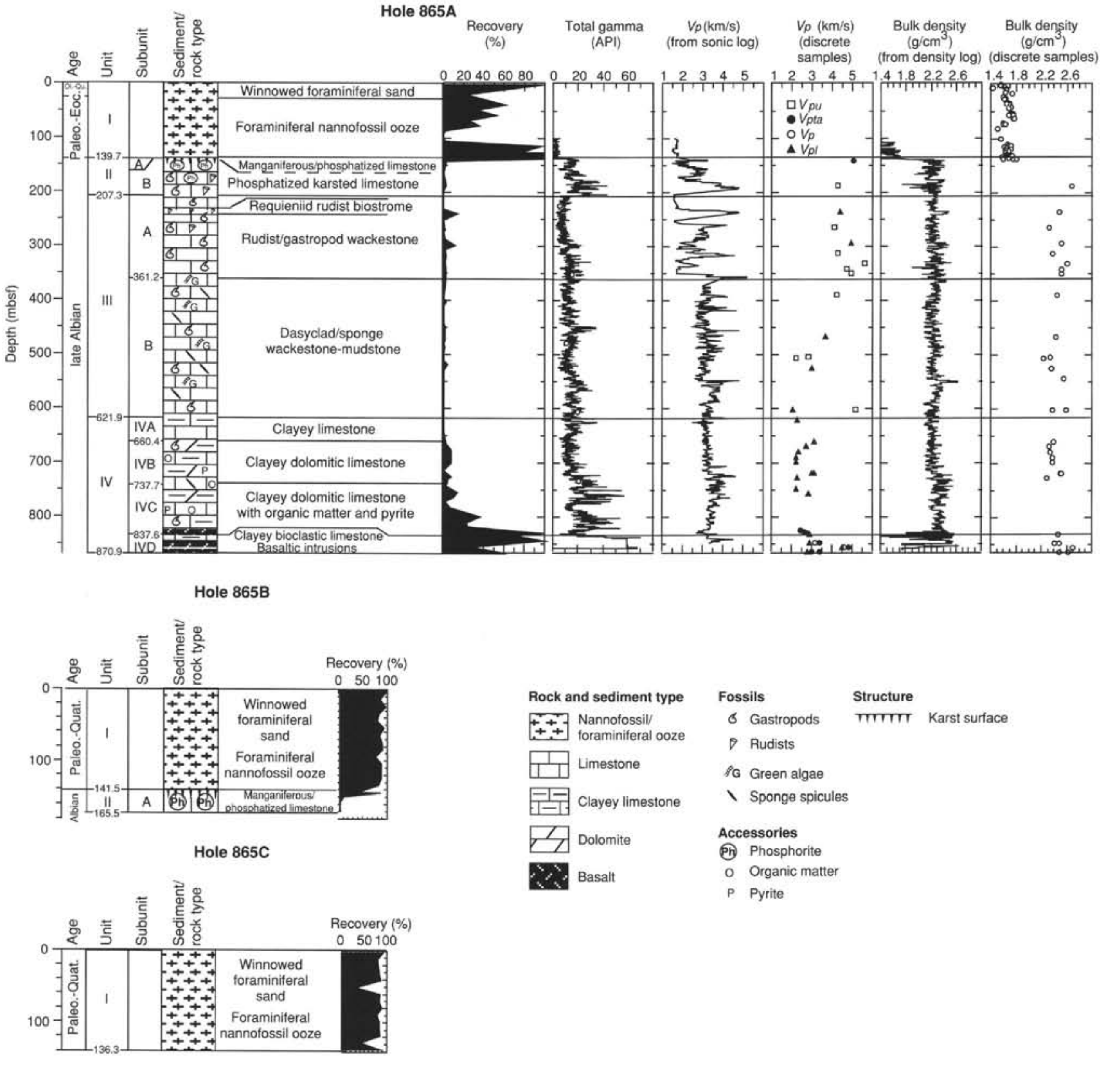

Figure 5. Summary of lithologic, biostratigraphic, physical properties, and logging data from Site 865. Measurements of *P*-wave velocity are discriminated for orientation: V_{pu} = unoriented; V_{pta} and V_{p+6} are transverse (horizontal); V_{pl} = longitudinal (parallel to core). Ages of pelagic sediments come from Hole 865B; other data are from Hole 865A.

1. Unit VIII (1620.0–1339.7 mbsf). Barremian dolomitized and undolomitized oolitic/oncoidal grainstone. Most of this unit is pervasively dolomitized, except for the lowest 19 m above basalt. Dolomitization generally decreases upward and becomes patchy at the top of the unit. Common biogenic components are gastropods, bivalve fragments, echinoid spines, and green algae. Coral fragments and bryzoans are rare.

2. Unit VII (1339.7–1203.4 mbsf). Barremian dolomitized oolitic/peloidal grainstone, oncoidal wackestone, with algal laminites and clay/organic-rich layers. The main characteristics of this unit are the pervasive sucrosic dolomitization and abundance of oncoids. Biogenic components include oncoids, benthic foraminifers, peloids, fragments of rudist and other bivalve shells, serpulid worm tubes, echinoids, corals, nerineid gastropods, stromatoporoids, and dasycladacean algae.

3. Unit VI (1203.4–791.8 mbsf). Aptian cyclic packstone/wackestone with algal laminites, clay/organic-rich layers, and patchy dolomitization. The primary characteristic of this unit is the cyclic repetition of lithologies in meter-scale, shallowing-upward sequences that imply small fluctuations in relative sea level. Cycles typically begin with peloidal wackestone or packstone and grade upward to wackestone or mudstone. Sequence tops are commonly truncated and show small-scale desiccation cracks, implying emergence and erosion. A caprinid rudist biostrome occurs in the middle of the unit.

4. Unit V (791.8-676.6 mbsf). Aptian oolitic grainstone. This unit is 115 m of massive, well-sorted, oolite grainstone with cross lami-

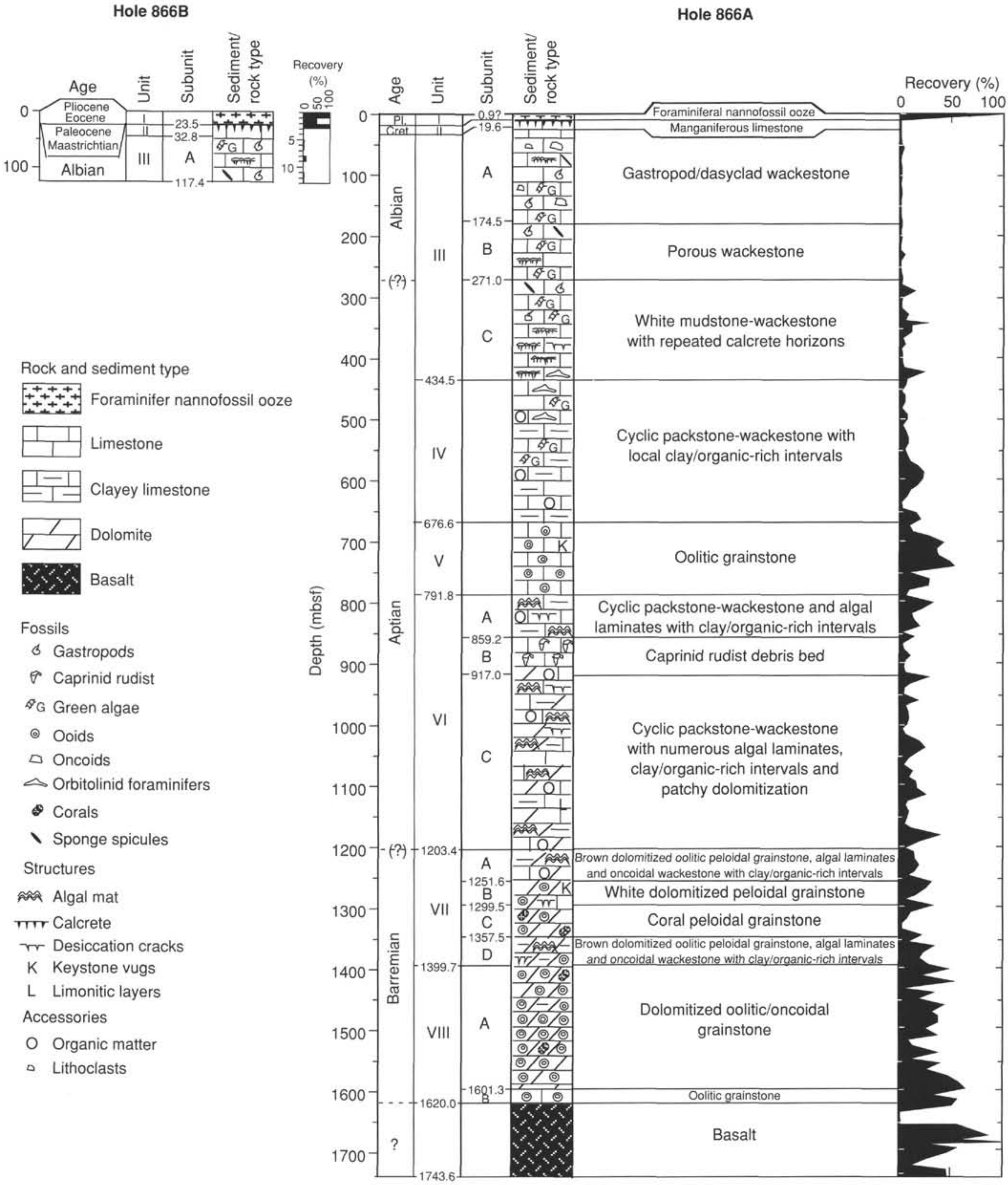

Figure 6. Site 866 hole summary, including age, lithology, core recovery, physical properties, and downhole logs. Measurements of velocity on discrete samples are labeled for direction: V_{pu} is unoriented; V_{pt} (A) is transverse (horizontal) in Hole 866A; V_{pl} (A) is longitudinal (parallel core-axis) in Hole 866A; V_{pt} (B) is transverse in Hole 866B; V_{pl} (B) is longitudinal in Hole 866B.

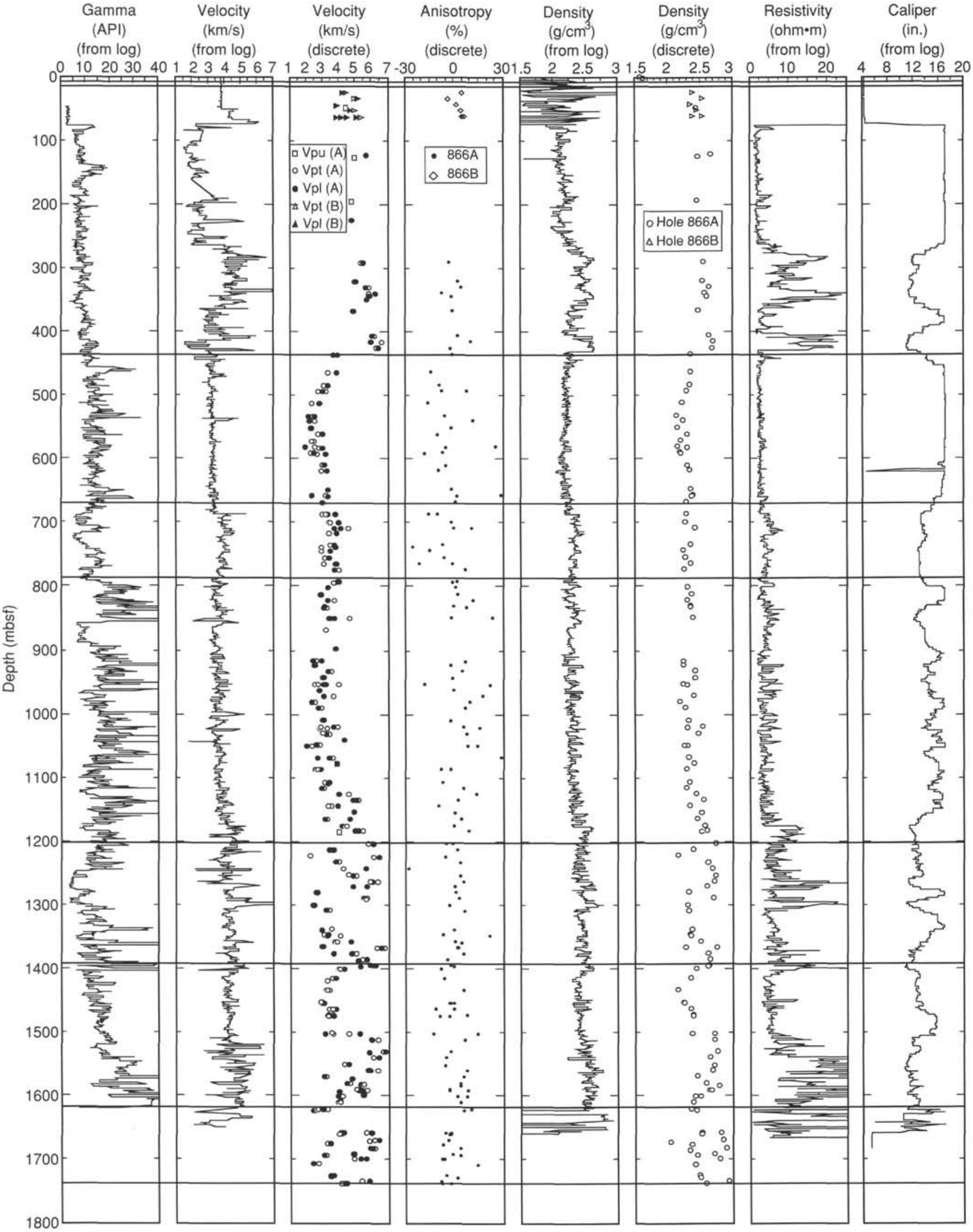

Figure 6 (continued).

nations in some spots. Punctuating the grainstone are thin units of rudstone, with large fossils, and wackestone, with abundant micrite. Locally, ooids and peloids are blackened by manganese oxides. Peloids, grapestones, intraclasts, rare oncoids, bivalve debris, corals, and gastropods all occur as components.

5. Unit IV (676.6–434.5 mbsf). Aptian cyclic packstone/wackestone with scattered clay/organic-rich layers. Bioturbated peloidal packstone, wackestone, and grainstone with gastropods and foraminifers characterize this unit. Meter-scale submergence-emergence cycles, similar to those in Unit VI, occur with decreasing frequency upward. Biogenic components are bivalve fragments, dasycladacean algae, and scattered lignite fragments. Smectite clay layers occur in the lower part of the unit and decrease in frequency upward.

6. Unit III (434.5–19.6 mbsf, Hole 866A; 117.4–32.8 mbsf, Hole 866B). Aptian to Albian wackestone and mudstone. This unit is primarily wackestone with lesser amounts of mudstone, packstone, and grainstone. Common biogenic components are gastropods, bivalves, benthic foraminifers, echinoids, ostracods, sponges, and dasycladacean algae. Rare components are corals, serpulid worm tubes, and bryzoans. Aragonitic fossils have been largely dissolved to create moldic porosity. Calcrete layers occur and decrease in frequency upward.

7. Unit II (19.6–0.9 mbsf, Hole 866A; 32.8–23.5 mbsf, Hole 866B). Cretaceous manganiferous limestone. This poorly recovered unit is known from only a few small pebbles of manganese-encrusted limestone and is inferred from comparison with the mineralized limestone unit on Allison Guyot (Site 865). It represents the mineralized surface of the shallow-water limestones.

8. Unit I (0.9–0.0 mbsf, Hole 866A; 23.5–0.0 mbsf, Hole 866B). Maastrichtian to upper Pliocene foraminiferal nannofossil ooze. This layer represents the post-drowning history of the guyot and consists of winnowed and reworked sediments.

Beneath the limestone cap, drilling penetrated 125 m of probable tholeiitic to transitional alkalic basalt, with 37% overall recovery. The basalt is subaerial and lightly to heavily altered. Red clay zones represent subaerial weathering and development of lateritic soils. Poorly recovered rubble zones imply that the lavas were aa flows. Above the basalt/limestone contact, volcaniclastic grains are not overly abundant and persist for only about 40 m, suggesting that any volcanic remanent was small, short-lived, and probably not close to the site.

Physical Properties

Bulk-density and sonic-velocity measurements showed remarkable trends. Rather than increasing monotonically downward, large variations exist (Fig. 6). High sonic velocities (4.4–6.5 km/s) and densities (2.4–2.7 g/cm^3) occur in the layer from 270 to 420 mbsf. Beneath this layer is a zone, approximately 780 m thick, of lower velocities and densities (1.8–4.5 km/s and 2.1–2.4 g/cm^3). Below 1200 mbsf, with the occurrence of the pervasive dolomitization, sonic velocities and densities generally increase, but vary considerably with layer diagenesis (2.1–6.8 km/s and 2.15–2.75 g/cm^3). Integration of these data with the sonic logs suggests that the top of this layer (the boundary between Units VI and VII) causes the seismic-reflection horizon originally thought to be the top of the volcanic pedestal.

Downhole Logs

Downhole logs illuminate the sedimentary column and provide a framework for understanding the lithologic variations seen in the cores (Fig. 6). Resistivity logs show peaks of high values between 270 and 420 mbsf, that correlate with layers of white mudstone-wackestone, which also show high values in density and seismic velocity. The resistivity log also has peaks in the lower, dolomitized sections of the column, where seismic velocities vary considerably. Gamma-ray counts also show variable and elevated values in the bottom section of the limestone, as well as higher up in the cyclic packstone-wackestone of Unit VI. On a small scale, many of these variations appear cyclic and may be related to relative sea level fluctuations.

Seismic Stratigraphy

Seismic profiles across Resolution Guyot show layering that appears superficially like that at Site 865. The top-of-shallow-water limestone reflector occurs virtually at the seafloor because overlying pelagic sediments are thin. Within the upper 0.3 s twtt of the limestone are a series of reflectors, beneath which only relatively weak seismic horizons appear. The deepest that can be seen in the site survey seismic profiles is at 0.96 s twtt. which was thought to be the top of the volcanic pedestal beneath the carbonate cap. Drilling results showed that the multiple reflectors at the top of the section correlate with the hard, mudstone-wackestone layers between 271 and 434 mbsf. Because these layers have high seismic velocities, a velocity inversion occurs beneath them, and this is probably the reason that the deeper seismic horizons are weak. The horizon thought to be volcanic basement was instead the top of the pervasively dolomitized layers at about 1203 mbsf. Actual basement was reached 417 m deeper. Another important aspect of these seismic layers is that many are not continuous across the entire guyot, implying that they were formed by local diagenetic conditions and facies variations. This fits with the idea that the lagoon was shallow with lateral variability in sedimentary facies.

Interpretations

Cores from Site 866 record virtually the entire history of guyot formation: volcanism, platform formation, diagenesis, and drowning. Although previous ideas of the age of the edifice were approximately correct, the drilling results show that many long-held ideas are misconceptions. Resolution Guyot is composed mostly of carbonate cap. The volcanic pedestal below is only about 500 m higher than the top of the adjacent basaltic plateau that underlies most of the Mid-Pacific Mountains. This finding suggests that the Mid-Pacific Mountains may have been an extensive shallow-water platform during the Early Cretaceous. The contribution of reefs to the building of the shallow-water limestone cap may have been overestimated, as reef debris is surprisingly sparse throughout the section at Site 866. Velocity inversions caused by extensive differential diagenesis within the limestone cap caused misinterpretation of the depth of the volcanic edifice because seismic velocities were underestimated and large acoustic impedance contrasts were formed within the section, masking true basement. This implies that estimates of limestone cap thicknesses for other guyots may be similarly erroneous. Finally, the growth of the limestone cap was not simple. During the Barremian and Aptian periods, a thick shallow-water limestone section was built during a time of rapid subsidence. At some time during the Albian, platform growth was terminated, probably by emergence and karstification. Regional uplift of the Pacific Plate, causing a relative sea-level fall, is one possible explanation for this.

Sites 867/868

Sites 867/868 are located at 21°20.96′N, 174°18.57′E and 21°21.17′N, 174°18.56′E in water depths of 1352 and 1385 m, on the northern rim of the summit of Resolution Guyot, (Fig. 3) in the western Mid-Pacific Mountains. Site 867 is atop the perimeter mound that fringes the summit of the guyot, whereas Site 868 is on a terrace, approximately 30 m deeper and 400 m outside the perimeter mound. Because of the shallow water depth, a separate beacon had to be used for Site 868; hence, it is cataloged as a different site than Site 867. Owing to their proximity in space and in scientific theme, the sites have been paired for the purposes of our reports.

Proposed Site Hue-B was to be a single, shallow-penetration (approximately 300 m) hole drilled into the perimeter mound surrounding the summit of Resolution Guyot. We had assumed that this mound was a Cretaceous reef that had drowned and, perhaps, even been emergent owing to relative drops in sea level. Our goals for drilling at the site were (1) to examine the biota and vertical development of a Cretaceous reef, (2) to determine the cause and timing of drowning, and (3) to determine the magnitude of relative changes in sea level and karsting. A second hole (Site 868) was drilled because results from previous Leg 143 sites suggested that a significant gap in time existed between the oldest platform carbonates and the first pelagic sediments to accumulate atop the platform. It was thought that the terrace might be a sea-level lowstand reef complex whose drilling might help to fill the gap.

Sites 867/868 are not at the precise location of proposed Site Hue-B, but 1 2 and 1.0 nmi (2.2 and 1.9 km), respectively, to the southeast. Because the perimeter mound is lineated along the rim of the summit, it was reasoned that almost any location on the mound would produce similar results, so the ship was moved on thrusters to the top of the mound near Site 866. Likewise, Site 868 was occupied by moving the ship about 400 m northward to the terrace near Site 867.

Coring began at Site 867 at 0900 UTC on 24 April 1992, and drilling was finished at Site 868 at 1330 UTC, 28 April, after 4.2 days. Two holes were drilled at Site 867; both were spudded-in with no guidebase on hard limestone having virtually no sediment cover. The first hole (Hole 867A) consisted of a single core that was drilled with the diamond bit. The small-diameter BHA sheared off at the outer core barrel, so the hole was terminated.

The second hole was drilled with the new polycrystalline (PDC) bit. This is an experimental bit that has cored limestone on land with success. We had one aboard the ship and thought that it might improve recovery in these limestones, so it was pressed into service. The PDC bit cored slowly in hard limestone, but with excellent recovery. Hole 867B was drilled to a depth of 76.9 mbsf in 23.5 h with 29.2% average recovery. Average recovery would have been higher, but the section contained a 9-m cavity, which, of course, yielded no core. Hole 868A, the only hole drilled at that site, penetrated 20.3 mbsf in 16.8 h, and 46.3% of the section was recovered. Hole 867B was terminated at 76.9 mbsf, rather than the planned 300 mbsf, mainly because at depth the limestone facies reverted to lagoonal, rather than the reefal, facies we sought. Consequently, drilling operations were moved downslope to Site 868. Drilling was terminated at Site 868 when time ran out on the drilling schedule for this site and it was necessary to begin transiting to the next site.

Lithology

Cores from Sites 867/868 consist of shallow-water limestone with a thin veneer of pelagic limestone. Based primarily on benthic foraminifers, the shallow-water limestone is Albian in age, whereas planktonic foraminifers and calcareous nannofossils indicate an Eocene age for the overlying pelagics. Two lithologic units were recognized at Site 867, and Site 868 fit within the second, stratigraphically lower unit from Site 867. These units (Fig. 7) are described as follows:

1. Unit II (10.0–0.0 mbsf, Hole 867A; 76.8–0.29 mbsf, Hole 867B; 20.3–0.0 mbsf, Hole 868A). Albian bivalve/gastropod/echinoid wackestone-to-packstone, grainstone-to-floatstone beach deposits, and oolitic grainstone. A variable amount of skeletal material is present, including rudists, sponges, and corals. These limestones have two outstanding characteristics. First, they display meter-scale, fining-upward, transgressive-regressive sequences modulating an overall shift from restricted lagoon to open-marine shoreface going up the section. Second, virtually the entire sequence, down to at least 62 mbsf has centimeter-scale dissolution cavities, many of which contain speleothems that imply dissolution in the lower vadose zone. Some cavities may be much larger; one section about 9 m in length, gave no resistance to the drill string and was thought to be a cavity. Unit II has been subdivided into three subunits, the uppermost of which is distinguished by multiple generations of internal sediment (mudstone) of different colors and compositions, the most prominent of which is dark brown, fine-grained phosphatic material. The second subunit is the same, except for the absence of cavity infilling and phosphatization. The entire section drilled at Hole 868A has been distinguished as the third subunit because it consists mainly of sequences of sponge bioherms. This section also contains a layer of red-stained limestone that suggests emergence.
2. Unit I (0.29–0.0 mbsf, 867A). Eocene foraminiferal nannofossil limestone, heavily replaced and impregnated with phosphate and manganese dendrites. This unit represents the first permanent pelagic sedimentation atop the guyot.

Interpretations

Findings at Sites 867/868 have two important implications. First, the dissolved cavities containing speleothems are strong evidence of emergence and confirm inferences of karsting, based on seismic-reflection profiles and multibeam echo-sounder data over Resolution and other Pacific guyots (van Waasbergen and Winterer, in press). Furthermore, the depth of the dissolution, 62 mbsf at Site 867, combined with the nearly 100 m of limestone relief above the site in the guyot center, together imply a relative fall in sea level of at least 160 m. Second, the cores from Sites 867/868 contain much less reefal material than expected. The perimeter mound, once thought to be a reef, may be only a perimeter island chain. Furthermore, the volume contribution from reefs to the building of the carbonate platform atop the guyot may be smaller than previously thought. Future drilling during Leg 144 should help to put this finding into perspective.

Site 869

Site 869 (proposed Site Syl-3) is situated at 11°00.01′N, 164°44.97′E, at a water depth of 4827 m, 45 nmi (83 km) southwest of the atoll-guyot pair, Pikinni Atoll (formerly Bikini) and Wodejebato Guyot (formerly Sylvania) (Fig. 4). Drilling at this location was planned to provide a basinal reference section for comparison to Leg 144 drill holes on the summit of Wodejebato and prior drilling on Pikinni. Site-survey data suggested that a thick, layered succession of sediments at the site consisted mainly of turbidites. Volcanic basement is not obvious in the site-survey seismic lines; thus, drilling was not expected to encounter basement basalt. Approximately 850 m of penetration was planned, and the expectation was to bottom in Cretaceous volcaniclastics produced by constructional volcanism on either or on both Wodejebato and Pikinni.

The location of Site 869 was chosen to be close enough to receive sediments shed mainly by the atoll-guyot pair, but far enough away so that one would not block sediments of the other. We assumed that sedimentation at an adjacent basinal hole would parallel and complement that on the atoll-guyot pair. For example, erosional hiatuses on the summit might be expected to produce sediments on the archipelagic apron, thus filling "missing chapters" in the geologic history provided by summit holes. Drilling at Site 869 was undertaken to address the following primary goals: (1) determining the volcanic history of Pikinni/Wodejebato; (2) developing a model of Cretaceous, mid-ocean guyot/atoll carbonate platform formation and evolution; (3) comparing the timing and effects of relative sea level fluctuations among Pacific guyots and their relationship to world wide sea-level curves; and, (4) deciphering the cause(s) for the drowning(s) of some Marshall Islands guyots (such as Wodejebato) vs. the existence of Cenozoic reefs on nearby atolls (such as Pikinni).

Two holes were drilled at Site 869, an APC/XCB hole (869A), and a RCB hole (869B), the latter located 30 m east of the former. Our operational plan was to use the APC/XCB combination to obtain relatively undisturbed cores from the upper 300 to 400 m of the sedimentary column. In analogy to Site 462, hard chert layers were expected to frustrate drilling at about 300 to 400 mbsf, and a round-

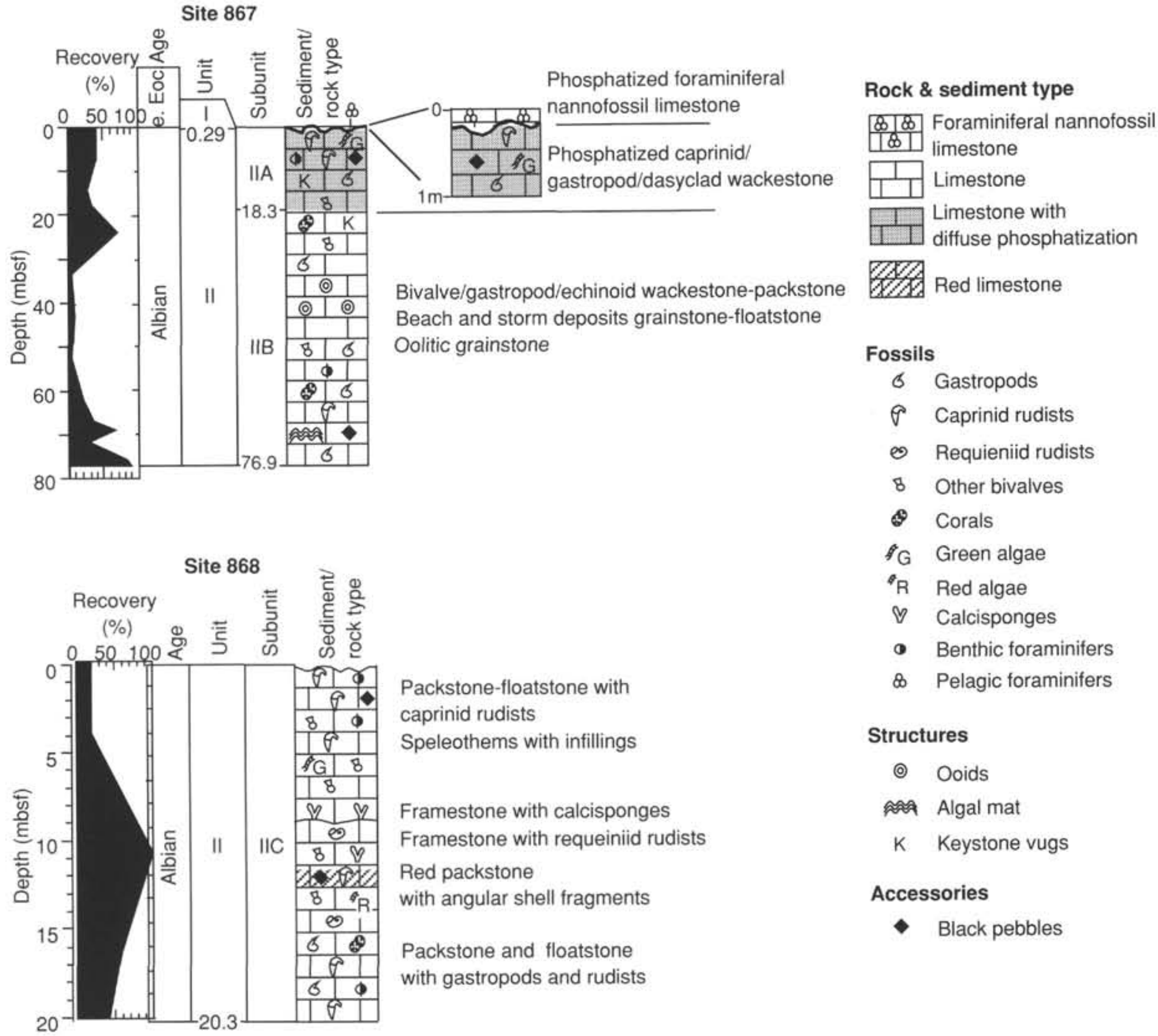

Figure 7. Sites 867/868 hole summary.

trip was planned to change to an RCB bit and begin a second hole. Chert and porcellanite were encountered at much shallower depths than expected, and Hole 869A was terminated at a depth of only 166.5 mbsf. Hole 869B was washed to 140.0 mbsf and cored continuously to a total depth of 796.2 mbsf. Hole 869B was terminated when time for drilling ran out. Logging runs were conducted in Hole 869B with four tool strings: the quad tool, FMS, Japanese magnetometer, and geochemical tool. The quad tool made a complete run, but pipe had to be lowered to 235 mbsf so that the FMS and magnetometer could get through bridges. Only 200 m of hole was covered with the geochemical tool before time ran out.

Core recovery in Hole 869, drilled with the APC/XCB combination, was mostly excellent, with the average being more than 100% for the APC cores and 77.6% overall. In Hole 869B, recovery was variable. In cherty sections, recovery was generally low. In contrast, recovery in Cretaceous volcaniclastic turbidites was typically in excess of 60%. In general, recovery increased downhole in Hole 869B, averaging about 20% from 200 to 500 mbsf and increasing to 70% at the bottom of the hole.

Age Constraints

Cores from Site 869 range in age from Cenomanian to early Miocene, with age data mainly coming from calcareous nannofossils. Within the stratigraphic succession, we recognized five hiatuses: between the upper Coniacian and lower Santonian, between upper Maastrichtian and lower Paleocene, within the upper Paleocene, between the upper Oligocene and lower Miocene, and post-early Miocene age sediments, which are missing at the seafloor. The most prominent of these hiatuses spans up to 10 m.y. and includes the K/T boundary.

Lithology

Three sedimentary units were distinguished in Site 869 cores (Fig. 8), from oldest to youngest, they are described as follows:

1. Unit III (796.2–207.7 mbsf). Upper/middle Cenomanian to lower Maastrichtian/upper Campanian volcaniclastic sediments interlayered with nannofossil and radiolarian claystone. This unit is characterized by numerous gray-to-green-volcaniclastic sandstone, siltstone, and breccia layers intercalated with lighter-colored claystone. Most appear to have been deposited by turbidity currents, grain flows, or mass flows. Seven subunits were defined on the basis of changes in the balance of volcaniclastic sediments and claystone. Basalt clasts, some as large as 80 mm in diameter, occur in the breccias and in some volcaniclastic layers with sand-size grains. Alteration of the basalt has been moderate; zeolites are a common cement. Unequivocal shallow-water debris is virtually absent in the Cenomanian

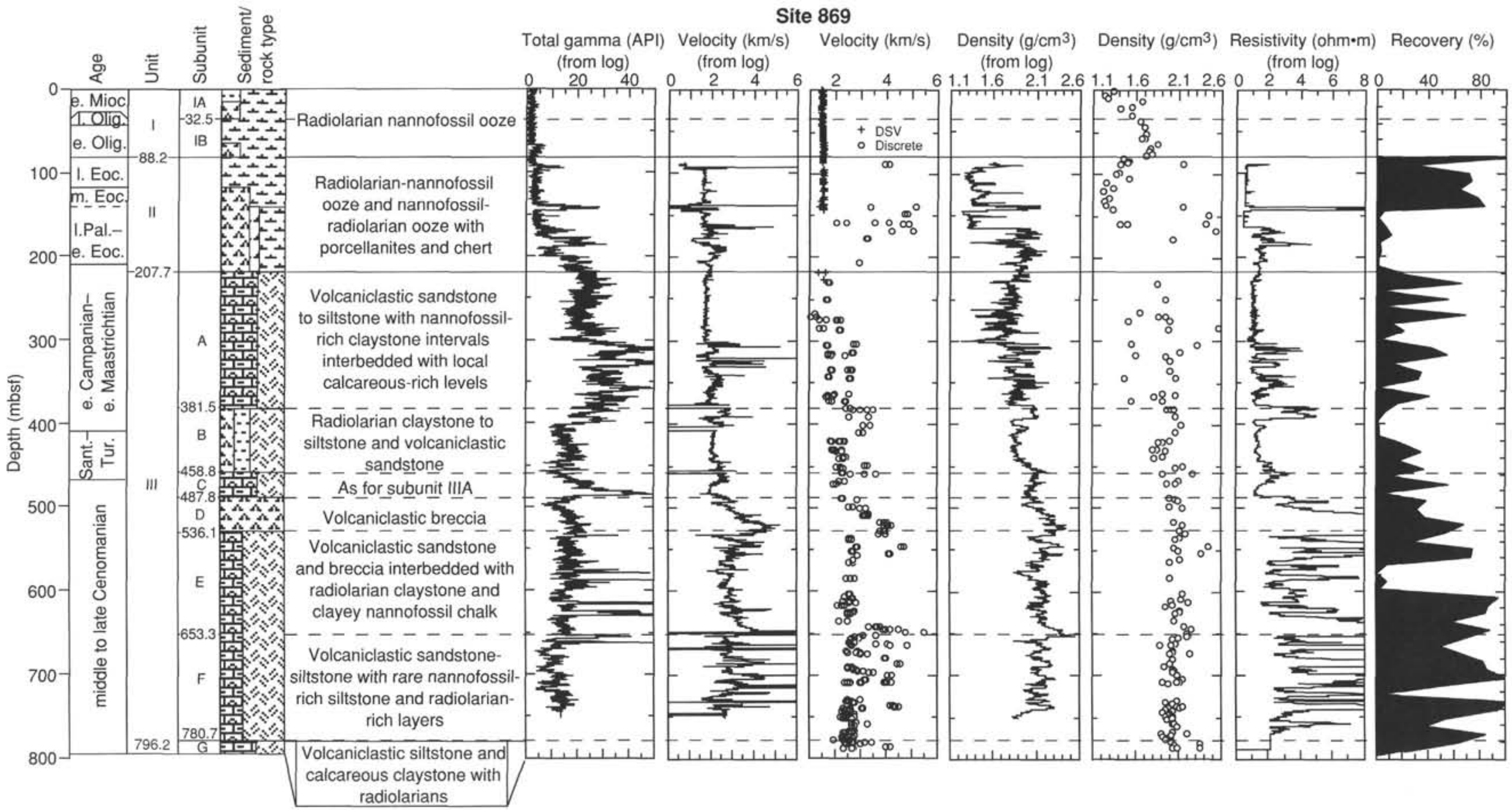

Figure 8. Site 869 hole summary, including age, lithology, core recovery, physical properties, and downhole logs.

section (one fragment of one larger foraminifer), but is sometimes present in minute proportions in the Upper Cretaceous section. Bivalve shell, gastropod, red-algal, and recrystallized skeletal fragments were recognized, as were orbitoid foraminifers, micritic ooids, peloids, and glauconite. Coalified woody fragments occur in one core. The sedimentation rate in the Cenomanian sequence was high; more than 300 m of volcaniclastics was deposited within the time of the latest Cenomanian nannofossil Zone, CC10. This suggests a minimum sedimentation rate of 60 m/m.y., but the entire 300 m may have been laid down in less than 1 m.y. Sedimentation rates slowed later during the Cretaceous and averaged about 15 m/m.y.

2. Unit II (166.5–88.2 mbsf, 869A; 207.7–140.0 mbsf, 869B). Upper Paleocene to upper Eocene radiolarian-nannofossil ooze and nannofossil-radiolarian ooze with porcellanite and chert. Recovery of this unit was poor, but it appears to consist of alternating layers of hard chert and soft ooze. Porcellanites and cherts are more abundant at the bottom of the unit and decrease upward. Layers of nannofossil limestone and chalk occur in places throughout the unit.

3. Unit I (88.2-0.0 mbsf). Upper Eocene to lower Miocene clayey nannofossil ooze and radiolarian-nannofossil ooze. Radiolarians, nannofossils, sponge spicules, and clay are major components. Color and composition show repetitive changes on various scales as the mix of principal components varies.

Downhole Logs

Sonic velocity and density correlate well throughout most of Hole 869B (Fig. 8). High variability in both resistivity and sonic velocity indicates variability in porosity. Sonic velocity and density generally increase downhole, but do not follow a simple compaction profile, which implies diagenesis and compositional and grain-size effects. A notable feature of the logs is that velocity, resistivity, and density decrease downward through certain intervals, contrary to the normal compaction profile. The gamma-ray log displays numerous short-wavelength peaks that correlate with clay intervals. This log also shows a broad region of high values that apparently were caused by ashy sediments between about 200 to 400 mbsf within the Campanian to Maastrichtian section.

Seismic Stratigraphy

Site-survey seismic-reflection profiles over Site 869 show a series of reflector packets beneath the seafloor. The seafloor itself shows relief of tens of meters and apparent erosional features consistent with sediments younger than early Miocene age being absent at the site. Between the seafloor and 0.190 s twtt are two sets of reflectors having significant relief that implies channelized turbidity current sedimentation. These correlate to Cenozoic sediment layers. Between 0.19 and 0.345 s and 0.44 and 0.53 s twtt are relatively transparent layers that bracket a series of relatively flat seismic horizons. These reflectors correspond to Upper Cretaceous volcaniclastic turbidites. At the bottom of this packet is a prominent, continuous reflector at 0.44 s twtt that appears to correlate to the base of a thick breccia. The seismically transparent layers above are Upper Cretaceous to Lower Tertiary sediments of the upper part of lithologic Unit III and the lower part of Unit II. Those transparent layers below 0.44 s twtt correspond to layers composed mainly of claystone. A series of reflectors from 0.53 to 0.64 s twtt mark the positions of Cenomanian volcaniclastic sediments. Hole 869B terminated in these sediments. Two faint reflectors are seen beneath the TD, at two-way traveltimes of 0.89 and 1.05 s twtt. Extrapolating seismic velocities, their predicted depths are 1000 and 1230 mbsf. No indication is seen that either horizon marks the top of the underlying oceanic crust. Instead, the seismic sources used to gather the existing data appear inadequate for penetrating to basement.

Interpretation

Cretaceous sediments cored at Site 869 show rapid sedimentation of volcaniclastic debris during the Cretaceous, beginning with extremely high rates during the Cenomanian, lower rates in the Turonian to Santonian, then moderately rapid through the Campanian. Cenomanian plant fragments and Campanian shallow-water debris imply the existence of land and carbonate shoals. Abundant volcanics of Cenomanian and Campanian age imply two stages of volcanism on the nearby volcanic edifice(s). Previous dredging from Wodejebato Guyot recovered Albian, as well as Campanian, shallow-water limestones (Lincoln et al., in press); thus, an Albian or older edifice must lie beneath. This implies a stage of volcanism that was not penetrated by drilling at Site 869. At the end of the Cretaceous, volcanism ceased in the vicinity of the drill site, and subsequent sedimentation was mainly pelagic, dominated by radiolarians and nannofossils, together with input from turbidity currents carrying biogenic debris.

IMPLICATIONS OF DRILLING RESULTS

Vertical Trajectories of Seamounts

An important objective of Leg 143 was to unravel the complicated history of relative vertical motions of the guyots, by our trying to separate tectonic uplift and subsidence (including isostatic effects) from eustatic sea-level fluctuations. The two Mid-Pacific Mountains Cretaceous seamounts had possible multistage vertical histories that alternated between flooding and emergence. The history of these relative sea-level changes is schematically shown in successive panels of Figure 9. The western part of the Mid-Pacific Mountains (MPM) (Fig. 1) comprises several broad plateaus where volcanic basement is at about a 3 to 3.5-km depth, covered by Barremian (about 121 Ma; Kent and Gradstein, 1985) to Holocene pelagic sediments 0.5 to 1.0 km thick. Flat-topped seamounts surmount the plateaus and rise to depths of about 1.5 km; these are known from seismic-reflection and swath-bathymetry studies and from dredging to be capped by shallow-water limestone of Barremian-Albian (121-98 Ma) age. The plateau region is bordered on the west by the deep Pacific Ocean floor, of Late Jurassic (about 150 Ma) age (Nakanishi et al., 1989). The age of oceanic crust beneath the western MPM is unknown, but we estimate it to be about 130 Ma. A fracture zone separates the MPM from the older crust to the north. The earliest history of the plateau is speculative, but is plausibly modeled (shown in Fig. 9A), at 121 Ma, with normal depth for crust of 9 Ma juxtaposed vs. crust of 29 Ma.

Drilling during Leg 143 showed that the basalt of the edifice beneath the carbonate platform at Resolution Guyot is reversely magnetized and of Barremian age. We tentatively correlate this reversal with magnetic anomaly M–1, dated at about 121 Ma (Kent and Gradstein, 1985). We assume that the underlying and surrounding plateau basalt is of the same age. Figure 9B, shows the plateau basalt and Resolution Guyot, which drill data indicate, built itself up as an island. The seamount subsided quickly and a shallow-water carbonate bank established itself on the eroded volcanic pedestal (Fig. 9C). At first, the bank was fairly open to normal marine waters, but sedimentation raised the depositional surface very close to sea level, and more restricted circulation conditions prevailed during most of the Barremian-Aptian (about 121–116 Ma). Carbonate production rates were high, and occasional turbidity currents and debris flows swept material from the bank down the slopes into the adjacent basins, which were only about 0.5 to 1.0 km deeper than the bank top. These redeposited sediments were recovered in cores at DSDP Site 463, about 45 km east of Resolution Guyot (Thiede, Vallier, et al., 1981).

During the Barremian-Aptian, the bank was occasionally at depths of 10 to 20 m, and oolite shoals or rudist banks extended into the platform interior; but mainly the water level fluctuated between shallow subtidal and supratidal. Exposure surfaces and algal mats were frequently developed.

Preliminary shipboard paleontological data do not allow us to say whether the more open conditions correlate with relative rises in sea level elsewhere on the globe (Schlanger, 1986). Further shore-based paleontological and Sr-isotope studies are expected to sharpen the stratigraphic resolution required to address the correlation problem.

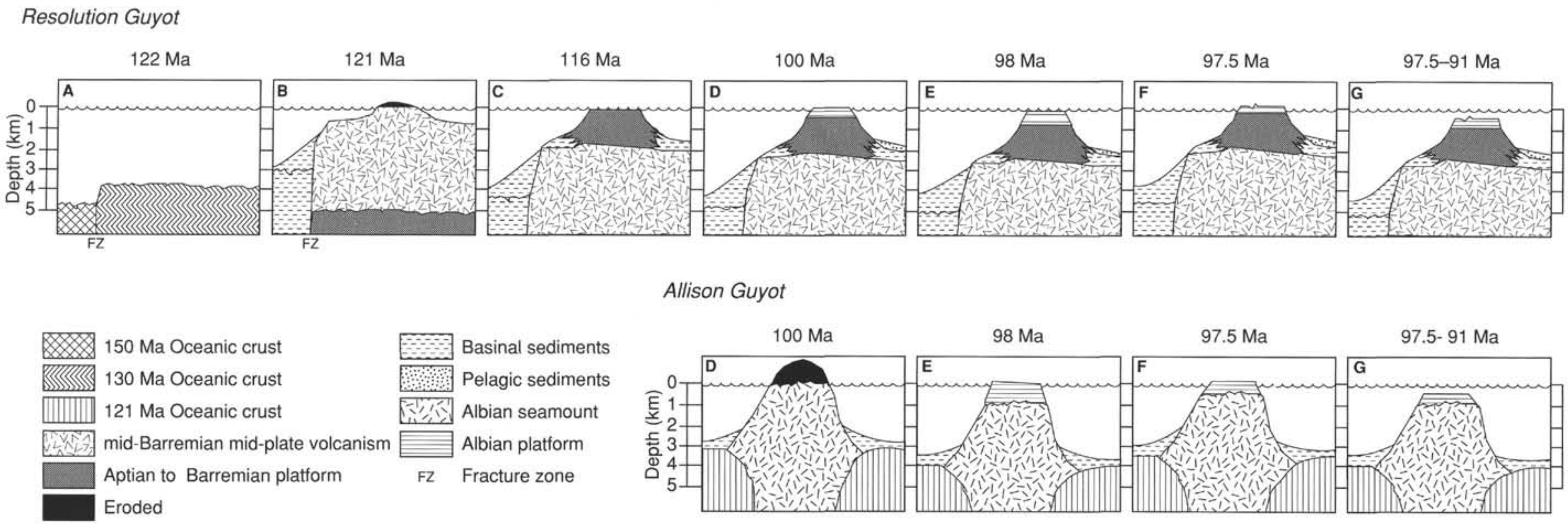

Figure 9. Schematic evolution of the Mid-Pacific Mountains (MPM) region including Resolution Guyot (Sites 866–868), and Allison Guyot (Site 865) in the central MPM. **A.** Formation of oceanic crust. **B.** Building of MPM plateau and Resolution Guyot pedestal. **C.** Formation of Barremian-Aptian carbonate platform. **D.** Albian carbonates deposited on Resolution and Allison volcano forms. **E.** Co-eval Albian carbonate caps form on both guyots; **F.** Fall in relative sea level emerges both guyot summits. **G.** Guyot platforms drown.

At some time during the Albian (precise dating is uncertain), shallow-water carbonate sedimentation ceased on Resolution Guyot. A relative sea level fall is credited with dissecting the surface of the carbonate body and imposing an irregular relief. Final submergence took place in Maastrichtian or earlier time judging from the age of the sampled pelagic cover.

At the same time that the final carbonate growth phase (Albian) took place on Resolution Guyot, another bank began growing on Allison Guyot, in the central MPM about 700 km to the east. Here, the seamount foundations have been dated (Winterer et al., in press) at about 101 Ma. Drilling during Leg 143 at Allison Guyot showed about 730 m of late Albian lagoonal and swamp sediments overlie and are interbedded at the bottom with basalt sills. Seismic data suggest a moderate additional thickness of platform sediments above the volcanic pedestal. Thus, subsidence was relatively rapid (about 300–400 m/m.y.) during the growth of this carbonate bank.

After only 1 to 2 m.y. of growth, a major relative fall in sea level (Fig. 9F) left the banks at both Allison and Resolution Guyots emergent by at least 150 to 200 m, as shown by the relief of the eroded upper surface of the guyots, which contain karstic sinkholes and troughs as much as 75 m deep, now buried under Upper Cretaceous and Cenozoic pelagic sediments. The upper part of the Albian lagoonal sediments in Leg 143 drill holes is riddled with cavities, some of which are lined by speleothem calcite that formed in the vadose zone, above the water table. Some cavities have been back-filled by Upper Cretaceous pelagic sediments. The final drowning of Allison Guyot (and plausibly for Resolution Guyot; Fig. 9G) was prior to the middle Turonian (about 90 Ma), as dated by the oldest fossils in pelagic sediments on Allison. Re-submergence occurred without establishment of new shallow-water carbonate banks, even though the guyots were in very low latitudes (Sager et al., in press). The cause of the drowning remains as mysterious now as it was prior to Leg 143 drilling.

Platform Anatomy

The Albian carbonate platform at Resolution Guyot had a morphology very unlike Neogene Pacific atolls (Fig. 10). Instead of a wave-resistant reef at sea level, surmounted partly by low islands and surrounding a deeper lagoon, the Early Cretaceous oceanic platform had a submerged platform edge, at a depth of about 30 m, with sponge reefs near the edge, and probably with rudist and coral communities on the uppermost slopes near the edge. Sand islands formed a discontinuous mound about 0.5 km inward from the shelf break, and these partly protected the very shallow, interior, lagoonal part of the platform. In none of the profiles of three holes across the perimeter of Resolution Guyot, from lagoon to island to edge, did we encounter a coral reef or masses of rudists.

Regional Tectonics

The large plateau surmounted by Resolution Guyot has a present-day depth of 3 to 3.5 km, very near to the actual depth of the volcanic platform beneath the Resolution carbonate strata, with the corollary that this whole region was at very shallow depths during late Barremian time (about 121 Ma). Unless the western Mid-Pacific Mountains were mechanically decoupled from the adjacent deep seafloor immediately to the west, of Jurassic age (about 150–160 Ma), then this old oceanic crust was also about 2 to 2.5 km shallower than normal for its age at 121 Ma (Fig. 9B).

SPECIALIZED STUDIES

Pore-Water Ventilation

Shipboard pore-water composition measurements suggest that fluid exchange is occurring between the surrounding seawater and the interstitial waters of Allison and Resolution guyots. Pore-water compositions in both pelagic caps and thick shallow-water limestone sequences contain less sulfate than seawater and some ammonium, indicating that a slight amount of compositional evolution has occurred. However, the pore-water samples generally are similar to seawater. Because the relatively high organic content in some layers within the platform would allow for more of a diagenetic change and because the observed porosity development would have altered the major-element composition of the pore water, we have inferred that these guyots are well-flushed, rather than just being relatively inert geochemical systems.

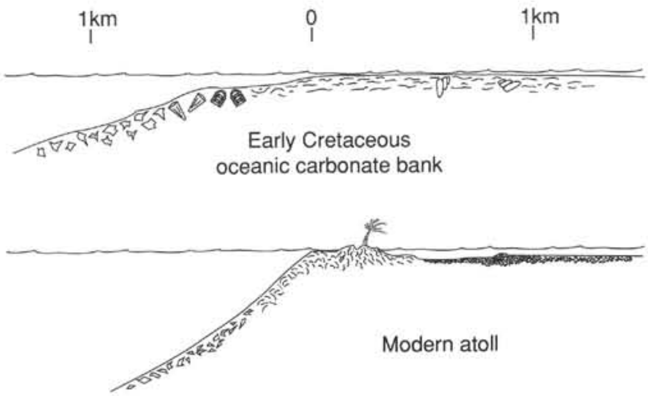

Figure 10. Comparison of the profile of the edge of Resolution Guyot during Albian time with a similar profile of a typical modern atoll. Drawings have no vertical exaggeration.

Borehole temperature logs from Allison (Site 865) and Resolution guyots (Site 866) show that downhole temperatures increase at an average rate of about 5°C km. Thus, advective circulation cannot be vigorous enough to erase thermal increases associated with the regional heat flow. However, a surprisingly low geothermal gradient is indicated by borehole temperature measurements and may result from advective cooling of the platform. The existing thermal gradient provides a mechanism to stimulate circulation within a guyot, given some minimal permeability.

Organic Geochemistry

High concentrations of organic carbon occur in the shallow-water carbonates drilled at both Resolution (Hole 866A) and Allison (Hole 865A) guyots. At Resolution, thick sequences that contain algal laminations with up to 2.9% total organic carbon (TOC) are common in the Aptian Section. Both hydrogen indexes and gas-pyrolysis chromatograms indicate a marine origin for this organic matter. A few beds with up to 14.2% TOC were also recovered, but the organic matter in these beds is of a terrestrial or degraded marine origin. At Allison Guyot, organic-matter concentrations having up to 35% TOC were encountered. Sites 865 and 866 revealed that environments suitable for organic-matter preservation occurred during the Early Cretaceous in the lagoonal facies of Mid-Pacific Mountains guyots. The amount and quality of this organic matter is comparable to many petroleum source rocks from continental margins.

Igneous Petrology

Igneous rocks were recovered from three holes drilled during Leg 143: Hole 865A (Allison Guyot), Hole 866A (Resolution Guyot), and 869 (apron site near Wodejebato Guyot and Pikinni Atoll). At Allison, a series of sills has intruded upper Albian sediments at the bottom of the Hole 865A (840-871 mbsf). These intrusions are of alkali basalt, similar in composition to the lavas dredged previously from the flanks of the guyot. These sills may represent a late pulse of volcanism, or alternatively, they may have formed during a subsequent magmatic event unrelated to the previous volcanism, possibly as the guyot passed over a hot spot. Unlike the classic Darwinian theory of atoll development (Darwin, 1842), in which volcanic basement plays a passive role in the development of the limestone cap, the volcanic material drilled at Allison augmented the construction of the cap.

A sequence of subaerial lava flows was drilled beneath Barremian-age sediments at the bottom of Hole 866A on Resolution Guyot. These lavas are separated by reddish rubbly and lateritic intervals, thought to be the product of tropical or subtropical weathering during exposure on a volcanic island. The Resolution Guyot lavas have intraplate tholeiitic or transitional compositions, and lack the strongly defined alkalic signature of the Allison Guyot sills. The guyot conforms to the Darwinian model in which an eroded and subsiding volcanic island passively provides a pedestal for reef or carbonate platform development. However, the depth to basement (1620 mbsf) indicates that the volcanic pedestal is much smaller than expected.

Volcaniclastic siltstones, sandstones, and breccias (with basaltic clasts) form thick section in the lower part of Hole 869B. The precise provenance of these turbidites and debris flows remains unclear. The deposits are composed primarily of glass shards and clasts that have been altered to palagonite, smectite, and zeolites. They probably were the product of shallow submarine basaltic volcanism, but there may also have been a subaerial component. Textural evidence suggests that redeposition occurred shortly after eruption.

Rudist Paleontology

Rudist bivalves were one of the main groups of bioherm-building organisms during Cretaceous time. They have been dredged from numerous Pacific Ocean guyots and are thought to have been abundant on these edifices. What has been obscure is the precise role they played when creating the carbonate caps of these features. Are they primary framework or merely baffles? How densely are they packed together and over how wide a zone are they common? Are they major sediment producers?

Sites 867/868 were planned to drill through the reef on the perimeter of the summit of Resolution Guyot, and we expected to recover sections of rudist framework. Yet, even in these cores, rudists were isolated from each other and mostly fragmentary. Four closely related types of caprinid rudists were recovered. These are smooth forms, roughly circular in outline, weakly coiled, with an elongate lower valve (which was presumably buried for over half its length in sediment) and a relatively long, cone-shaped upper valve. These types of rudist would be incapable of forming dense, strong frameworks. Instead, their primary function would have been to baffle the peloidal packstone sediment found between them and so to form mounds.

The back-reef site (866), contained debris of another, probably closely related caprinid, *Praecaprina*. In general, rudist debris was not abundant at this site, indicating that clastic material derived from the bioherms occupied a relatively narrow zone.

Drilling at Site 865 recovered some small requieniid rudists. These had an auger-like spiral lower valve and bun-shaped cap, features that signify adaptations to a shallow, muddy, lagoonal environment.

Rudists make useful biostratigraphic indicators only when their stratigraphic occurrences can be compared with a large database of total ranges of forms from deposits independently and reliably dated. This is not currently the case, because the existing database of global ranges of Barremian-Aptian rudists is patchy and inaccurate. Nevertheless, at the generic level, there is a strong measure of agreement among the forms encountered on the Leg 143 guyots and their known occurrences elsewhere. Thus, *Praecaprina* was encountered in sediments dated by benthic foraminifers as Aptian; it is known in the early Aptian in France and in Texas. Similarly, probable representatives of the genus *Planocaprina* occurred in Albian age sediments; other known occurrences are in the Albian of Mexico.

Rudists on Pacific guyots also are of significance for understanding mid-Cretaceous paleoceanography because of the information they contribute about directions of larval-dispersing currents between Tethys and the Caribbean. The specimen of probable genus *Planocaprina*, encountered at Resolution Guyot, is a Caribbean form. Should this identification be confirmed by later work, it demonstrates that during late Albian time, the main current direction was westward across the Pacific Ocean.

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*Abbreviations for names of organizations and publication titles in ODP reference lists follow the style given in *Chemical Abstracts Service Source Index* (published by American Chemical Society).

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