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1. INTRODUCTION AND SCIENTIFIC OBJECTIVES[1]

Shipboard Scientific Party[2]

The western Pacific Ocean is strewn with chains and clusters of Cretaceous seamounts, many of which are now flat-topped guyots having summit depths of about 1500 m (Menard, 1964; Matthews et al., 1974; Winterer and Metzler, 1984; McNutt et al., 1990). Most of these guyots are capped by pelagic and shallow-water reefal sediments overlying volcanic substrate. They are inviting targets for drilling because the sediments on their summits and flanks preserve a record of relative sea level and paleoceanography. Furthermore, their foundations yield clues about the volcanic and tectonic history of the Pacific Plate and the geochemical evolution of the upper mantle beneath the Pacific Ocean.

Guyot reefs can serve as "dip sticks" to monitor relative changes in sea level during times of reef development, when upward reef growth kept pace with the tectonic subsidence of their foundations (Wheeler and Aharon, 1991). Reefal sediments record in their mineralogy, textures, and fossils the timing of rises and falls of relative sea level. The mineralogy and chemistry of the volcanic foundations are clues to the nature of the parent mantle material, the processes of melt extraction and differentiation, and the time of emplacement of the lavas. Thus, guyots can yield constraints on a broad range of fundamental questions regarding Pacific tectonics, global sea-level history, and the enigma of carbonate platform drowning.

Legs 143 and 144 constituted an integrated campaign of drilling western Pacific Cretaceous reef-bearing guyots surmounted by carbonate caps. Ten drill sites were scheduled for the two cruises, located on seven guyots spanning about 30° of latitude and 35° of longitude (Figs. 1 and 2). Sampling over a broad geographical area was conceived to provide a basis for separating tectonic and eustatic sea level signals. The volcanic pedestals beneath the carbonate caps were targeted to yield data critical for tracing the volcanic and tectonic history of the Pacific Plate. Leg 143 specifically targeted guyots at three sites: summit drilling of two guyot summits in the Mid-Pacific Mountains (Allison and Resolution guyots) and an archipelagic apron near Wodejebato Guyot (formerly Sylvania) in the Marshall Islands. In addition, a short engineering test was scheduled at Anewetak Atoll to examine the feasibility of drilling in the shallow lagoon of a modern atoll.

DRILLING OBJECTIVES

Volcanic Edifices

Beginning in the late Barremian (about 125 Ma), a large region of the present-day western Pacific Ocean, measuring perhaps 3000 km in diameter, was the scene of large-scale mid-plate volcanism (Schlanger et al., 1981; Menard, 1984; Winterer and Metzler, 1984). Not only did this volcanism form many of the western Pacific seamounts and guyots (Watts et al., 1980; Sager, 1992), it also appeared as widespread intrusives within the thin layer of deep-sea sediments (Larson and Schlanger, 1981) and perhaps generated the huge volcanic pile of the Ontong-Java Plateau (Tarduno et al., 1991). Although the source of this volcanism is not certain, it may be represented today by the cluster of Neogene volcanic chains and modern active volcanoes in the southeastern Pacific Ocean (the "Superswell" of McNutt and Fisher, 1987). This cluster is one of the centers of intense oceanic volcanism in the Southern Hemisphere erupted from isotopically anomalous mantle (the "Dupal" and "HIMU" anomalies; Hart, 1984; Castillo, 1988; Smith et al., 1989).

Horizontal and Vertical Tectonic Motions

As new volcanoes formed successively in this region of the central South Pacific Ocean, the motions of the Pacific Plate carried them progressively to the north and northwest along zigzag horizontal trajectories (Duncan and Clague, 1985). For Cretaceous seamounts, the total northward drift was as much as 30° to 35° (Duncan and Clague, 1985; Sager and Pringle, 1988). Some volcanoes formed over persistent hot spots that generated linear seamount chains, but the origins of most are still uncertain. Changes in plate motion have produced intersecting and overprinting of chains in some places, resulting in complicated geologic histories for some seamounts. The pre-Late Cretaceous part of this plate motion history is poorly constrained by existing data.

The more northerly guyots preserve a history of subsidence, followed by emergence above sea level, then re-submergence. Guyots of the Japanese Group (e.g., Takuyo-Daisan Guyot, formerly Seiko), at 30° to 35°N, have summits with drowned carbonate platforms and terraced carbonate banks. They have no more than about 200 m of carbonate sediments, and radiometric and paleontological dates indicate that they are probably of Albian age. Farther south, in the band about 18° to 28°N, reef-bearing guyots are drowned mature atolls with perimeter mounds (reefs?) and lagoonal sediments greater than 700 m thick (e.g., Allison, Resolution, and "MIT" guyots). Available dates suggest that these have foundations of late Barremian-Aptian age and reefal sediments that may extend into the Albian. Both of these northern bands of guyots were emergent (to as much as 200 m above sea level) and developed a karstic topography prior to their final drowning in the mid-Cretaceous (Winterer et al., in press). South of about 20°N, late Albian and younger pelagic sediments overlie the reefal strata; farther north, where these pelagic sediments are absent, the reefal strata are encrusted by phosphorite and manganese oxides.

To the south, in the Marshall Islands region, the reef-bearing guyots show an even more complex history of vertical motions, with as many as three epochs of reef growth. There are numerous modern atolls in the region, and drilling on two of these (Pikinni [formerly called Bikini] and Anewetak [formerly Enewetak, and Eniwetok]) shows that they have been growing since Eocene time. Dredges from several guyots in the Marshall Islands, and drilling results from nearby basinal sites, show the presence of rudist reefs of Late Cretaceous (Campanian and Maastrichtian) age (Larson and Schlanger, 1981; Moberly, Schlanger, et al., 1986). Moreover, on Wodejebato Guyot, reefal fossils of an even older reef of Early Cretaceous age have been dredged (Lincoln et al., in press).

Platform Drowning

Northwestern Pacific Cretaceous guyots present the "paradox of platform drowning" (Schlager, 1981) in classic form: why do carbon-

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

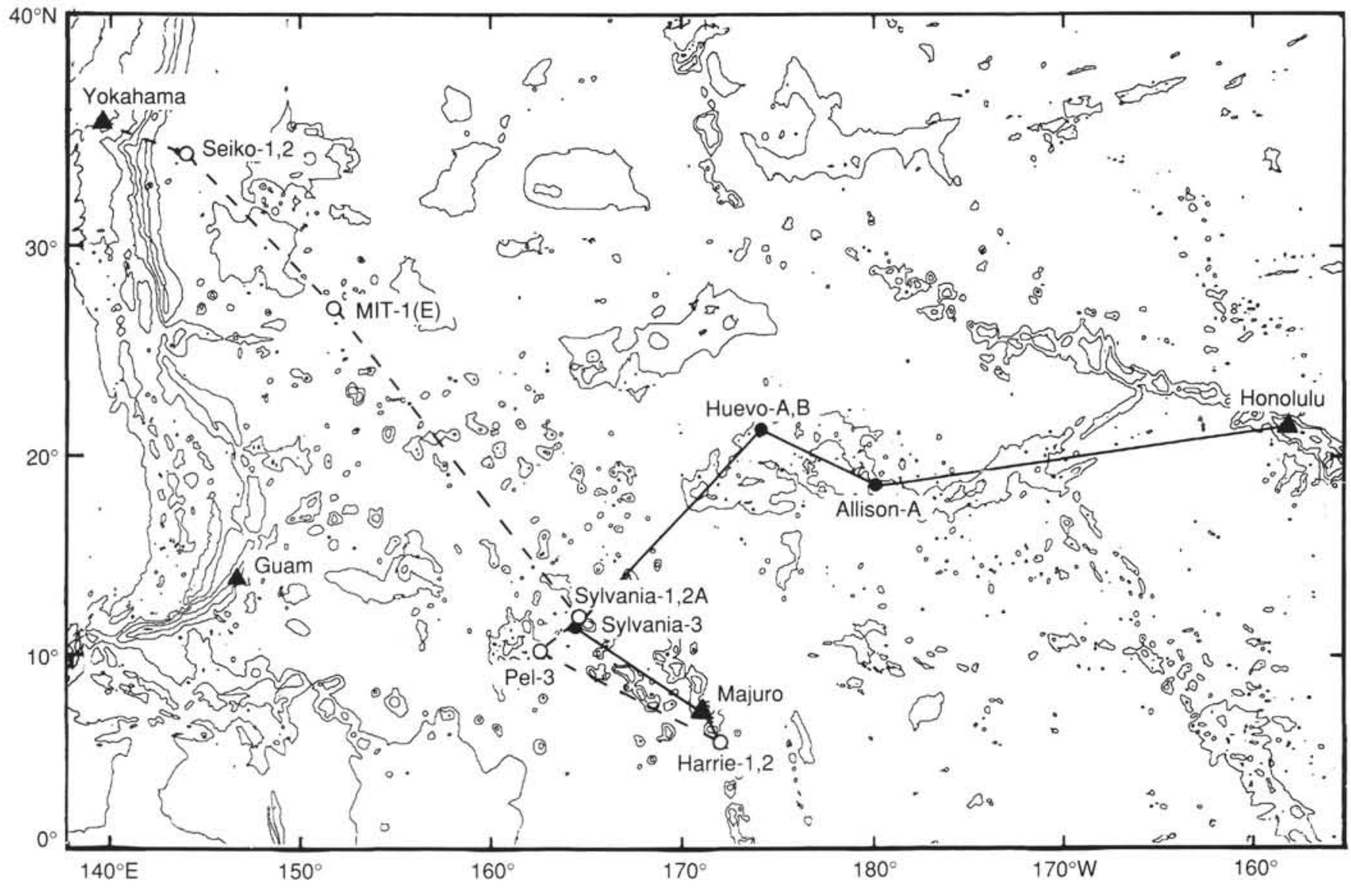

Figure 1. Generalized ships' tracks and locations of drill sites for Legs 143 and 144. Solid line represents Leg 143 track; filled circles show Leg 143 drill sites. Dashed line shows proposed Leg 144 track; open circles denote proposed Leg 144 drill sites. Bathymetric contours from DBDB5 gridded bathymetry data set.

ate platforms drown, when the growth potential of healthy platforms is one or two orders of magnitude higher than long-term (10^6 yr) rates of tectonic-subsidence or sea-level-rise? Why does one platform reef drown when another on an adjacent edifice survives? Additional questions are (1) why was platform drowning of such widespread occurrence in the mid-Cretaceous and (2) whether this drowning was a single, catastrophic event or the result of many small events.

Stratigraphy

Although the biota of shallow-water carbonates can give only limited stratigraphic control, strontium-isotope curves from the mid-Cretaceous provide an alternative means of dating. Calibration of the time of drowning may thus be possible by analysis of the atoll carbonates without resorting to inference from the overlying pelagic carbonates, which may be separated from the underlying limestones by a substantial stratigraphic gap.

Changes in Sea Level

Sequence stratigraphic studies of Cretaceous marine strata on and fringing the continents have been interpreted as indicating large eustatic shifts of sea level (Haq et al., 1988), but given that the Cretaceous world was nearly ice-free (Barron and Washington, 1982), both the causal mechanisms and the amplitudes are subjects of debate; some even question the eustasy itself. Because the reefal sediments of the western Pacific guyots are both nearly antipodal to the continent-tied sequences and in a wholly different tectonic setting, it is of great interest to obtain sea-level records from a number of co-eval Cretaceous guyots to test and quantify the eustatic hypothesis. Seismic reflection records of the lagoonal facies on the guyots (some with sediments about 600 to 800 m thick) show many continuous reflectors, reminiscent of the reflectors in Cenozoic atoll lagoons where drilling has shown that these reflectors correlate with emersion surfaces created by decreases in sea level (Folger, 1986).

Biotic Provinces and Migration Routes

Western Pacific Cretaceous guyots formed far from the main rudist reef regions of the Tethys seaways and the circum-Mediterranean and Caribbean provinces. The affinities of the shallow-water assemblages of the oceanic Pacific are imperfectly known; however, drilling should provide clues about their degree of provinciality and migration routes.

Ventilation of Pore Water

Residence times and chemical evolution of waters within the carbonate caps of guyots have a significant influence on the extent and nature of carbonate diagenesis. Consequently, to understand limestone cap formation, it is critical to know whether the caps are open or closed chemical systems. If the system is closed, interstitial waters may be primary connate waters and their compositional changes either responsible for or the result of diagenetic changes within the platform. Alternatively, if the system is open, fluid circulation within the potentially permeable limestones flushes large volumes of seawater through the reefal structures. To determine residence times and interstitial fluid evolutionary paths it is necessary to measure their chemical compositions, strontium-isotopic ratios, and temperatures.

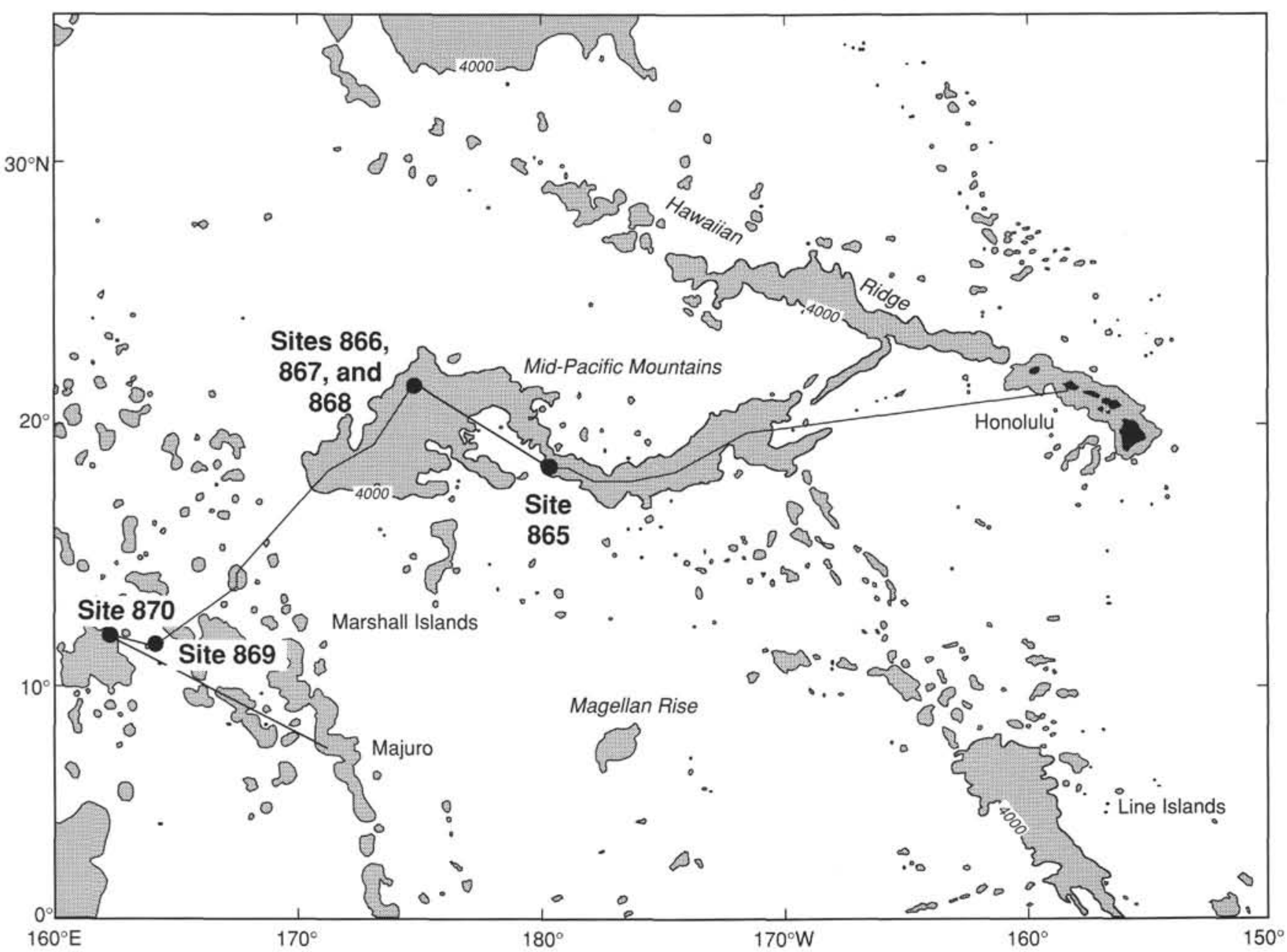

Figure 2. Location of Leg 143 drill sites and principal seamount chains, western central Pacific Ocean basin. Stippled areas are shallower than 4 km. Line shows track of *JOIDES Resolution*.

Post-drowning History

Biogenic pelagic cap sediments, deposited above the carbonate compensation depth (CCD), provide an estimate of the age of reef platform drowning. Furthermore, these sediments also provide an oceanic stable-isotope record, which is especially important for the Upper Cretaceous and Paleogene, now represented in the Pacific Ocean only by dissolved samples, mainly from deeper water. The occurrence of high-fertility indicators in the planktonic biotas from the pelagic caps can also be used to track the post-reef plate tectonic trajectories of the guyots.

Igneous Geology and Radiometric Dating

Igneous materials may be encountered either as basaltic basement or as volcaniclastics mixed with sediments above basement. Studies of igneous rocks will indicate eruptive mechanisms and environment, whether subaerial or submarine. Geochemical characteristics can yield magmatic affinities indicating differentiation and mixing mechanisms as well as providing a guide to the tectonic regime of the guyot's eruptions. Furthermore, radiogenic isotopes (e.g., Sr, Nd, and Pb) characterize mantle magma sources and can be used to examine the evolution of the Dupal Anomaly.

Radiometric dating (principally ^{40}Ar–^{39}Ar) of basalts and volcanics indicates the age of the volcanic pedestal beneath the guyot reef cap. This dating will provide age constraint for the beginning of reef formation as well as for the age and age progression of the seamount chain.

Summary

Leg 143 was designed to address a number of fundamental problems concerning guyot development by coring selected guyots and flanking basinal sites, including the following: timing and causes of platform drowning; timing and amplitude of relative changes in sea level and their relation to regional tectonics and eustatic sea level; seamount latitude changes, as recorded in the paleomagnetism of pelagic and lagoon sediments, as well as in the underlying volcanics; ages of the volcanic edifices, as clues about the direction and rates of age progression; longevity and evolution of the Dupal lavas' mantle source; and provinciality of Cretaceous reefal and shallow-water organisms and post-reefal paleoceanographic reconstruction.

DRILLING STRATEGY

Based upon available geophysical and geologic data from the western Pacific Ocean, a set of 11 targets was chosen for Legs 143 and 144. These were divided among several major seamount groups that spanned about 30° of latitude and stretched from the eastern Mid-Pacific Mountains to the Japan Trench (Fig. 1). One target, Seiko-1 (Takuyo-Daisan), is one of the northern tier of guyots at about 34°N. Four sites are located on guyots in the 18° to 28°N band of volcanic edifices: Site All-A (Site 865) on Allison Guyot, Sites Hue-A (Site 866) and Hue-B (Sites 867/868) on Resolution Guyot, and "MIT"-1E on MIT Guyot. Another six sites are found in the Marshall Islands: Syl-1 and Syl-2A atop Wodejebato Guyot and Syl-3 (Site 869) in the nearby basin, Har-1 and Har-2 on Harrie Guyot, and Pel-3 on Lo-en Guyot.

Because chosen guyot targets were too numerous and far-flung to be completed during a single ODP leg, the work was divided between Legs 143 and 144 to make a transect from the Mid-Pacific Mountains to the Japanese Seamounts with an intermediate port call at Majuro Atoll in the Marshall Islands (Fig. 1).

During Leg 143, the main target of the leg was Resolution Guyot, in the western part of the Mid-Pacific Mountains (Fig. 3), where seismic data show a thick Cretaceous carbonate cap having a karstic summit. A multiple-reentry site, Hue-A (Site 866), was planned to obtain deep penetration in the lagoon, about 1 km inward from the perimeter reef. A major goal at this site was to penetrate at least 200 m into the volcanic pedestal underlying the reef so that good paleomagnetic, age, and geochemical data could be obtained. Another Resolution site, Hue-B (Sites 867/868), was planned to be cored to a depth of about 300 mbsf (to reach levels beneath the karstified summit zone) on the perimeter mound, which was thought to be a drowned Cretaceous fringing reef.

On the way to Resolution Guyot, a single-bit site (Site 865) was planned to drill through the pelagic cap and about 300 m of lagoonal sediments atop Allison Guyot, in the central Mid-Pacific Mountains (Fig. 3). A major objective at Allison was to compare the seismic stratigraphy of the lagoonal sediments with that at Resolution.

After Resolution Guyot, a final basinal fan site, Syl-3 (Site 869), was planned for drilling southwest of Wodejebato Guyot in the central Marshall Islands, downslope from Pikinni Atoll (Fig. 4). About 800 m of sediment was visible on the site-survey seismic profiles, but the depth to basaltic basement was uncertain. However, it was thought that the site would yield not only a redeposited record of Early Cretaceous and Campanian-Maastrichtian reefing on Wodejebato, but also a record of Eocene-Holocene reefing on Pikinni. After completing operations at Site 869, the final planned stop was the lagoon at Anewetak Atoll for an engineering test (Site 870). The purpose of drilling at Anewetak was to learn if the ship could be kept positioned for drilling in very shallow water (about 30 m). Although Site 870 was dedicated to engineering, cores were taken in the upper part of the lagoonal sediments.

RESULTS FROM PREVIOUS DRILLING IN THE MID-PACIFIC MOUNTAINS

Before Leg 143, four holes were drilled in the Mid-Pacific Mountains during four separate legs of the Deep Sea Drilling Project (DSDP) (Fig. 3), as follows:

1. Site 44 (Leg 6), on the top of Horizon Guyot,
2. Site 171 (Leg 17), at the western end of Horizon Guyot,
3. Site 313 (Leg 32), at the eastern end of the Mid-Pacific Mountains, and
4. Site 463 (Leg 62), on the sediment apron east of Resolution Guyot.

Site 44

Site 44 (Shipboard Scientific Party, 1971) is located close to the summit of Horizon Guyot, at a depth of 1478 m. Before reaching the basement objective here, drilling was terminated by hard Eocene cherts that prevented penetration with the flat-face diamond bits in

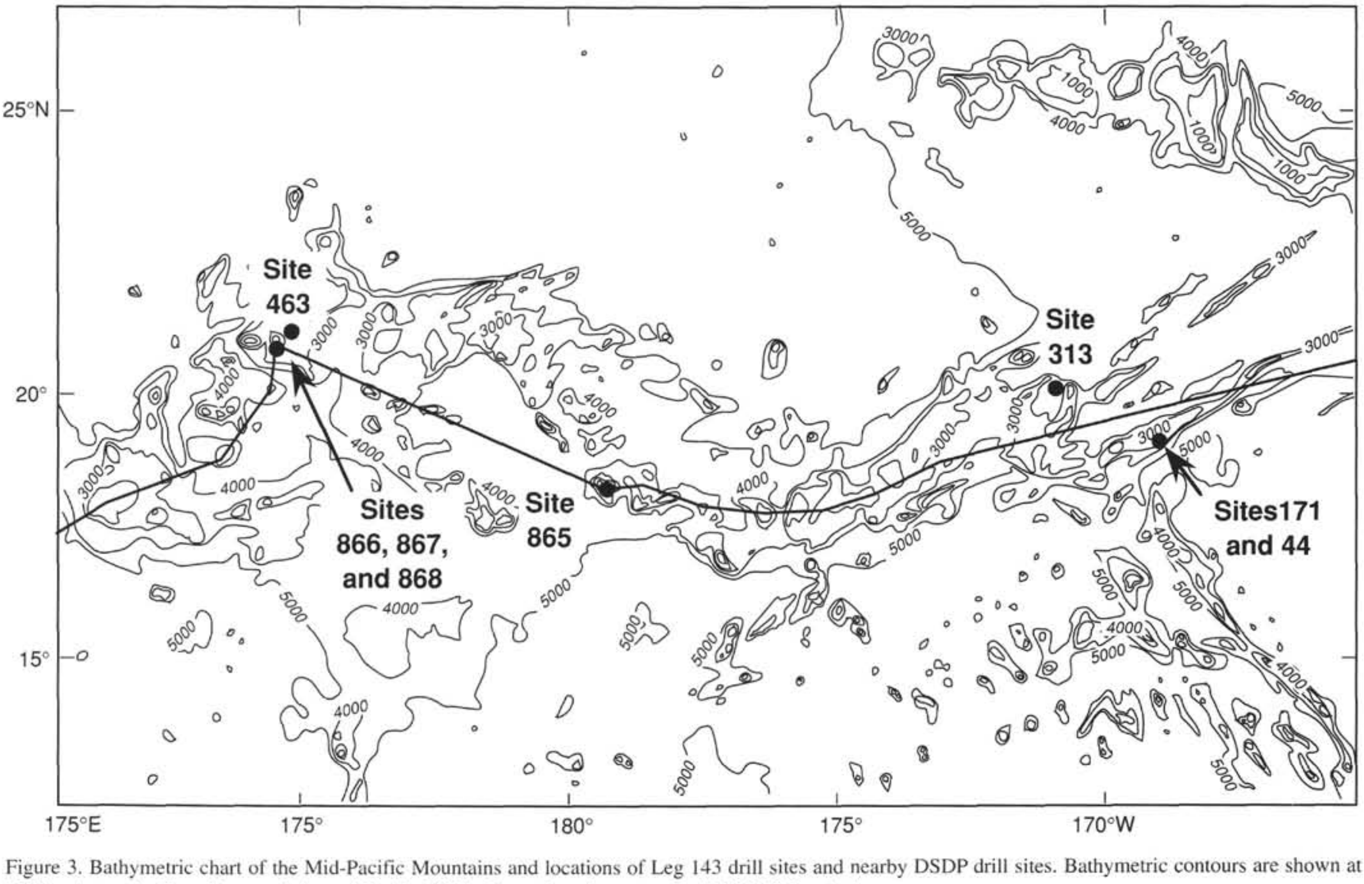

Figure 3. Bathymetric chart of the Mid-Pacific Mountains and locations of Leg 143 drill sites and nearby DSDP drill sites. Bathymetric contours are shown at 1000-m intervals (from Mammerickx and Smith, 1985). Heavy line shows track of *JOIDES Resolution*.

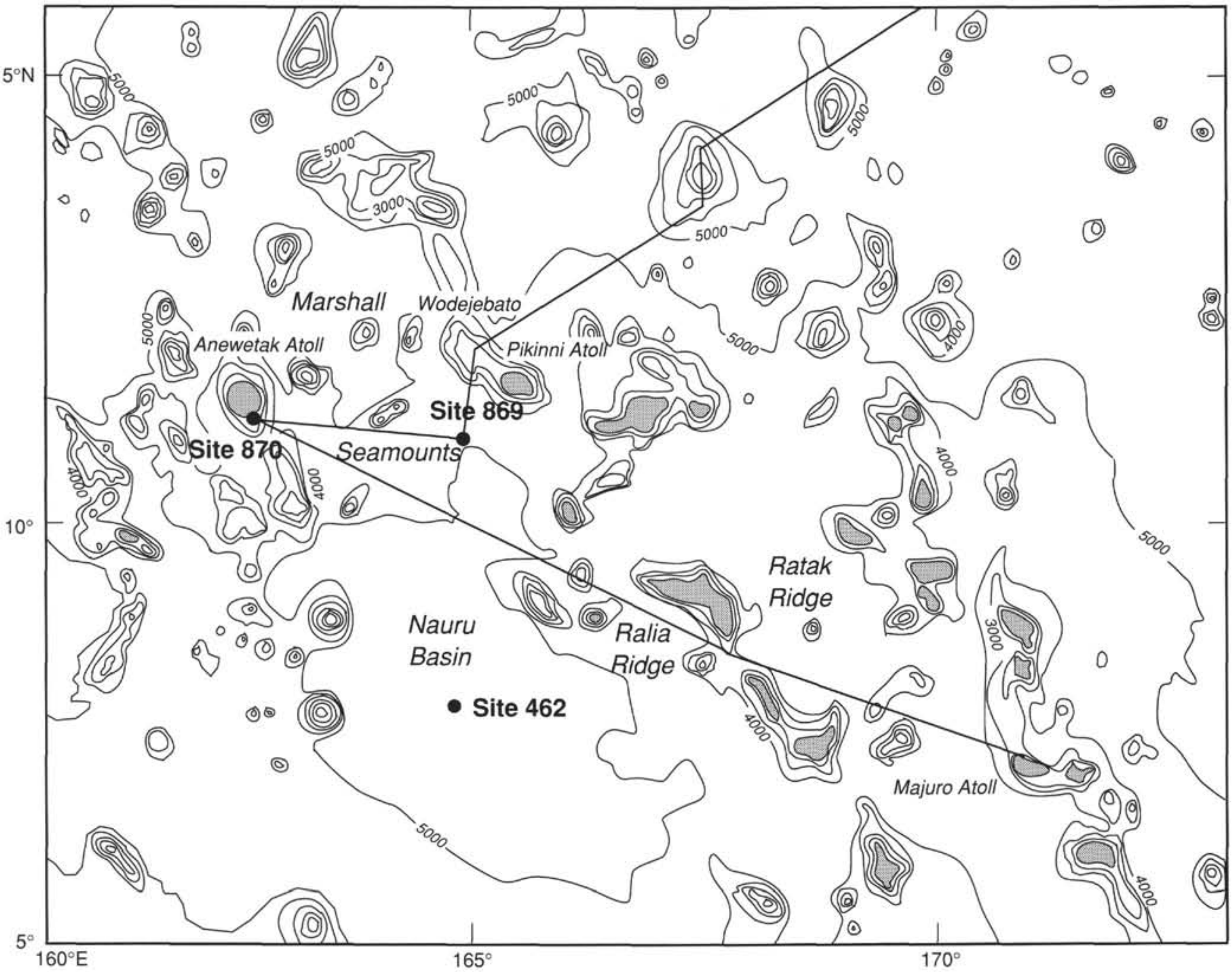

Figure 4. Bathymetric chart of the Mid-Pacific Mountains and locations of Leg 143 drill sites and nearby DSDP drill sites. Bathymetric contours are shown at 1000-m intervals (from Mammerickx and Smith, 1985). Heavy line shows track of *JOIDES Resolution.*

use in the early days of the DSDP. Five cores of nannoplankton chalk to ooze were retrieved that ranged in age from early Oligocene to middle Eocene.

Site 171

Site 171 (Shipboard Scientific Party, 1973) is located at a depth of 2290 m in a broad saddle between Horizon Guyot and an unnamed guyot to the west. The drill penetrated 148 m of Quaternary to middle Eocene calcareous ooze and 214 m of Upper Cretaceous cherty chalk and volcanic siltstone overlying 8 m of subaerial flow basalt and 7 m of basalt conglomerate. Below the conglomerate is 134 m of reefal limestone, of middle Cretaceous (probably pre-Cenomanian) age, resting on weathered vesicular basalt. Because time was running out at the end of Leg 17, the limestone was drilled quickly, and only an artificial slurry of ground up limestone fragments was recovered.

Limestone fragments included pelletal and bioclastic grainstone, and skeletal fragments including large mollusks, green algae, coralline algae, and echinoid spines and plates. Dolomite rhombs in micritic limestone fragments, drusy calcite fillings in molluscan shells, and the presence of moldic porosity all point to a long history of diagenesis.

The surface separating the reefal limestone from the overlying conglomerate and basalt is highly irregular, as seen on reflection seismic records at the drill site, and suggests a period of emergence and erosion prior to final drowning of the reef.

The Turonian volcaniclastic sediments, which contain woody plant fragments and pollen grains, suggest renewed volcanism on a wooded island in the early part of Late Cretaceous time, perhaps synchronous with the beginnings of mid-plate volcanism along the Line Islands and Musicians Seamount chains (Schlanger et al., 1984; Pringle, in press).

Site 313

Site 313 (Shipboard Scientific Party, 1975) is located in the eastern Mid-Pacific Mountains, about 230 km northwest of Horizon Guyot. The site is in a small basin among seamounts, at a depth of 3484 m. Pelagic Cenozoic sediments are about 230 m thick at the site and overlie about 170 m of Maastrichtian cherty chalk, which in turn rests on about 194 m of Campanian calcareous nannofossil limestone and volcanic sandstone, siltstone, and breccia in turbidite sequences. Altered, moderately vesicular, alkalic basalt lies beneath the Campanian sediments.

Site 463

Site 463 (Shipboard Scientific Party, 1981) is located in the western part of the Mid-Pacific Mountains, about 24 nmi (44.4 km) northeast of the northeastern rim of Resolution Guyot. The site is on the sediment apron flanking the guyot, at a depth of 2532 m. The Cenozoic sequence is about 55 m thick and consists of nannofossil ooze that ranges from Pleistocene to middle Eocene in age. The Upper Cretaceous sediments are about 395 m thick and consist of cherty nannofossil chalk. Albian and upper Aptian sediments are mainly multicolored pelagic limestone, about 130 m thick. The lower Aptian, which is about 110 m thick, consists of multicolored and carbonaceous limestone and an interval about 11 m thick of tuffaceous limestone.

The lowest part of the Aptian and the upper Barremian sequences, which are about 240 m thick, consists of pelagic limestone interbedded with layers of redeposited, shallow-water debris (bioclasts, oolites, glauconite, and basalt chips) as graded turbidite beds and debris-flow deposits. Basement was not reached at this site.

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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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