4. SITE 431: YŌMEI SEAMOUNT

Shipboard Scientific Party[1]

SITE DATA, HOLE 431

Date Occupied: 5 August 1977 (0700 Z) (5 August 1977 [1800 L])

Date Departed: 5 August 1977 (1958 Z) (6 August 1977 [0658 L])

Time on Hole: 12 hours, 58 minutes

Position: 42°25.44′N, 170°32.68′E

Water Depth (sea level): 1703.8 corrected meters, echo sounding

Water Depth (rig floor): 1713.8 corrected meters, echo sounding

Bottom Felt at: 1714.5 meters, drill pipe

Penetration: 9.5 meters

Number of Holes: 1

Number of Cores: 2

Total Length of Cored Section: 9.5 meters

Total Core Recovery: 3.33 meters

Percentage Core Recovery: 35.1

Oldest Sediment Cored:
Depth sub-bottom: 9.5 meters
Nature: Mn-oxide-rich sand and gravel
Chronostratigraphy: Quaternary
Measured velocity: 1.7 km/s

Basement: Not reached

Principal Results: Two holes were drilled in what appeared to be a faulted terrace on Yōmei, a small seamount north of Nintoku Seamount, in the Emperor Seamount chain. In Hole 431 we cored the interval 0 to 95 meters twice, and recovered a total of 3.33 meters of sand and centimeter-sized unconsolidated gravel. This material is composed of 90 per cent angular iron-manganese fragments and 10 per cent rounded pebbles, sponge fragments, foraminifers, and authigenic silicates. The pebbles are extremely heterogeneous, and include andesites, dacites, granites, schists, and quartz sandstones, all thought to be ice-rafted. These rocks proved to be the most southerly exotic material encountered in our drilling up the seamount chain. The sand and gravel contain both planktonic and benthic foraminifers and Pleistocene to Recent subarctic nannofossils. Drilling of the hole was terminated by mechanical failure of the bottom-hole assembly and/or excursion of the ship from the beacon, the effect of which was to twist off the bottom sub below the lower bumper sub, dropping the bit and inner core barrel.

SITE DATA, HOLE 431A

Date Occupied: 5 August 1977 (20330 Z) (6 August 1977 [0730 L])

Date Departed: 6 August 1977 (1318 Z) (7 August 1977 [0018 L])

Time on Hole: 16 hours, 38 minutes

Position: 42°25.39′N, 170°32.60′E

Water Depth (sea level): 1704.3 corrected meters, echo sounding

Water Depth (rig floor): 1714.3 corrected meters, echo sounding

Bottom Felt at: 1713.5 meters, drill pipe

Penetration: 17.0 meters

Number of Holes: 1

Number of Cores: 2

Total Length of Cored Section: 17.0 meters

Total Core Recovery: 4.35 meters

Percentage Core Recovery: 25.6

Oldest Sediment Cored:
Depth sub-bottom: 17.0 meters
Nature: Mn-oxide, zeolite, calcareous sand and silt
Chronostratigraphy: Middle Eocene
Measured velocity: ~1.5 km/s

Basement: Not reached

Principal Results: The bottom conditions at Hole 431 appeared to be unstable, and the *Glomar Challenger* was offset 500 feet at 230° from Hole 431. Hole 431A penetrated 17.0 meters of soft sand and fine gravel, of which 4.35 meters were recovered. Core 1 consists of 80 per cent fine iron-manganese fragments; the remainder is composed of authigenic silicate grains, ice-rafted pebbles, and calcareous sand. Core 2 is composed principally of authigenic silicates, and the remaining half consists of iron-manganese fragments, palagonite, and calcareous sand. Core 1 contains principally Quaternary planktonic foraminifers, although some benthic forms of the same age are also present. The Pleistocene/Eocene hiatus may be represented in Core 2; it is widely represented in cores taken from the chain to the south. Middle Eocene species were identified in the core-

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catcher sample of Core 2. Nannofossils are Quaternary; siliceous microfossils are present but rare. Drilling of the hole was terminated by mechanical failure of the bottom-hole assembly and/or excursion of the ship from the beacon, the result of which was to twist off the bottom sub below the lower bumper sub, dropping the bit and inner core barrel.

BACKGROUND AND OBJECTIVES

Choice and Location of Site

Site 55-1 is on a faulted terrace deposit on Yōmei Seamount (Seamount "C" of Greene et al., 1978), about 60 nautical miles north of Nintoku Seamount (see Figure 1). The site was located on a seismic profile obtained on line 17 of a survey by the R/V *S. P. Lee* in October 1976 (Dalrymple et al., this volume). The reasons for selecting this preliminary site were as follows: (1) the 80-kJ sparker profile revealed a sedimentary cover about 200 meters thick above a clearly defined acoustic basement, and (2) a hummocky reflector tentatively identified as reef deposits lay to the seaward (northeast) side of the faulted terrace segment, mantled by perhaps 40 to 100 meters of sedimentary cover (Figure 2). It was thought that the stratified rocks here were terrace deposits, transported to the site from a source near the crest of the seamount that probably contained some local debris from the nearby reef. Site 55-1 Alternate is on a third block-faulted terrace about 3 nautical miles to the northeast (Figure 2). At least two acoustic stratigraphic units could be separted on the 80-kJ profile, but they appeared less likely to contain locally derived materials than the deposits at Site 55-1. Sediments at Site 55-1A also appeared to be about 200 meters thick; 3.5-kHz profiles at both Site 55-1 and Site 55-1A showed little transparency.

Before drilling at Site 430, we planned to make a short pass over both sites with the *Glomar Challenger*, execute a loop, return to the most favorable of the two sites, on the basis of available records, then drop the beacon and drill. If estimated sediment depths and acoustic transparency were identical on the *Challenger* records, however, we planned to drill at Site 55-1, since it seemed most likely that local material would be recovered.

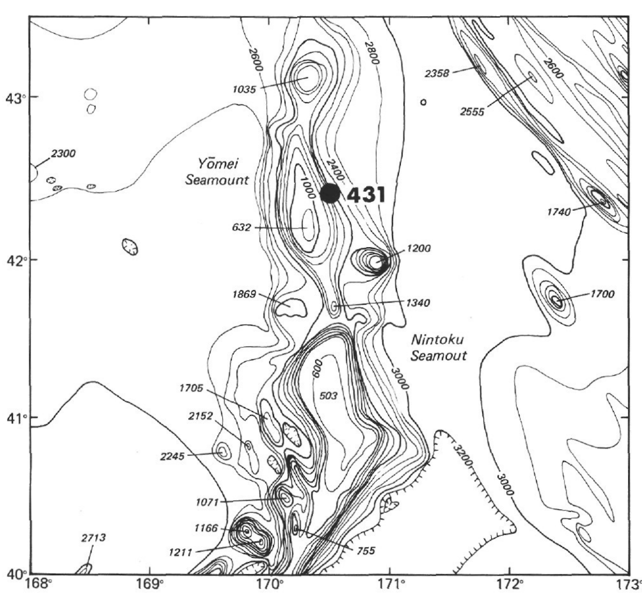

Figure 1. *Location of Site 431. Bathymetry after Chase et al. (1970).*

As the *Lee* crossed the faulted terraces while it steamed southwest across Yōmei Seamount, it further traversed a broad platform, to the southwest, penetrated by a central peak of basalt (see Figure 2). This platform had been interpreted as principally constructional, with what appeared to be reef material on the seaward (northeast) side. Behind this reef the platform consisted of at least 200 meters of presumably lagoonal sediments, but acoustic basement could not be resolved from records acquired before the cruise. We thus found ourselves in a situation similar to that before we occupied Site 430, and we decided to pass over the broad platform on direct approach to our Sites 55-1 and 55-1A. If, as at Site 430, acoustic basement could be resolved, and if the 3.5-kHz profile should reveal surface transparency equal to or better than that at Sites 55-1 and 55-1A, we wished to reserve the option to drill on the platform. We located a position on the *Lee* profile about 3 miles southwest of Site 55-1 and designated it Site 55-1 alternate prime. The stratigraphy at this site appeared to be nearly identical to that of the sediment pond around Site 430, and we decided to use measured interval velocities from that site to determine sediment thickness at Site 55-1A′. Not having drilled materials acoustically similar in the terrace deposits of Sites 55-1 and 55-1A, we were unable to revise our estimates of sediment thickness there.

In the light of our experience at Site 430, the recovery of basalt seemed easily within our operational capabilities unless we again experienced failures in the drilling apparatus. We realized, however, that recovery of a complete Tertiary stratigraphic section was very unlikely because as our pre-site acoustic records of Yōmei Seamount appeared identical to those for Ōjin, where thin Quaternary sands lay directly on Eocene shallow-water sediments.

OPERATIONS

Pre-Drilling Site Survey

Between Suiko and Nintoku seamounts are several smaller, unnamed seamounts (Figure 3). One of these, Yōmei Seamount (formerly Seamount "C" of Greene et al., 1978), situated just south of Nintoku, was surveyed by the R/V *S.P. Lee* in October, 1976 for Leg 55. A 80-kJ sparker profile across the seamount shows central peaks surrounded by a broad, flat to gently dipping platform (Figure 2). The two prominent peaks forming the central part of the seamount appear to be eroded volcanoes that were islands fringed by reefs when wave activity beveled the platform. The *Lee* profile indicates that a thin cover (approximately 0.03 to 0.1 s) of stratified material lies above a relatively flat, gently undulating acoustic basement. On the northeast flank of

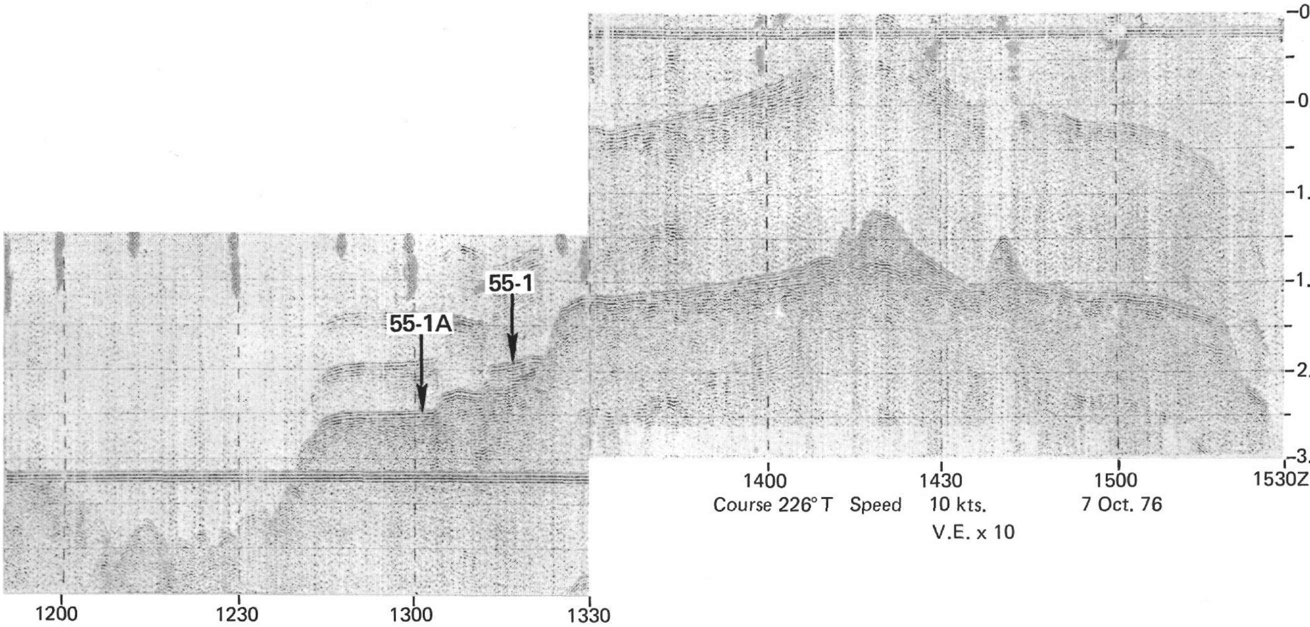

Figure 2. *U.S. Geological Survey's* S.P. Lee *seismic reflection profile, showing locations of the originally proposed Sites 55-1 and 55-1A (see Figure 3).*

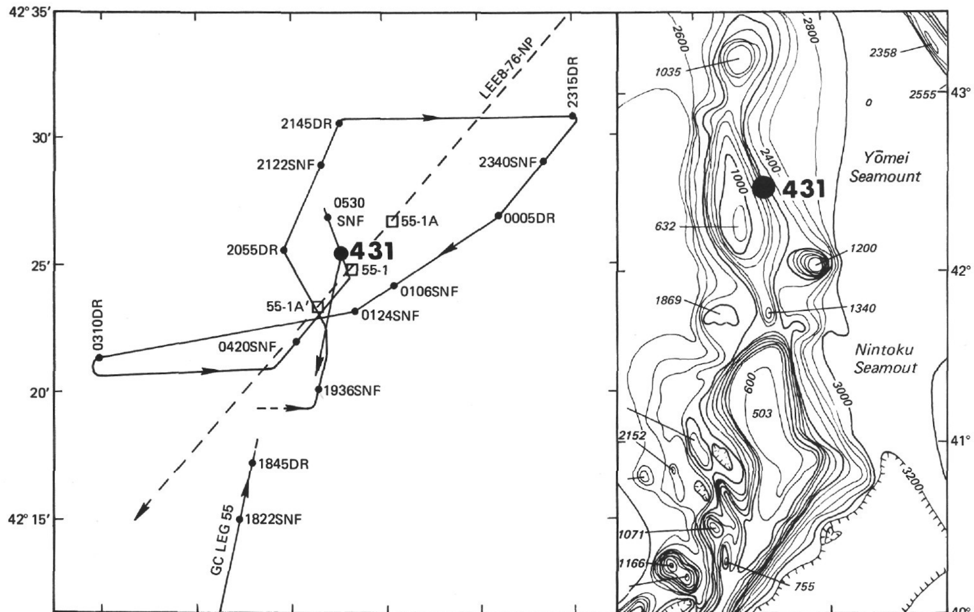

Figure 3. *Bathymetry of the central Emperor chain near Site 431, showing the* Glomar Challenger *Leg 55 and* Lee *8-76 NP tracks. Depths in fathoms. Bathymetry after Chase et al. (1970). Proposed Sites 55-1, 55-1A, and 55-1A′ shown by squares.*

this seamount, three prominent downdropped basement blocks are capped with what may be marine terrace deposits (Figures 2 and 4). These features resemble the major fault scarps on the south flank of Kilauea and the west flank of Mauna Loa (Stearns and Macdonald, 1946; Moore, 1964). Proposed Sites 55-1 and 55-1A are on these faulted steps (Figure 2).

Site 55-1 is on the first or upper faulted step and Site 55-1A is on the third or lower step. The *Lee* profile shows subsurface stratigraphy at Site 55-1 of synclinally dipping strata that lap onto acoustic basement at the southwest limit of the step and onto a rounded subsurface acoustic buttress at the northeast limit (see Figure 2). Acoustic basement at this site is relatively smooth

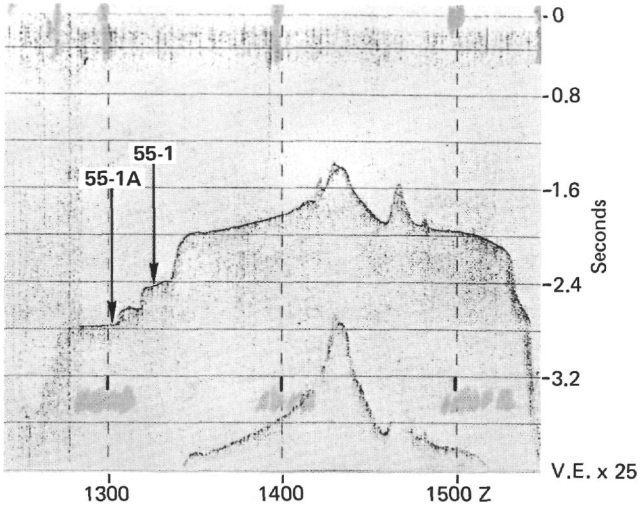

Figure 4. *U. S. Geological Survey's* S. P. Lee *3.5-kHz profile, showing locations of the originally proposed Sites 55-1 and 55-1A (see Figure 3).*

and gently curved (concave upward), and appeared fairly deep (approximately 0.2 s) near the center part of the step, beneath the axis of the syncline.

Subsurface stratigraphy at Site 55-1A is similar to that at Site 55-1, except that the stratified sediment cover appears to be thinner, about 0.1 s thick. Acoustic basement is irregular and dips slightly back into the seamount (southeast).

We traversed the general region of Yōmei Seamount near its northeast flank with the *Challenger's* 3.5-kHz profiler to locate areas of unconsolidated surficial sedimentary cover. Also, we decided that if less than 400 meters of sediment overlay basement, and if bottom conditions appeared soft along the east edge of the flat terrace-like platform, then we would consider a third site (Site 1A′) for drilling (Figure 3).

The approach to Site 431 began on a course of 013° true, but shortly after a satellite fix at 1822 Z, 4 August 1977 (0522 L, 5 August), we encountered traffic in heavy fog and were forced to deviate from our intended course and to maneuver to avoid collision. At 1930 Z (0630 L) we resumed a course of 013° true at a speed of about 6 knots until 1953 Z (0653 L), then steered 000° true until 2005 Z (0705 L) and changed course to 322° true to pass over one of three potential sites (55-1A′), which we crossed at about 2015 Z (0715 L) at a speed of about 4 knots. The seismic profile (Figure 5) from this traverse did not resolve the depth to acoustic basement, so we dropped the site from consideration. At 2055 Z (0755 L), we changed course to 025° true, and at 2145 Z to 090° true, to intersect the *Lee*'s lines at proposed Site 55-1. This profile (Figure 6) fails to duplicate the terrace profile of the *Lee* line; we concluded that these terrace features may have resulted from hinge faulting. We decided to tighten up the traverses around Site 55-1. Satellite fix at 0124 Z (1224 L) indicated that the *Challenger* had passed about one mile south of Site 55-1. We changed course to 260° true, then at 0310 Z (1410 L) to 088° true. At 0400 Z (1500 L) 5 August, we turned to 041° true and proceeded parallel to the *Lee* track until 0456 Z (1556 L), when we changed course to 340° and passed over proposed Site 55-1 at 4 knots. The first step was readily identified in this profile (Figures 7 and 8), and verified the presence of sediment in this area. The beacon was dropped at 0515 Z (1615 L), about 0.7 mile north of Site 55-1. We continued on course until 0530 Z (1630 L); when we had retrieved the geophysical gear, we proceeded back along a course of 160° to the beacon. The 3.5-kHz profile (Figure 9) showed nearly 0.02 s of well-layered reflectors indicative of poorly consolidated to semiconsolidated sediments.

Throughout the survey, the navigational data indicate that the speed and track of the *Challenger* was continually and unpredictably influenced by strong surface currents. The survey track shown in Figure 3 may therefore be in error by as much as 2 or 3 nautical miles.

Site 431 was on the first faulted step about 0.5 nautical miles from its distal edge. The 3.5-kHz record of the *Challenger* (Figure 9) shows two shallow reflectors (0.02 s and 0.06 s beneath the sea floor) forming a tight anticline beneath a low gentle hump. These reflectors drop off rapidly toward the southwest, and disappear beneath the penetration depth of the profile. In the *Challenger*'s seismic reflection profiles (Figure 6), 0.15 to 0.20 s of well-layered reflectors appear to form a gentle syncline. Strata near the axis of this syncline are generally flat, however, and suggest a lack of structure.

Drilling Operations

Our final approach to Site 431 was parallel to the fault bench upon which Site 55-1 is situated; we attempted to locate a suitable sediment cover for spudding in. The beacon was dropped at 0515 Z (1615 L) on 5 August 1977. We steamed past the beacon for about 10 minutes, and then discovered that we had been running oblique to the terrace; the beacon had been released on a gentle ridge that parallels the northeast edge of the terraced fault bench (Figure 7). We restationed the ship over the beacon at 0700 Z (1800 L), but because both the profile obtained by the R/V *S. P. Lee* in crossing the edge of this bench in October 1976 (Figure 2) and our own seismic profiles (Figures 5 and 6) showed distorted layers at 35 to 80 meters directly beneath this bench, we decided to offset immediately in a direction away from the edge. Site 431 is at 42°25.44′N, 170°32.68′E. While we were moving, the 3.5-kHz records showed considerable penetration (up to 0.045 s), and reflectors near the beacon site deepened and flattened. The string was dropped and the bit spudded in at 1115 Z (2215 L). We took a 9.5-meter punch core but recovered only 20 per cent of the core. (See Table 1 for coring summary.) We took a second punch core in the same interval and recovered a small amount of gravel-sized material rich in broken iron-manganese oxide fragments. We washed this interval and a second 9.5-meter interval to stabilize the bottom-hole assembly. As the third 9.5-meter interval was being cored, at 1500 Z (6 August, 0200 L) and at a sub-bottom depth of 29 meters, the drill pipe began to vibrate on the drilling platform, broke free, and began to rotate independently. We pulled the drill string and

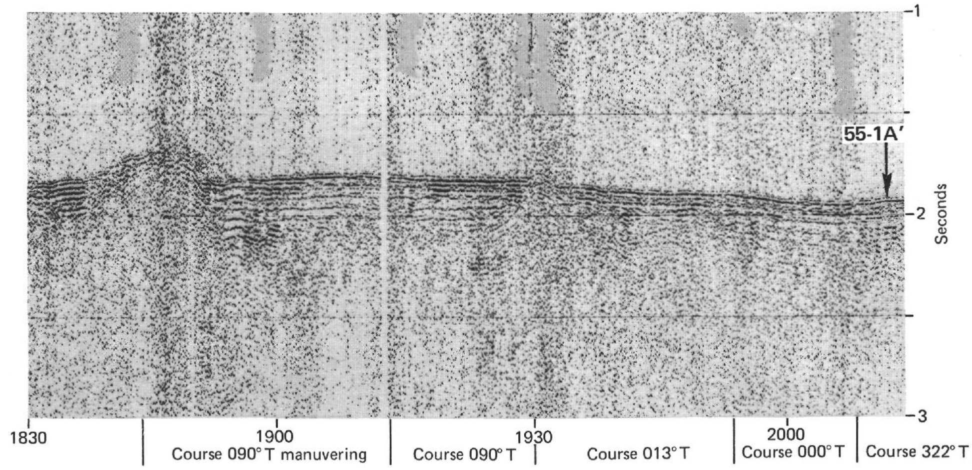

Figure 5. Glomar Challenger *seismic reflection profile across Site 55-1A'.*

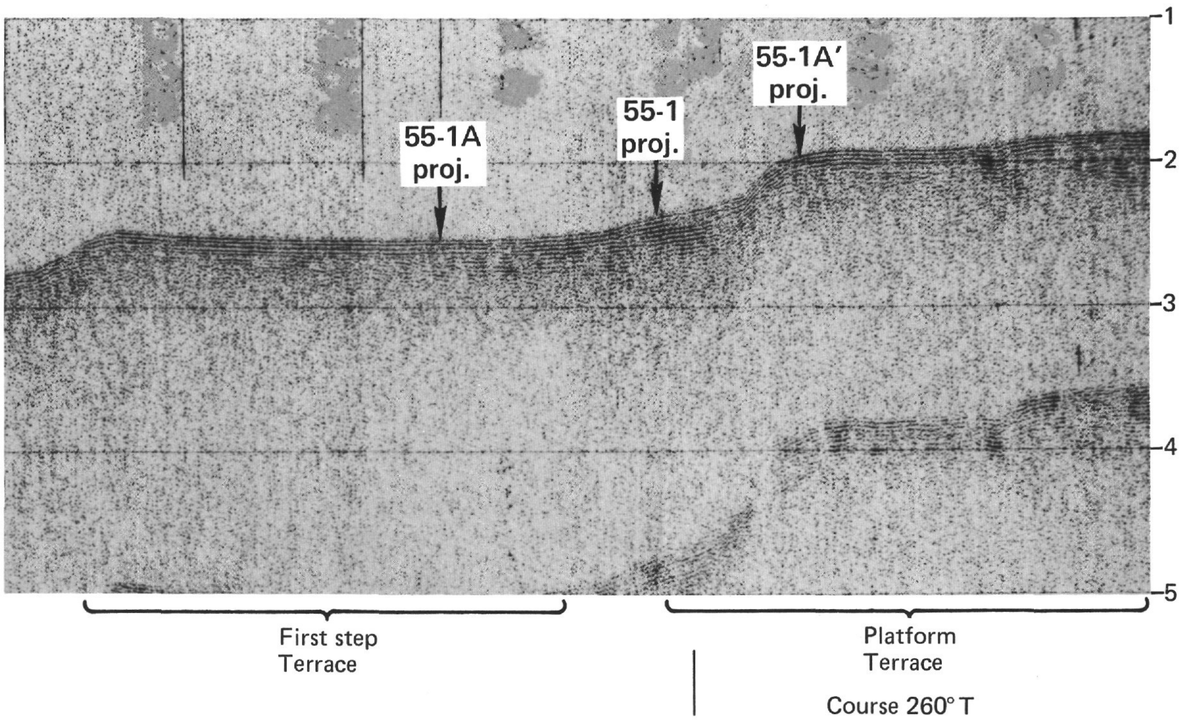

Figure 6. Glomar Challenger *seismic reflection profile across seamount south of proposed Sites 55-1, 55-1A, and 55-1A' (see Figure 1).*

found it twisted off at the upper thread of the 9-meter bottom sub, directly beneath the lower bumper sub. The remainder of the bottom-hole assembly, including the bit and inner core barrel, was lost.

We concluded that drilling conditions were unsuitable at this location, and offset the *Glomar Challenger* another 500 feet at 230° true, to Hole 431A, at 42°25.39'N; 170°32.60'E. At 2030 Z, 5 August (0730 L, 6 August) a new bottom-hole assembly was made up and run in. Hole 431A was spudded at 0220 Z (1320 L) on 6 August, and we took two cores of iron-manganese oxide and zeolitic and calcareous sand and silt below mudline. We retrieved Core 2 from the core barrel with difficulty, and both overshot and barrel appeared to bend within the lower part of the bottom-hole assembly. The bit was pulled above mudline and a new core barrel successfully seated, but the drillers washed down until the lowest bumper sub was buried. While they washed down to a depth of 33 meters below mudline in soft material, the drill pipe on the platform began to vibrate, and sheared off at 0600 Z (1700 L) on 6 August. When the drill string was pulled, we found that the same threads on the same bottom sub immediately below the lower bumper sub had been sheared off, and the splines of the open bumper were badly bent.

The captain, the cruise operations manager, the drilling superintendent and the two co-chief scientists met to examine the cause of the failures. All agreed that the

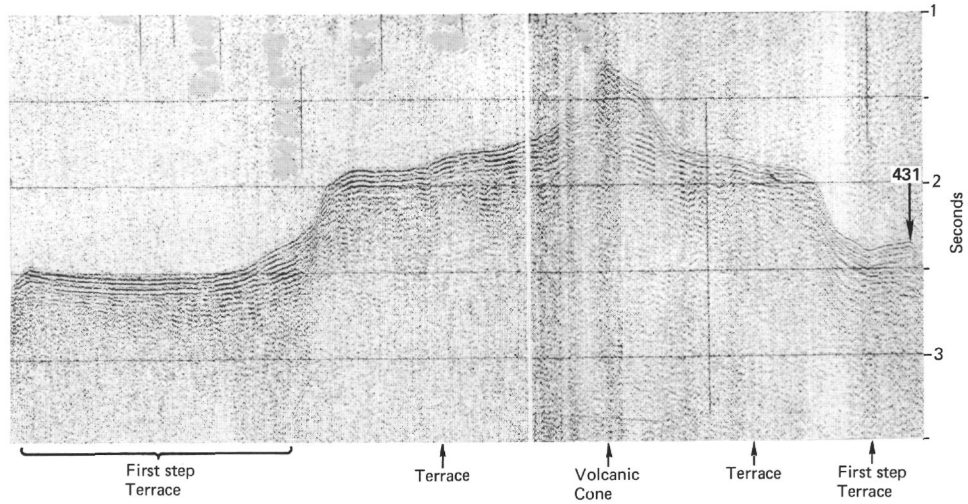

Figure 7. Glomar Challenger *5-s seismic reflection profile across Site 431, showing physiographic features used in locating site (see Figure 1).*

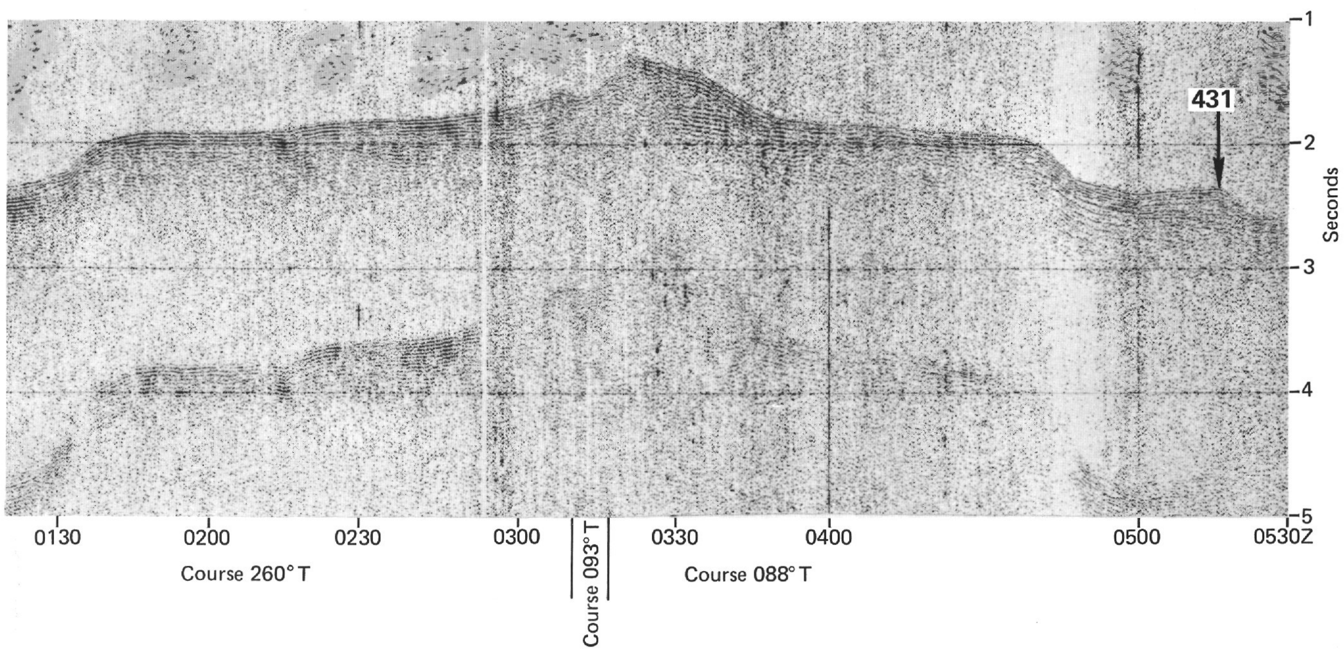

Figure 8. Glomar Challenger *10-s seismic reflection profile across Site 431 (see Figure 1).*

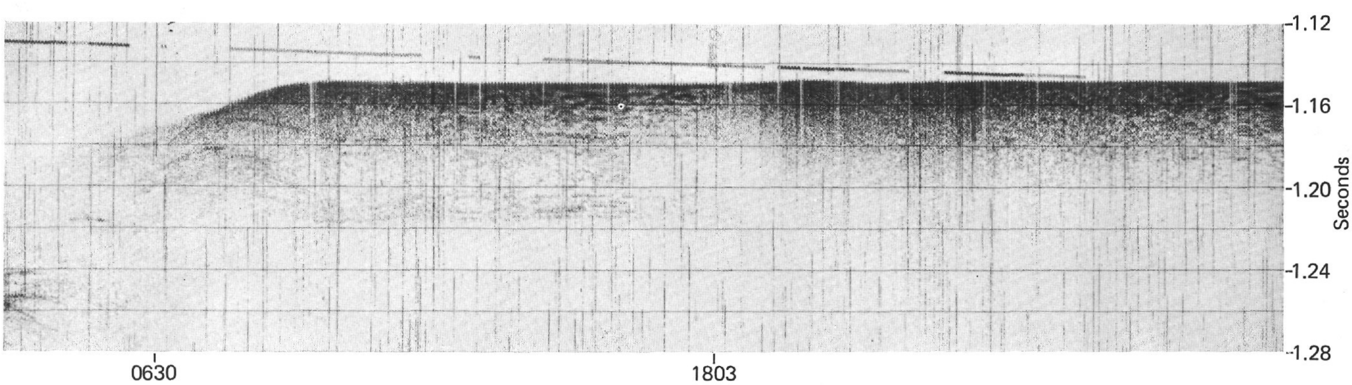

Figure 9. Glomar Challenger *3.5-kHz profile across Site 431.*

TABLE 1
Coring Summary, Site 431

Core	Date (Aug. 1977)	Time (L)	Depth from Drill Floor (m)	Depth below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Recovery (%)
Hole 431							
1	5	2335	1714.5-1724.0	0.0-9.5	9.5	1.90	20.0
2	6	0032	1714.5-1724.0	0.0-9.5	9.5	1.43	15.1
Total					19.0	3.33	18.5
Hole 431A							
1	6	1405	1713.5-1721.0	0.0-7.5	7.5	2.10	28.0
2	6	1510	1721.0-1730.5	7.5-17.0	9.5	2.25	23.7
Total					17.0	4.35	25.6

TABLE 2
On-Site Satellite Navigation Positions, Site 431

Core	Time (Z)	Latitude	Longitude	Satellite No.	Statistics	Altitude (°)
Hole 431						
1	5 Aug. 0712	42°25.203'N	170°33.343'E	46	Poor (suspect)	13
2	5 Aug. 0736	42°25.739'N	170°32.525'E	19	Good	27
3	5 Aug. 0756	42°25.856'N	170°32.017'E	12	Poor	15
4	5 Aug. 0922	42°25.257'N	170°31.918'E	19	Good	57
5	5 Aug. 1040	42°25.439'N	170°32.151'E	20	Poor-Good	15
6	5 Aug. 1412	42°25.353'N	170°32.728'E	20	Poor-Good	12
7	5 Aug. 1728	42°25.395'N	170°32.719'E	46	Good (suspect)	51
8	5 Aug. 1908	42°25.418'N	170°32.678'E	46	Fair-Good (suspect)	19
Hole 431A						
9	5 Aug. 2032	42°25.398'N	170°32.583'E	19	Good	64
10	5 Aug. 2220	42°25.399'N	170°32.616'E	19	Good	18
11	6 Aug. 0204	42°25.403'N	170°32.567'E	20	Good	16
12	6 Aug. 0436	42°25.361'N	170°32.596'E	13	Good (suspect)	46
13	6 Aug. 0512	42°25.380'N	170°32.607'E	37	Very Good	12
14	6 Aug. 0612	42°25.357'N	170°32.640'E	47	Very Good	18
15	6 Aug. 0650	42°25.358'N	170°32.669'E	12	Good	19
16	6 Aug. 1024	42°25.357'N	170°32.622'E	19	Good	20
17	6 Aug. 1216	42°25.339'N	170°32.530'E	14	Fair-Poor	13

weak points in the bottom-hole assemblies were the small bottom subs, which had been machined in drydock in Long Beach, and which had apparently been overshortened and weakened. No old bottom subs were on board the *Challenger*. If these subs were the weak link for breakage, then four causes were possible for the bending of the bumper sub splines:

1) too much weight had been applied to the string;

2) ship's positioning system had allowed sharp excursions of the ship off beacon;

3) strong bottom currents were causing oblique spudding directions;

4) the two holes had been in "dipping formation," causing the bit to bend obliquely upon entering bottom. Geophysical evidence, however, indicated flat-lying strata and easy entry below mudline, suggesting that the strata were drillable. Nevertheless, it was agreed to abandon Site 431 and move the *Challenger* to the nearest large platform with better geophysical evidence of flat and regular sediments. We felt that the best site of this type was proposed Site 55-5, on Nintoku Seamount at 41°20'N, 170°21'E, about 60 nautical miles to the south. At 1318 Z, 6 August (0018 L, 7 August), we left Site 431. We occupied the site a total of 30 hours, 8 minutes.

On-Site Positioning

After we left Site 431 and after we lost the lower part of the bottom-hole assembly at Site 432, we began to suspect a fifth possible explanation for breakage of the bottom subs and bending of the bumper subs: currents were moving the beacon systematically along the bottom, causing the ship's positioning system to follow, and thus bending off the drill pipe fixed below mudline. An examination of satellite navigation fixes received while on station above Holes 431 and 431A supports this idea. Table 2 lists the satellite data received on these two stations (Satellite 46 was reported unreliable several days after these records had been taken, but it seems to have been operating well during 5-6 August). Figure 10 shows sequential plots of fixes during time on Holes 431 and 431A.

Originally, coordinates of the last three readings for Hole 431 were averaged to obtain the position of the hole. After the 500 feet offset at 230° true, which began at 1953 Z, 5 August (0653 L, 6 August) and was completed at 2030 Z (0730 L), we realized that the average satellite fixes on Hole 431A did not show the proper sense of offset from Hole 430. The coordinates of Hole 431 were then "calculated" with the known offset coordinates from the average position of Hole 431A. When we plotted the fixes received at Hole 431 sequentially (Figure 10), we observed a northward drift of nearly 600 feet between 1412 Z and 1908 Z on 5 August (0112 L to 0608 L, 6 August). Extrapolation of this drift puts the ship at its calculated position at 1953 Z (0653 L), when offset began. If the drift is real, the ship would have been following a beacon moving northwest at a rate of about 90 ft/hr when the drill string sheared above mudline at Hole 431. After offset, the satellite fixes show a steady southeast trend from 0204 Z (1304 L) to 0605 Z (1750 L) on 6 August, and if these fixes represent positions of the ship following a moving beacon, the rate of movement is about 100 ft/hr. The ship would have moved roughly 180 feet between the spudding in of Hole 431A and withdrawal of the drill string above mudline after bending was suspected. The ship and beacon would have moved another 180 feet between the time Hole 431A was respudded and the failure of the bottom-hole assembly. At a water depth of 1714 meters, an offset of 3 per cent (167 feet) is considered the acceptable deviation, without damage to the drill string, while the drill string is rotating, and 5 per cent (281 feet) is considered to be the maximum acceptable deviation with no rotation.

The pattern of satellite fixes at Site 431 is quite different from that at Site 430 and particularly from that at Hole 430A (Figure 11). Here the fixes show no consistent direction of pattern of offset, but scatter in an ellipse whose dimensions are about 300 by 350 feet. Ex-

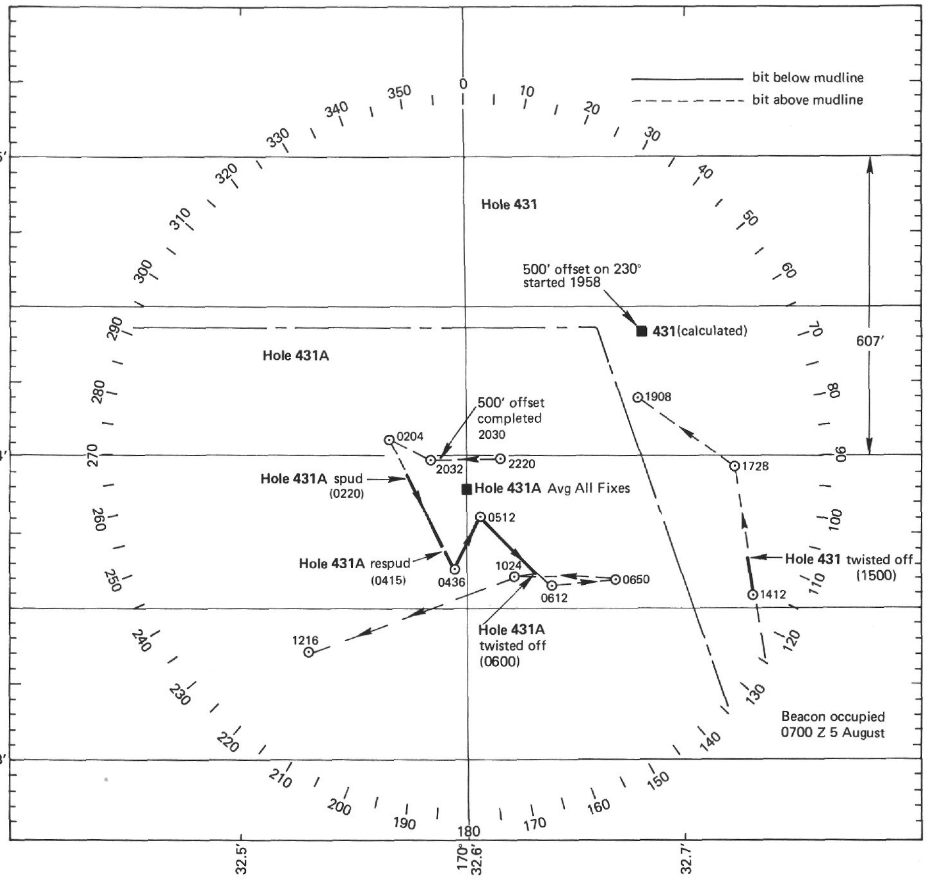

Figure 10. *Mercator plot of satellite navigation locations during occupation of Site 431.*

cept for the excursion at 1902, which is probably spurious, apparent rates of movement between fixes are, for the most part, less than 50 ft/hr.

Errors exist in individual positions read by satellite navigation, the ship's heading (nearly constant during our time on both Hole 431 and Hole 431A), and inertial systems; we feel that the apparent consistency of the movement direction (NNW 0400-1900Z; SW 0200-0650) could be explained by either diurnal or tidal bottom currents of only one or two knots, moving the beacon at 100 ft/hr (0.016 knots). This would not be noticeable in the ship's positioning system, but would place a bending stress on pipe in the ground, particularly on bottom-hole assemblies weakened by over-machining of sub threads. We recommend that heavier dead weights and a grappling or anchoring system be added to beacons dropped in waters thought to have strong water currents and smooth, hard pavement-like floors.

Post-Drilling Operations

At 1318 Z, 6 August 1977 (0018 L, 7 August 1977), *Glomar Challenger* left Hole 431A on a course of 335° true. At 1330 we changed course to 190° and passed over the site at about 4 knots. The seismic reflection profile obtained upon departure shows Hole 431A to be near the back edge of the terrace (Figures 12 and 13). At this site approximately 0.25 s of well-layered sediments appear to overlie the acoustic basement. At 1354 Z (0054 L), speed and course were changed to 9.4 knots and 194° true, and we headed for proposed Site 55-5 at latitude 41°19.6′N, longitude 170°22.1′E on the northern end of Nintoku Seamount.

SEDIMENTARY LITHOSTRATIGRAPHY

At both Hole 431 and Hole 431A, after recovering only two cores, we had to terminate drilling because of loss of the bottom-hole assembly. An iron-manganese oxide gravel was cored at Hole 431. At Hole 431A, the iron-manganese oxide gravel of the first core was underlain by a silicate sandy gravel in the second (see table below). The sediment covering the terrace of this unnamed seamount was predominantly authigenic, the product of alteration of volcanic material. The sediment was highly deformed, and any appearance of size-grading in the cores is an artifact of drilling.

Hole	Unit	Lithology	Cores Represented	Depth Below Sea Floor (m)
431	1	Fe-Mn oxide gravel	1, 2	0–9.5
431A	1	Fe-Mn oxide gravel	1	0–7.5
431A	2	Zeolitic sandy gravel	2	7.5–17.0

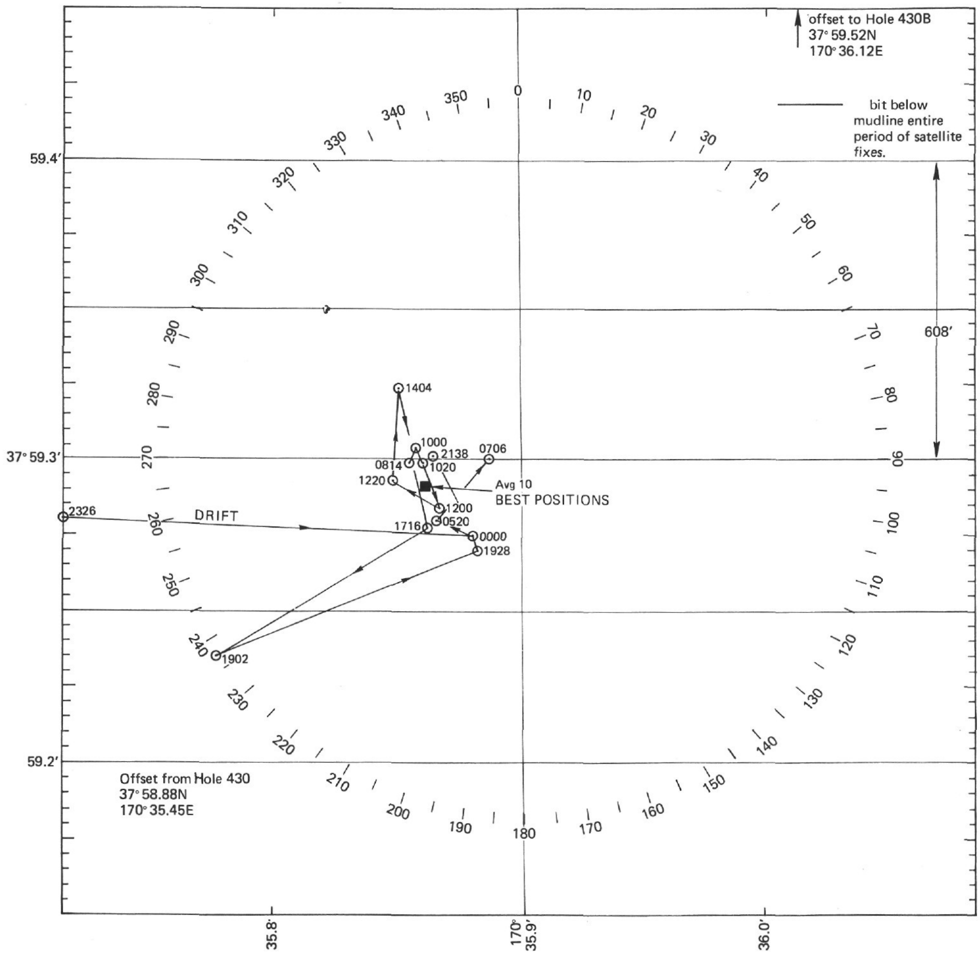

Figure 11. *Mercator plot of satellite navigation locations during drilling of Hole 430A.*

Sediment Description

Hole 431

The gravels of Cores 1 and 2 (both representing the same cored intervals) are approximately 90 per cent iron-manganese oxide fragments, which give the sediment its distinctive black color (4.5YR N2.5/0). The remaining 10 per cent of the sediment is made up of rounded pebbles, sponge fragments, calcareous foraminifers, and authigenic silicates (clays and zeolites) and phosphates. The heterogeneous composition of the rounded pebbles characterizes them as ice-rafted glacial detritus. They are andesites, dacites, sandstones, schists, granites, and quartz. Particle size in the sediment ranges from sand-size grains up to 3-cm fragments. The abundant chips of rust in Core 2 are scrapings from the drill pipe. Microscopically, the silty fraction of the core consists of calcite clasts (80%), Mn micronodules (10%), sponge spicules (10%), and quartz (traces).

Hole 431A

The iron-manganese oxide gravel recovered in Core 1 is very similar to that described above for Hole 431, except that the contribution of authigenic silicates is somewhat greater. Macroscopically, the sediment appears to be 80 per cent iron-manganese oxide fragments and 20 per cent clays and phosphates plus calcareous sand and rounded, glacially transported pebbles. Microscopically, the sandy fraction consists of foraminifers (35%), Mn micronodules (30%), volcanic fragments (15%), and carbonate clasts (5%).

The sedimentological change to a sandy gravel in Core 2 is emphasized by the overall color change from black to olive-brown (2.5Y 4/4). The major components are authigenic silicates (clays, zeolites) and phosphates (olive-yellow, 2.5Y, 6/6), ranging from sand-size particles to a few clasts up to 3 cm. Macroscopically, the sediment can be divided as follows: 50 per cent silicates, 20 per cent iron-manganese oxide fragments, 20 per cent calcareous components, and 10 per cent altered basalts. The iron-manganese particles sometimes occur in clasts ranging up to 3 cm, but predominantly as sand-size grains. Within the sand, white calcareous concretions occur randomly dispersed. Microscopically, these concretions are calcite (90%), clay (10%), and traces of volcanic glass and iron-manganese oxide fragments. The finest fraction of one gravel bed, a clay-mineral mud, has the following microscopic composition: phosphate

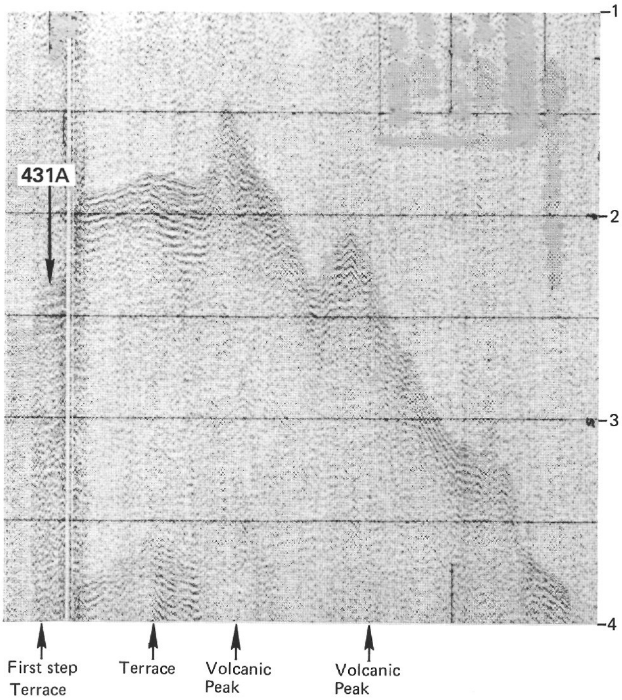

Figure 12. Glomar Challenger *5-s seismic reflection profile on departure from Hole 431A.*

(carbonate apatite) (10%), altered basalt (5%), Mn micronodules (30%), calcite clasts (10%), volcanic glass (5%), quartz (15%), clay (20%), and zeolites (5%).

BIOSTRATIGRAPHY

Recovery of sediments at Site 431 was disappointingly small because of drilling equipment failures at both Hole 431 and Hole 431A. The data following are based on the limited samples available.

Hole 431

Foraminifers

In Cores 1 and 2, the black loose sandy material contains Quaternary foraminifers. The core-catcher samples and such samples as 1-2, 20-22 cm, and 2-1, 11-14 cm contain rare to frequent planktonic foraminifers such as *Globorotalia truncatulinoides* (very rare), *G. inflata, G. scitula, Globigerina bulloides, G. glutinata, Neogloboquadrina dutertrei,* and *N. pachyderma.* This assemblage indicates a temperate to subarctic zone water mass. Relatively abundant and large Quaternary benthic foraminifers (see Hole 431A) reflect present water depth of the seamount.

Calcareous Nannofossils

Core-catcher samples of Cores 1 and 2 and an additional three samples from Section 2-1 (709 cm, 25-27 cm, and 119-121 cm) were studied. Calcareous nannofossils range from extremely rare to common in these samples, and assemblages are marked by low species diversity, which may be a result of low water temperature. The microflora generally consists of *Coccolithus pelagicus* (abundant), *Cyclococcolithus leptoporus,* and *Gephyrocapsa oceanica* (common to rare). This assemblage may belong to the subarctic zone of the modern coccolithophorids biogeography, according to McIntyre and Be (1967). Only Sample 2-1, 119-121 cm, contains a more diversified nannofossil assemblage, which consists of *Helicopontosphaera kamptneri, H. wallichii, Discolithina japonica,* and *Syracosphaera pulchra,* in addition to typical cold-water assemblages. The occurrences of *Gephyrocapsa oceanica* and the absence of *Pseudoemiliania lacunosa* suggest that all these samples are upper Pleistocene to Holocene. As at previous sites, these samples are assigned tentatively to the interval NN 20 (*Gephyrocapsa oceanica* Zone) to NN 21 (*Emiliania*

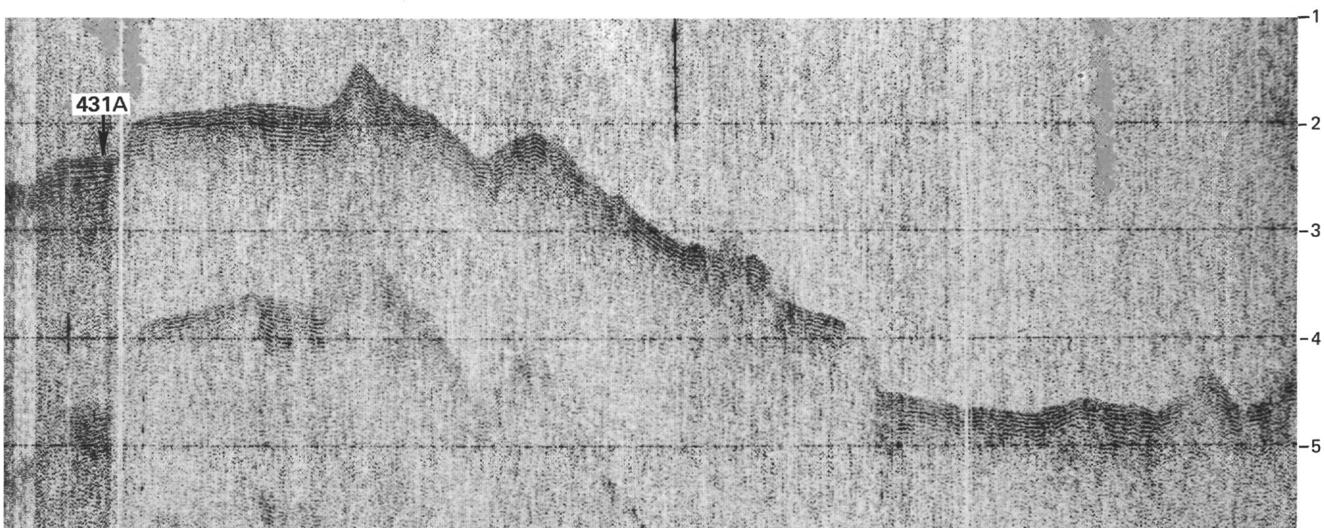

Figure 13. Glomar Challenger *10-s seismic reflection profile on departure from Hole 431A.*

huxleyi Zone) because of the difficulty of identifying *Emiliania huxleyi* in transmitted-light microscopes.

A single specimen of discoaster occurs in Sample 2-1, 119-121 cm, and has been probably reworked from Neogene sediments.

Radiolarians and Silicoflagellates

Although radiolarians are present in Core 1, Hole 431, none of them are diagnostic of either age or environment. In Core 2, a few Quaternary radiolarians are present, and the assemblage generally indicates transitional biogeographic environments. No silicoflagellates were found.

Hole 431A

Sediment recovered from Hole 431A is similar to that of Hole 430. Fine- to medium-grained sand consists chiefly of foraminifers (Samples 1-1, 22-28 cm and 1-1, 90-97 cm). These are well preserved, and include species such as *Globorotalia inflata, G. crassaformis, Globigerina bulloides, G. calida, G. glutinata, Neogloboquadrina dutertrei, N. pachyderma,* and *Orbulina universa.* The Quaternary benthic foraminfers are large, and include *Pyrgo depressa, Cassidulina subglobosa, C. lomitensis, C. translucens (*abundant), *Pullenia subcarinata, Planulina wuellerstorfi, Uvigerina peregrina, U. hispida,* and *Rupertina stabilis.* Rare specimens of the following genera are present: *Quinqueloculina, Lenticulina, Rhabdammina, Ehrenbergina, Spiroplectammina, Dorothia, Gyroidina, Carpenteria, Oridorsalis, Eponides,* and *Cassidulinoides.* The core-catcher sample of Core 2 and Sample 2-1, 125-130 cm contain some poorly preserved Paleogene planktonic foraminifers. Typical species include *Globorotalia bullbrooki, G.* cf. *spinuloinflata, Globigerina yeguaensis,* and *Globigerinatheka* sp. These species indicate that Core 2 is middle Eocene. Thus, the Pliocene-upper Eocene hiatus may be represented within Core 2.

Calcareous Nannofossils

In total, three samples (1-1, 4-6 cm; 1, CC; and 2, CC) were available for this investigation. Both Core 1 samples contain rare to common calcareous nannofossils, poorly to moderately well preserved. As in Hole 431, the species diversity is low. *Coccolithus pelagicus* and *Cyclococcolithus leptoporus* are fairly dominant, and only a few other species, such as *Gephyrocapsa oceanica, G. caribbeanica,* and *Helicopontosphaera kamptneri* are even rarely present. These two samples also contain a small number of *Pseudoemiliania lacunosa;* thus, it is possible that they are lower Pleistocene (NN 19 *Pseudoemiliania lacunosa* Zone).

Nannofossils in Sample 2, CC are extremely rare, and only *Coccolithus pelagicus* and *Cyclococcolithus leptoporus* are present.

Radiolarians and Silicoflagellates

In Sample 431A-1, CC and at the top of Core 2, *Druppatractus acquilonius* is present. Geologically, the latest appearance of this species in the North Pacific is known to have been about 0.4 m.y. ago; the age of sediments in this hole would seem therefore to be at least 0.4 m.y. In Sample 2, CC, which consists of loose sandy sediments, radiolarians are present but rare.

No silicoflagellates were recovered from this hole.

SEDIMENT CHEMISTRY

Surface sea water was analyzed for calibration purposes, but no interstitial water was analyzed. $CaCO_3$ in a sample of calcareous Fe-Mn sand (Sample 431A-1-1, 43-45 cm) proved to be 27.5 weight per cent. A second carbonate bomb determination on zeolitic Fe-Mn sand (Sample 431A-2-1, 71-72 cm) showed no $CaCO_3$ (Table 3). The crust of an iron-manganese nodule containing some siliceous material (Sample 431-2-1, 20-22 cm) was analyzed by XRF methods (Table 4), and contained 17.37 per cent total iron (as Fe_2O_3) and 25.5 per cent MnO. Since the MnO standards aboard ship are those expected for basaltic rocks, the extrapolation to such large values is nearly 10^2. Nevertheless, the analyst has used these standards for manganese-rich rocks in the past, and gives outside limits of 24 to 27 weight per cent MnO for the analyzed sample.

PALEOENVIRONMENT

Recent foraminiferal ooze directly overlies the Eocene sediments at Site 431, indicating that Pleistocene-Eocene sediments are missing. The stratigraphic history thus appears to be similar to that on Ōjin Seamount at Site 430 to the south. The Recent benthic foraminifers indicate a bathyal habitat for the sediments, but planktonic foraminifers and calcareous nannofossils

TABLE 3
$CaCO_3$ Analyses, Carbonate Bomb Method, Hole 431A

Core	Section	Interval (cm)	$CaCO_3$ (%)
1	1	43-45	27.5
2	1	71-72	0

TABLE 4
X-Ray Fluorescence Analysis of Manganese-Iron Oxide Nodule from Hole 431

Sample		2-1, 20-22 cm
Major-Element Oxides (wt. %)		
SiO_2		30.10
TiO_2		0.99
Al_2O_3		6.00
Fe_2O_3 (Total)		17.37
MnO		25.50
MgO		3.53
CaO		7.66
K_2O		1.20
P_2O_5		0.75
Total		93.10
Loss on Ignition (wt. %)		17.60
H_2O^+	wt. % Composition after baking off H_2O	6.15
CO_2		2.92

suggest a transitional to subarctic overlying watermass. Compared with tropical areas, the composition of both planktonic foraminiferal and calcareous nannofossil species suggests relatively low productivity for this region, but the good preservation of these specimens appears to indicate their deposition above the CCD. The missing Eocene through Pleistocene geological interval at this site, like that on Ōjin Seamount, thus indicates subsidence of the seamount to near its present depth during the corresponding interval of geological time. The complete absence of sediments deposited during this time span, and the lack in sediments here of a finer grain fraction, strongly indicate submarine erosion during the subsidence history of this seamount.

The iron-manganese and silicate sediments at Holes 431 and 431A are predominantly of authigenic origin. Alteration of volcanic material is the most probable process for formation of the authigenic minerals. Since formation, however, these materials have been transported and deposited at their present location. Classically, iron-manganese and silicate sediments are associated with cold, oxygenated deep water. Although the depth of the seamount is shallow, the sediments may indicate slow deposition through cold, oxygenated waters.

PHYSICAL PROPERTIES

The samples obtained from Hole 431 appeared to be highly sorted during core retrieval, so no physical properties were measured. Core 1 of Hole 431A also was sorted; its density was measured by the GRAPE method, but the variation may not reflect *in-situ* gradation. Core 431A-2 appeared by eye to be more uniform, and the density and velocity measurements support this observation. Three velocity measurements were attempted (through the core liner). The sonic pulse was very attenuated after passing through the unconsolidated sand, and "first arrivals" were too weak to be accurately distinguished. The "first peak" and "first zero crossing" were measured in Samples 431A-2-1, 92 cm and 431A-2-1, 98 cm, respectively; the agreement of these two measurements is surprising in view of the poor signals and different techniques used here.

Another velocity measurement was attempted on Sample 431A-2-2, 10 cm, but the attenuation was so great that not even a rough estimate could be made.

Table 5 presents the data obtained.

TABLE 5
Velocity and Density Measurements, Hole 431A

Sub-bottom Depth (m)	Sample (Interval in cm)	Velocity (km/s)	GRAPE Density (g/cm^3)
0.60	1-1, 60		1.69
0.70	1-1, 70		1.84
0.80	1-1, 80		1.79
0.90	1-1, 90		1.75
1.00	1-1, 100		1.83
1.10	1-1, 110		1.79
1.20	1-1, 120		1.82
1.30	1-1, 130		1.86
1.40	1-1, 140		1.91
7.90	2-1, 40		1.50
8.00	2-1, 50		1.53
8.10	2-1, 60		1.53
8.20	2-1, 70		1.53
8.30	2-1, 80		1.53
8.40	2-1, 90		1.52
8.42	2-1, 92	1.63 ± 0.10	
8.48	2-1, 98	1.63 ± 0.10	
8.50	2-1, 100		1.51
8.60	2-1, 110		1.52
8.70	2-1, 120		1.52
8.80	2-1, 130		1.49
8.90	2-1, 140		1.44
9.10	2-2, 10	Attenuated	

CORRELATION OF SEISMIC PROFILES WITH DRILLED SEQUENCE

Like Ōjin, Yōmei Seamount has a thin sedimentary veneer which complicates seismic interpretation. The combination of a long bubble pulse, hard bottom, and internal ringing prevents definitive identification of many structural features. Nevertheless, general morphology and local acoustic windows allowed us to infer the identity and origin of many sedimentary units. The acoustic stratigraphy of Holes 431 and 431A are shown in the seismic reflection profiles collected aboard the *Glomar Challenger* (Figures 5 and 6). The broad flat platform that surrounds the central, acoustically opaque peaks of the seamount appears to have a very thin (less than 0.15 s) sedimentary cover, most of which is masked by the bubble pulse (Figure 14). This sedimentary unit thickens from the distal edge of the platform to the base of the central peaks, where more than 0.2 s of sedimentary detritus may have accumulated. At Site 431, on the first faulted step below the western edge of the platform, we observed nearly 0.3 s of well-layered, strong, continuous reflectors. Although the surface of the acoustic basement is not well defined, a zone of fuzzy acoustic properties, and not continuous reflectors, marks the position of acoustic basement. Basement is overlain by one acoustic unit, synclinally dipping and well stratified, and consisting of alternating, uniformly spaced reflectors. We infer that this unit is a marine terrace deposit.

Site 431 is on a prominent rounded mound that marks the distal edge of the step. Acoustic basement appears to lie about 0.2 s beneath the surface of the mound. Assuming a velocity of 1.8 km/s, we calculate that about 180 meters of sediments overlie the probable volcanic basement.

The 3.5-kHz profile obtained aboard the *Glomar Challenger* (Figure 9) shows two well-defined anticlinally folded reflectors at 0.02 s and 0.06 s beneath the mound's surface. This indicates that the surficial sediments have either been folded or are draped over a deeper subsurface feature. The latter is more probable, because the *Lee* profile (Figure 2) shows a rounded acoustic buttress at depth that exhibits many hyperbolic reflectors. This acoustical characteristic and the geomorphic form of the feature are characteristic of a reef. The relatively transparent upper acoustic unit in the 3.5-kHz *Glomar Challenger* profile is probably the zeolitic sandy gravel collected in the second core at Hole 431 (see Figure 15).

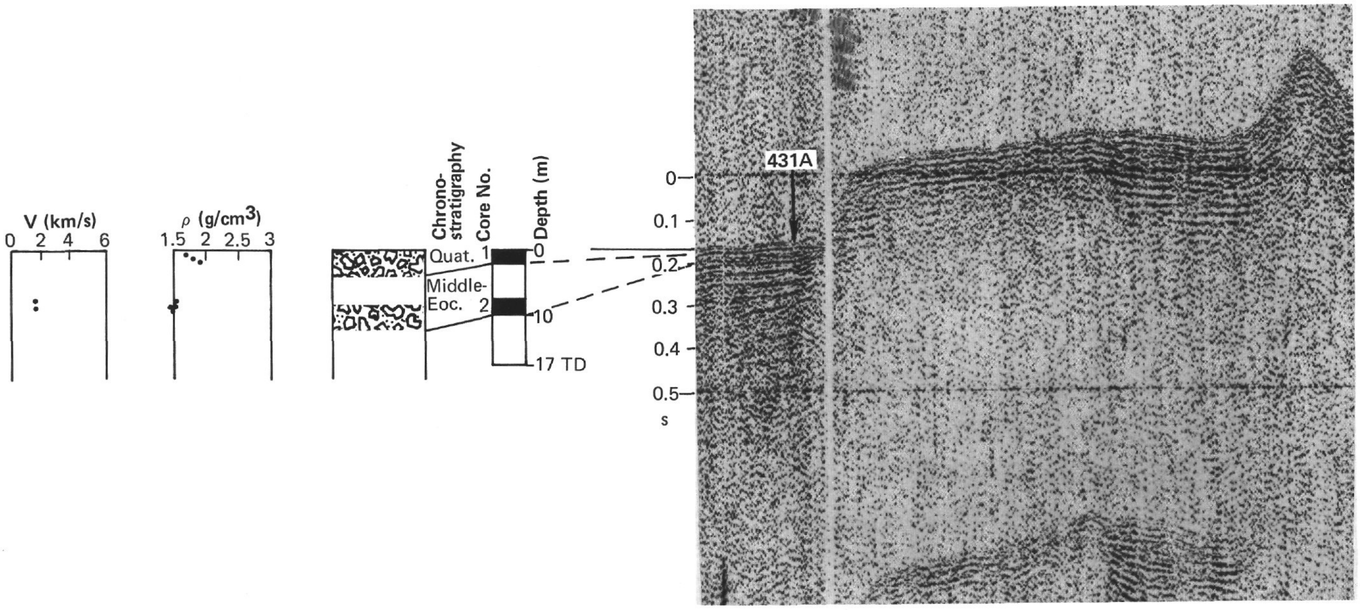

Figure 14. *Correlation of seismic reflection profile with physical properties and lithologic column, Hole 431A.*

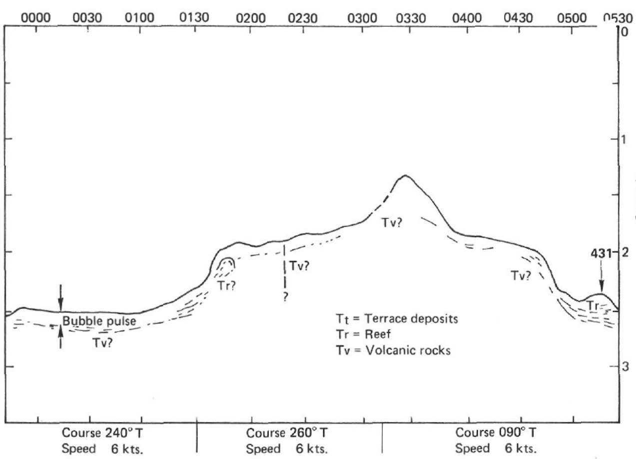

Figure 15. *Line drawing of* Glomar Challenger *seismic reflection profile across Site 430, showing geologic interpretation of acoustic features.*

No sonobuoy profiles were attempted at this site, because the areal extent of the fault step is limited, the surrounding bottom topography is steep and irregular, and the internal reflectors do not lie flat. For the shallow subsurface reflectors, average seismic velocities of 1.63 km/s — based on the physical property measurements made on sediments from Hole 431A — were used.

Since recovery at Site 431 was limited to the upper 10 meters of sediments, we could not correlate the seismic reflectors in the seismic reflection profiles with the sedimentary units of the cores. The core stratigraphy is shown in Figure 14.

SUMMARY AND CONCLUSIONS

Although we did not deeply penetrate Site 431, the cores of the upper 17 meters did allow us to study parts of the Cenozoic history of the seamount.

In Hole 431 we cored the interval 0 to 9.5 meters twice, and recovered a total of 3.33 meters of sand and centimeter-sized unconsolidated gravel. This consists of 90 per cent angular, apparently broken and transported iron-manganese oxide fragments and 10 per cent rounded pebbles, sponge fragments, foraminifers, and authigenic silicates (clays, zeolites) and phosphates. The pebbles are extremely heterogeneous, and include andesites, dacites, granites, schists, and quartz sandstones, all probably ice-rafted. These rocks proved to be the most southerly exotic material encountered in our drilling up the seamount chain, and place the North Pacific ice-rafting boundary between latitudes 41°20′N and 42°25′N. The sand and gravel contain both planktonic and benthic foraminifers and Pleistocene to Recent subarctic nannofossils. The hole had to be terminated because of mechanical failure of the bottom-hole assembly and/or excursion of the ship from the beacon, resulting in loss of the bit and inner core barrel.

Hole 431A penetrated 17 meters of sand and fine gravel, of which 4.35 meters was recovered. Unit 1 (Core 431A-1) consists of 80 per cent fine iron-manganese fragments and 20 per cent authigenic silicates, plus calcareous sand and rounded, glacially transported pebbles. Unit 2 (Core 431A-2) consists principally of authigenic zeolites, palagonite, and calcareous sand. Core 431A-1 contains principally Quaternary planktonic foraminifers and calcareous nannofossils; planktonic foraminifers in Core 431A-2 are middle Eocene.

These iron-manganese and silicate sediments are predominantly authigenic, and they were probably formed by alteration of volcanic material. Although the depth of the seamount is shallow, the character of the sediments probably indicates slow deposition and a high degree of sorting through cold, well-oxygenated waters.

The Pleistocene/Eocene hiatus, which is widely represented in cores from the Emperor chain to the south, was also identified at Site 431. One Miocene discoaster was found in Section 431-2-1. The significance of this single specimen is not clear. If there is in fact a hiatus between the shallow-water Eocene sediments and the Quaternary bathyal sediments at Site 431, the history of the seamount must be very similar to that of Ōjin Seamount (Site 430 Report, this volume), where the same hiatus exists, and of Kōkō Seamount (Site 308, Leg 32; see Larson, Moberly, et al., 1975). In Hole 308 at Kōkō, Quaternary volcanic sand directly overlies lower Eocene volcanic-biogenic siltstone. (The other hole on Kōkō, 309, has Quaternary overlying upper Oligocene or lower Miocene. This hole is only one core deep, however.) Factors which may have influenced the development of these hiatuses include (1) erosion by bottom currents before deposition of the Quaternary sediments, (2) rapid subsidence at some time in the Eocene, (3) non-deposition between the Eocene and the Quaternary, and (4) erosion of the seamount near sea level before deposition of the Quaternary materials. In our opinion, some combination of (1) and (2) above probably account for the observed hiatus in this portion of the Emperor Seamount chain. In any case, the history of Sites 430 and 431 must have been very different from that of Midway Atoll in the Hawaii chain (Ladd et al., 1970) and that of Meiji Seamount at the north end of the Emperor chain (Creager, Scholl, et al., 1973). At Midway there is a complete sequence, laid down after the late Miocene, of shallow-water carbonates interbedded with some clay. At Meiji there is a nearly complete Upper Cretaceous (Maestrichtian) to Pleistocene sequence of marine ooze, clay, chalk, and volcanic ash.

Site 431 is on a bench underlain by the "terrace deposits" described by Greene et al. (1978). The surprisingly thick and concentrated iron-manganese pavement may or may not be a local feature. Individual fragments of material contained 24 to 27 weight per cent manganese oxide. If the widespread surfaces mapped as terrace material all prove to be capped by some 9 meters or so of iron-manganese pavements, the holes at Site 431 may suggest exploration aimed at possible development of a significant new discovery of iron-manganese oxide in fairly shallow water along the Emperor Seamount chain.

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SITE 431 HOLE CORE 1 CORED INTERVAL: 0.0-9.5 m

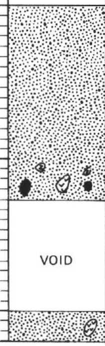
TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SILICOS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
QUATERNARY	NN20-NN21	AG					1	0.5 1.0					Iron manganese oxide gravel, black 7.5YR 2.5/0 90% Fe-Mn crust fragments 10% rounded pebble glacial debris (andesite, quartz, dacites, schist, granite) sponge fragments *recent foraminifera* silicoflagellates, phosphates Size of components ranges up to 3 cm Artificial sorting due to washing
							2		VOID				**S.S. CC, finest sand** 80% unspecified carbonate 10% micronodules 10% sponge spicules TR quartz $CaCO_3$ % interval 43-45 cm = 27.5%
		AG	CM	FM	B		CC					*	

SITE 431 HOLE CORE 1* CORED INTERVAL: 0.0-9.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SILICOS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
QUATERNARY	NN20-NN21		RM RM CM				1	0.5 1.0					Iron manganese oxide sandy gravel, black 7.5YR 2.5/0 Same composition as 431-1 Size grading artificial due to washing Rust chips from core pipe *$CaCO_3$ % interval 71-72 cm = 0%* *Represents second punch core at same interval as Core 1.
			RP	FP	B		CC						

SITE 431 HOLE A CORE 1 CORED INTERVAL: 0.0-7.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SILICOS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE
QUATERNARY	NN19-NN21	AG	CM				1	0.5				* CC
								1.0				*
							2		VOID			
			RP	RM	B		CC					



LITHOLOGIC DESCRIPTION

Iron manganese oxide sandy gravel, black

Fine sand:
50% Fe-Mn sand
50% Calcareous sand

Sand and gravel:
80% Fe-Mn breccia
20% Limestone fragments, volcanic rocks (rounded)

Size of particles 0.1 to 3 cm
Fe-Mn crust fragment are smallest (0.1 to 1 cm), with calcareous sand and other materials (volcanic rocks, rounded glacial erratics, sedimentary-indurated pieces, limestone) largest; in Core Catcher volcanic gravel 2 x 3 cm.

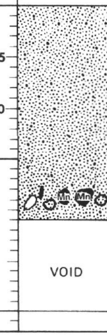
At 1.80 m non-indurated yellow sediment (10YR 7/6)

S.S. (at 1.80 m):
40% unspecified carbonate
20% clay
15% micronodules
10% volcanic fragments
10% quartz
5% phosphates
TR altered basalt, and zeolite

S.S. (at 0.10 m) made from finest part of sandy gravel:
35% forams
30% micronodules
15% volcanic glass
5% quartz
5% heavy minerals
5% sponge spicules
5% unspecified carbonate
TR clay and zeolite

SITE 431 HOLE A CORE 2 CORED INTERVAL: 7.5-17.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SILICOS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE
QUATERNARY				RM	B		1	0.5				* G.S CC
		RP						1.0				**
EOCENE							2		VOID			
		RP	RP	B	B		CC					



LITHOLOGIC DESCRIPTION

2.5Y 4/4

Heterogenous zeolitic iron manganese sand, olive brown, with particles olive-yellow (2.5Y 6/6), black, and white

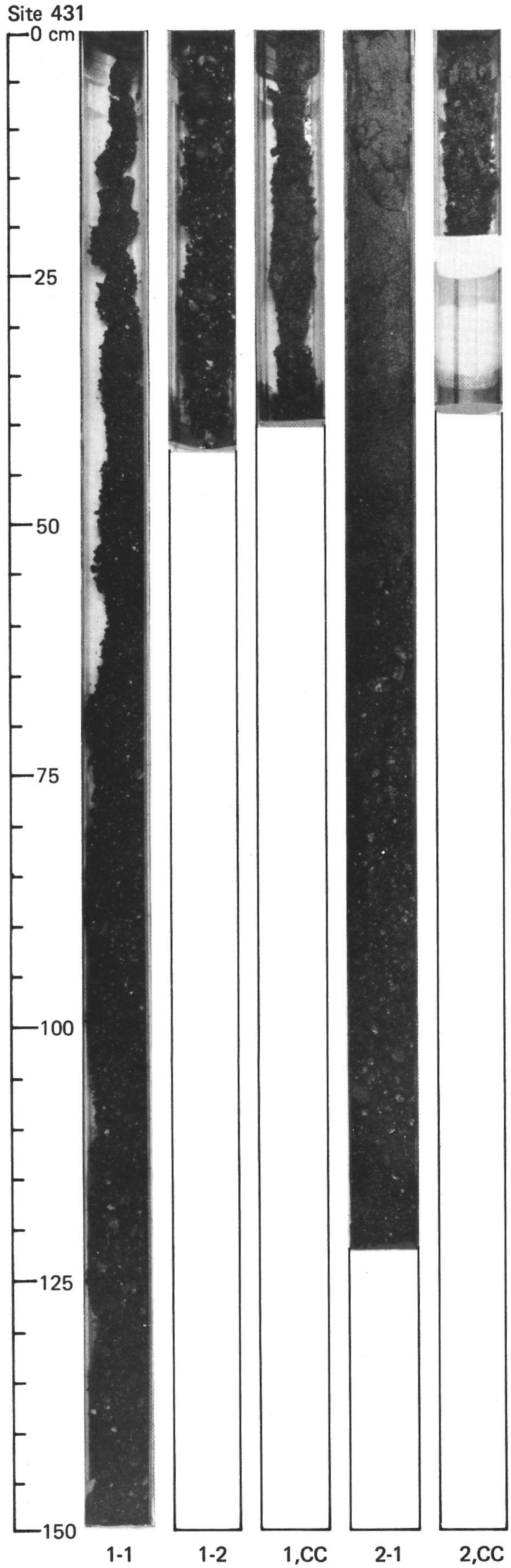
Sand appears to be made of:
20% Mn-Fe particles
20% calcareous clastic sand
10% altered basalt grains
50% authigenic, sedimentary particles

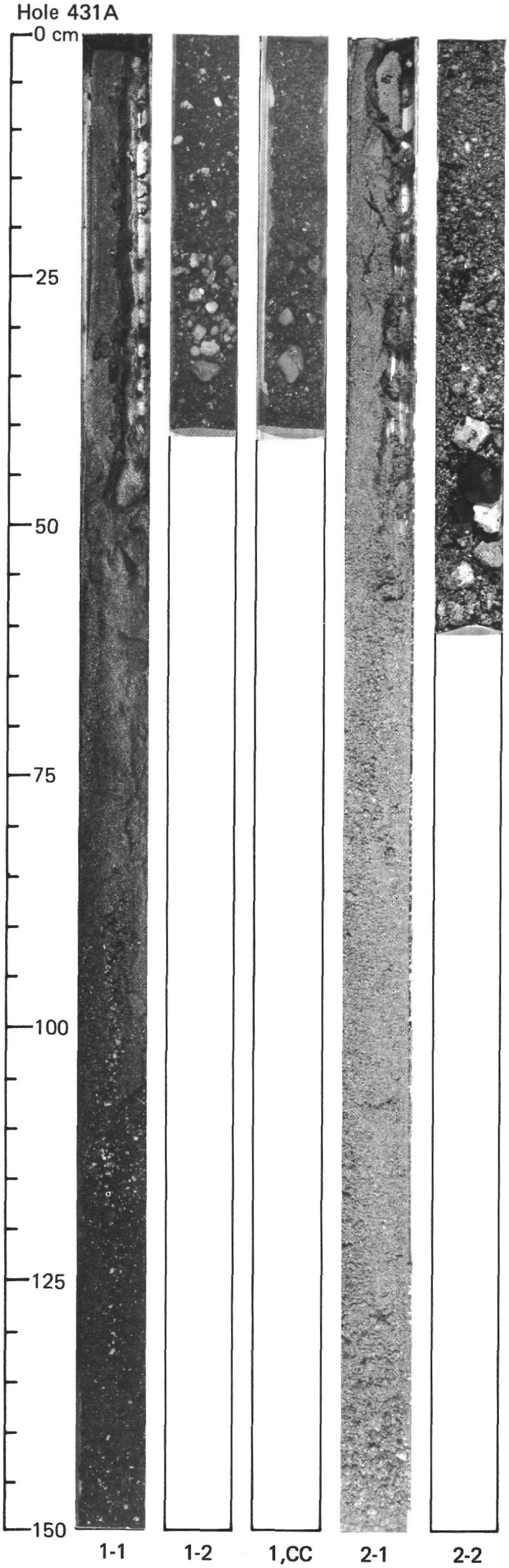
Size 0.5 mm to 3 cm graded due to drilling. At ≃1.90 m big pieces of Mn-Fe crust (the biggest 5 x 3 x 2 cm has 2 zones, one Mn-Fe only, one more "breccia" of silicates and Mn-Fe oxides) and fragments of sandstone (light olive brown 2.5YR 5/6) and indurated sediment (olive yellow 5Y 6/6), mud in Core Catcher.

S.S. (at 0.10 m):
15% micronodules, 40% carbonate unspecified
15% clay
5% phosphates
10% volcanic fragments
10% sponge spicules
5% quartz
TR palagonite, and zeolites

S.S. (at 2.00 m) yellow gravel:
30% micronodules (clastic)
25% clay
10% zeolite and phosphates
15% quartz
10% unspecified carbonate
5% volcanic glass
5% altered volcanic fragments

S.S. (at 2.00 m) white concretion:
90% carbonate (unspecified clastic)
10% clay
TR volcanic glass and micronodules


Site 431
0 cm
25
50
75
100
125
150
1-1
1-2
1,CC
2-1
2,CC


Hole 431A
0 cm
25
50
75
100
125
150
1-1
1-2
1,CC
2-1
2-2