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FEB 77 J R HEIRTZLER, P T TAYLOR, R D BALLARD N00014-74-C-0262
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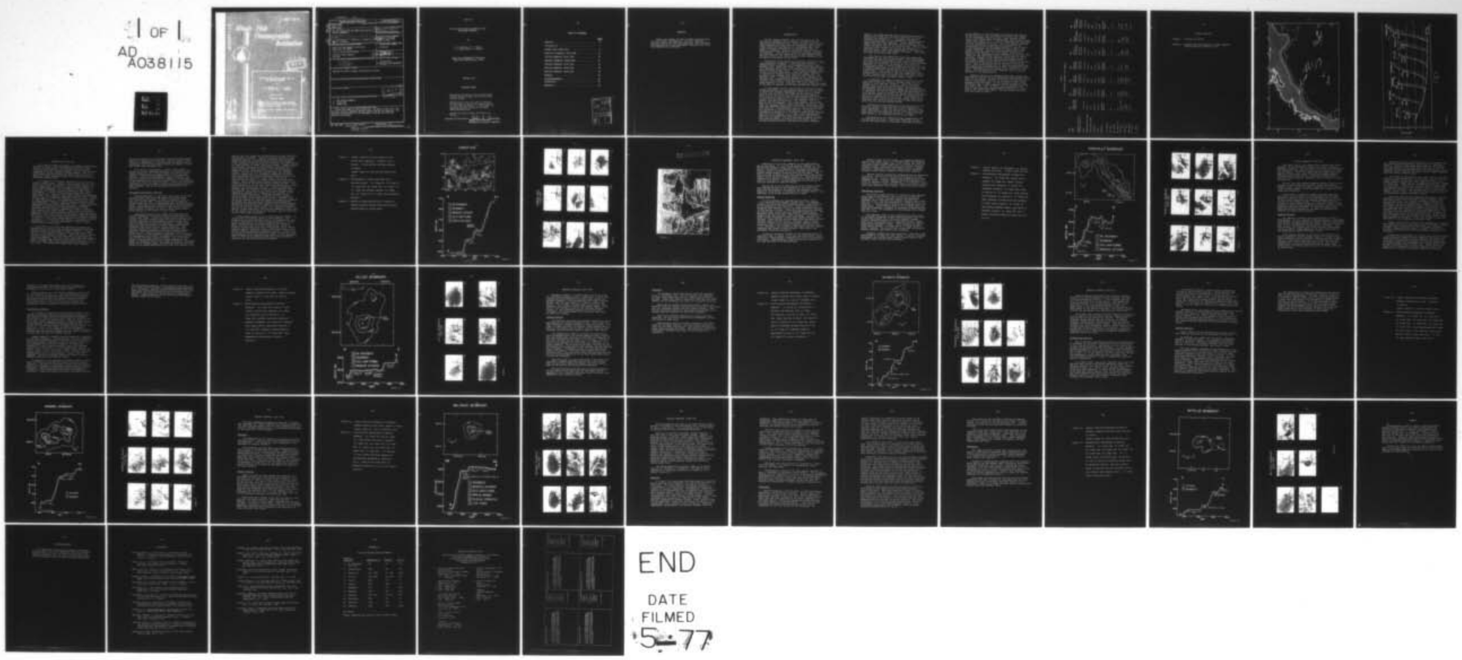

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THE 1974 ALVIN DIVES ON CORNER RISE AND NEW ENGLAND SEAMOUNTS

by

J. R. Heirtzler, P. T. Taylor,
R. D. Ballard and R. L. Houghton

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February 1977

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Approved for Distribution John I. Ewing
John I. Ewing, Chairman
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TABLE OF CONTENTS

ABSTRACT

During the summer of 1974 an ALVIN dive was made on Corner Rise, and Nashville, Gilliss, Rehoboth, Manning, Balanus and Mytilus Seamounts. The principal characteristics of the topography, sediments and rocks were observed and recorded.

INTRODUCTION

As the longest seamount chain in the Atlantic, the New England seamounts are of special interest to marine geologists and geophysicists. There are more than 30 major peaks extending for some 1,000 km southeast from the continent margin off New England to the Bermuda Rise. The chain terminates abruptly on its eastern end with the Nashville Seamount. However, the Corner Rise is a cluster of seamounts 300 km still further to the east and more than halfway from the continent to the Mid-Atlantic Ridge. The major peaks of all these Atlantic Ocean seamounts rise as much as 3 km above the sea floor.

Relatively little descriptive material exists for these large submarine volcanoes. A few have been surveyed bathymetrically, dredged, or photographed (Ziegler, 1955; Walczak, 1963; Uchupi and others, 1970; Taylor and Hekinian, 1971; McGregor and Krause, 1972; McGregor and others, 1973; and Taylor and others, 1975). As with most seamounts, their origin is largely speculative. They have been considered to delineate a fracture zone (Drake and others, 1963) or possibly to be a mantle plume (Wilson, 1963; Morgan, 1971 and Vogt, 1971). Although an Eocene age was estimated for shallow water limestones dredged from the western seamounts (Ziegler, 1955; Uchupi, 1968) the chain is situated on ocean basement that has a magnetic age ranging from Cretaceous on the east to Jurassic on the west (Pitman and Talwani, 1972).

In the summer of 1974, upon returning from the Project FAMOUS submersible diving programs (Heirtzler and van Andel, in press) the research submersible ALVIN, with its tender the R/V LULU and escort R/V KNORR had the opportunity to study briefly the Corner Rise and New England Seamounts. Dive sites were made on seven of these peaks shown in Figure 1 (Corner Rise and Nashville, Gilliss, Rehoboth, Manning, Balanus and Mytilus Seamounts). The deepest, 3040 m, was made on Mytilus Seamount. Geological sampling studies were made with in situ samples being collected. Television videotapes and numerous photographs, both oriented and hand held were obtained. The Seamounts proved to be much more rugged and geologically complex than expected. The degree of ruggedness is similar to a continental mountain and suggests that the term "seamount" is, in fact, quite appropriate. Sampling of the seamounts were carried out from both the ALVIN and the KNORR. The ALVIN was able to gather in situ and oriented samples of basalt while the KNORR, using standard dredging methods, gathered few basalt fragments.

However, the KNORR dredged these seven seamounts and two others here called Lulu and Alvin between Gilliss and Rehoboth (see Appendix I). In another, and nearly simultaneous project the R/V ATLANTIS II dredged some of these and seven other seamounts. Visual observations showed that there were many more glacial erratics on the western seamounts than on the easterly ones. The recovered rocks are being studied and will be the subject of a separate paper. Some color photographs of the sea floor are given by Heirtzler and others (in press). Other black and white photos are given here.

The value of the submersible dives was appreciably diminished by the lack of survey data. Only one seamount (Gilliss) has been surveyed in detail by the narrow-beam Navy Sonar Array System (Taylor and others, 1975) and some seamounts are mislocated on charts up to a few miles. Nevertheless, since it would probably be difficult to get a research submersible to this area again it was felt that a reconnaissance dive program would be of scientific significance. This study is the first reported direct observation of the sea floor from the Mid-Atlantic Ridge to Bear Seamount where two ALVIN dives were made several years ago by Milliman and Emery (unpubl. comm.).

To maximize the number of seamounts studied the dive sites were chosen for logistic factors rather than for greater or less geologic interest. Sites which were reached early in the day during periods of favorable weather were those selected for dives. Before daybreak the seamount would be located by KNORR and surveyed briefly to determine its general extent, depth and configuration. A transponder would be placed near depths where ALVIN could dive and the submersible would be able to proceed upslope during her traverse of the sea floor. LULU attempted to determine local surface currents and thereby position herself such that ALVIN would be carried to near the transponder by the time she reached bottom.

Although the dives were made at the beginning of the hurricane season it was possible to plan operations to avoid rough seas. ALVIN was restricted to depths of less than 3300 meters at that time so she could only reach the upper parts of the seamounts (Figure 2). Effects of the Gulf Stream or its countercurrent were not found.

Positioning of the submersible was accomplished with a range-range technique. LULU would determine its own bearing and range from a transponder, emplaced previously by the KNORR, and also determine the bearing and range of ALVIN from LULU. Thus the position of ALVIN with respect to the transponder would be known. Upon occasion ALVIN could itself interrogate the transponder and directly locate itself with respect to it. Both of these means of obtaining relative navigation were poor: the first because LULU did not have good bearing resolution with respect to the transponder and the second because ALVIN's "line-of-sight" to the transponder was frequently blocked by small topographic features. However, vertical positioning of the ALVIN was satisfactory, since the depth, altitude and heading of the submersible were recorded by an internal data logger and the approximate track of ALVIN could be reconstructed. Because of the imperfect navigation, we plot in this report, depth versus time instead of depth versus horizontal distance or projection of the track on a horizontal distance or projection of the track on a horizontal plane. This presentation gives a line with zero slope when the submersible is stopped and so gives a completely inadequate representation of the slope of the side of the seamount. This presentation does, however, aid in giving a synopsis of the observations.

Normally one to a few hundred meters were covered for each hour on the bottom, with bottom time being approximately three to four hours. Round trip travel time from the surface to the seamount was also of the order of three hours depending upon the depth. In this report we show a rough bathymetric map of each seamount with the submersible track as a short line. This is only an approximation to the actual track which has numerous small excursions to either side of the approximate track. The particulars for each dive are given in Table I.

TABLE I

NEW ENGLAND SEAMOUNT DIVE SUMMARY

DIVE	537	538	539	540	541	542	543
AREA	Corner Rise (South Ctr)	Nashville (S side)	Gilliss (NW side)	Rehoboth (SE side)	Manning (S of peak)	Balanus (SW of peak)	Mytilus (W of peak)
Approx. 35°09.1'N Position 48°10.[illegible]'W		34°45.9'N 54°05.5'W	35°36.4'N 58°38.6'W	37°26.4'N 59°47.1'W	38°07.2'N 61°00.4'W	39°23.9'N 65°27.1'W	39°24.4'N 67°08.2'W
Date	21 Aug 74	24 Aug 74	25 Aug 74	27 Aug 74	28 Aug 74	30 Aug 74	1 Sept 74
Reached Bottom (GMT)	1330*	1455*	1450*	1554**	1756**	1658**	1658**
Left Bottom (GMT)	1751	1813	1850	2007	2107	2048	1949
Duration	4h 20m	3h 18m	4h 0m	4h 13m	3h 11m	3h 50m	2h 51m
Pilot	Foster	Donnelly	Foster	Donnelly	Foster	Donnelly	Foster
Observers	Heirtzler Ballard	Ballard Houghton	Ballard Taylor	Heirtzler Houghton	Heirtzler Taylor	Ballard Heirtzler	Heirtzler Taylor
No. Station	3	3	3	4	3	3	4
lbs rock	46	c. 30	c. 50	c. 50	c. 60	89	c. 40
No. Scoop	1	1	0	0	0	0	1
Fr. EGG b & w	561	1 roll	1 roll	399	782	468	c. 450
Port b & w	2 or 3 rolls	1 roll	3 rolls	2 rolls	3 rolls	1 roll	2 rolls
clr	1 roll	2 rolls	2 rolls	0	1 roll	1 roll	0
Stbd b & w	2 rolls	2 rolls	2 rolls	2 rolls	2 rolls	2 rolls	2 rolls
clr	3 rolls	1 roll	2 rolls	1 roll	2 rolls	1 roll	0
CTFM photos	1 roll	0	1 roll	0	0	0	1 roll
TV, reels	2	1	2	0	1	1	1

* T.Z.3
** T.Z.4

Figure Captions

Figure 1. Location of dives.

Figure 2. Generalized cross section of each seamount showing portion covered in dive.

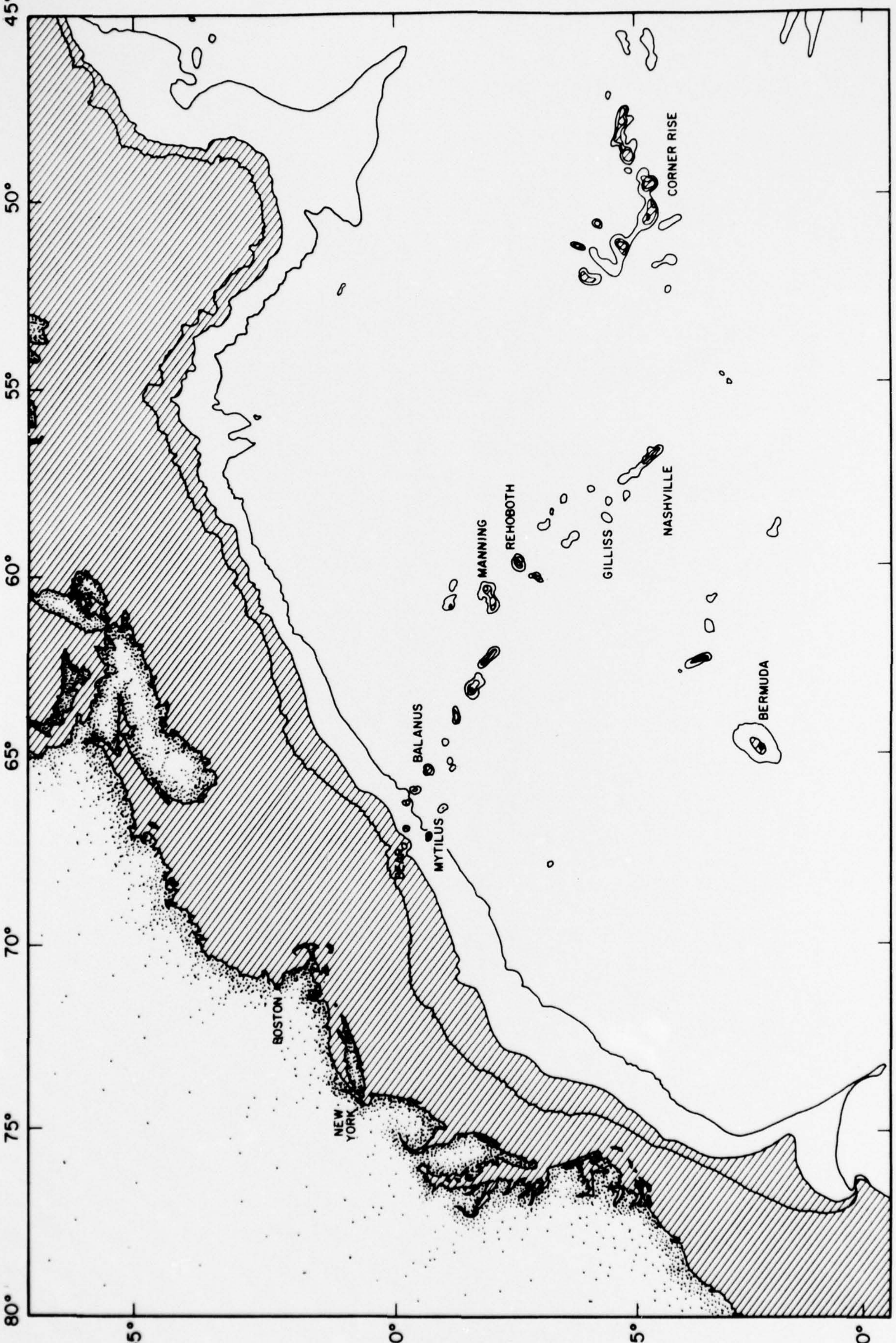

45°
50°
55°
60°
65°
70°
75°
80°
45°
40°
35°
30°
CORNER RISE
NASHVILLE
GILLISS
REHOBOTH
MANNING
BALANUS
MYTILUS
BERMUDA
BOSTON
NEW YORK

Figure 1.

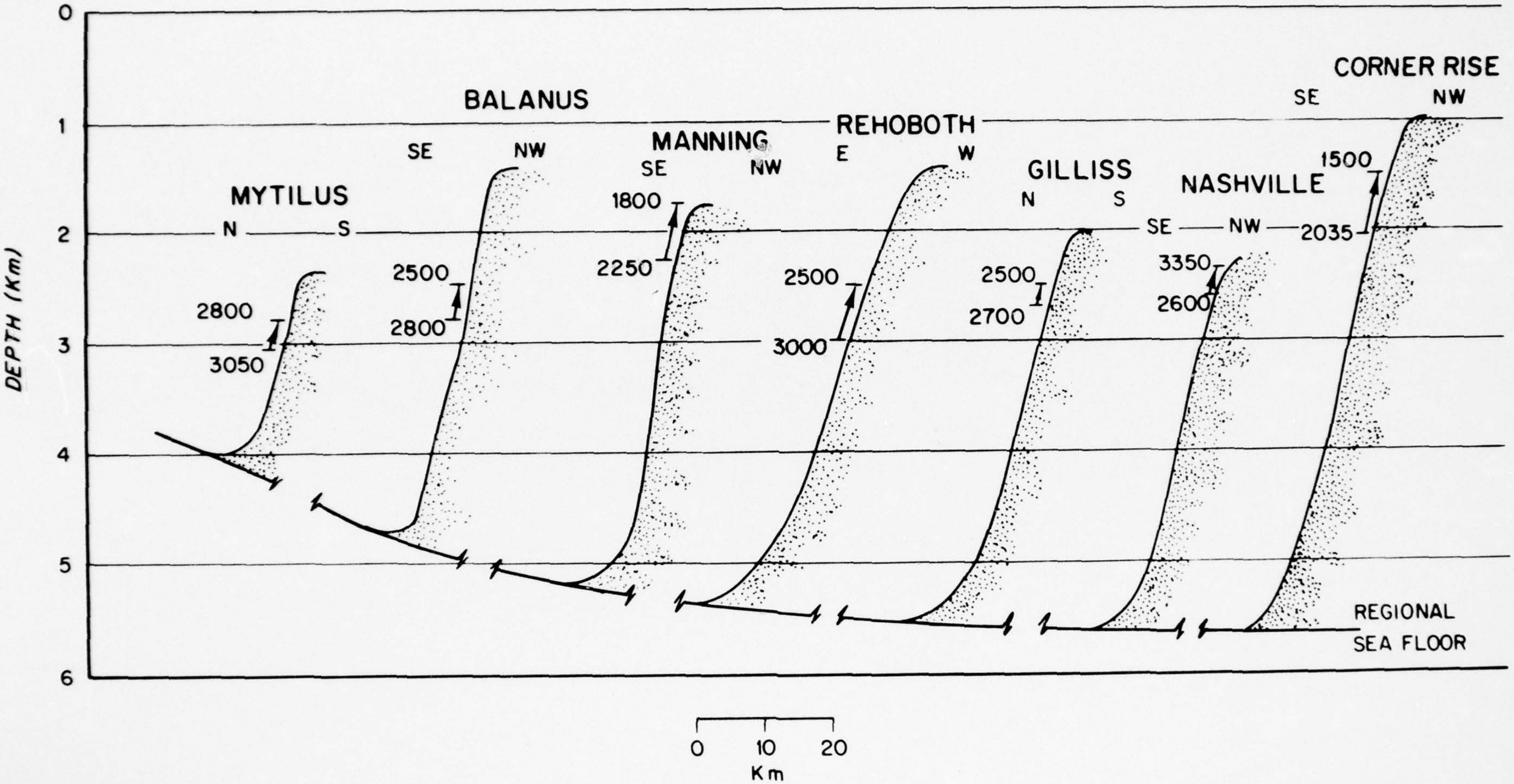

DEPTH (Km)
0
1
2
3
4
5
6
MYTILUS
N
S
2800
3050
BALANUS
SE
NW
2500
2800
MANNING
SE
NW
1800
2250
REHOBOTH
E
W
2500
3000
GILLISS
N
S
2500
2700
NASHVILLE
SE
NW
3350
2600
CORNER RISE
SE
NW
1500
2035
REGIONAL
SEA FLOOR
0
10
20
Km

Figure 2.

CORNER RISE (DIVE 537)

The dive on Corner Rise began at a depth of 2035 meters (Figure 3) where a heavily manganese-encrusted outcrop surface was encountered. The outcrop has a staircase structure with rock surfaces exposed in near vertical rises separated by gentle sediment covered benches. The first and deepest outcrop observed was blocky and fractured. A sample of highly weathered basalt was recovered from this manganese covered scarp.

At a depth of 1950 meters (85 meters up the section) a break in slope occurs forming a broad terrace where an old pillow-lava surface is exposed. The elongate pillows are old in appearance, lacking a palagonite outer surface and coated with manganese. In all cases the pillow forms point down the present slope and exhibit no post-volcanic disturbance. A highly altered basalt sample was taken from this flow. Farther up the terrace slope only sediments were found. This sediment ramp abuts against a near vertical scarp in which is exposed a massive outcrop surface, similar to that seen below it. This manganese covered scarp rises 50 meters before coming to another terrace covered entirely with sediments. A sample recovered from this cover contained deep-water Pleistocene mollusks and corals. Samples of volcanic rock seen lying on the sediments were highly vesicular and scoriaceous, resembling cinders in furnaces. This terrace also abuts against a steep scarp in which are exposed a massive outcrop section similar to that previously described. This scarp rises for 260 meters (1800-1540 meters). The face of the scarp contains several small sediment benches in which are found ripple marks and more Pleistocene mollusks and corals. This sector of the seamount, therefore was represented by a step-like morphology. Figure 4 shows several bottom photographs.

Just before this scarp was reached, the submersible passed over a series of very unusual topographic forms that can most easily be described as buttes (Figure 5). These buttes are flat topped features three to four meters high and one to two meters in diameter. There were six to twelve of these forms separated from each other by approximately their own diameter. They are rugged rock forms that resemble certain eroded basalt structures in Iceland near the rift zone. No doubt, the formative mechanism is different in the two cases. The submersible passed over these features quickly and their size prohibited a good bottom photograph from being obtained, but they were clearly visible. This situation illustrates the limitation of recording events by photograph; the eye has greater resolution, depth of field and a more rapid response time.

At a depth of 1540 meters a terrace occurs which is covered by a thick manganese pavement. The pavement has a knobby appearance and in places covers the entire bottom surface. Circular pits commonly occur in the pavement, exposing a semi-lithofied sediment surface beneath. The pits also provide an opportunity to measure the thickness of the pavement which at times exceeds 60 cm. The manganese surface has joints or seams giving it a slab-like appearance. Undercutting of the pavement by erosional processes has, in some instances, led to the collapse of portions of the pavement.

Volcanism and Tectonic Activity

Observations made in the inner rift valley of the Mid-Atlantic Ridge (MAR) show that when molten lava comes into contact with seawater at depth it quickly builds a series of pillow forms. These pillows act as conduits through which the lava is transported away from the source areas. Individual pillow tubes coalesce to form flow fronts which advance across the sea floor. The resulting distribution system is similar in form to lobate delta fronts which develop at the mouths of major rivers.

Observations made on the slopes of Corner Rise and several seamounts in the chain verified the presence of similar lava flows. Unlike the fresh pillows found on the youngest volcanoes extending down the axis of the MAR rift valley, those seen on the seamounts were extremely well worn and heavily encrusted with manganese. Fresh pillow lavas are characterized by a glassy outer surface which quenched first during initial pillow formation. This rapidly cooled outer coating weathers away with time, initially forming palagonite, and later exposing duller appearing inner layers of basalt which has cooled at a slower rate. As the palagonite disappears, it is replaced by a manganese coating which thickens with time as precipitation from the water column continues. All of the lava flows on the seamounts had this latter appearance, the amount of manganese being great enough to weld the individual forms into a coherent mass. The flows were similar to those found at the GLOMAR CHALLENGER drill site 332B located 20 km west of the rift valley of the Mid-Atlantic Ridge (Heirtzler and Ballard, in press). The pillow forms observed on the seamount, however, are primarily elongated, pointing down-slope; exhibiting no post volcanic tectonic disturbance. A few isolated pillow blisters were seen but the wide variety of forms typical of recent flows were absent. Samples taken from several locations on the seamount flows proved to be highly weathered alkaline basalt. The flows were best preserved at the outer edge of terraces in the seamount slopes. Farther in from the terrace edge, the sediment cover increased until it completely blanketed the flows. Terraces containing similar preserved volcanic terrain are also common the west wall of the inner rift valley (Ballard and van Andel, in press) beneath which are fault scarps. These scarps expose bedrock sections consisting of truncated pillows overlying a massive basalt section. This latter section is cut by small lenticular dikes and is inter-layered with welded fault breccia. A similar exposure, however, was not observed on the vertical seamount scarps. The coherent lava flows at the edge of the terraces were immediately replaced by a massive outcrop surface on the vertical scarp face below. Truncated pillows having a radial columnar joint pattern typical of fault scarps in the inner rift valley floor were not seen. Whether this can be attributed to a smaller amount of extrusive volcanism or whether the long period of weathering and manganese deposition has obscured these patterns was not determinable. The vertical outcrop face is typical of the massive basalt section of the rift valley walls. The surface is blocky in nature, highly fractured, and contains numerous joints; some of the joints, most of which are vertical, are of sufficient size to form large reentrants.

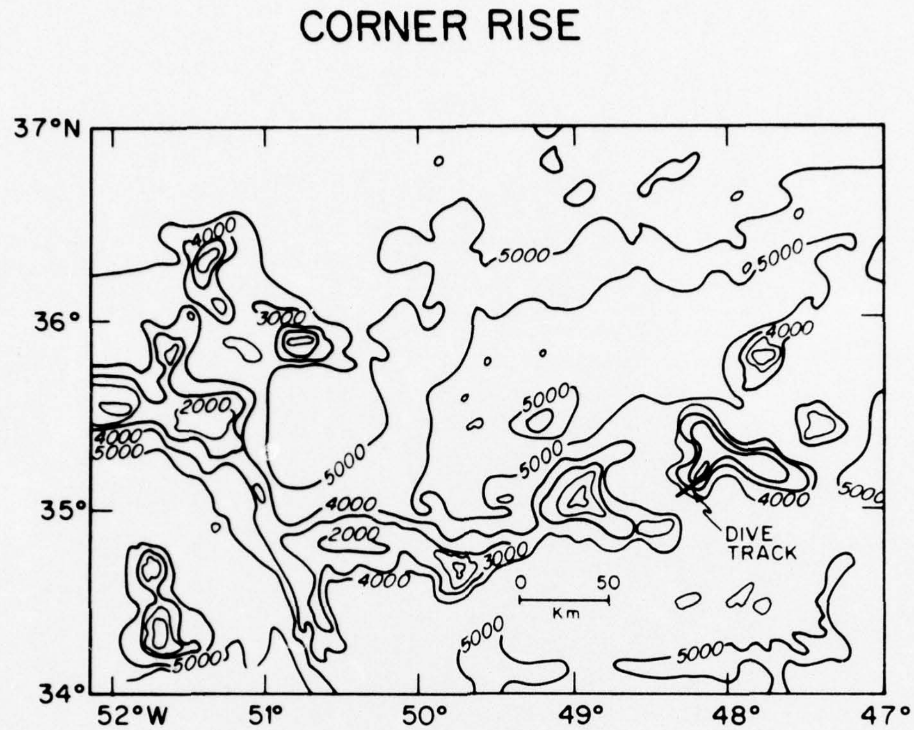
These scarps appear to be of fault origin, however, no recent signs of tectonic activity were observed. Any evidence of dip-slip movement such as slickenslide or fault gouge is obscured by the thick manganese coating. If the fault scarps consist of massive basalt which cooled at depth, the major relief of the seamounts may be due to faulting rather than constructive volcanism. Such a deter-mination was not possible, since a large percentage of the overall seamount slopes are sediment covered. In any case, the origin of these vertical-fault scarps is critical to an understanding of the constructional mode of these seamounts, that is, have these seamounts been built up by primarily intrusive or extrusive volcanic processes?

Figure 3. (Upper) Location of dive tracks on the Corner Rise Seamounts. Contours are in meters. A 50-kilometer distance measure is shown.

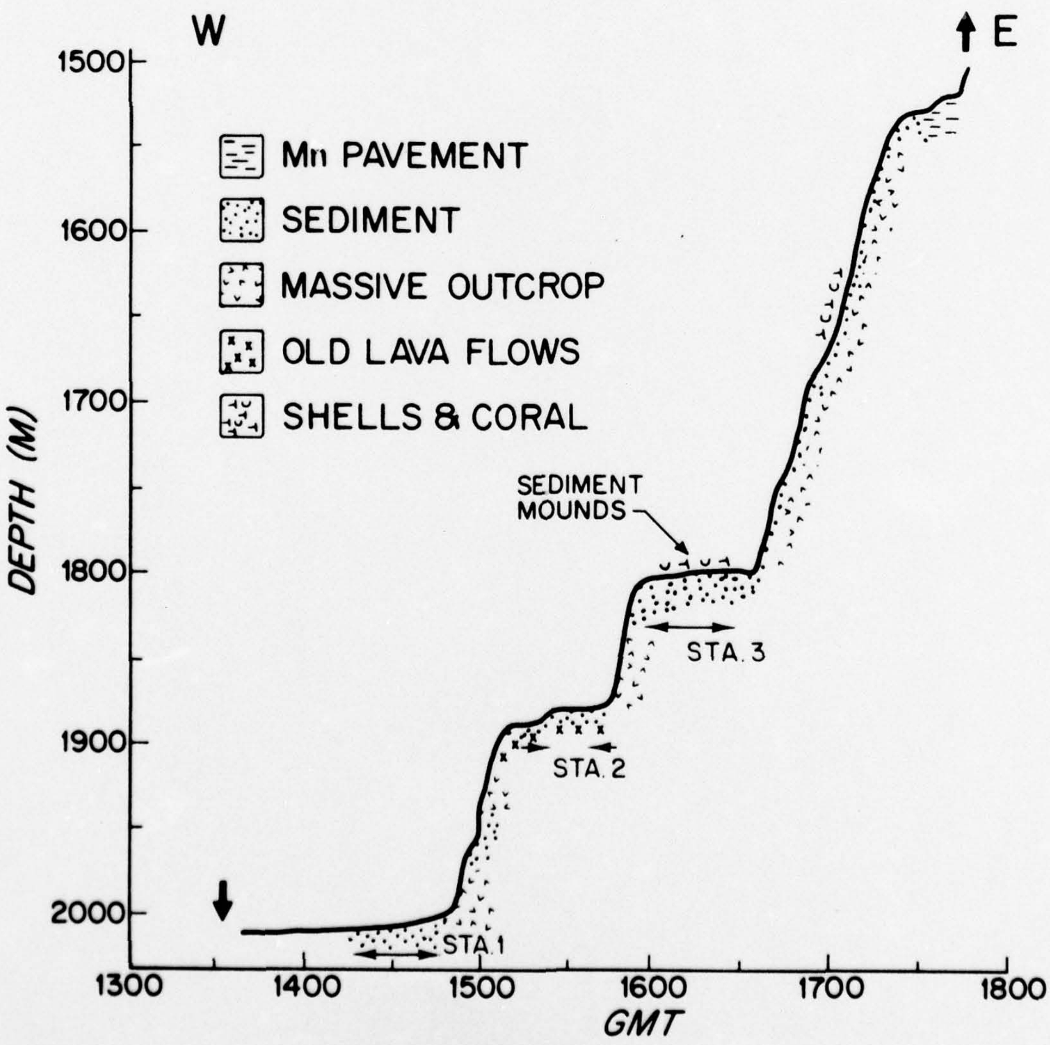
(Lower) Depth vs time for the Corner Rise dive.

Figure 4. Photographs of Corner Rise made with external camera. (a) frame 81; (b) frame 90; (c) frame 150; (d) frame 157; (e) frame 171; (f) frame 306 sediment mounds; (g) frame 491; (h) frame 479; (i) frame 515; manganese pavement.

Figure 5. Sketch of submersible ALVIN (7 meters in length) passing through erosional features called buttes on Corner Rise.



CORNER RISE
37°N
36°
35°
34°
52°W
51°
50°
49°
48°
47°
4000
3000
2000
5000
DIVE TRACK
0
50
Km



W
E
Mn PAVEMENT
SEDIMENT
MASSIVE OUTCROP
OLD LAVA FLOWS
SHELLS & CORAL
SEDIMENT MOUNDS
STA.1
STA.2
STA.3
DEPTH (M)
1500
1600
1700
1800
1900
2000
1300
1400
1500
1600
1700
1800
GMT

Figure 3.

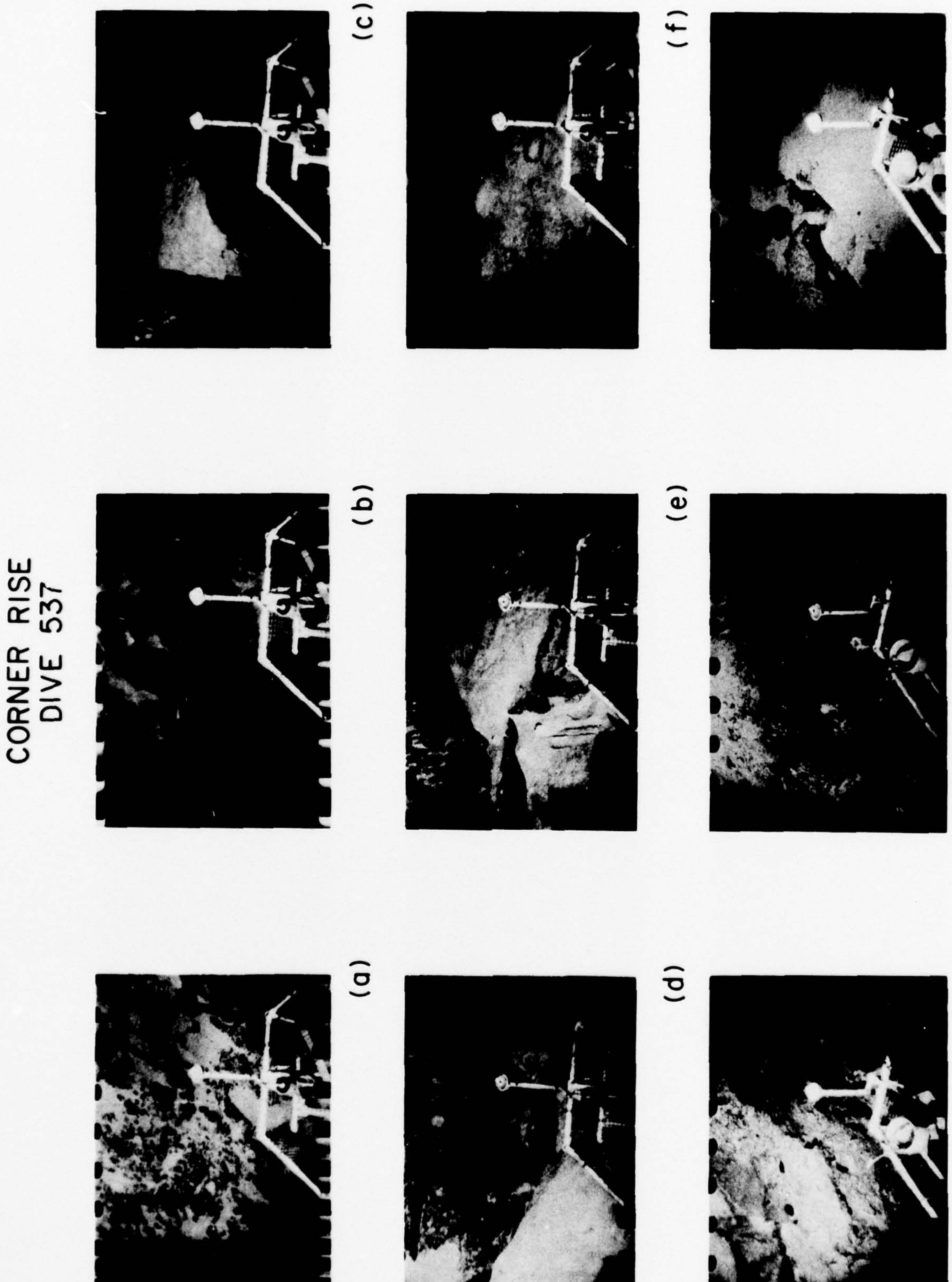


Figure 4.

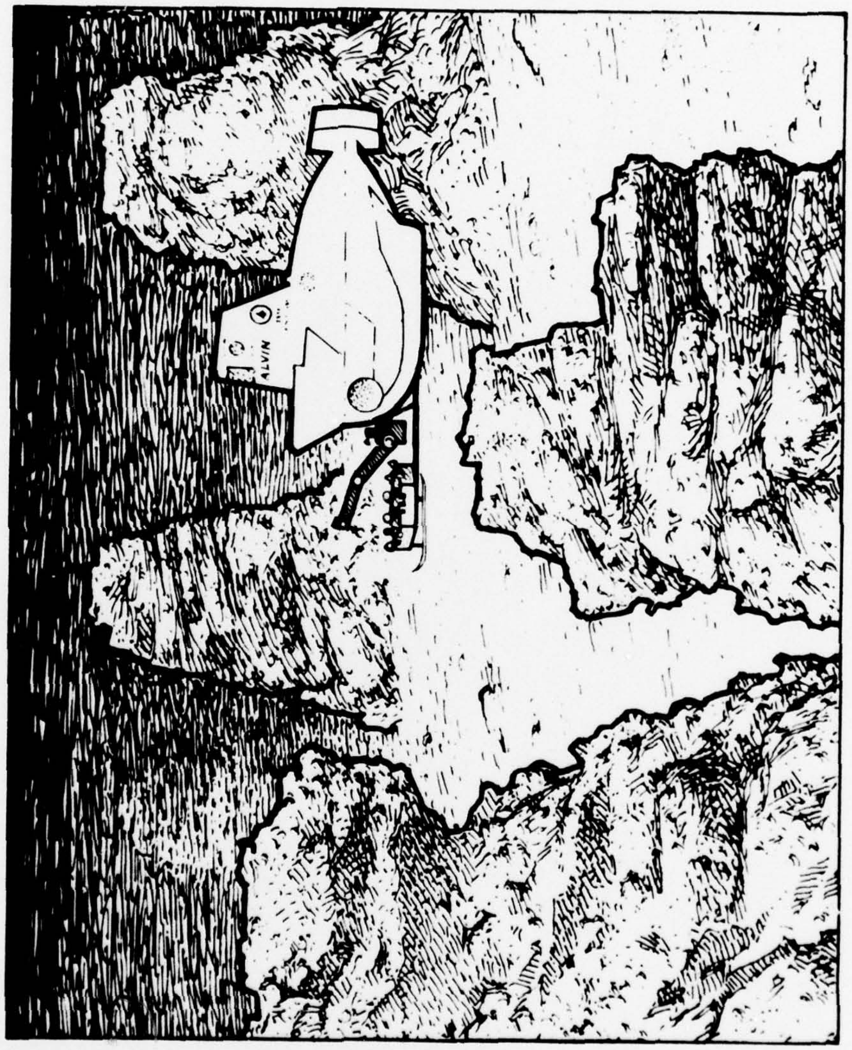


Figure 5.

NASHVILLE SEAMOUNT (DIVE 538)

Nashville is the first seamount at the southeastern end of the chain. It is also the largest seamount in the New England seamount group, being some 30 km long and 9 km across. Nashville is elongated in a northwest-southeast direction and is divided into four prominent and distinctive equally spaced summits along the axis of the mount. The dive site was situated on the most southeasterly and largest summit region of this seamount (Figure 6). ALVIN began its traverse at a depth of 2,582 meters and the dive was terminated at 2,326 meters, visually examining the bottom for a vertical distance of some 260 meters.

During Leg 43 of the Deep Sea Drilling Project (DSDP), site 382 was drilled to the southeast of our dive site. This hole was placed at the base of the seamount in water depths of 5,527 meters of sediments and volcaniclastics, the lowermost of which was Maastrichtian or older.

Igneous Features

On this seamount we observed massive-shear (slopes $\simeq 90°$) outcrops of presumably igneous rock. All exposed surfaces are encrusted with manganese making identification of the underlying rock difficult. Vertical igneous outcroppings were observed on all the other seamounts explored in this series of dives. These vertical walls are probably the single most significant and unexpected observation. The extremely sharp nature and angularity of these outcrops suggest that they represent fault surfaces. One particular shear outcrop displayed 3 meter deep cracks incising the surface. These ravine-like features could represent erosion centered along vertical joints. However, some of these vertical igneous walls displayed obvious igneous pillows suggesting that certain scarps represent lava-flow fronts. It is, therefore, not surprising that these vertical igneous exposures are formed by both primary (flow fronts) and secondary (faulting) processes.

In one of the walls, formed by the rapid cooling of an extrusive flow, a ravine is cut into the outcropping front, revealing a stratigraphic succession of five or six separate flow units. Unfortunately, these ravine-like features are too wide and deep to be photographed.

Shortly after the dive began, an elongated manganese coated lava tongue, some 1 to 2 meters wide, was observed. This was the best example seen of an igneous lava tube or extrusive tongue which flowed over the original sediment covered surface, indicating secondary periods of igneous activity. Throughout this dive, several more elongated igneous pillows (short tongues of lava) were observed.

Another igneous morphology encountered was an extrusive-lava flow. This 10 to 20 cm thick flow covers an older surface but is, in turn, covered with manganese and a thin sediment veneer. Further upslope there were exposures of piles of igneous pillows. Therefore, in a relatively short vertical distance, three distanct forms of extrusive igneous rocks were observed; lava tongues, flows and pillow fronts.

Sedimentary Features

The ALVIN touched bottom in a region of fine sediment, which rose up and formed a dust-like cloud around the submersible. A short distance upslope the manganese pavement, which comprised the seamount surface, was tilted some 20° to 30°, and was subsequently incised by gully-like features. A stratigraphic sequence was observed along the inner walls. These ravines were 4 to 4.5 meters deep and revealed an apparent sequence of manganese covered sediment and lava flow. The thickness of the discrete units ranged from 5 to 6 cm.

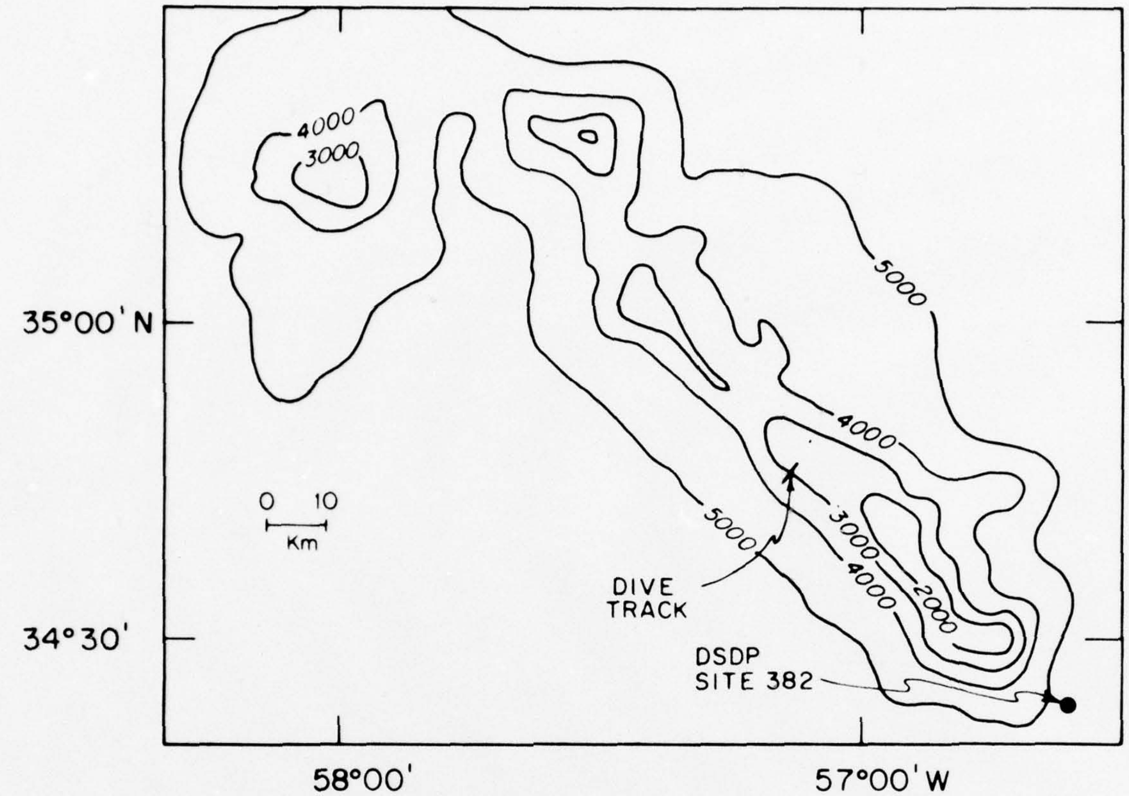
The sediment cover is not significant on this sector of the mount; manganese covered igneous pavement was seen to protrude through the rather thin sediment veneer. Locally, sediment appears to thicken behind rock ledges, which serve as sediment traps, indicating gravity induced downsloping sediment movement. Other evidence of down-slope moving sediment was observed in a trough within an igneous outcrop. This ravine was filled with a mixture of pelagic sediment and broken coral fragments.

Sediment ripples were very localized. They were first encountered at a depth of 2,345 meters. From the oriented photographs the current which formed these ripples, most probably, came from the west-northwest.

Figure 6. (Upper) Details of bathymetry (in meters) showing dive site. (Lower) Depth vs time.

Figure 7. Miscellaneous photographs of Nashville Seamount. (a) frame 109, basalt flow or tongue; (b) frame 123, basalt lightly covered with sediment; (c) frame 130, manganese pavement; (d) frame 208, rocks at station 3; (e) frame 215, rocks covered with manganese at station 3; (f) frame 293, small sediment covered area with evidence of small scale slumping; (g) frame 297, arm holding sediment scoop, some waves in sediment surface; (h) frame 308; and (i) frame 338 showing basaltic forms near end of dive.

NASHVILLE SEAMOUNT



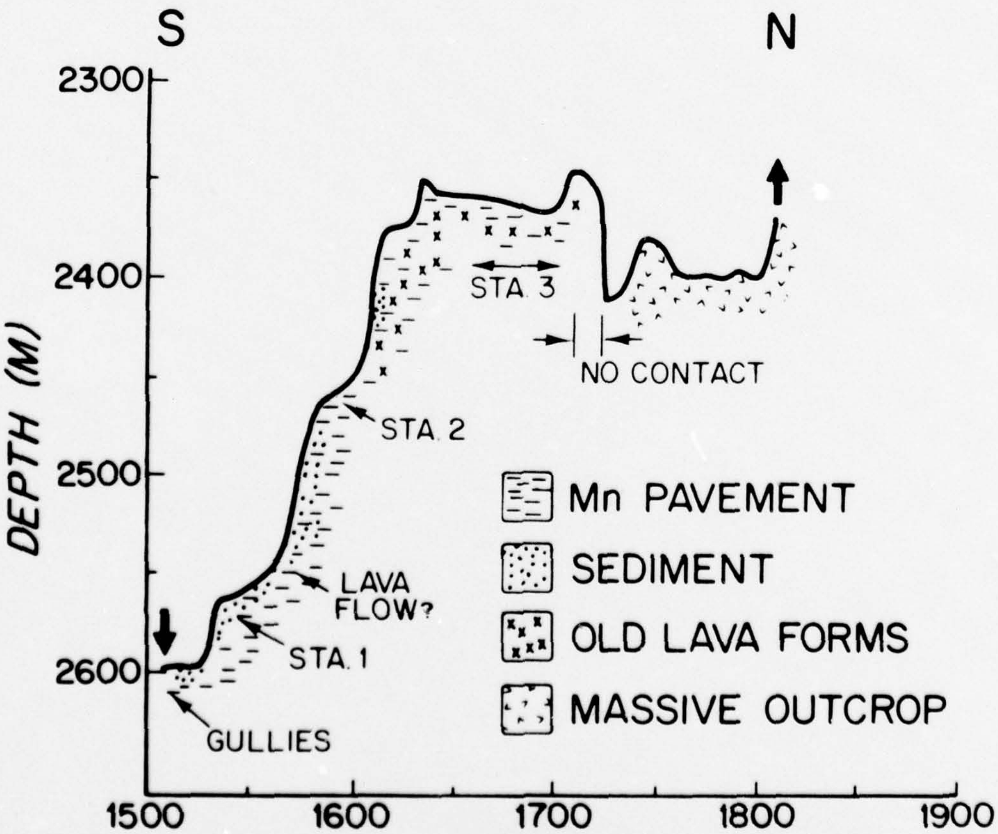


Figure 6.

NASHVILLE SEAMOUNT
DIVE 538

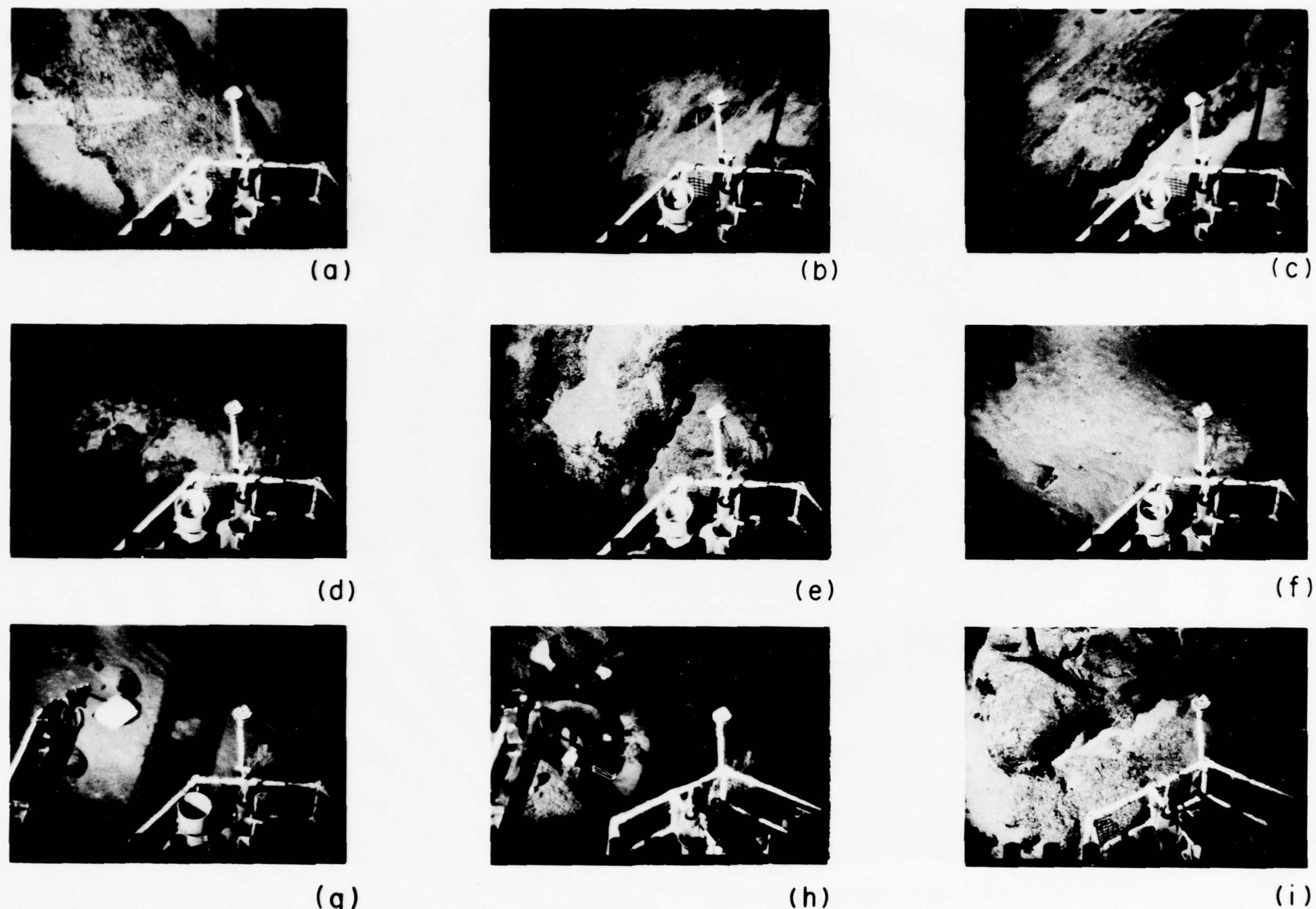


Figure 7.

GILLISS SEAMOUNT (DIVE 539)

The third dive of this series was situated some 190 km northwest of the Nashville Seamount dive site on Gilliss Seamount, Figure 8. The dive began at a depth of 2689 meters and terminated 2487 meters; total vertical distance covered was 202 meters. This dive ended some 530 meters below the summit of the southern peak of this twin-peaked seamount. The submersible track was in a generally southeasterly direction moving upslope covering a total of some 570 meters horizontally.

By far, the most commonly observed bottom features were manganese covered igneous outcrops. There were several igneous forms: relatively small fragments of broken pillows, large pillows, massive, shear outcrops and a linear wall or ridge-like structure.

Large areas of sediment accumulation were generally restricted to the terrace-like steps formed by the shear outcrops. However, there is thin sediment cover on some of the igneous exposures and sediment movement around large pillows on the steeper slopes. A region which had been covered by large sediment slumps or flows was found. These sediment flows had been subjected to current action and flow directions could be obtained. In addition, from ripple marks and bottom organisms we are able to determine the presence of bottom water movement.

Igneous Features

An igneous or tectonic wall was found at a depth of 2600 meters. It has a relief of about 18 meters. Continuous transmission frequency modulation (CTFM) sonar indicated that this feature is approximately 475 meters long and oriented at 320° or in a northwesterly-southeasterly direction. With this azimuth, the igneous wall would have the same general strike as radial ridges mapped by the sonar array system and presented by Taylor and others (1975).

This igneous feature is similar to the "pillow lava walls" located on the Puna Ridge, Hawaiian Islands by the Deep Submergence Vehicle SEACLIFF (Heezen, personal communication). They found these walls to be located along the sub-parallel rifts on the Puna ridge crest. The Gilliss igneous wall is some 40 meters wide and 18 meters high while walls of the Puna Ridge are up to 16 meters wide and 66 meters high.

The exact nature of the structure of this igneous wall was obscured by an apparently thick cover of manganese, however, igneous pillow forms were observed. By analogy with the Hawaiian pillow lava walls, the Gilliss wall is proposed to have been determined by the same general stress mechanism which produced the larger radial ridges emanating from the central seamount peak.

At a depth of 2560 meters very steep, massive outcrops were initially encountered. On the lower part of the dive igneous pillows of various sizes, some very large, were found, however, higher up on the seamount there was a change in morphology. These massive outcrops have vertical slopes in some places. These shear igneous outcrops represented the submarine morphology of the upper third of the section observed on this dive. The outcrop were of limited vertical extent, varying from a few meters to over thirty and were interrupted by sediment covered terraces.

Since the outcrops were manganese encrusted it was not possible to determine their exact nature; however, there were indications, along several sections of the face, of pillow-like forms. The presence of exposed pillow-like features on the shear outcrops gives support to the idea that these vertical surfaces represent flow fronts. That is, these vertical cliffs are primary features which were extruded when the seamount was initially being built. From our data it is not possible to determine the thickness of the flows which built up the shear outcrops. Since we are able to observe only the terminal edge of the flows, which were quenched by seawater, it was not possible to note any indication of the presence of multiple flows.

These shear volcanic outcrops are arranged in a terrace-like fashion along the upper part of our dive path. Between recessed shear outcropping the volcanics were sediment-covered terraces about 10 meters in width. The height of the shear outcrops varied, but was generally around 15 to 20 meters.

Noting the relationship of our dive site with the radial ridges previously mapped on this seamount, we propose that these vertical volcanic outcrops represent the surficial structure of these radial ridges. This would suggest that the radial ridges are constructional in origin and are the product of feeding from a radial vent. While Taylor and others (1975) considered this as a possible origin they preferred to interpret the radial ridges as erosional features. The deep submersible data have allowed us to distriminate between the constructional and erosional mechanism as an origin of the radial ridges.

Large pillows, up to 10 meters diagonally, were found at the beginning of the dive. Lava flows covered with up to 3 to 6 cm of manganese pavement were found surrounded by varying sized pillows and broken pillows or boulders. This latter rubble-like material had, obviously, been moving downslope. Several of the larger pillows were collapsed or broken suggesting that they had been hollow.

Sedimentary Features

At a depth of 2610 meters we encountered several long tongue-like sediment-debris flows partially covering over the previously deposited brown-colored-pelagic sediment. The lengths of these sediment flows could not be determined, since their source was unobservable. They are about 10 to 20 cm high and are composed mainly of hight and dark colored coarse material, predominantly pterapod shells, and are similar to the starved ripples of Heezen and Hollister (1971, their Fig. 9.18). Since these particular sedimentary features, on the Gilliss Seamount, are not actually ripple features the term starved ripple would not apply; therefore, we will refer to them as sediment tongues.

These asymmetric sediment tongues flowed in a southwest to northeast direction. The steep sides of these asymmetric ripples face southeastwards and indicates the lee direction. This would suggest, therefore, that the current producing this asymmetry was from the northwest. The detailed bathymetry of this seamount suggests that these sediment tongues moved downslope from the northwesterly oriented radial ridge into the topographic saddle formed between two radial ridges. Taylor and others (1975) indicate a pelagic sedimentation rate of approximately 1 cm/m.y. for this seamount. Since the sediment tongues are free of pelagic sediment they must be relatively recent.

In addition to the asymmetric sediment tongues, ripple marks and leaning organisms can provide relative current direction. Sea pens at 2600 meters tilted from the south-east to the northwest, suggesting a bottom current from the southeast. Ripple marks photographed at 2590 meters are oriented in a north-northeasterly--south-southwesterly direction. These photographs and others not shown indicate that the bottom currents, in the region of the dive, are of variable direction about a northwesterly-southeasterly axis. We cannot, however, generalize and state that this represents the overall direction of bottom-water flow in the region since the dive was located in a topographic saddle. Local morphology may be controlling the bottom currents found on our dive.

Figure 8. (Upper) Detailed bathymetry of Gilliss Seamount, showing dive track, depth in meters. (Lower) Depth vs time plot for Gilliss dive.

Figure 9. Miscellaneous photographs of Gilliss Seamount. (a) frame 163, station 1 rock lightly covered with sediment; (b) frame 251, basaltic rock at Station 2; (c) frame 388, sediment area with scattered pterapod fragments; (d) frame 423, sediment with ripple marks, approaching station 3; (e) frame 454, sediment covered basaltic rocks at station 3; (f) frame 496, large manganese covered basaltic rocks at station 3.

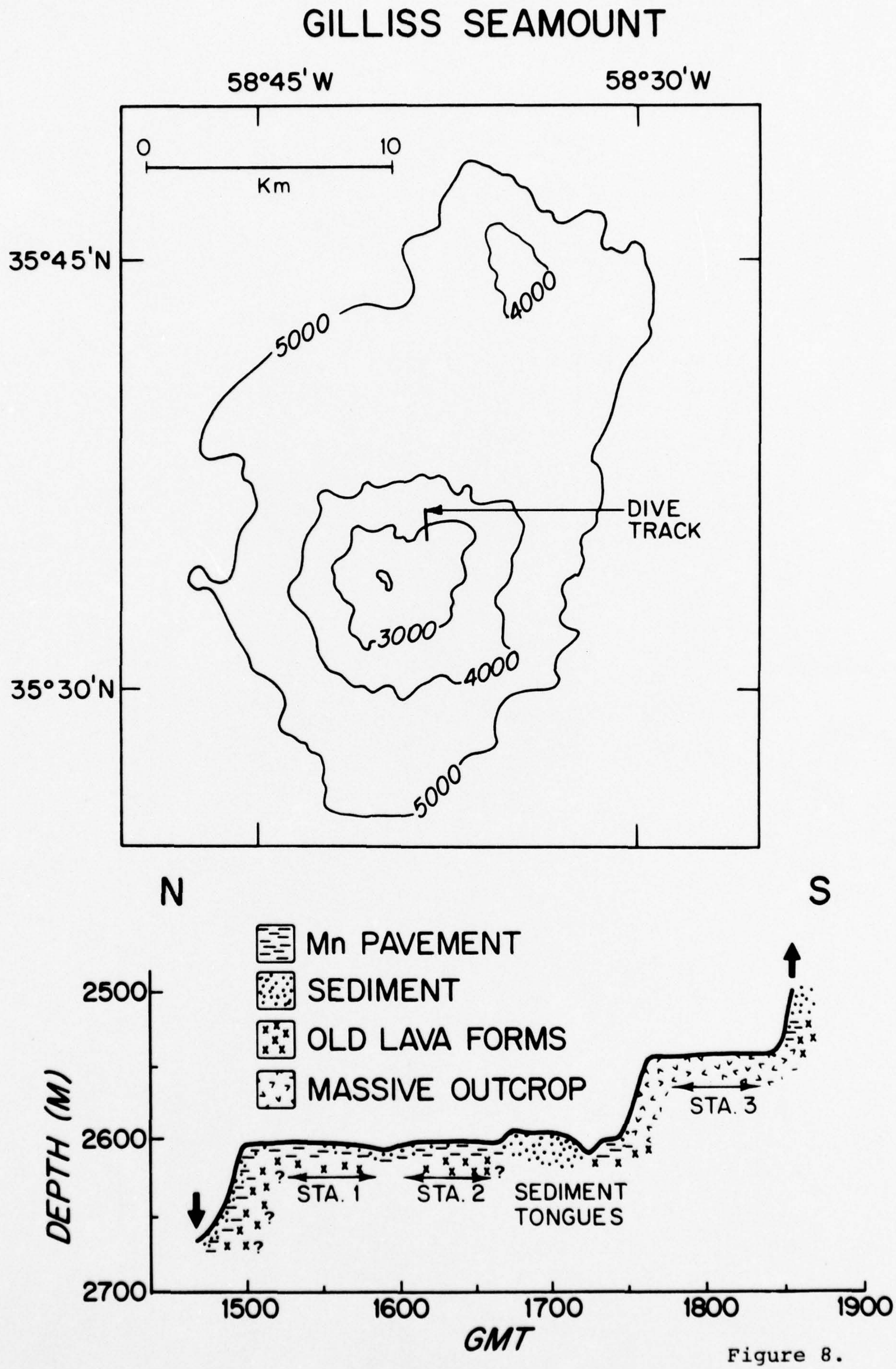

GILLISS SEAMOUNT
58°45'W
58°30'W
0
10
Km
35°45'N
35°30'N
5000
4000
3000
4000
5000
DIVE
TRACK
N
S
Mn PAVEMENT
SEDIMENT
OLD LAVA FORMS
MASSIVE OUTCROP
DEPTH (M)
2500
2600
2700
STA. 1
STA. 2
SEDIMENT
TONGUES
STA. 3
1500
1600
1700
1800
1900
GMT

Figure 8.

GILLISS SEAMOUNT
DIVE 539

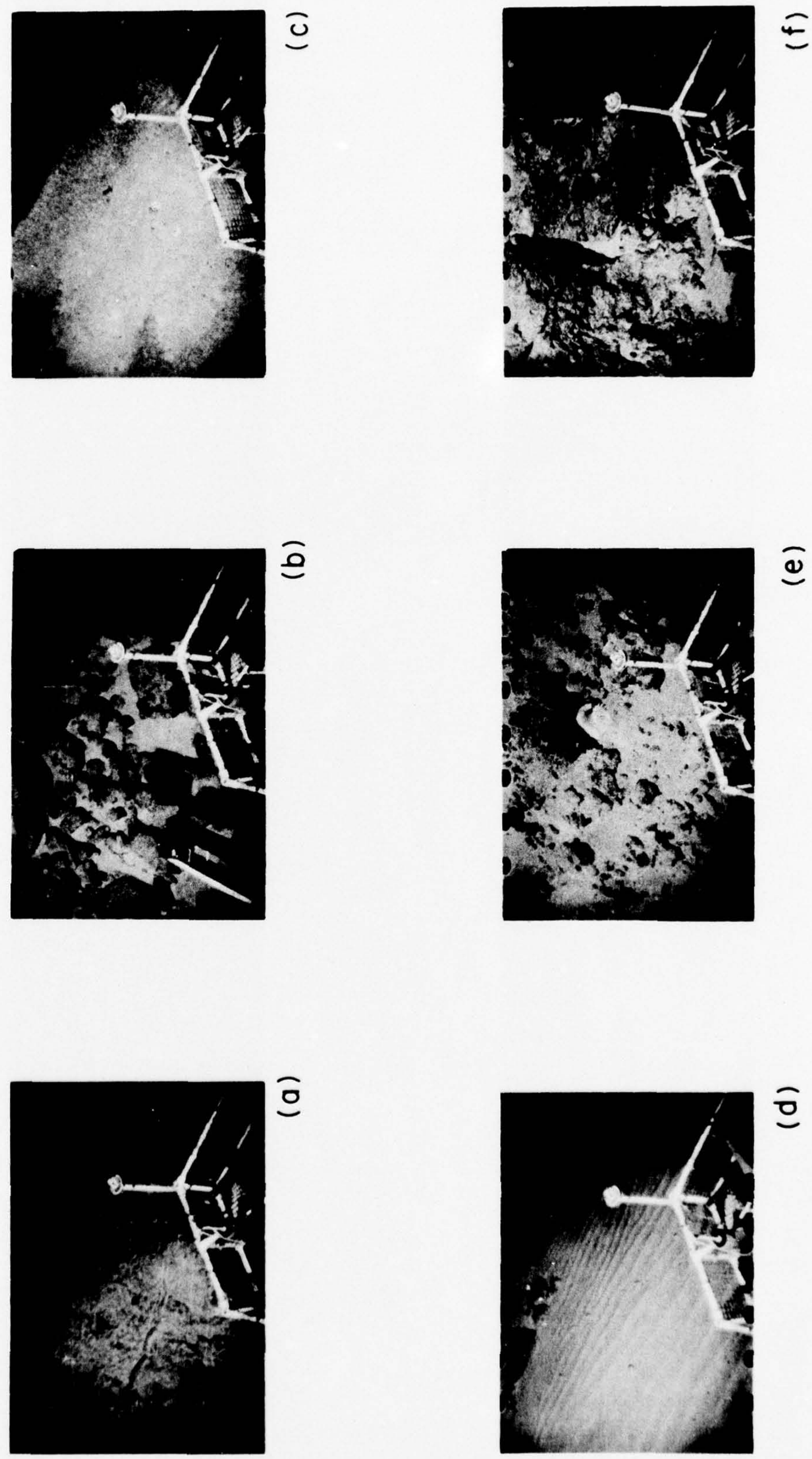


Figure 9.

REHOBOTH SEAMOUNT (DIVE 540)

Rehoboth Seamount is located nearly half way along the New England Seamount Chain. There are, in fact, two northeasterly-southwesterly oriented peaks called the Rehoboth Seamount. The northeasterly one rises from the abyssal depth of 5000 meters to a depth of about 1600 meters. Its neighbor, situated about 30 miles to the southwest, has a peak at about 2400 meters depth. ALVIN dived to the southerly face of the northern seamount (Figure 10) and proceeded upslope to the north and northwest. We investigated this slope from 3000 meter to 2500 meter depths.

Igneous Feature

The seafloor traversed was sediment covered and had an approximately 30 degree northward slope. There were two very distinctive nearly horizontal, igneous outcrops. The lower of these was about 100 meters thick centered about a depth of 2750 meters and the upper one had about the same thickness and was centered about a depth of 2500 meters.

The submersible landed on sediment covered terrain. After proceeding about 100 meters upslope a small scarp or wall was discovered, upthrown to the west and extending to the north paralleling the track of the vessel. The scarp face was vertical and the throw was 2 to 3 meters. At first it was thought that this scarp was comprised of compacted sediment. After numerous attempts to break and pry off pieces of this material it was thought that the material may be igneous. Subsequently this wall was sampled and found to be basalt. This type basalt showed no pillow structure and is thus different from that reported from the dive on Gilliss Seamount or on the Puna Ridge where broken pillows were observed.

The small scarp or wall terminated in the lower outcrop area. Samples were obtained in the lower outcrop area and post dive inspection showed them to be basalt. Must of the outcrop was covered with manganese.

The upper outcrop area had much the same appearance as the lower but the upper part of the upper outcrop appeared to be a volcanic flow front while the lower part appeared to be a massive outcrop.

Sediments

The sediments encountered during this dive appeared to be a calcareous ooze. On this seamount the sediment had many gouge marks one-half to a meter long and 10 to 20 cm deep. These were seen at especially 2950 and 2650 meter depths, and are probably the result of biological activity.

There was no evidence of glacial erratic rocks, but downhill from the igneous outcrop areas one would occasionally see rock fragments broken from the larger outcrops. The diving scientists learned to anticipate the approach of an outcrop area by watching for such rock fragments.

There were numerous sponges, sea urchins and fish observed. No live corals were seen but manganese covered some areas of dead coral.

Some sediment waves were seen, especially just down-slope of the upper outcrop. The less rigid coral forms could also be seen undulating in the currents flowing over local ridge and down the slope. The direction of currents indicated by sediment waves and by moving coral was consistent.

Figure 10. (Upper) Detailed bathymetry of Rehoboth Seamount showing dive track, depth in meters. (Lower) Depth vs. time for Rehoboth dive.

Figure 11. Miscellaneous photographs of Rehoboth Seamount. (a) frame 81, intersection of sediment and basaltic well or ledge; (b) frame 82, close up of wall; (c) frame 185, rocks near end of wall; (d) frame 247, rocks at station 2; (e) frame 269, gouge marks in sediment between stations 2 and 3; (f) frame 277, sediment ripples, approaching station 3; (g) frame 362 and (h) frame 376, rocks at station 3.

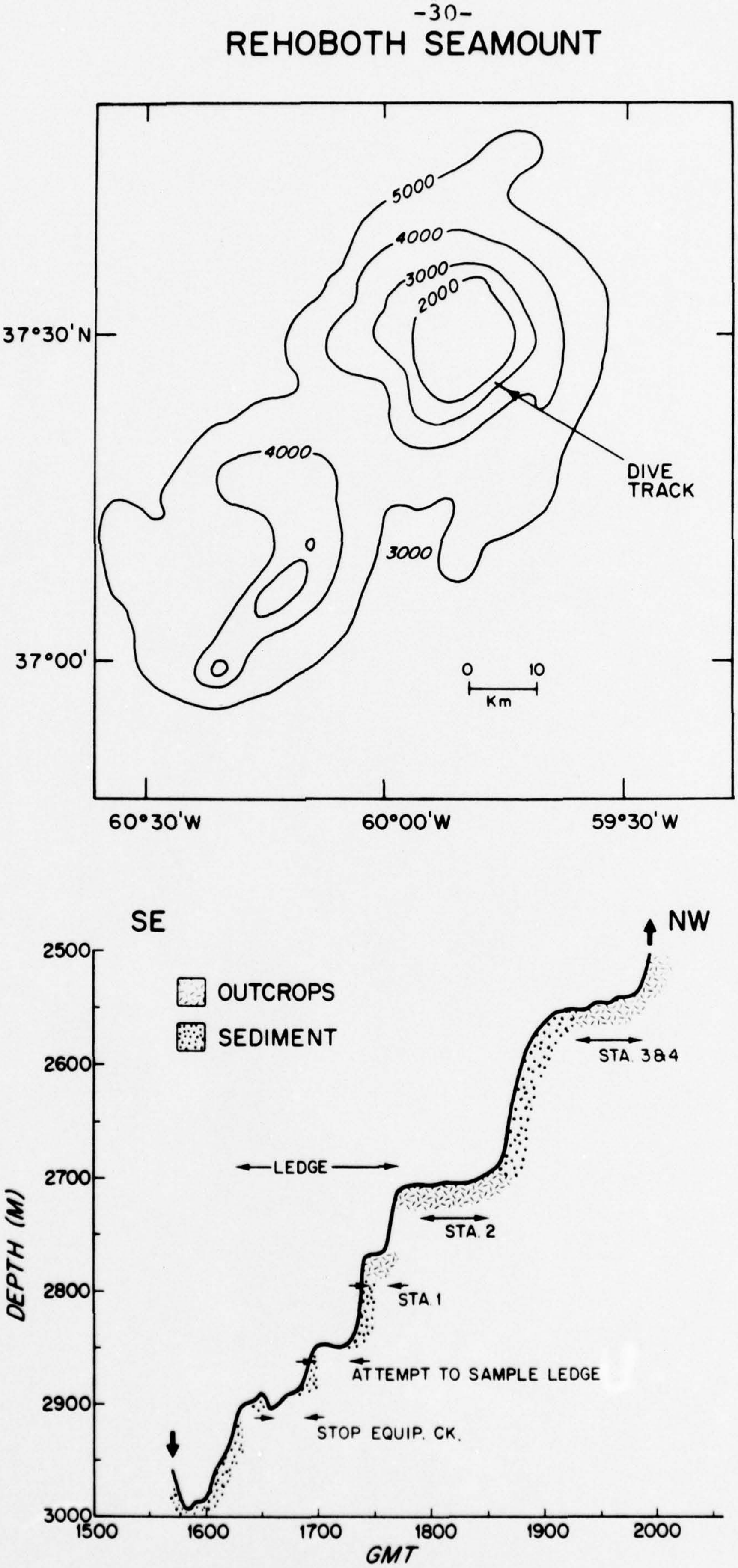

REHOBOTH SEAMOUNT
5000
4000
3000
2000
4000
3000
DIVE
TRACK
37°30'N
37°00'
0
10
Km
60°30'W
60°00'W
59°30'W
SE
NW
OUTCROPS
SEDIMENT
STA. 3&4
LEDGE
STA. 2
STA. 1
ATTEMPT TO SAMPLE LEDGE
STOP EQUIP. CK.
DEPTH (M)
2500
2600
2700
2800
2900
3000
1500
1600
1700
1800
1900
2000
GMT

Figure 10.

REHOBOTH SEAMOUNT
DIVE 540

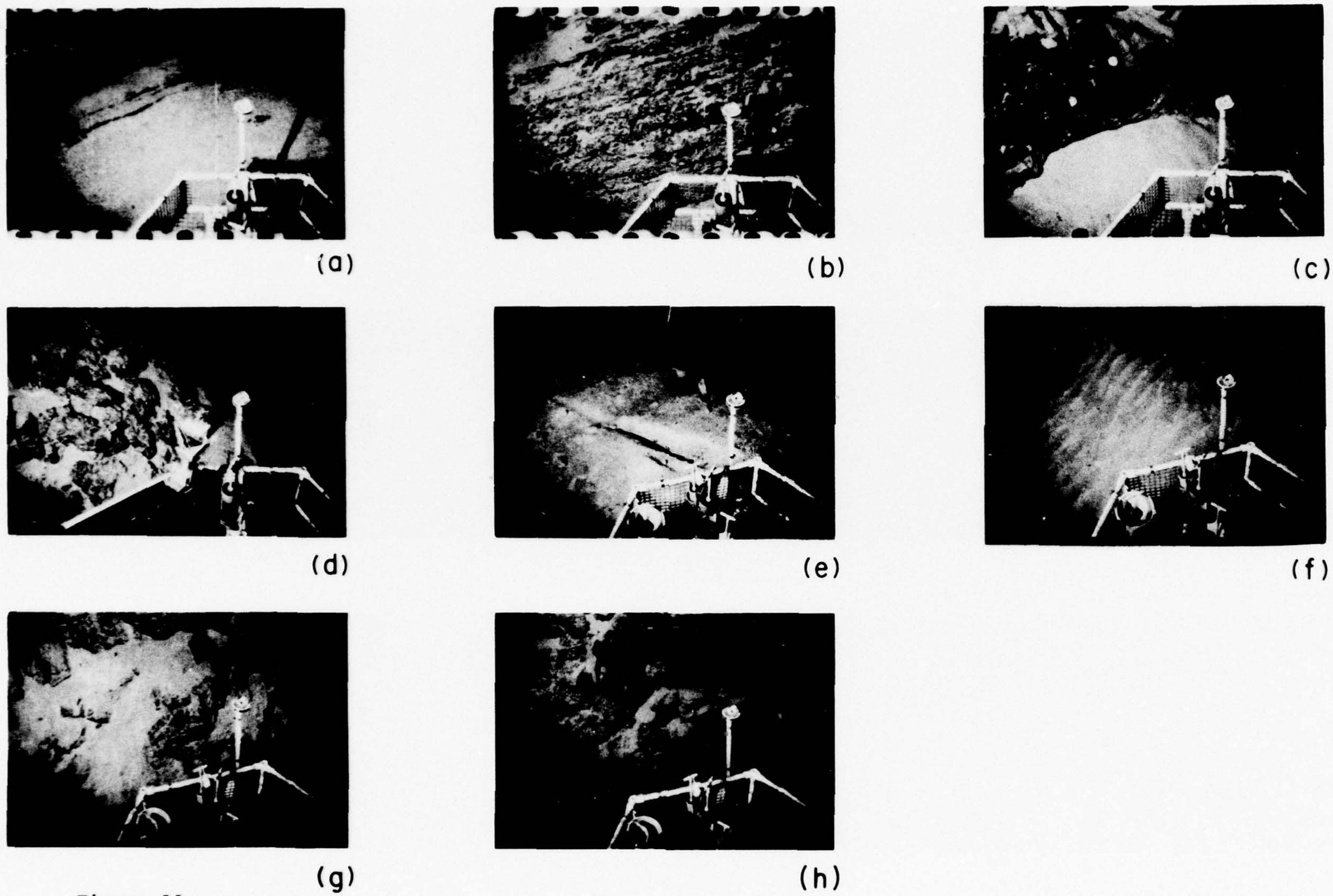


Figure 11.

MANNING SEAMOUNT (DIVE 541)

Manning Seamount represents the mid-point between Nashville on the southeastern end of the chain and Bear on the northwestern (Figure 1). This seamount was the site of the fifth dive in the series. The submersible traverse extended in a northwesterly direction up the west peak of this twin peaked seamount (Figure 12). Depth range of our observations was from 2252 meters to 1800 meters or 452 meters vertically. Horizontal distance covered was estimated to be approximately 3200 meters.

The single most commonly observed submarine morphology of this seamount was the shear, massive igneous outcrops with slopes varying between 60° and 90°. The second commonly viewed bottom type was a mixture of pelagic sediment (predominantly foraminiferal ooze) and broken fragments of manganese coated corals. This mixture of sediment and coral fragments formed a uniform bottom cover or mat across several sectors of this mount. With few exceptions, these bottom forms, the igneous outcrops and sediment-coral mix, comprised the submarine morphology observed during this dive.

Sedimentary Features

One of the most significant aspects of the occurrences of sediment on the Manning Seamount is their relationship to the igneous outcrops. Throughout this dive there was evidence of downslope sediment movement. In most instances broken fragments of coral, thinly covered with manganese, are intermixed with the pelagic sediment forming a sediment mix or mat. It is not apparent how the corals were broken and subsequently moved downslope but presumably downflowing pelagic sediment is partly responsible since the two are intertwined.

On a small scale, the pelagic sediment and coral fragment mix were found to be moving downslope around the igneous outcrops even down the faces of the shear volcanic outcrops (Figure 12). Larger scale sediment slumps or flows were also observed. A lobate mound, approximately 60 cm high and several meters wide, of pelagic sediment and coral fragments has moved over similar type sediment. Gravity sliding is the most probable mechanism which produced this sediment slump mound.

At several locations, along the dive, sedimentary ravines or gullies were observed. These features were of varying sizes the largest being 10 meters long, 3 meters across and 1 meter deep. A large igneous outcrop was located at the head of this gully and the gully floor was filled with coarse sediment (pterapod shells); there were indications of downslope movement within these gullies. In one case the sediment gully had raised rims, about 5 cm high, above the base level, resembling natural levees.

Throughout this dive there were no indications of bottom current activity, as evidenced by current ripple mark, sediment striations or leaning bottom organisms. This was in contrast to the other seamounts where evidence of bottom water movement was observed. It is possible that the dive on Manning Seamount occurred on the lee side of this feature and was shielded from the movement of bottom waters.

Igneous Features

Large igneous pillows surrounded by pelagic sediment were commonly observed at the beginning of this dive.

We observed, at a depth of 2100 meters, manganese pavement tilted and broken. This pavement was approximately 8 cm thick. Assuming a manganese accumulation rate of 2 mm/10^6 yr this would indicate that the upper section of the Manning Seamount was Eocene in age.

The most commonly observed bottom morphology on the Manning Seamount were the massive, shear igneous outcrops. These were similar in overall shape to the other shear outcrops observed during this series of dives. On this particular seamount, however, their occurrence was much more numerous, being observed along practically the entire traverse. These outcrop exposures did not reveal pillow-like forms that were found on some of the other seamounts. These igneous exposures had more of a shear-like appearance. It is difficult to believe that these phillow-like features indicate an origin different from the igneous cliffs observed on the other seamounts. More likely, it represents the random sampling nature of the deep submersible operations.

The appearance of joint-like features on the face of some of the outcrops may indicate an intrusive origin for these igneous morphologies. If these outcrops represent an intrusive igneous origin then this would suggest that a great deal mass wasting was necessary to expose the interior of the intrusion. It is not possible to determine unequivocally the origin of the very steep slope observed on this seamount solely on the basis of photographic and direct observations; however, the origin of these features is very important in determining the mechanism by which these seamounts were formed.

Figure 12. (Upper) Detailed bathymetry of Manning Seamount showing dive track. Contours in meters.

(Lower) Depth vs. time for Manning dive.

Figure 13. Miscellaneous photographs of Manning Seamount. (a) frame 127; (b) frame 258; (c) frame 388; (d) frame 400; (e) frame 469; (f) frame 491; (g) frame 547; (h) frame 606; (i) frame 620. These photographs were taken at nearly equal time intervals during dive. They all show a steep rock face. (c) and (d) show sediment chutes (see text).

MANNING SEAMOUNT

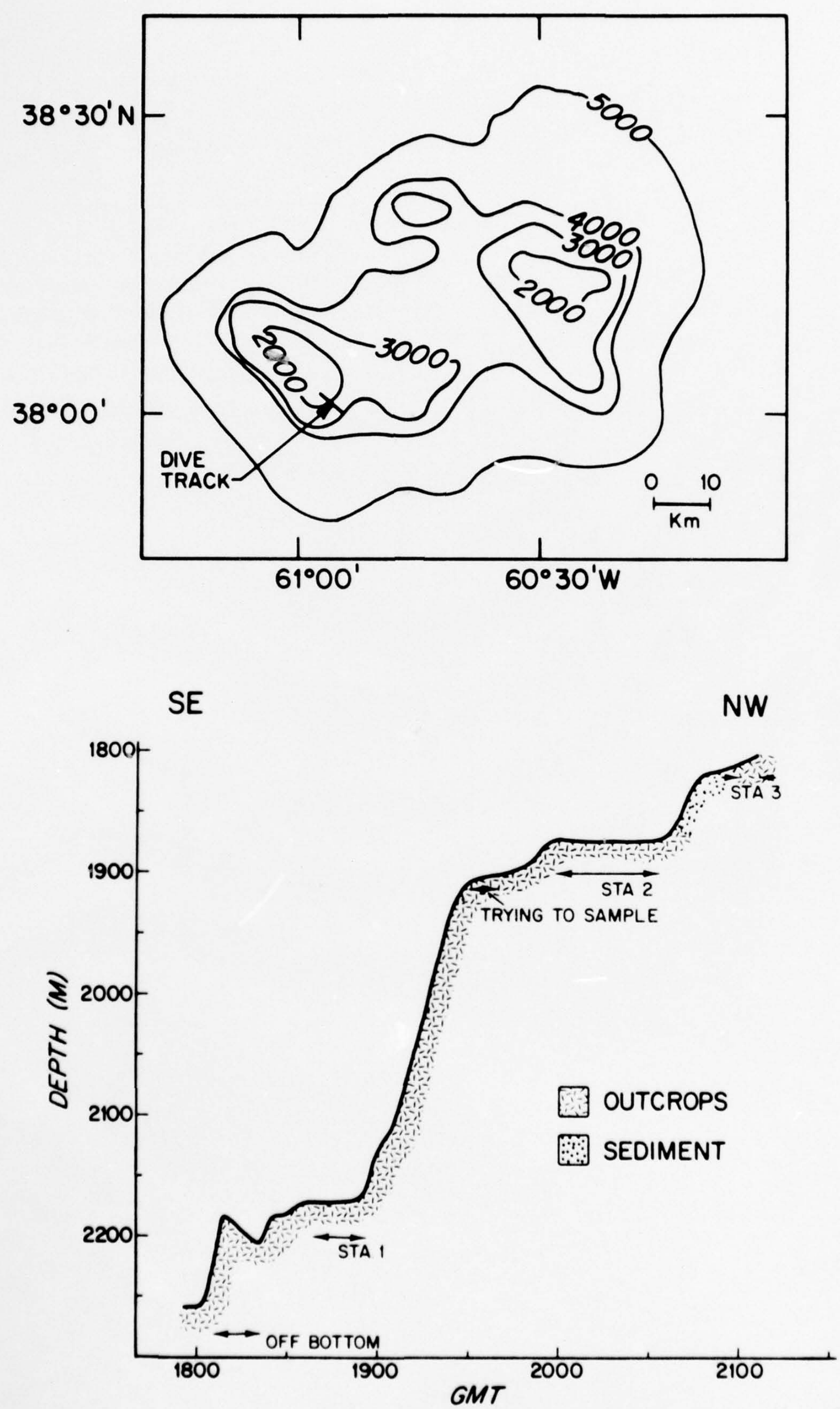
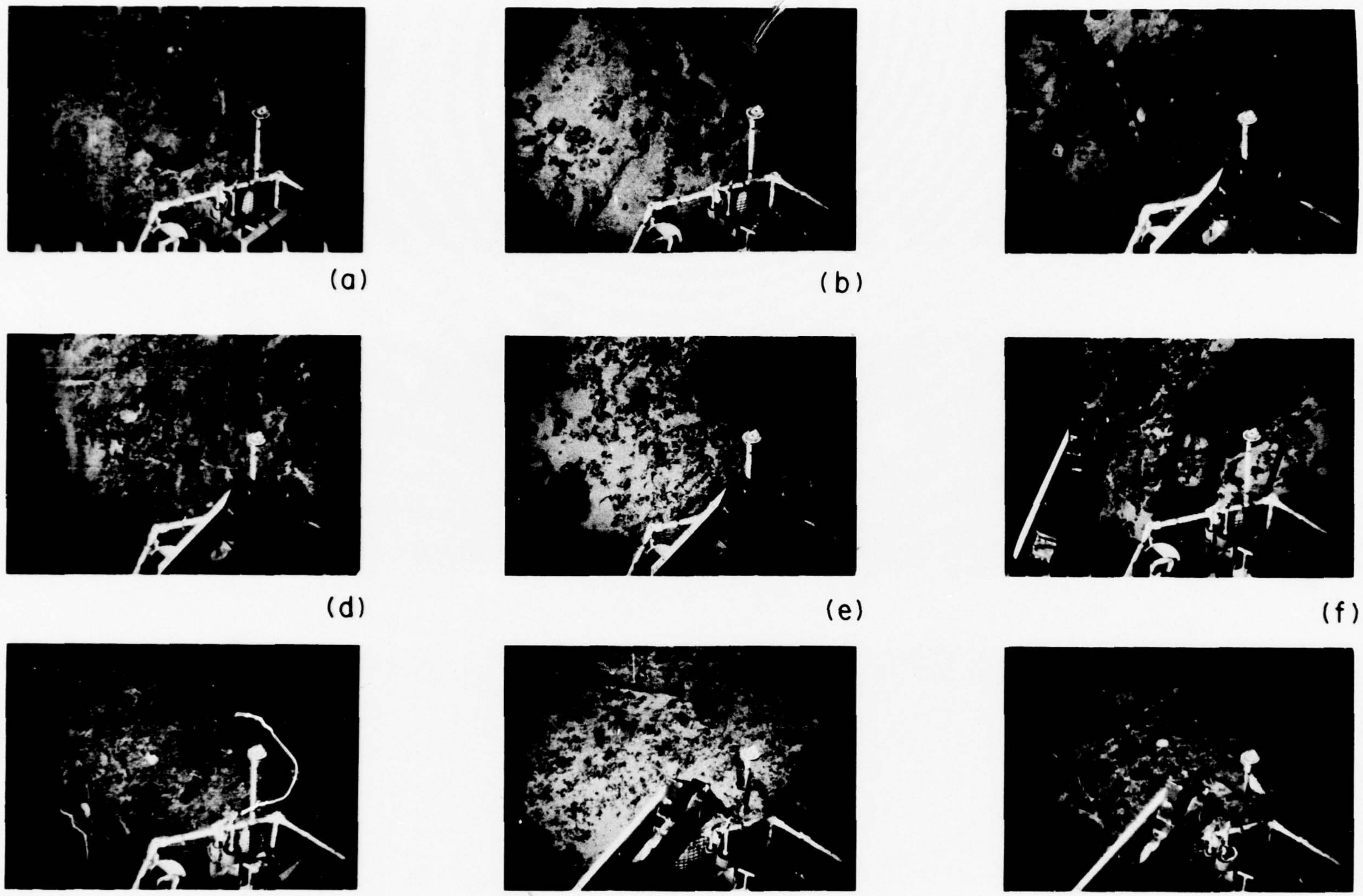


Figure 12.

MANNING SEAMOUNT
DIVE 541



(a) (b) (c)
(d) (e) (f)
(g) (h) (i)

Figure 13.

BALANUS SEAMOUNT (DIVE 542)

The dive commenced southwest of the peak of Balanus and proceeded in a general northerly direction (Figure 14). The slope was more gentle than on other seamounts and was entirely sediment covered until an outcrop was encountered at the upper end of the traverse.

Sediments

The sediments did not exhibit any special geological characteristics. Glacial rocks were occasionally seen on the sediments. This marked the first appearance of an abundance of glacial erratics.

The sediments had many small pits measuring about 100 cm long, 50 cm wide and 50 cm deep. Sometimes these holes appeared to be covered across the middle creating a burrow with two exits. Crustaceans of some type resided in these--their tentacles would be frequently visible. They were red colored but probably not lobsters since no claws were seen. There were ripple marks in the sediments at the top of the traverse near the base of the outcrop. The movement of coral also gave an indication of bottom current flowing to the west or southwest, the same as on the ocean surface.

Igneous Outcrop

Small non-glacial rocks became more numerous as we proceeded up slope until an outcrop was observed. It was vertical for about 10 meters with no ledge on which to set the sub. The top of this outcrop was flat for a few meters and was heavily covered with glacial material. ALVIN spent nearly three hours working along the face of this outcrop which had a southwest strike. Each time sampling was attempted the submersible would push itself away from the vertical face. To get samples it was necessary for the pilot to drive into the face while one of the scientists operated the mechanical arm.

There were many crumbly rocks near the base but the face had few loose rocks of a size that could be sampled. One "cave" leading about 2 meters into the face was seen. A Morey eel was inside. Many of the rock pieces appeared to be parts of lava blister pillows. At 1930 GMT rocks were observed which appeared to be layered as if from individual lava flows.

Figure 14. (Upper) Detailed bathymetry of Balanus Seamount showing dive track, depth in meters. (Lower) Depth vs. time for Balanus dive.

Figure 15. Miscellaneous photographs of Balnaus Seamount. (a) frame 151 and (b) frame 170, small holes and pits in sediment; (c) frame 273; (d) frame 287; (e) frame 297; (f) frame 320; (g) frame 335; (h) frame 350; (i) frame 413. (c) through (i) show rocks with minor amounts of interspersed sediments at stations 2 and 3. Some of the rocks with no manganese coating, as in (c) are glacial erratics.

BALANUS SEAMOUNT

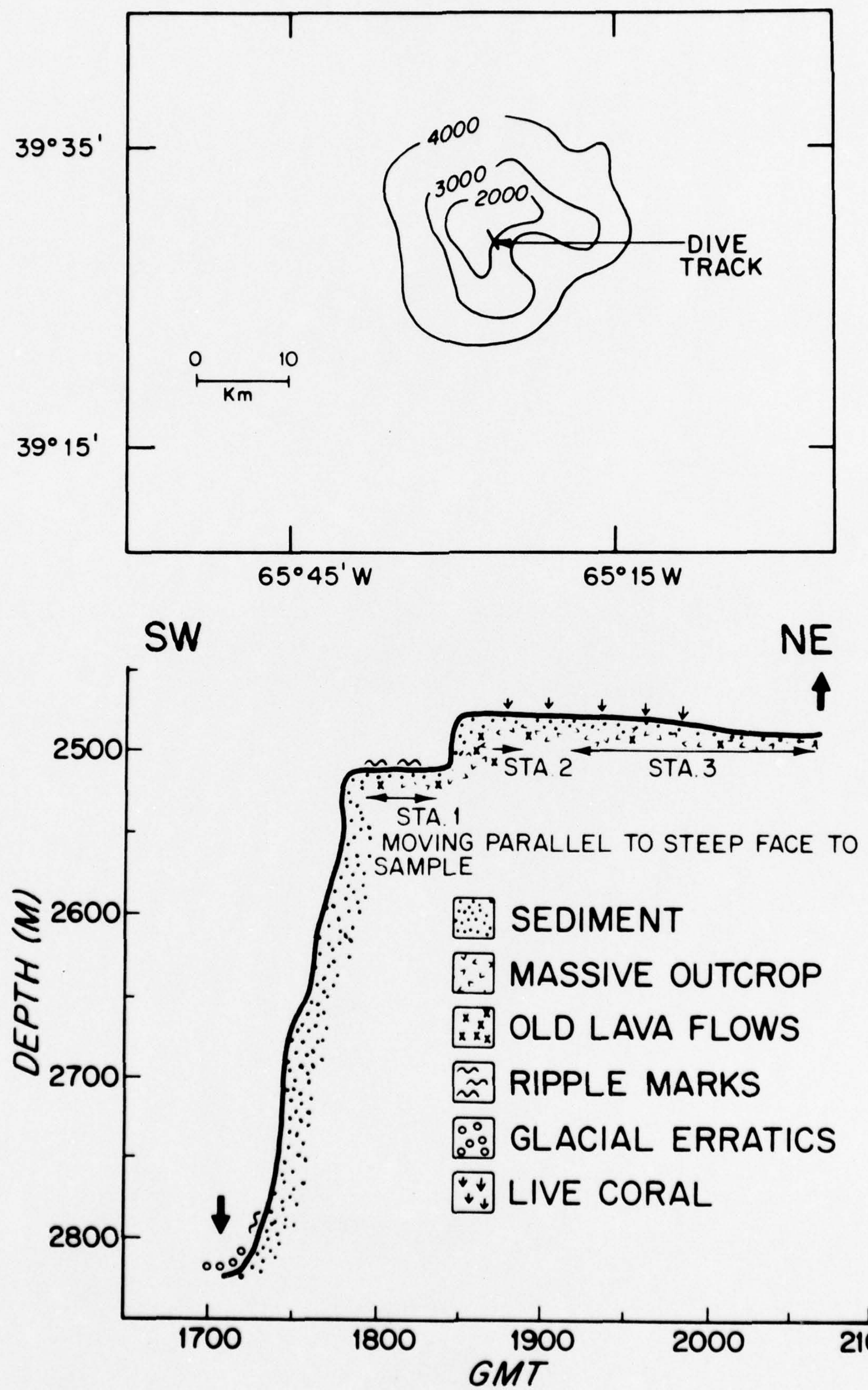


Figure 14.

BALANUS SEAMOUNT
DIVE 542

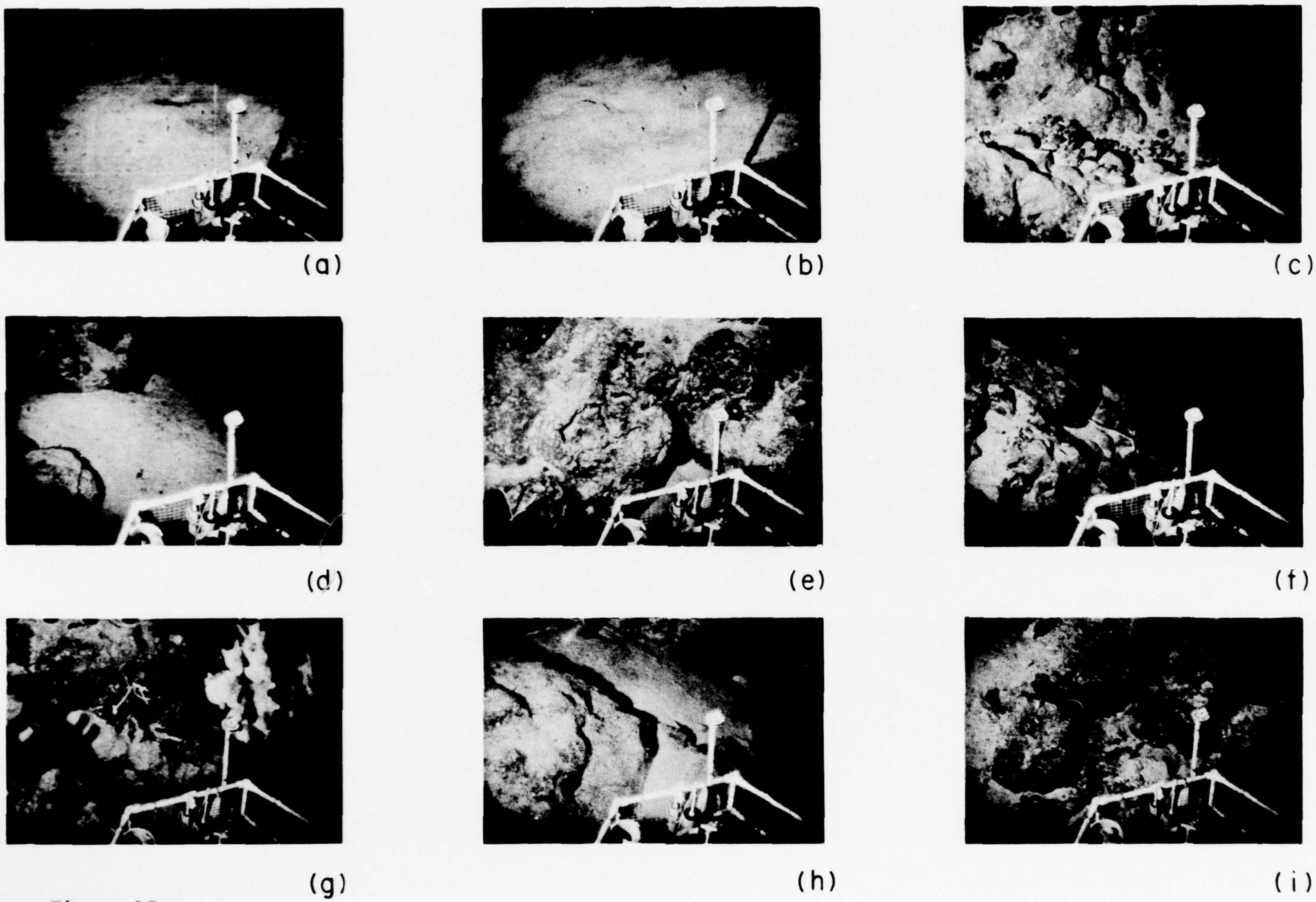


Figure 15.

MYTILUS SEAMOUNT (DIVE 543)

Mytilus Seamount, the site of the last dive in this series, is located on the Continental Rise in water depths of about 4,000 meters. It is situated 70 km to the south of the main axis of the New England Seamounts.

Mytilus is the most thoroughly studied seamount in the chain and in many ways the most unique. Seismic profiles across it (Uchupi, 1968; Emery and others, 1970) have shown that there is a cap of relatively transparent material of about 300 meters thickness. The contact between this cap and the underlying, more opaque material lies at approximately 3,000 meters depth, the operational limit of the submersible at the time of this study. Uchupi (1968) interpreted this transparent layer to be an organic reef, and the contact of the transparent and opaque seismic reflectors to represent a wavecut surface. Johnson and Lonsdale (1976) made a detailed study of Mytilus and employed bottom current meters, bottom photography and temperature probes together with results gathered using a deeply towed instrument package. They found a complex bottom sediment regime with variable bottom water flow.

The ALVIN submersible traverse began on the north side of the seamount at a depth of 3,057 meters and it extended in a southerly direction to a depth of 2,772 meters (Figure 16).

Sampling

In view of the previously mentioned studies, acquiring bottom samples was considered to be the prime objective of this dive. The first sampling site was at a depth of 3,009 meters. At this station the samples consisted of a variety of calcitic specimens (intrasparite, oosparite grading to an oosparrudite and a biosparite and biomicrite) and a quartz arenite. This first sampling site supported the carbonate reef hypothesis of Uchupi (1968). In the intrasparite 150 to 420 microns long gastropod fossils occur preferentially elongated in subparallel linear bands, possibly representing bedding planes. These fossils could not be identified. Scattered throughout the matrix of the oosparrudite are authogenic calcite crystals, chambered gastropods, foraminifera, one mollusc fragment and coral fragments. The fragmentary nature of these and the remaining components suggest that this limestone is a beachrock. The quartz arenite is cemented by calcareous material and intermittently cut by authogenic calcite veinlets; no marine fossils were noted.

Station 2 was occupied at a depth of 2,963 meters. One rock, a biomicrite, was collected at this sampling site. This specimen displays prominent algal strands winding through a matrix of cryptocrystalline to finely crystalline calcite. The algae was identified as Melobesia, a family which presently grows on the outermost ridges of reef-breccia platforms (R. Johnson, personal communication, 1975). These occurrences offer evidence of a 3,000 meter subsidence for this seamount.

Fifteen samples were recovered at Station 3, in water depth of 2,819 meters. Eleven of these rocks were glacial erratics, the others were a quartz arenite and a subphyll-quartz aernite. In the former, unsorted, angular and highly pitted quartz grains are found. The latter is a homogeneous equigranular quartz sandstone in a calcite matric with a highly arenaceous component.

The final dive stop, station 4, occurred at a depth of 2,773 meters. One sample, an equigranular quartz arenite, was recovered.

Foraminiferal content of all the samples obtained is poor in reference to abundance and diversity. The following genera could be identified (in order of decreasing abundance): Quinqueloculina, Textularia, Pyrgo (?), Spiroplectammina, Bolivinia (?), Rotalia. Since the genera are all long-ranging, Upper Cretaceous-Recent, we are only able to establish a maximum age (Tjalsma, personal communication).

Morphology

Mytilus Seamount, like the other in this dive series, exhibited a varied bottom structure. Slopes ranged from nearly flat to shear (90°) outcrops. While there were some shear outcrops on Mytilus, there were proportionally fewer than had been observed on the other seamounts in this dive series. There were manganese covered outcrops of either igneous or reefal material. Since all of the surfaces were coated with manganese, it was usually impossible to tell the nature of the exposures. In certain instances the submarine outcrops appear to be igneous while other massive exposures are most likely reefal. The occurrence of igneous outcrops on this dive is significant in understanding the nature of the reefs. If some of the outcrops seen on this dive are truly igneous, then the carbonate reef could be mantling the igneous seamount top, or the relationship between the reef and the underlying igneous base might be more complex. However, since no igneous (basaltic) samples were retrieved during this dive, we have no evidence, other than outcrops morphology, to indicate that there were any igneous material along our dive traverse.

This seamount was unique in the series since there were significant amounts of apparently ice-rafted debris. Rock sampling was done on the hypothesis that rounded and faceted rocks were more likely to be glacial erratics and were avoided. However, this criteria cannot be considered fool-proof, since most of the samples recovered at Station 3 were granites, obviously glacial erratics.

Throughout the major part of our dive sediment occurred in gullies, restricted areas or in relatively small patches. There were indications of sediment movement downslope. However, it was not until a depth of 2,782 meters that there were any indications of sediment striations due to currents. From these oriented photographs we have determined the current direction to be from the south-southwest. At about 3,000 meters depth the ALVIN was pushed by a current from the northeast; it was not strong enough to hamper operation but was readily noted. These varying current directions are consistent with the current meter results of Johnson and Lonsdale (1976) who also found that the bottom currents varied with time at a single location. It was from the south-southeast and subsequently abruptly shifted to a current from the north to south flow.

Another unique finding of the Mytilus dive was the occurrence of outcropping yellow and reddish-yellow stratified rocks. They were observed through the viewport at Station 4, 339 meters below the summit of Mytilus. Unfortunately, the photographs of this feature did record the details of this outcrop. This brightly colored outcrop occurred at the base of a 30 cm high ledge of either manganese covered igneous or reefal material. The basal section was a 7.5 cm high bright yellow strata overlain by another 7.5 cm high reddish-yellow surface. This outcropping represented the brightest colors observed during the entire series of dives.

The origin of this brightly colored outcropping strata is not certain, but may be the result of organic matter in a section of the carbonaceous reef. Certain species of coral boring algae are reddish or yellowish in color.

There were many sponge-like forms observed on this seamount; most had a light spiral form and were unlike sponges on the other seamounts. These were white and gave the appearance of whipped cream. They frequently had a diameter of 50 cm or more and a height somewhat more. They became grey, whispy, collapsed, and more diaphanous when dead.

Subsidence

The upper portions of both Bear (1102 meters) and Mytilus (2269 meters) seamounts were dredged by Zeigler (1955) and shown to contain carbonate rocks deposited in a shallow water environment. Our results confirm these results for Mytilus.

Zeigler's investigation suggested that the carbonate rocks were of an age between Upper Cretaceous and Eocene. Our study of Mytilus rocks gives a similar age range estimate. Thus one might assume a subsidence of 110 to 3000 meters in 50 to 70 million years or from about 15 to 60 meters per million years. Menard (1964) estimates about 30 meters subsidence per million years for several seamounts in the western Pacific.

Since Bear and Mytilus are the only two New England Seamounts that have a record of subsidence one can only surmise that this is because they are closest to the continent. There is no clear evidence that an age gradient exists along the seamount chain.

Figure 16. (Upper) Detailed bathymetry of Mytilus Seamount showing dive track with contours in meters.

(Lower) Depth vs. time for Mytilus dive.

Figure 17. Miscellaneous photographs of Mytilus Seamount. (a) frame 109; (b) frame 155; (c) frame 224; (d) frame 218; (e) frame 292; (f) frame 380; (g) frame 394. (a) is rubbly slope just below cape; (b) through (g) are on cap with relatively small amount of manganese coating. The more rounded rocks are usually glacial erratics and the more angular ones usually coral. (e) shows large sponge-like form.

MYTILUS SEAMOUNT

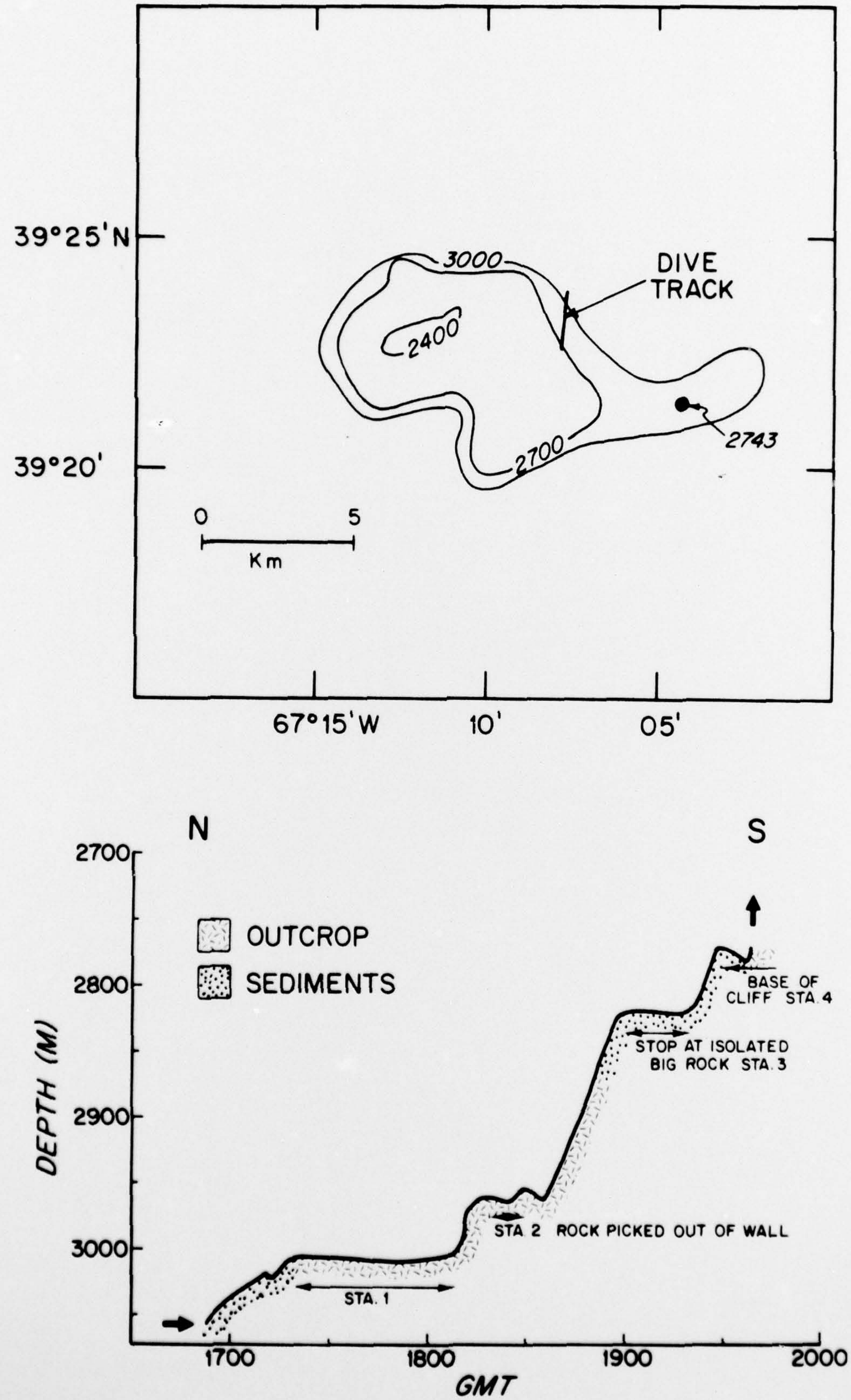
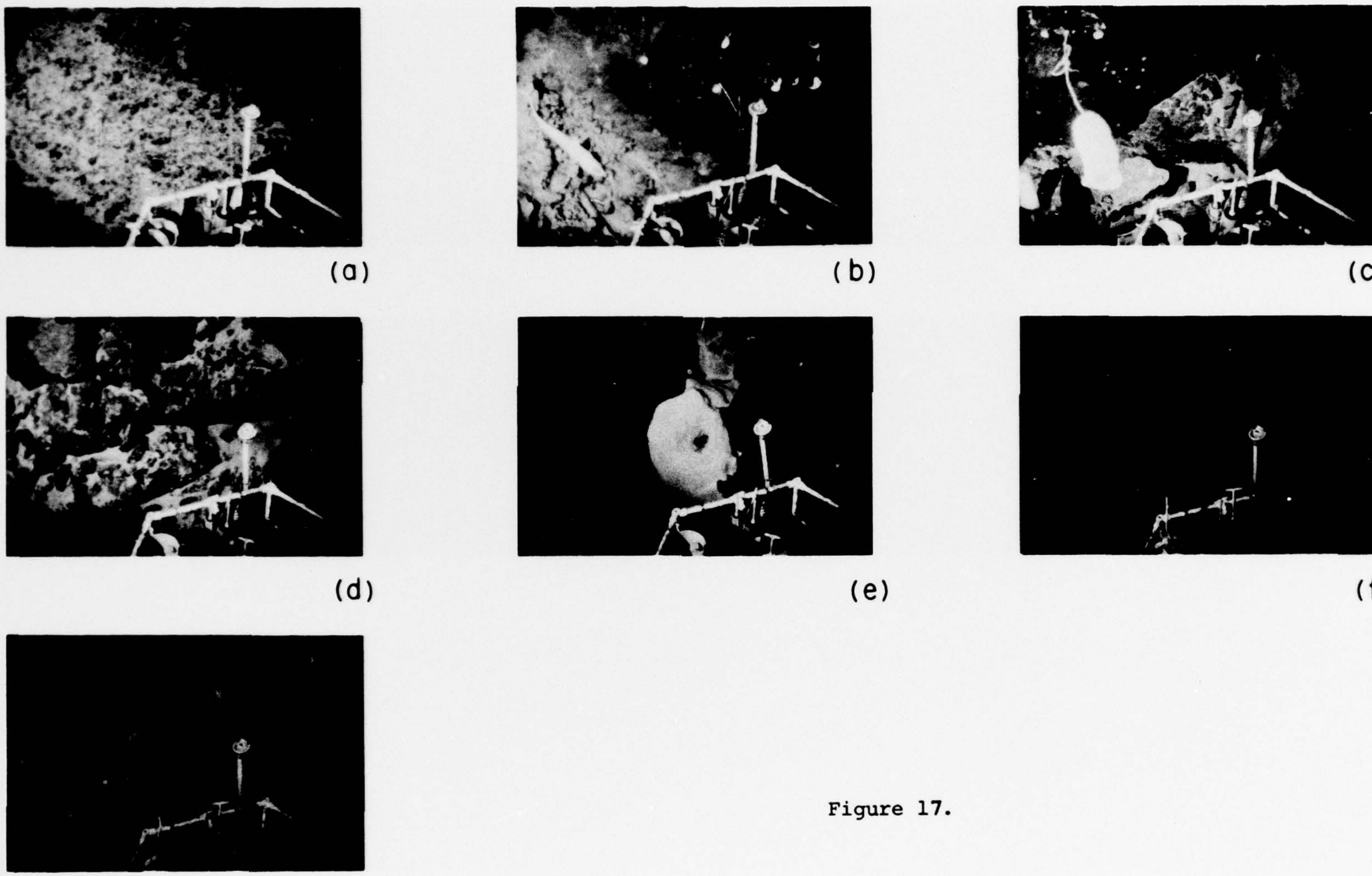


Figure 16.

MYTILUS SEAMOUNT
DIVE 543



(a) (b) (c) (d) (e) (f) (g)

Figure 17.

SUMMARY

Reconnaissance dives on seven of the New England Seamounts showed them to be rugged igneous features with pillow and massive basaltic rock exposures the dominent bottom type. A unique wall-like or radial dike was observed on two seamounts. Glacial erratics are rare on the east end of the chain but numerous on the west end. There are small bottom water currents that transport sediment sometimes causing sediment waves. There is a bottom biological population that distinctly varied from the eastern to the western seamounts.

Mytilus was found to have a 300 meter shallow water coral cap rising above its volcanic base at 3,000 meters. None of the other seamounts visited on this cruise gave evidence of subsidence.

ACKNOWLEDGEMENTS

We especially appreciate the support of Emerson Hiller, Master of the R/V KNORR and his crew, Richard Flegenheimer, Master of the DSRVT LULU and his crew, Lawrence Shumaker, Head of the Deep Submergence Group and in particular pilots Wilson, Donnelly and Foster.

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APPENDIX I

Dive and Dredge Station Numbers

General Location[+]		KNORR Sta. #	Dredge #	Dive #
1.	G. Challenger Site 332	156	29	536
2.	Corner Rise	158*	30*	537
3.	Nashville	161, 162*	31, 32*	538*
4.	Gilliss	165, 166*	33, 34*	539
5.	"Lulu"	168*	35*	---
6.	"Alvin"	169*	36*	---
7.	Rehoboth	171	37	540
8.	Manning	174*	38*	541
9.	Balanus	177, 178	39, 40	542
10.	Retriever	180	41	---
11.	Physalia	181*	42*	---
12.	Mytilus	182*	43*	543*

*no basalt

[+]Exact locations are given in log of cruise track.

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