WOODS HOLE OCEANOGRAPHIC INSTITUTION
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ALVIN DIVES ON THE CONTINENTAL MARGIN OFF THE SOUTHEASTERN UNITED STATES JULY 2-13, 1967

by

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TECHNICAL REPORT

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Approved for Distribution ________________

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Introduction

In late June and July, 1967, the Deep Submergence Research Vehicle (DSRV) ALVIN, aboard its mother ship, LULU, proceeded from the spring base of operations, Nassau, to its home port of Woods Hole. During this trip, from July 2 to July 14, a series of five dives were made by ALVIN on the Blake Plateau off Georgia and South Carolina, and on the continental slope north of Cape Hatteras (Figure 1). The objectives of the dives were as follows:

1. Investigate the manganese and phosphate deposits of the Blake Plateau. The manganese and phosphate-bearing areas, which exceed 1.5×10^4 km^2 are defined from numerous dredgings, bottom photographs and soundings (Pratt and McFarlin, 1966) but *in situ* examination was expected to reveal new insights into the relationship of the deposits to their substrates and general environment and shed light on the origin of the concretions. The dives were planned for the western periphery of the manganese pavement area, from about 31° to 33°N.

2. Investigate depressions on the Blake Plateau, from which discharge of fresh or brackish water has been indicated (Manheim, 1967). In particular, confirmation of the report by the Renolds Aluminum Co., DSRV ALUMINAUT of loss of buoyancy in a shallow depression was sought. Special equipment capable of monitoring both bottom water and resistivity

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(salinity) and resistivity of pore water in bottom sediments was developed for use with ALVIN. Submarine discharge, in combination with erosion and transport by Gulf Stream waters (Pratt, 1966), may have promoted formation of the deep, karst-like depressions along the Florida-Hatteras slope. In addition to their hydrologic interest, the depressions were expected to reveal outcrops of deeper strata.

3. Investigate reef-like features or mounds which have been reported on the outer edge of the continental shelf and on the Blake Plateau and at the base of the Florida-Hatteras slope. The shallower shelf reef is believed to be a Pleistocene algal reef (Menzies et al., 1966). Stetson et al. (1962) report that the deeper banks are accumulations of deep-sea coral and coral debris, whereas Elazar Uchupi and E. F. K. Zarudzki (this institution) feel that some of the features may be surface representations of exhumed erosional structures.

Equipment

Description and operation of DSRV ALVIN has been reported by Mavor et al. (1966), and the below summary is limited to sensing instruments mounted on the outer hull, cameras and sampling gear.

a. Current Meter

A Savonius rotor is mounted on the conning tower of ALVIN (Figure 2); the rotor's revolutions may be read in knots on a meter inside the submarine.

Direction of the current must be estimated visually, or determined from the heading of the submarine.

b. Thermistor

The sensing element is mounted on the underside of the Savonius rotor, and temperatures can be read on a meter inside the submarine to within a reproducibility of about 0.2°C. The thermistor was calibrated with a laboratory thermometer by F. T. Manheim, C. Porembski, and E. F. K. Zarudzki by placing both thermometer and thermistor in water and ice baths. A plot of the results is shown in Figure 3. At higher temperatures the thermistor indicates temperatures higher by 2°C than the mercury thermometer readings. At the lower temperatures the thermometer reads the temperature several tenths of a degree centigrade lower. Unfortunately, the mercury thermometer used in calibration was broken before return to the laboratory and could not be checked against a thermometer of known accuracy. The readings are therefore reported as measured.

In addition to the above discrepancies, the thermistor frequently showed large and rapid temperature variations at depth (Figures 7-9, 11) which, since they were usually not reflected in corresponding resistivity fluctuations of surrounding water are assumed to be instrumental rather than natural.

Temperatures recorded in the water column on every dive were usually lower during ascent than descent. We have considered the possibility that exchange of water at the thermistor position may be greater during descent than ascent, with resulting delay in thermistor response to ambient temperature. In dive 204, however, the submarine purposely drove from Gulf Stream water into colder slope water, and relative temperature variations in dive 203 checked with corresponding resistivity measurement changes. Hence, at least in some of the dives, the differences appear to be real; that is, descent and ascent were through different water masses. As discussed later, accurate resistivity measurements on the ascent during dive 201 were made impossible by bottom sediment which adhered to the resistivity probe, thus preventing a comparison with water temperatures.

c. Resistivity (by F. T. Manheim)

A bottom resistivity probe for use with ALVIN was developed in collaboration with Mr. C. F. Grice of the Weston Co., marine subsidiary of the Schlumberger Well Surveying Corp. (Figure 2). When the submarine rested on bottom the probe's electrodes, which were imbedded in a spring-loaded plastic plate, pressed against the sediment. An apparent bottom sediment resistivity could be read inside the submersible through an AC measuring circuit (actually a Schlumberger electronic mud tester). The device is able to measure the electrical resistivity of sediment to a maximum penetration depth of about 30 cm.

The purpose of the probe was to provide a sensitive means of detecting anomalous water resistivities reflecting salinity and/or temperature, both in bottom waters and in pore waters of bottom sediments. Such anomalous water properties might be difficult to detect in areas of submarine seepage because of rapid mixing with sea water but should be obvious in the pore fluids of the sediments.

Although the sought-for depressions were not reached, the resistivity sonde performed stably and well in all dives. The instrument was able to distinguish between poorly permeable materials such as hard limestone bottoms and softer sediments, even when the former were overlain by thin beds of calcareous ooze (Figure 4). This sensitivity results from the fact that bottom sediment resistivity is influenced both by the resistivity of pore water and by porosity, since for all practical purposes mineral grains are infinitely resistive.

The resistivity tool is not basically intended to register salinity in the open ocean but does give electrical resistivity of water to three significant figures when properly calibrated and when more than about 30 cm distant from the bottom. The values obtained in several dives (Figures 7-9, 11) cannot be converted to salinities which meet hydrographic accuracy requirements because the temperature measurements were not accurate enough, because the temperature and resistivity sensing units are four meters apart, and because greater precision in resistivity readout would be needed. Furthermore, in dives 201 and 202, where soft bottom sediments were encountered, enough sediment evidently clung to the resistivity probe to change the water resistivity readings to erroneously high values after the submersible left the bottom. The effect gradually diminished during ascent, and in dive 202 resistivity values had virtually returned to normal by the time the vessel reached surface.

d. Suspended matter (by F. T. Manheim)

Efforts were made by Manheim and Milliman to develop a visual target system which would permit visual estimation of the water turbidity, the idea being to calibrate the observations against measurements of total particulate matter in water samples from selected water layers. After experimenting with several patterns suggested by W. S. von Arx, a "TV" type test pattern was found best, and the target was encased in plastic and mounted on the front of the sample rack, about 2 m away from the bow porthole. However, the patterns distinguishable in clear water were still discernable in waters containing less than about 5 mg/l total suspended matter, which exceeds any values seen by us near or above the bottom (see below).

Ultimately, the best means of estimating suspended matter, though subjective, proved to be total distance of visibility using a constant light source. If objects having sufficient contrast are available, camera rangefinders can be of some help in making the distance estimate. Figure 5, taken from many suspended matter measurements along the Atlantic continental margin, shows the relationship between Secchi disc depths and total suspended matter, and a roughly analogous relationship appears to hold for "total distance of visibility" under submarine conditions. An accurate "Secchi disc" measurement on bottom could be made by placing a white disc on the bottom and backing away with the ALVIN until sight is lost, but this might take undue time if done too often. Photometer equipment should be considered for future work.

Water samples were filtered on board LULU through 0.45 m millipore filters, and washed with distilled water. Total suspended matter and combustible organic matter were determined later in the laboratory as on previous occasions (Manheim, et al., 1966).

e. Sampling gear and rack

The rack or "basket" is attached to the submersible's underbelly and extends forward (Figure 2). On the present cruise the rack carried two Lucite water samplers, sediment coring tubes, a geologic pick, a pry bar, and on the last dive, a net rigged around a metal frame (used as a rake). The water samplers consisted of plastic cylinders fitted with lead-weighted and O-ring sealed closing flaps. The samplers could be closed by rotating them lengthwise with the wrist of the mechanical arm.

f. Photographic equipment

ALVIN is equipped with a stereo-mounted pair of Edgerton cameras on the outer forward hull. The cameras are operated from the inside of the submarine and pictures can be taken manually or programmed to be taken at specific intervals of stroboscopic illumination. A 16 mm Bell and Howell movie camera and several 35 mm still cameras were aimed by hand through the three port holes in the hull. Kodak EF color film, nominally rated at ASA 160, can be forced to ASA 640 during development and proved to work well for the conditions on the bottom, even when full light capacity was not used. This is advantageous from the point of view of conserving the vehicle's battery power for extended dives.

Itinerary

Original plans called for preliminary oceanographic observations at the location of proposed dive sites by D. A. Ross, Woods Hole Oceanographic Institution, from the R/V GOSNOLD. Due to scheduling difficulties, the GOSNOLD left early (Friday, June 31, 1800 hours) from West Palm Beach and therefore could not accompany LULU on the cruise. Ross planned to make temperature measurements of the bottom water, using a recently developed temperature sensitive pinger (Ross and Hunt, 1967). Due to malfunction of several pieces of equipment and lack of time, measurements could not be made, and the GOSNOLD continued north to Woods Hole.

In place of GOSNOLD, the M/V HUMBLE, from the Marine Acoustical Service, Miami, acted as an escort ship during the entire cruise. LULU and HUMBLE left the docks at West Palm Beach July 2 at 1200.

The first dive was scheduled for Monday, July 3, in a depression at about 27°50-28°20'N, 79°30'W on the Blake Plateau, but was cancelled because of rough seas (greater than 2 m). With the strong northward transport of the Gulf Stream, it would have been difficult to remain near this station until the next day. Course was therefore set for the southern part of the manganese pavement area. After a preliminary echo sounding survey, ALVIN dive #200 was made, with Marvin McCamis and Val Wilson as pilots and R. M. Pratt as observer.

After Pratt's dive, LULU steamed west to about 31°17'N, 78°55'W, the site of ALUMINAUT'S reported loss of buoyancy. Traverses intersecting the eastern and northern positions of the depression shown on the map of Uchupi (1967) failed to find bottom relief greater than about 20 m, with slopes less than 1°. Because of inability to find depressions similar to those previously described from the area and because of the hazard of attempting a dive in the axis of the Gulf Stream, it was decided to make the Wednesday (July 5) dive at the western margin of the maganese pavement area, near the base of the Florida-Hatteras slope. Frank T. Manheim accompanied pilots Marvin McCamis and Valentine Wilson on dive 201.

Following this dive, another attempt was made to find the ALUMINAUT "hole." LULU steamed south over the central portion of the indicated depression without finding appreciable bottom relief. LULU continued south and dive No. 202, with E. F. K. Zarudzki as an observer, was made on Thursday, July 6. The location was 31°10'N, 79°15'W, in the phosphate nodule area (Pratt and McFarlin, 1966). Following attack on the submarine by a swordfish, the dive was aborted.

A final crossing of the ALUMINAUT "hole" occurred on the way northward from the above position. This time, a small break in the topography was observed but the relatively minor relief did not appear to warrant a special dive at this point.

LULU then continued north and dive 203 took place in the coral mounds, slightly west of the low hills which characterized the beginning of dive 201. John D. Milliman accompanied the pilots on this dive.

At the termination of the dive, LULU and HUMBLE sailed to Charleston, South Carolina, arriving at 0900, Saturday, July 8. Pratt and Zarudzki departed the ship to return to Woods Hole.

The second leg of the cruise left Charleston at 1200 hours on Monday, July 10, with Manheim and Milliman as the scientists aboard. The original schedule called for a dive on the algal ridge at the seaward edge of the continental shelf off Long Bay and a dive in a reported depression (60 m relief) on the continental slope (32°32'N, 78°28'W). Rough seas (state 3+ to 4) forced cancellation of both dives. LULU then steamed north in an attempt to make a dive off Onslow Bay. Again, rough seas forced cancellation.

A site was chosen on the upper continental slope off Cape Hatteras, where we could investigate both the slope-shelf transition and also the northern extension of the algal ridge as well as the temperate to semi-tropical faunal transition. While surveying this dive site, LULU was carried northward by currents which prevented a return south to the dive site. Therefore, an alternative site was chosen.

The final site for dive 204 was on the continental slope, north of Cape Hatteras. In addition to bottom conditions, observation by echo sounder of a prominent scattering layer in the water column provided a feature of special interest. Dive 204 was made on Thursday, July 13; Manheim and Milliman accompanied pilot McCamis on the dive.

Worsening weather and increased sea state forced the shortening of the dive. As ALVIN began ascent, the sample rack was mistakenly jettisoned, with the resulting loss of rack, sampling tools, resistivity probe and samples.

At the conclusion of dive 204 the LULU and HUMBLE steamed for Little Creek, Virginia. Upon arrival, both Manheim and Milliman departed LULU for Woods Hole.

Personnel Expedition Leader - W. O. Rainnie

LULU

Master	Larry Hunt
1st Mate	Phil Bergstrom
Ch. Engin.	Ken Costa
Engineers	Ted Curtis
	Mike Fields
Deck	Buddy Gordon
	Skip Baugh
Cook	Tom Jacobus
Messman	Scott Walker

ALVIN

Sr. Pilot	Marvin McCamis
Co-Pilot	Valentine Wilson
Crew Chief	George Broderson
Technicians	Dave Mason
	Pat O'Malley
	Chuck Porembski
	Miles Anderson
	Cliff Hinton
	Russ Graham
Crew Chief of 2nd DSRV	Roger Weaver
Scientists	F. T. Manheim (U.S. Geol. Survey, WHOI)
	J. D. Milliman (WHOI)
	R. M. Pratt (Va. Polytechnic Inst.)
	E. F. K. Zarudzki (WHOI)

Dive Reports

The following pages are reports of operations and observations made during dives 200 through 204. Each report is in three parts: The dive synopsis, the dive report, and the dive log.

ALVIN Dive 200

Synopsis

Date : July 4, 1967

Time : 1355-1809 (EDT)

Location : 31°18'N, 78°53'W -- manganese nodule-pavement area on Blake Plateau

Personnel: M. McCamis - pilot

V. Wilson - co-pilot

R. M. Pratt - observer

Temperature and Resistivity

The surface temperature as measured during the resistivity cup calibration by the external thermistor was 31°C. Temperature decreased gradually toward bottom to about 14°C on bottom. Near the bottom at least two temperature inversions were noted with temperature fluctuations of 16° or 18° up to 19° or 20° and back again. Temperatures remained at 14 to 14.5° on bottom throughout the dive. This temperature is considerably higher than other measured bottom temperatures in the vicinity and may be associated with the dive location toward the axis of Gulf Stream flow.

Resistivity measurements during this dive were unsatisfactory. Readings of the cup at the surface were erratic and fluctuated widely. Later experimentation showed that it takes several minutes for the instrument to stabilize after being turned on. Also, unfamilarity with the instrument resulted in a scale error making the readings unprecise.

Bottom Topography

We landed on a smooth to very gently rolling bottom with numerous ripple marks and occasional scour marks around obstructions. Throughout the dive this was the characteristic topography. Most notable relief was a broad depression several meters deep and of unknown lateral extent. The floor of the depression was flat with an unrippled fill of loose sand and gravel. Straight ridges on the side of the depression are characterized by manganese slabs. Total relief on the entire dive was 10-12 meters.

Physical Measurements on Bottom

The most interesting aspect of dive 200 was the current on bottom. The first impression upon reaching bottom was that everything was in motion. Hydroids and sponges oscillated in the current and fish were pointed upstream. Everywhere sand and debris was moving along the bottom. Sand ripples were in active motion and large sponges and rocks had scour depressions around their base, and lee side accumulations behind them. At one stop the sand seemed to have formed dunes with a wave length of about 3 to 5 meters. The only place with no active motion on bottom was the depression but here the sediment was very coarse loose sand suggesting recent filling.

Actual bottom currents measured with the submarine sitting on bottom ranged from 25 to 75 cm/sec, always flowing northward.

In general, visibility was excellent to the limits of light (10-15 m).

Biology

The most surprising aspect of the dive was the abundance of life on bottom. Everywhere we looked, fish and crabs were visible. Most of the fish were small (5-10 cm) and had a density of about 1 per 25 to 50 m^2. One large (40-50 cm) grouper-like fish swam around the submarine for about 10 minutes. A 2-meter thresher shark was observed on the way down and a 1-meter mottled dogfish was seen on bottom.

Sessile life was always in evidence on bottom but was never really abundant. Large sponges and various hydroids were the dominant forms; other organisms included crinoids, gorgonians, echinoids and a big round, red sponge.

Bottom Sediments

Bottom deposits were of two types: (1) loose well-sorted *Globigerina*-pteropod sand and (2) manganese nodules and indurated sand lumps. The bottom sediments were much as we have previously described from dredge hauls and photographs in the area. Where rippled, the sand was composed of *Globigerina* tests but where accumulation was evident in depressions the sand had a large percent of pteropods, small bits of coral and other debris.

The manganese concretions were in the form of large plates of broken pavement. Toward the end of the dive a gentle ridge feature, showing prominently on the sonar, was found covered with large manganese slabs. Slabs ranged up to 3 or 5 m in maximum size. A few slabs appeared cracked and broken and at one place slabs seemed to be piled upon each other. One slab, measuring 44 x 26 x 10 cm, was recovered after much effort (WHOI Sample 2700). It seemed to be thoroughly embedded in the bottom.

When we first landed on bottom scattered mounds of indurated ooze were observed. The largest was about .5 meters in diameter. Apparently, the indurated ooze or limestone just forms lumps lying in the surface sediment and has no connection with underlying formations. Its exact nature was not investigated although one 10 x 10 cm lump of indurated ooze was easily picked from the bottom. Unfortunately this lump and a sand core were lost during ALVIN'S recovery.

Dive Log

Time (EDT)	Depth (m)	
1350	surface	Launch
1355	surface	Submerged
1402	229	Color changing from blue to purple
1403	268	Color change from deep purple blue to blue black
	300	Six-foot thresher shark observed by pilot
1410		Approaching bottom; much suspended matter (snow) in water
1426	535	Reached bottom. Bottom is Globigerina sand, with occasional small manganese nodules. No visible ambient light. Drifting with bottom current to North at about 62 cm/sec.
1429	531	White to light brown sand bottom. Not as much snow near bottom as further up in water column.
1437		Attempting to get on bottom and hold. Finally held with lift props and main prop both going. Current 50 cm/sec from 150° to 180°.
1439	539	Sitting on bottom and trying to recover small slab. Water temperature 14°C. Globigerina sand with active ripples. Lee side accumulations behind sponges and coral, and scour depressions around all obstructions.
1515		Trying to pick up mn nodules. Several 20-30 cm nodules in front of the sub. Rat-tail fish. Numerous small corals and sponges, 6 to 10 cm high. Nothing large. Little swirls of sediment everywhere and constant sand movement. Sessil growth in constant motion.
1525	543	Give up on attempt to recover a nodule. Current 25 to 35 cm/sec from 160 to 180°. Rippled ooze all the way.
1532	543	Three-cm reddish crab. Bottom completely rippled.
1536	543	Stop on bottom. Retrieve 10 cm piece of indurated ooze. Irridescent greenish fish heading into current. Small amount of snow.

Dive Log Con't.

Time (EDT)	Depth (m)	
1540	543	Pick up water sample 1, and sand core. Photographing a large 40-50 cm grouper-like fish which is swimming around the submarine. Large (20-30 cm high) calcarenite mounds on bottom.
1614	542	Driving to west. Can't stop on bottom without reversing props. Current 75 cm/sec from 180.
1635		Large mn slabs and broken pavement. Slabs 4-5 m across surrounded by rippled sand. Occasional sponge and coral on the mn; mn shows black and stark against the sand background. Mn forms ridge of some linear extent as observed and also recorded on sub sonar.
1644	547	Sitting on bottom in depression. Coarse sand to gravel with much broken coral and pteropods in the sediment. No ripples, some possible dunes, no sessil life. Sediment seems to fill the shallow depression; ALVIN skid tracks reveal loose sand, 5-10 cm deep. Collected water sample 2.
1715	546	Trying to pick up mn nodule on bottom. <u>Globigerina</u> sand with 8-10 cm long ripples; dunes in distance with 3-5 m wave length and large sponges in holes.
1725		Picked up 20 cm Mn nodule. Sample tray full. Proceed toward the west on course 200. Large 10-cm round sponge under submarine.
1745	542	Dropped ascent weight and start for the surface. As seen as we left bottom the snow started.
1802	168	Zone of salps in water, and numerous live <u>Globigerina</u> (?).
1904	100	Very blue water; clear to surface.
1809	surface	

ALVIN Dive 201

Synopsis

Date : July 5, 1967

Time : 1207-1758 (EDT)

Location : 31°48'N, 79°12'W - on western margin of manganese pavement and east of coral banks on Blake Plateau

Depth Range: 514-555 m

Personnel : M. McCamis - pilot
V. Wilson - co-pilot
F. T. Manheim - observer

Geology and Topography

The general geological features of the bottom traversed in the present dive are interpreted in Figure 4 which incorporates the submarine observations as well as subsequent examination of rock specimens recovered by means of the mechanical arm. W. A. Berggren and co-workers determined the age of the out-cropping strata as Campanian-Maestrichtian in age (Upper Cretaceous), chiefly on the basis of foraminifera.

The western portion of the traverse consisted of rounded hills and valleys apparently transitional from the large coral ridges observed by Milliman in dive 203. Well-developed longitudinal ridge formations were not noticed but at least a few hills and one prominent gulley had amplitudes as high as 10 m and were aligned north-south. The sediments appeared to be silt to sand sized skeletal debris (carbonate) for the most part, with occasional fragments of dead deep water corals. Organisms were actively burrowing in these sediments, as evidenced by frequent conical holes, 5-10 cm in widest diameter and numerous empty worm tubes lying on the surface.

At approximately station "G" the hills appeared to contain somewhat darker sediment patches, which appeared firm but were oozy when cored. A sample of the dark material proved to be chiefly glauconite with some small phosphorite grains. On reaching the flat portion of the traverse at about 554-555 m depth the bottom resistivity rose sharply although no outcrops or rocks were observed. This suggested hard (low porosity) rock beneath a thin sediment cover and was confirmed by the fact that the skids no longer plowed deep grooves. At Station I symmetrical ripple marks, 4 cm high and about 35 cm from crest to crest were observed for the first time. Coarser calcareous debris lay in the troughs and a sprinkling of dark particles appeared. At "J" the sediment became more cohesive and pronounced rippling and undulations were noted, generally oriented north-south. At "K" the bottom became covered with dark nodules, first small and pebbly but soon larger lumps, cobbles, and then slabs appeared.

First evidence of probable outcropping formation was noted at "L-M" where slabs of whitish calcareous siltstone to silty limestone were noted, along with cobbles to large brown-black boulders, as much as 2-3 m wide and 1-1 1/2 m thick, probably consisting of Mn and Fe-impregnated phosphorite. At "N" a clearly outcropping shelf of whitish-buff silty limestone with a brown-stained and bored upper surface was reached, photographed and sampled. The broken-off portion of the outcrop formed a step about 5-20 cm high, striking W-E as far as the eye could see, although some parts were partly covered with calcareous skeletal ooze. Samples from "L-M" and from the outcrop had similar (Upper Cretaceous) faunal assemblages according to W. A. Berggren.

Although the dark nodules were occasionally imbedded superficially in the lighter limestone slabs, they appeared to be a lag deposit lying irregularly on the sediment bottom. The white-buff material was firm to slightly plastic (easily scraped with the mechanical arm) and occurred in well-defined localities or in observed outcrop. This material was obviously easy to erode, and one would judge from the identified samples that it may have been of uniform age (Campanian-Maestrichtian), and seemed to form the flat floor of the traverse area.

Bottom Life

Estimated abundance of organisms for the surface of the traversed area is averaged below. Since several types of small fish as well as crabs did not seem particularly disturbed by the presence of the submarine until the craft came quite close, the impression is that the estimates are not appreciably influenced by the vessel's intrusion, although this could be in error. Sizes and areas are corrected insofar as possible for optical distortion by calibration with measured portions of the mechanical arm and basket.

Organism	No. individuals	Avg. size or range (cm)
Hermit crabs and small crustaceans	20-many thousands per 100 m^2	less than 3
Small fish	10-80/100 m^2	10
Large crabs	1-15/100 m^2	7-25 (body)
Snails	0-10/100 m^2	1-12
Squid	0-6/100 m^2	8
Spiny urchins	0-5/100 m^2	18 when extended
Sea cucumbers (holothurians)	0-6/100 m^2	15
Shrimp-like organisms	0-4/100 m^2	4

Only one large fish, a 1 1/2 m Mako shark was observed. This specimen was resting on or near bottom and raised a cloud of sediment when he was aroused by the submersible and flashed past. The most common small fish appeared to be small deep-sea eels, dull brownish-buff with poorly marked mouth and eyes (frequently not evident at all), 6-20 cm in length. They moved very slowly and often rested near or on the bottom with their bodies curved around a nodule or projections from the bottom. Small skates about the same size were somewhat less common, followed by half-dollar sized hatchetfish (Sternoptyx). These bright silvery forms seemed to frequent water about 4-6 m or more above the bottom, darting straight downward at a speed of 1-3 m/sec and then moving back up again without stopping. Other fish noted were rat-tailed fish (morids), several red, bass-like fish about 20 cm long, silvery, goldfish-like fish having a rapid (8 m/sec) darting motion when disturbed, and a golden pouched fish with antennae-like projections below and above the jaw (Chaunax). This specimen was half buried in the mud before being disturbed. Productivity and frequency of both fish and invertebrates increased greatly on encountering the ripple-marked area, and at this point masses of small crustaceans (?), moving in jerks every few seconds were observed.

Less common invertebrates observed included octopus, starfish and a few brittle stars. No living bivalves were seen, although a large dead valve was noted. Hydroids were very common once the rippled areas were reached and from the abundance of empty (worm ?) tubes one would assume that worms were common. Deep-water corals (Lophelia and Dendrophyllia), alcyonarian corals, hydroids, sponges and bryozoans typically grew out from the tops of hard surfaces such as the phosphatic Mn slabs, whereas serpulid and other carbonate-secreting worms and siliceous sponges preferred the undersides of more massive slabs, along with unidentified gelatinous growths. No living deep-water corals were seen before the area of rubble bottom was reached.

Bottom Currents

The ALVIN current meter is located atop the conning tower nearly 4 m from the skids. To check currents closer to sea bottom I practiced measuring (mentally) distances of 10-50 cm in the water by comparison with calibrated portions of the mechanical arm. Then, by counting the number of seconds required for omnipresent "snow" of suspended particles to pass through a given distance, speed could be measured in cm/sec. After a little practice, velocities thus gained agreed within 50% of those registered by the current meter in the upper water levels. Further, very slow speeds and water movements near the bottom could be estimated by this method.

Current meter velocities of about 0.4 knot or 20 cm/sec were obtained in the hill and valley region of Figure 4, whereas currents less than 1/4 knot (12 cm/sec) were obtained in the eastern part of the traverse. All currents were from the north. Visual estimates indicated that the currents remained fairly constant from above 4 m to within a few centimetrs from the bottom. Within 1 cm from the bottom currents declined sharply and became erratic, with little sediment movement noted.

The above observations contrast sharply with expectations based on the size and orientation of the ripple marks. These would lead one to expect a west-east current direction with currents above one knot. Apparently the currents are an intermittent feature on the bottom, and our dive came at a quiet time. No appreciable sediment movement was noted at any time during the dive although the ripples as well as 10-cm scoured swaths around larger boulders and irregularly covered and uncovered phosphatic rubble provide evidence of such movement.

Suspended Matter

Quantitative data on suspended matter is included in a later section.

Fine filaments and flocs from less than 0.1 to 1 mm were noted in the surface waters. Roughly 30/liter could be counted. At depths of 10 to 150 m depth flocs increased in size and abundance occasionally reaching 1 cm in size. Living zooplankton could be observed when the descent slowed temporarily but these evidently made up only a small proportion of total matter, most of which consisted of unrecognizable or irregular aggregates, flocs or blobs. One characteristic hanging filament is shown in Figure 6. Marvin McCamis remarked that this was the largest concentration of suspended matter he had seen since diving in Woods Hole Harbor during summer plankton blooms. From 170 m the suspended particles decreased in size and remained roughly constant to the bottom.

On bottom the turbidity permitted a visibility of about 5 m but became somewhat clearer during the traverse. A water sample taken in the most turbid portion of the bottom, about 10-20 cm from the bottom during the early part of the dive, gave about 1.7 mg/l total suspended matter, with 76% combustible organic matter. One would judge that the suspended matter higher in the column would contain roughly comparable amounts of suspended matter but probably higher percentages of organic matter. See section on suspended matter for explanation of "TV target" observations.

Dive No. 201 Log

Time (EDT)	Depth (m)	Station	Observations Temperature and water resistivities noted in Figure 7.
1200	surface		Fine filaments and .1-1 mm flocs, est. at 30/l
1208	16		Suspended matter increasing
1209	26		Big flocs increasing line 6 visible
1211	55		Line 5 on TV target visible. Mac says it looks like Woods Hole Harbor during plankton bloom.

Dive No. 201 Log con't.

Time (EDT)	Depth (m)	Station	Observations Temperature and water resistivities noted in Figure 7.
1213	121		Big flocs; living zooplankton (movements noted). Target 6-12.
1214	150		
1216	172		Decrease in floc size
1219	240		Camera station to record "snow" (suspended matter).
1248	514	A	On bottom, silty calcarenite. Temperature 7.3-7.4. Bottom sediment resistivity (apparent) 1.69 ohm/m.
1255	515		Current from N 0.4 kn, temp. 7.1, bottom res. 1.78. Sudden current which died down.
1306			Move camera; shots of 11 cm crab.
1308	518	B	Smooth undulating bottom with hills and valleys 1-10 m in height. Many holes with conical sides, outer diam 8-10 cm.
1316			Hard-looking brown object, 5 cm; unable to confirm.
1319	520	C	Current 0.4 kn from due N. Bottom res. 1.50. Bottom current by floating "snow" 6 sec/100 cm; little sediment traction on bottom.
1326			Sediment becoming siltier, finer.
1336	521	D	Current 0.2 kn from N, Temp. 6.9°. Bottom res. 1.70.
1339	523		Bottom temp. 7.0. Visibility 15-20'
1341			Bottom temp. 6.9. Water sample of "snow" with 15% visibility.
1348	532	E	Current 0.06 kn from N, 2-5 cm/sec visual. Many eel-like fish.
1350			Movie of arm taking H_2O with small sampler Kodak EF rapid film at 640 (forced to stops assumption).

Dive No. 201 Log con't.

Time (EDT)	Depth (m)	Station	Observations Temperature and water resistivities noted in Figure 7.
1402			Temp. 7.1, visibl. 15-20', climbed 10 m. hill approx. N-S heading.
1406	542	F	Current 0.26 kn from N, plant debris moving 7 cm/sec near bottom; eel-turtle grass? Gully north-south.
1416	542	G	On hill darker, fine sediment, looked firm but proved soft on coring (CORE). Current from N 0.2 kn, 7 cm/sec bottom visual est. less turbidity. Many tubes (?) of worms or other organism brownish. 3-6 cm long. EXPERIMENT: stirred up strong cloud of mud on top of hill to check behaviour of suspended silt; some downhill motion, but mainly slow dissipation in various directions. Bottom res. 1.71.
1435	554.3	H	Bottom resistivity rises sharply 2.45-2.62. Temp. 7.1. Skids no longer make large grooves and holes in sediment. Wire coat-hanger and whitish material being nibbled by fish. Many large crabs to 25 cm.
1500		I	Ripple marks 4 cm high, 35 cm crest to crest, symmetrical; calcareous debris in troughs fine dark particles in soft bottom; apparently globi ooze. Movies.
1505			Masses of flea-like organisms, partly conceaned in carbonate skeletal debris, especially pteropod fragments. Move in jerks every few seconds. Mac went snail hunting.
1510			Stubby, varicolored-splotched fish ranging from greenish fluorescent to pink; hangs motionless on bottom (9 cm long).
1535		J	Great increase in productivity with rippled and undulating sediment, but flat terrain as far as the eye can see (25'); sed. more cohesive, many eel-like fish, octopus, red snapper, misc. fauna.; hairy bottom (hydroids).
1540	556	K	Reached brown, nodule-covered bottom, first many dark grains on bottom, then plates and irregular lumps and cobbles, partly covered

Dive No. 201 Log con't.

Time (EDT)	Depth (m)	Station	Observations Temperature and water resistivities noted in Figure 7.
			with ooze; large squarish rock, dark, probably Mn-impregnated phosphorite, 40 x 30 x 15 cm.
1608		L	Collected first size hunk of plastic white silty limestone from plate 10 cm thick, 40 cm in diameter, brown stained and worm bored on top. Also hard black rock, phosphatic, lemon sized. Noted eel-like fish wrap themselves around knobs of material; pieces of rock are partially imbedded in a dirty buff-white calcareous ooze. Rubbly bottom; only 4 kg/m^2 (estimated) visible.
1618			Many slabs of cemented ooze-siltstone-limestone.
1628	555	M	Huge boulder, 2-3 m wide, 1-1 1/2 m thick, coated with Mn and hard, with scoured depression around. Failed to pry loose piece because of risk to arm but took pictures. Bottom res. 2.8.
1644		M_1	Obtained moderate-size boulder which turned out to be a micaceous fine-grained granite-syenite on later examination. Many flat dark-colored slabs; strange bluish-white fish, 4 cm long, with spike on head.
1647	556	M_2	Black cobbles in sandy-appearing Globigerina (?) ooze in linear arrays approximately N-S lineation. Strong resemblance to patterned earth in Arctic regions. Sampled small cobble.
1657	556		Temp. 7.0, pictures through bottom port; hard impermeable bottom (res. 2.9) lightly covered with calcareous ooze.
1705		N	Outcropping shelf of whitish-buff calcareous siltstone or silty limestone with brown stained surface. E-W trend. Pictures. Obtained cracked fragment. Bottom res. 2.8. Checked to EF film and took pictures of ledge, organisms, etc.
1731			Start to surface
1758			Reached surface

ALVIN Dive 202

Synopsis

Date : July 6, 1967

Time : descent 1340 (EDT)

on bottom 1422

off bottom 1432

surface 1501

Location: 31°11'N, 79°18'W - phosphate and Mn nodule area on Blake Plateau

Personnel: M. McCamis - pilot

V. Wilson - co-pilot

E. F. K. Zarudzki - observer

Temperature and electric resistivity of water column

The resistivity probe read 447.8 units, while the surface water sample was calibrated at 176.5 units, yielding a ratio of 0.394 which was assumed to be constant.

During the descent, the temperature readings were taken at about 90 second intervals, while the resistivity of water was determined at about 5-minute intervals. A total of five temperature and resistivity measurements were made on the ascent. The results are shown in Figure 8.

Rapid water temperature fluctuations were observed between the depths of 150 and 480 meters. Sometimes the departure from a temperature mean was as much as 5°C. As mentioned above, such fluctuations may reflect either unstable water "filaments" with the Gulf Stream or more likely, some error in the submarine's thermistor.

Bottom Topography

The bottom at the point of arrival of ALVIN was predominantly flat within the range of vision some 10 to 12 meters. The surface showed current rippling. The alignment of ripples, which were some 2 inches high and 12 inches long showed that the observed bottom current of 0.5 kt and flowing from 150° magnetic course was persistent in this area.

Physical Measurements on Bottom

Only one reading of electric resistivity of the bottom sediment was made. It was 1.45 ohm-m (corrected); comparable to that obtained from soft carbonate ooze in the first part of Dive 201.

Biology

During the descent the "snow" effect was observed from the surface of about 40 meters above the bottom. The "snow" particles became finer with increasing depth. Microscopic size creatures (about 5 to a cubic foot) were noted at 310 meters. At 470 meters a sardine-size fish and a small jellyfish appeared. At 560 meters a ribbon-like fluorescent creature 8 inches long, 3/4 inches wide, undulated past the window.

On the bottom, small scattered fist-size clumps of deep sea coral flourished. A solitary clump of branch coral about 18 inches high was noticed.

Sediments

The soft sediments (ooze) on the floor of the Blake Plateau were arranged, obviously by a bottom current action, into series of small ripples. The sediments were winnowed behind the protecting clumps of deep sea coral.

Swordfish Attack

At 1426 the submarine maneuvered from its original place of descent to a spot some 3 meters ahead to take photographs of a single large deep-sea coral specimen. At 1428, I suddenly heard a scraping sound on the hull coming forward and slightly below me. Thinking that the noise had been caused by the submarine drifting and scraping over the sea floor, I looked down and saw that we were still stationary on the bottom. Simultaneously with the noise, Mr. Wilson, the co-pilot, whose station was at the starboard window, recoiled from it exclaiming: "We've been hit by a fish!" Indeed, outside his window we saw a large fish, apparently captive, violently trying to disengage itself and in the process tearing some of the skin and flesh off its back. A small amount of blood was flowing out of these tears.

We quickly realized it was a large swordfish which in ramming us had wedged its sword between the forebody and afterbody of ALVIN. Since there was a possibility that the sword had damaged the sub's electrical wiring, as indicated by a "leak detector" meter shortly after we decided to abort the dive. (It was determined later that the "leak" indication was not serious and was completely coincidental but at the time dictated surfacing.)

During ascent we observed that the fish's sword was thrust full length in the joint of the hull and firmly wedged. The fish periodically struggled, but failed to break free. At the surface, divers threw a noose around the fish's tail, securing it to the submarine.

As ALVIN was being hoisted onto LULU, the fish struggled violently again, breaking off its sword which was left stuck in the gap between the hulls. However, having the fish secure by the tail, we were able to hoist it aboard. On the deck the fish was weighed and measured. It was a small specimen of Xiphidae, 2.45 m long, weighing 89 kg. The reddish, bubbly stomach protruded from its mouth. The lower jaw also was broken by the impact some 8 cm from the tip. This fish was killed and its abdomen opened for the intestine investigation. Since no ichthyologist was present aboard during that cruise, we could not determine the sex of the fish, which in the case of swordfish is quite a difficult matter. The intestines contained a small amount of nondescript grayish substance, slightly granular and slimy. As ALVIN had surfaced, however, both the pilot and several others on LULU had seen the fish vomit out what appeared to be numerous squid.

During the submarine's ascent, I ascertained with Mr. Wilson who watched the incident through his port hole that the fish was lying on the bottom about 30 feet starboard from the place of ALVIN'S original landing. The fish suddenly rose from the bottom stirring up mud, turned and attacked ALVIN without hesitation, striking just below the starboard window. The inclined surface of the fiberglass hull deflected the sword towards the joint in hull and the sword thus was thrust in as far as its base. The point and left side of the sword missed the electrical cables and disconnect box and scraped along the steel inner hull causing the sound heard inside. The mass difference of one tenth of a ton of the fish versus fifteen tons of the submarine did not permit the fish's attack to register in a more dramatic manner.

On the tender, the crew removed the sword wedged in the submarine after some 2 hours' work. The inspection of the disconnect boxes showed no flooding and no damage to the insulation of electrical cables. Nevertheless, had the sword struck only one inch to the left, the cables could have conceivably been damaged.

Catches on deep lines and in trawls showed that the swordfish (Xiphias gladius) ranges as deep as 365 m. The ALVIN encounter and recent observations from another deep submersible DEEPSTAR 4000 (R. Haedrich, personal communication) in the northern Gulf of Mexico, indicate that the broadbill ranges at least to 610 m. In addition, these observations show that the broadbills will tolerate water as cool as 8°C and can lie on the bottom.

Dive No. 202 Log

Time (EDT)	Depth (m)	Observations
1340	0	Descending at 20 m/sec.
1348	158	Fine "snow".
1349	205	Rapid temperature fluctuations.
1355	310	Fine "snow"; microscopic creatures (about $5/ft^3$) darting about.
1402	470	Very fine "snow". One sardine-like fish; small jellyfish.
	550	Temperature fluctuations continue.
1415	562	External lights switched off; blue light still penetrates (?).
	593	Fluorescent ribbon passed the window; 8 inches long, 3/4 inches wide.
1422	610	Landed on bottom, headed SE.
1423	610	Bottom current measurement, 0.5 kts from 150°.
1424	610	Photo of bottom ripples and sand winnows, illustrating the bottom current from SE.
1425	608	Moving towards a lone branch of coral, 18 inches high.
1426	610	Photograph coral.
1428	610	Attacked by swordfish (8 feet, over 190 lbs.) at starboard porthole. Sword entered joint in fiberglass hull and became stuck there, capturing the fish. Photo of fish taken with hand camera. Check for leaks and wiring damage. Decided to abort dive.
1432	610	Beginning ascent
1500	2	Attendent skin-divers secure swordfish tail to submarine
1501	0	Surface

ALVIN Dive 203

Synopsis

Date : July 7, 1967

Time : 1415-1815 (EDT)

Location : 31°48'N, 79°15'W - coral banks on western edge of Blake Plateau

Personnel: M. McCamis - pilot

V. Wilson - co-pilot

J. D. Milliman - observer

Temperature and Resistivity Measurements in the Water Column

On descending and ascending, temperature and resistivity measurements were taken. Forty-three temperature and 29 resistivity measurements were made on descent and 24 temperature and 21 resistivity measurements on the ascent. Their variation with depth is shown in Figure 9. As with the measurements taken by Manheim, temperatures on the ascent were consistantly lower than descending values at corresponding depths. Unlike Manheim's observations, however, ascending resistivity measurements were not influenced by mud on the skids, and are therefore felt to be real, and constantly higher than corresponding descending values.

This increase in resistivity is expected with lower water temperatures. If one of the two parameters had remained constant, an instrument error would be suspected. Therefore it is felt that the temperature and resistivity measurements made during ascent are real, and represent passing through a different water mass.

Bottom Topography

Surface echo soundings revealed a series of coral banks or mounds with numerous side echos (Figure 10) in 500 to 550 m depth of water. A few tens of m above the bottom, ALVIN'S sonar showed these banks to be a series of elongate ridges and troughs trending NNE-SSW. The sonar screen had a radius of view of 1000 yards (900 m), yet the ends of most ridges were not detected, indicating ridge lengths in excess of 1 km. The wave length from ridge crest to the next successive ridge was estimated (from sonar) as 150 to 200 yards (135-180 m) the width of any wave crest being less than 10 m.

The two ridge crests visited shoaled to depths of 505 and 496 m; the intervening trough had a maximum depth of 54 m. Slopes varied from a few degrees at the base of the ridge to greater than 30 degrees near the crests. Average slopes are estimated as ranging from 25° to 37°.

Dune-like features were common in the troughs with reliefs of 2 to 4 m and wave lengths of 7 to 10 m. Many of the dunes were crescent-shaped and meandering; however, most dunes did seem to have a NS linear trend. Some rippled sand wand was seen, but the bottom generally was unrippled.

<u>Physical measurements on the bottom</u>

Bottom currents (measured by the Savonius rotor, 4 m above the bottom), although strongest on the ridges and weakest in troughs and leeward sides of ridges, were always strong (35 to 60 cm/sec) and always from the SW. Temperatures were 7.5° over the entire bottom. Resistivity measurements, both on the ridges and troughs, were generally lower than those made by Manheim. The coarseness and high porosity of the bottom sediments (see below) probably allowed water contact with the resistivity electrode, thus accounting for the low readings.

Throughout the entire dive visability was excellent. On bottom, pilot McCamis remarked that the water was as clear as any he had seen on previous dives. Bottom visability was estimated at approximately 30 m.

Biology

The most abundant concentration of life was at the top of the ridges. Deep-water branching corals, mainly the species Dendrophyllia profunda, cover perhaps 5 percent of the bottom. The coral Lophelia, was also common. Individual coral colonies varied in size, generally averaging about 15-20 cm in diameter and 10-15 cm high. The coral hosted a number of other organisms living within its confines. Anenomes and alcyonarians were present in sporadic amounts.. Orange brittle stars lived in corals, locally in high concentrations, greater than 100 individuals/m^2. Occasionally echinoids and gastropods were seen but their density was less than 1 individual/10 m^2. Large (greater than 20 cm across) spider crabs maneuvered on the bottom. The nature of the infauna is not known, but many tubes protruded from the sediment, their density being up to 500/m^2. These may be polychaete tubes.

Fish were never abundant. Some dogfish, rays, rat-tailed fish, and a pink snapper-like fish were seen.

Faunal density decreased down slope. In the troughs neither living coral nor any coral-dwelling organism were seen. As opposed to the abundant animal life seen on the ridges, the troughs seemed like a desert. Tiny bugs, similar to beach flea amphipods, were seen flitting around the bottom. Some small fish were seen together with several mottled dogfish, one small shark and numerous squid.

Prior to the dive, pilot McCamis baited a hook and attached it to the sled. On the trough bottom, when the line was grasped by the mechanical arm and the bait wiggled, the previously barren trough bottom began to come alive. Several crabs came up and tried to devour the bait. Several fish also approached but were chased away by the crabs. The speed with which mobile animals were able to respond to the baited hook makes me believe they were close-by, perhaps in hiding from ALVIN. Thus any estimate of mobile animals seen on the bottom may not be accurate since the animals may initially hide when ALVIN approached.

Sediments

Coarse sand and gravel, which comprises up to 40 percent of the sediment on the ridges, is primarily coral debris. The finer sand and silt contain many planktonic foraminifera and pteropods. The sediment becomes finer on the sides of the ridges, as coral debris decreases; near the base of the ridges, coral debris makes up as little as 5 percent of the sediment.

In the troughs between ridges, the sediment is much coarser. Estimated visually, the sediment contains more than 50 to 65 percent coral debris. The finer sediment is generally sparse although locally, especially in small depressions, it may be abundant. At several locations, a few blades of marine grass floated along the bottom.

Nowhere, on either the ridges or troughs, did I notice any rock outcrops. The only sedimentary structures of note were the rippled sands especially prominent in the troughs. The swift northerly currents flowing along the troughs nodoubt winnow most of the fine sediment and form ripple marks.

Although measured currents were faster on the ridges, the sediment is not as coarse. Perhaps the active coral colonies act as sedimentary baffles, thereby preventing sediment erosion. As sediment slumps off the ridges, the finer sizes are winnowed away, resulting in the prominent coral debris in the troughs. That this coral was transported from the ridges seems obvious since practically no living coral was seen in the troughs.

Several large (20-30 cm) piles of coral debris were seen on the ridge slopes. The origin of these mounds is not known, but they look similar to mounds of carbonates found in shallower water and which are made by burrowing shrimp and fishes. Perhaps similar organisms made these mounds.

Dive No. 203 Log

Time (EDT)	Depth (m)	Observations
1408	surface	Cup sensitivity (196); probe sensitivity (381); temp. 32°C.
1459	530	Reach bottom. Resistivity 1405. Muddy slope 4-5°. Crabs, worm tubes, a few skates, one rat-tailed fish 6 m away. Turning up slope--scattered living coral, 2-3 colonies/ft^2. Much coral debris in sediment.
		Living coral, can see polyps extended. Alcyonarians, about 1/m^2. Polychaete-like animals most prominent. Coral debris--2 to 7 percent--in a pelagic mud. Some gastropod fragments.
1520		Heading 220° slope at 1/2 kt., 15 percent of surface is living coral or coral debris.
1522		Lift off bottom--much snow.
1530	505	Top of ridge. Abundant living coral and debris--35-40 percent. Prominent species is Dendrophyllia profunda. Current out of south, 1.2 kts. muddy bottom with coral debris--sample was taken here.
1533	505	Mottled dogfish
1535	505	In front of submarine, ridge drops; slopes greater than 15°. Bottom fauna includes coral, brittle stars, polychaetes, alcyonarians. Resistivity measurement 1252.
1542		Moving to SE, going down slope, steep. Losing coral abundances. Sonar shows lineated ridges oriented NNE-SSW.
1555	546	In trough between two ridges. Bottom is a series of depressions, no hardrock. A current of .7 kts. Sediment mainly coral debris, but little living coral. Dunes running approximately NS, 2-3 m relief. Wave length less than 10 m.

Dive No. 203 Log con't.

Time (EDT)	Depth (m)	Observations
1606	546	Moving along bottom to SW. Visability 30 m. Large crabs. When ALVIN stirs up bottom, mud is winnowed away.
1611	546	Stop. Bottom has ripples, but generally a large dune feature. Coral debris estimated at 30-50 percent of bottom. Fish are scarce, only a few 10's m^2. Current 180, at 36 cm/sec. Pictures of mud streaming away in current as stirred up by ALVIN. Not much living sessile animals. Ridges oblong, but trending of long axis is NS. Sediment in some spots is quite muddy, especially in locally small depressions. Resistivity 1470. Current from SW at 32 cm/sec.
1636	546	Current 34 cm/sec from SSW.
1648		Moving SE to another coral ridge.
1657		Beginning up slope, 9-10°. Occasional mounds of coral debris, perhaps made by some animal.
1659	540	Ascending E up slope at 1/2 kt. Coral covers an estimated 75% of bottom. Much life in corals, especially brittle stars. Ridge trending E or N slope 20-30°.
1702	3	Steering NE at 1 kt.
1704	514	Stop. Resistivity 2530.
1707		Climbing again, heading NE at 1 kt.
1717		Reached the top of one ridge, trending along it SE. Steep terraine on either side--30°. No rock outcrops.
1717	505	Bottom still rising; sediment is much finer. Living corals, schools of squid.
1720	500	Strong current, still heading SE. Tremendous quantity of brittle stars in each coral clump; 20-100/m^2. Slopes on top very steep, 40° or more. Mud, coral debris. Crabs with heart-shaped carapice and long legs.

Dive No. 203 Log con't.

Time (EDT)	Depth (m)	Observations
1742	496	On top of ridge; going over the ridge to the east. Not much living coral or anything else.
1743	505	Heading N, with current.
1744	520	On lee side of ridge.
1749	522	Resistivity 1440, current 220° at 25 cm/sec. Muddy slope with some coral debris.
1755		Lift off bottom.
	175	Water sample taken in layer of high suspended matter.

ALVIN Dive 204

Synopsis

Date : July 13, 1967

Time : 1051-1401 (EDT)

Location : 35°37'N, 74°49'W--continental slope north of Cape Hatteras

Personnel: M. McCamis - pilot

F. T. Manheim - observer

J. D. Milliman - observer

Physical measurements of the overlying water column

The temperature and resistivity measurements made during dive 204 are shown in Figure 11. The resistivity probe did not operate correctly during descent; values read at depths greater than 175 m were completely anomalous, probably due to a loose wire connection. The resistivity probe was attached to the sample rack and was lost when the rack was jettisoned.

A clear transition between Gulf Stream and slope waters was noted at 250 m. As ALVIN steamed west, out of the Gulf Stream, temperatures dropped from about 14° to 9°. On ascent, we remained in the slope water, as shown by the closeness of fit with descending values below 250 m and difference from Gulf Stream values above 250 m.

Midwater Biology

Prior to diving, a deep-scattering layer was recorded at 1000 EDT, by surface sonar, using a 12 KC/sec transducer, a Gifft Precision Sonar Transceiver and a Gifft depth recorder, Model GDR-IC-19. A strong return occurred between depths of 212 and 286 m and weaker reflectors occurred at depths of 286 to 346 m and 392 to 448 m (Figure 12).

During ALVIN'S descent we passed through several layers in which various organisms were present, frequently to the exclusion of others. From a depth of 215 to 253 m, and again at about 500 m, large members of squid 10 to 24 cm long, were seen. A species of silvery-colored lantern-like fish 2 to 6 cm long, was prominent in depths from 253 to 350 m and 570 to 610 m. Another species of fish, longer (3 to 7 cm) and thinner, was seen at depths of 614 to 660 m. Small (1 1/2 to 5 cm), translucent shrimp-like crustaceans with red-orange-colored organs and long antennae (about 1 1/2 times body length) were present in large concentrations between depths of 370 and 510 m.

During ascent, about 1/2 km west of the descent area, a thick shrimp layer occurred between 415 and 345 m, a fish zone with some shrimp between 311 and 280 m, and a squid layer in depths of 280 to 240 m. These layers correspond closely with those observed during descent.

In the middle of each layer, populations were almost exclusively monospecific, but at the peripheries populations were mixed.

Independent volume estimates were made by Milliman and Manheim which, for the most part, agreed within a factor of 2. In low faunal densities, however, sporadic distributions resulted in estimates of unknown reliability.

The distribution of squid, fish and shrimp correspond closely with the depths of the strong and two weak reflecting layers, respectively (Figure 13). That squid and euphausids may be primary reflectors in scattering layers disagrees with the widely-held theory that only air-bladder animals (which neither squids or shrimp are) can be prominent sonic reflectors (see Hersey and Backus, 1962). It is concluded that while these animals might be numerically dominant in scattering layers., they do not represent the actual sound scatters.

Suspended matter was common throughout the water column. Large globs of flocculent material were prominent near the surface (less than 50 m) on descent and at less than 225 m on ascent. Highest total suspended matter concentrations (including microplankton) occurred at depths of 277 to 614 based on visual estimates as discussed previously. At 690 m suspended matter increased to the bottom. On ascent, suspended matter concentration seemed to vary directly as the plankton and nekton concentrations. This suggests either a causal relationship (plankton and nekton are attracted to suspended matter) or an effect (plankton and nekton produce, probably by defecation, much of the suspended material).

Bottom Topography

By plotting distance traveled (speed x time traveled) against depth at various times, a cross section of the bottom was made (Figure 14). The bottom slope averaged 14°, but in places, especially the upper parts of the traverse, slopes were greater than 70°. On the bottom traverse, sides usually shoaled to the left of the sub (south) as well as ahead (west), giving us the impression that we were traveling either up a hill side or gully. At depths of about 610 m, sonar showed steep walls on the south, west and north sides suggesting that we were at the head of a box canyon. Unfortunately at this point we had to terminate the dive.

Sediments

The bottom was covered with a fine mud, with small amounts of sand. Sediment color was dark olive brown. Shallow, small depressions 5 to 10 cm deep, were ubiquitous on the bottom; their origin is not known. The escarpment at 610 m exposed an unconsolidated outcrop with a large number of pelecypod shells.

Since no such pelecypods were seen living on the bottom and none have been found in North Carolina slope sediments studied at WHOI, it is assumed that these shells may be fossil fauna, either indicating the underlying strata or a slump deposit. If a rock outcrop, it might correspond with the Trent Formation (Miocene) (Heezen et al., 1959). A sample was taken, but the accidental jettisoning of the sample basket resulted in its loss.

The fact that no indurated outcrops were seen and that sediment is able to maintain its competency at such steep inclinations, seems surprising. Possibly the large amount of worm tubes in the sediment (see below) helps firm the sediment much the same as straw aids adobe.

Bottom Biology

The most conspicuous epibenthic animals observed were fish. On initial landing we passed through an extremely dense school of small (2 to 5 cm long) fish, an estimated 10^3 to 10^4 individuals m^3. Populations were so dense that our visibility was often less than 1/2 m. After several minutes of driving along the bottom, we passed out of this school.

Over most of the bottom traversed, there were relatively large numbers of benthic fish, primarily two types: a flat, sole-like fish, 8 to 15 cm long, and a slow-moving calico-colored, eel-like fish 3 to 20 cm long. The distributions of these fish varied; locally they could be absent or together could comprise populations greater than 1000/100 m^2. On several occasions the eel-like fish were seen burrowing into the bottom.

Other epibenthos was sporadic. Orange anemones in places reached concentrations of 300/100 m^2; for the most part, however, these anemones were very sparsely distributed. Occasional orange brittle stars and starfish were seen; a few crabs and one snail were also noted.

Polychaetes comprised an apparently flourishing infauna. Several types of tubes were noticed; some were white, straight tubes sticking straight out of the mud bottom, others were slime-covered, hoop-like tubes. Some polychaetes were seen extending from their tubes but for the most part no sign of life was seen. Total population of tubes ranged from less than 1000/100 m^2 to greater than 10^4/100 m^2; in the bottom near the steep escarpment, estimated populations exceeded 2 x 10^4/100 m^2.

Near the bottom, populations of small (less than 2 cm long), shrimp-like crustaceans were seen swimming in the water, occasionally resting on the bottom.

Dive No. 204 Log

Time (EDT)	Depth (m)	Observations
1051	22	Gelatinous flocs and blobs of suspended matter up to 1 1/2 cm in diameter
1056	38	Jellyfish same size as largest flocs of suspended matter. Suspended matter increases in concentration.
1100	79	Particulates no longer visable due to diminished light.
1105	88	ALVIN is rising--perhaps we have drifted into saltier water.
1106	80	Strong current
1110	157	Light extinct
1112	175	A few gelatinous flocs and blobs of larger size, but mainly around 0.2 to 1 mm.
1114	215	Squid becoming abundant
1115	223	Many squid 10-24 cm long, squirting yellow ink at submarine.
1120	246	Driving west because of severe NE drift. Altitude above bottom--4400 ft. some luminescent fish.

Dive No. 204 Log

Time (EDT)	Depth (m)	Observations
1124	248	Large numbers of squid, 20 seen in small area. Many luminescent plankton seen when lights out or dim. Luminescence when they bump against sub.
1126	253	Small fish, 2-6 cm long, minnow-like silver in color darting about in rapid motions. $600/10^3m^3$.
1136	277	Beginning to descend out of Gulf Stream. Rich plankton in fine snow. Fewer fish--$200\text{-}300/10^3m^3$.
1152	324	Many fish--$2000/10^3m^3$; some squid.
1154	370	Shrimp beginning to appear; some squid.
1155	408	Shrimp becoming almost exclusive--$5000/10^3m^3$. About 1 1/2 to 5 cm long, with long transparent bodies, with red-orange central organ; parallel antennae extending to rear about 1 1/2 times body length.
1157	420	Nearly exclusively shrimp--$6000/10^3m^3$. A 2m shark seen.
1204	510	Shrimp beginning to thin out.
1205	525	Many squid, thinning to $500/10^3m^3$.
1210	570	Shrimp very few; some squid. Small fish--$600/10^3m^3$. Long studded necklace-like objects, 3 to 20 cm long--Ctenophores (?). Some jellyfish.
1212	614	Fine snow; fish $300/10^3m^3$--a new species, longer (3-7 cm) and thinner.
1213	633	More necklace-like animals.
1214	651	Increasing numbers of long fish--1-3 x $103/10^3m^3$. Long fish has vibrating tail.
1215	660	Fish thinning to $200/10^3m^3$; some shrimp still present. Fine snow.
1216	667	Fish beginning to increase again.
1220	690	Near bottom--huge school of fish (2 to 5 cm long), and estimated population of $10^3\text{-}10^4/m^3$. Cannot see 1/2 m out of window.

Dive No. 204 Log

Time (EDT)	Depth (m)	Observations
1226	707	On bottom. Resistivity is not working correctly. Bottom current from west at 0.12 cm/sec. Sediment is fine mud with some sand. Visability very poor, less than 2 m. Sole-like flat fish dwelling on bottom; slow moving, eel-like fish (3 to 20 cm long) have brown, calico-like patches on body; fish population is patchy, but locally can reach 10-20/m^2. Many orange anemones, some orange starfish. Clumps of polychaete tubes--some white and extending out of bottom, others slime-covered, hoop-like tubes. Large pits and small borings on undulating bottom.
1235		Dive 1/2 kt west. Visability increasing to 5 to 8 m. Many animal tracks. Bottom shoals on south; perhaps we are in a gully.
1237	683	Stop. Near bottom current about 3 cm/sec. Water sample taken. Small shrimp (about 1 cm long) in water occasionally resting on bottom.
1246	683	Begin driving to west at 1 kt. Masses of polychaete bubes sticking out of bottom--4-10 x $10^3/10^2 m^2$. Fish common; flat fish move slowly over the bottom in starts and stops possibly causing many of the tracks we see. Eel-like fish appear to be burrowing into the bottom. Orange-colored brittle stars in clumps of 2-3/m^2.
1253		Driving 1/2 kt WNW. Pass over a small depression; bottom then rises sharply. Bottom shoals steeply to south.
1257	674	Polychaetes locally abundant--10 to 20/m^2.
1258		Slow to 1/8 kt because of poor visability.
1301	667	Stopped. Gooey mud; 5 to 10 cm deep (and diameter) holes in bottom.
1303		Started driving again 1/2 kt. 2000 fish/100 m^2. Large, orange starfish; 300 anemones/100 m^2; 5-10 x 10^3 polychaetes/100 m^2. Some small shrimp in water on bottom.
1306	655	Evidence of slumping; many 5-6 cm depressions. Few fish, bottom populations have decreased. Visability worsened fine snow and considerable mobile plankton dancing near window--luminescent.

Dive No. 204 Log con't.

Time (EDT)	Depth (m)	Observations
1308	648	Lost sight of bottom--probably another shallow depression.
1310	631	Better visibility, 6-10 m.
1311	629	Polychaete tubes with some worms sticking out.
1312	616	At head of an apparent box canyon, with almost vertical walls on south and west faces.
1317	595	Sonar indicates a wall to the north also. Abundant polychaete masses (10 1-2 x $10^4/10^2m^2$); these may help to support the steep slope. Outcrop of sediment with many small (3-5 cm) white pelcypod shells sticking out; this sediment is unlithified--sample taken of shells. Rills and vertical lineations downslope. Disipating mud flows downslope triggered by ALVIN'S movements. Suspended matter is fine and stringy. Weather worsening on surface; we are requested to come up.
1320	593	Sample rack accidently jettisened. On way up.
1339	415	Shrimp--$5000/10^3m^3$. Heavier snow.
	345	Marked decrease in suspended matter and also in shrimp.
	311	Fish zone--fish 3-4 cm long; some shrimp.
	280	Squid, 8-20 cm. Suspended matter increases.
	260	Strong current.
	240	Large school of squid, 10-14 cm long; some fish.
	224	Longer pieces of suspended matter, but otherwise water is comparatively clear. Few fish.
	186	Matter larger, but lesser concentration.
	175	Some light--water bluish color.
	52	Gelatinous-floculent suspended matter starts.
1401	0	Sparse suspended matter

Summary of Results

1. The dominant impression on the southwestern portion of the manganese pavement area was one of strong, north-flowing bottom currents (up to 75 cm/sec) and constant motion of coarse foraminiferal-petropod sand over the manganese-phosphate pavement. Occasional large slabs of iron and manganese-impregnated phosphate were noted and a 10 kg piece was recovered. Temperatures on bottom were 14-14.5°C at 530-550 m depth, reflecting the influence of the axis of the Gulf Stream.

2. Assuming previous reports by ALUMINAUT correctly located the position of depressions, we conclude that the depressions must be small and localized explaining why the depressions were missed on all sounding tracks. Other depressions which were potential sites for present or past ground water discharge could not be investigated, primarily because of strong currents or rough seas. Further investigations of such depressions by ALVIN will require detailed preliminary bathymetric surveys and perhaps greater speed capabilities on the part of the submarine tender.

3. At the western margin of the manganese pavement a bottom of low hills and mounds of calcareous ooze gave way to a flat floor of Campanian-Maestrichtian (Upper Cretaceous) limestone of about 555 m depth. The relatively erodable limestone was irregularly covered with lag gravels, slabs and boulders of iron and manganese-impregnated phosphate and phosphate limestone. Bottom temperature was about 7°C with low (less than 10 cm/sec) currents from the north. This reflects (probably temporarily only) influences of colder slope water; evidence of much stronger WE currents was noted from the rippled bottom oozes.

4. Dive 202 was aborted soon after reaching bottom due to an unusual swordfish attack. The attacker was later eaten by the crew.

5. The coral banks on the western edge of the Blake Plateau are actually a series of linear ridges and troughs, trending north-south. Wave lengths are about 80 to 100 m, and ridge lengths (north-south) are greater than 1 km. Relief of the western ridges (Dive 203) locally exceeds 50 m. On the eastern fringe (Dive 201) the relief is less than 10 m. A prolific coral community lives on the ridges; the troughs are relatively free of living epifauna, but do contain much coarse coral debris, apparently eroded from the ridges.

The regularity of wave length, together with the linear trend of the ridges paralleling the slope break suggest that the basement of the coral growth may be related to some regional (perhaps structural) feature. The coral, preferring to grow in clear water, free of moving sediment, grow on the topographic highs, therefore accentuating the ridges' relief.

6. Results for suspended matter sample collected from all dives are shown in the below table:

Dive No.	Depth (m)	Remarks	Total susp. matter mg/l	% combustible org. matter
200	543	bottom water	1.8	75
200	547	bottom water	2.2	83
201	518	Sta. E. Fig. 54 current 2-5 m/sec	1.7	76
203	175	water column; visually high concentration of suspended matter	0.15	>50*

*Ash content of 0.075 mg 15 too high due to incomplete washing of the filter and consequent partial weighing of salt residue.

The results confirm visual impressions that organic detritus forms the overwhelming proportion of suspended matter, even very close to the sea floor, in the areas studied. Even the ash itself appears to be largely associated with organic matter (e.g. diatom and radiolarian silica and inorganic residue of organisms) as examination of the filters under the microscope revealed relatively few mineral particles.

The sample from the water column in Dive 203 shows that a fairly thick rain of "snow" consisting of fairly large, easily discernible particles (though gelatinous and highly organic rich) need weigh very little.

Since the bottom sediments are known to contain only relatively small amounts of organic matter, bottom-dwelling organisms must be highly effective in consuming organic matter.

7. The deep scattering layer observed in the water column off the continental slope of North Carolina is comprised of layers of squid, myctophid-like fish, and shrimp-like crustaceans. In each layer one type of these three animals seems overwhelmingly dominant, giving a definite infra-structure to the scattering layer.

8. The steep slope observed on the continental slope off Cape Hatteras exceeds 70° in places. An apparent outcrop was seen and sampled, but the samples were subsequently lost when the sample rack was jettisoned. Polychaete worm tubes apparently increase sediment competency on steep slopes.

9. Bottom resistivity measurements appear to be convenient and effective in searching for salinity anomalies in pore water, as well as detecting anomalous water properties on the ocean bottom. Supplementary data on the response of the sonde to sediments having varying porosity will help quantify the results.

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Figure 1. Location and bathymetry of dive locations. Depths in meters. Bathymetric contours are based on Uchupi (1967). Star indicates approximate position of ALUMINAUT loss of buoyancy. Note that depths in dives 201 and 203, about 510 to 550 m, do not agree with the map contours. Elazar Uchupi informs us that the bathymetry in this area is based on relatively sparse lead-line soundings, chiefly from pre-World War I surveys. The ALUMINAUT hole and the narrow depression shown SE of dive 201 could not be confirmed by several traverses across them.

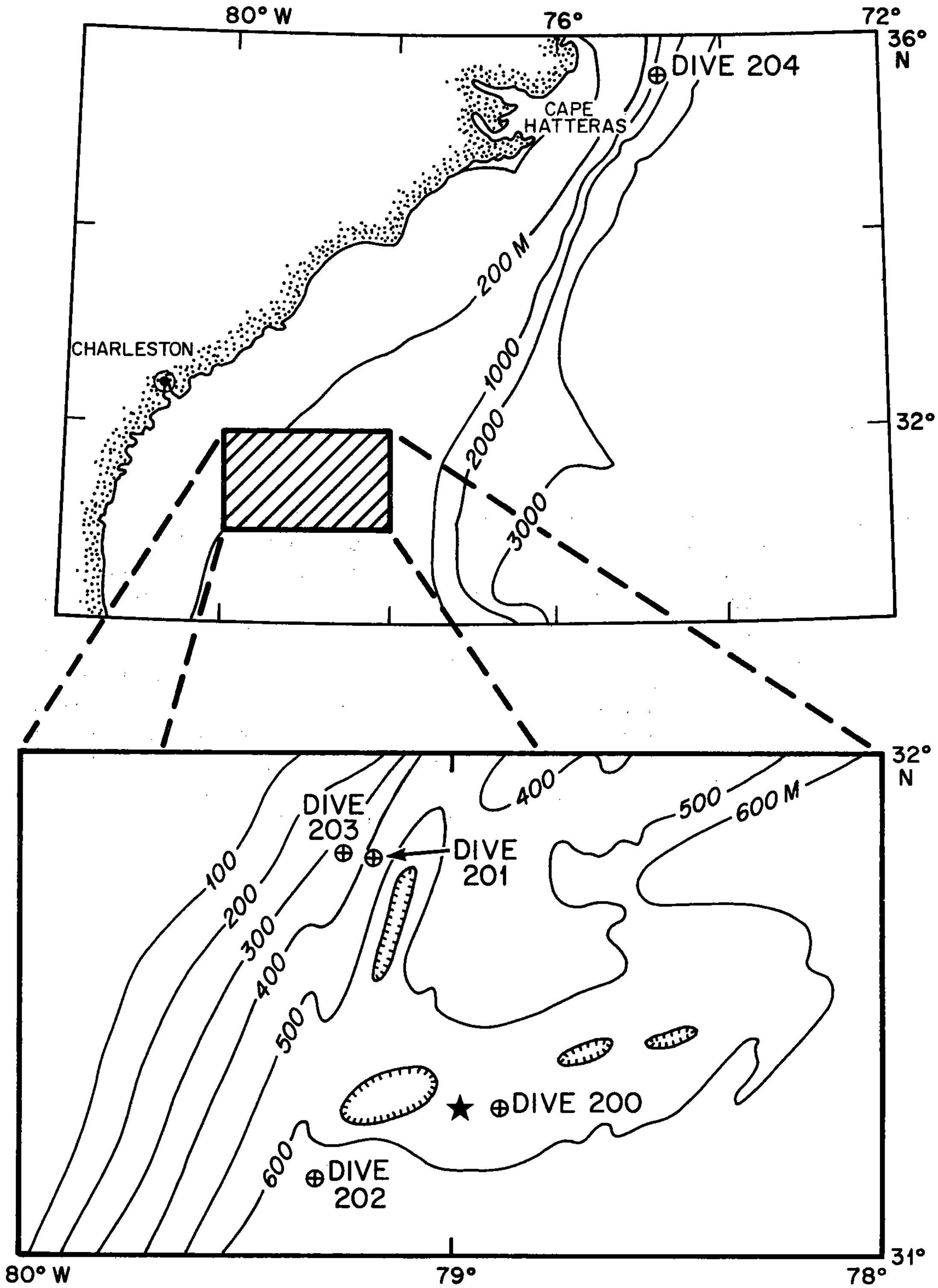
80° W
76°
72°
36° N
DIVE 204
CAPE HATTERAS
200 M
1000
2000
3000
CHARLESTON
32°
32° N
DIVE 203
DIVE 201
400
500
600 M
100
200
300
400
500
600
DIVE 200
DIVE 202
80° W
79°
78°
31°

Figure 1.

Figure 2. Photograph of ALVIN, showing: a) Savonius rotor and underlying thermistor; b) Edgerton cameras; c) sample rack. The sample rack is shown in closer detail in the lower left photograph. This photo was taken from ALVIN during dive 200. The numbers in the left inset refer to 1) coring tube; 2) large lucite water sampler in pick-up position; 3) pry bar; 4 and 5) water sampler receptacles; 6) TV target; 7) small lucite water sampler in pick-up position (only handle visable). The background shows manganese-phosphate pavement partly covered by alcyonarian corals and shifting *Globigerina* sand. The resistivity probe (approximately one meter long), shown in the lower right photograph, was attached to the under part of the sample rack (see arrow).

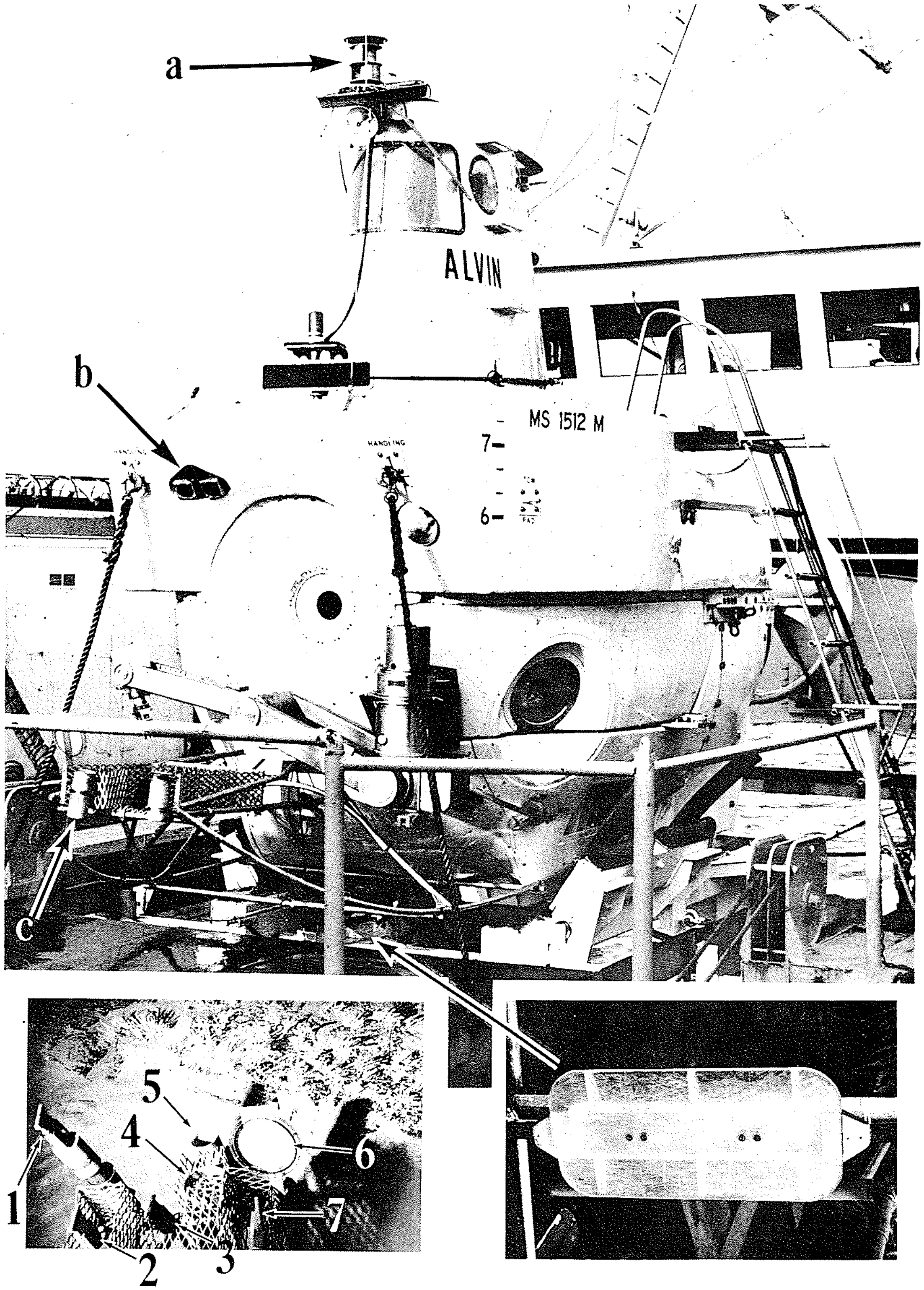

Figure 2.

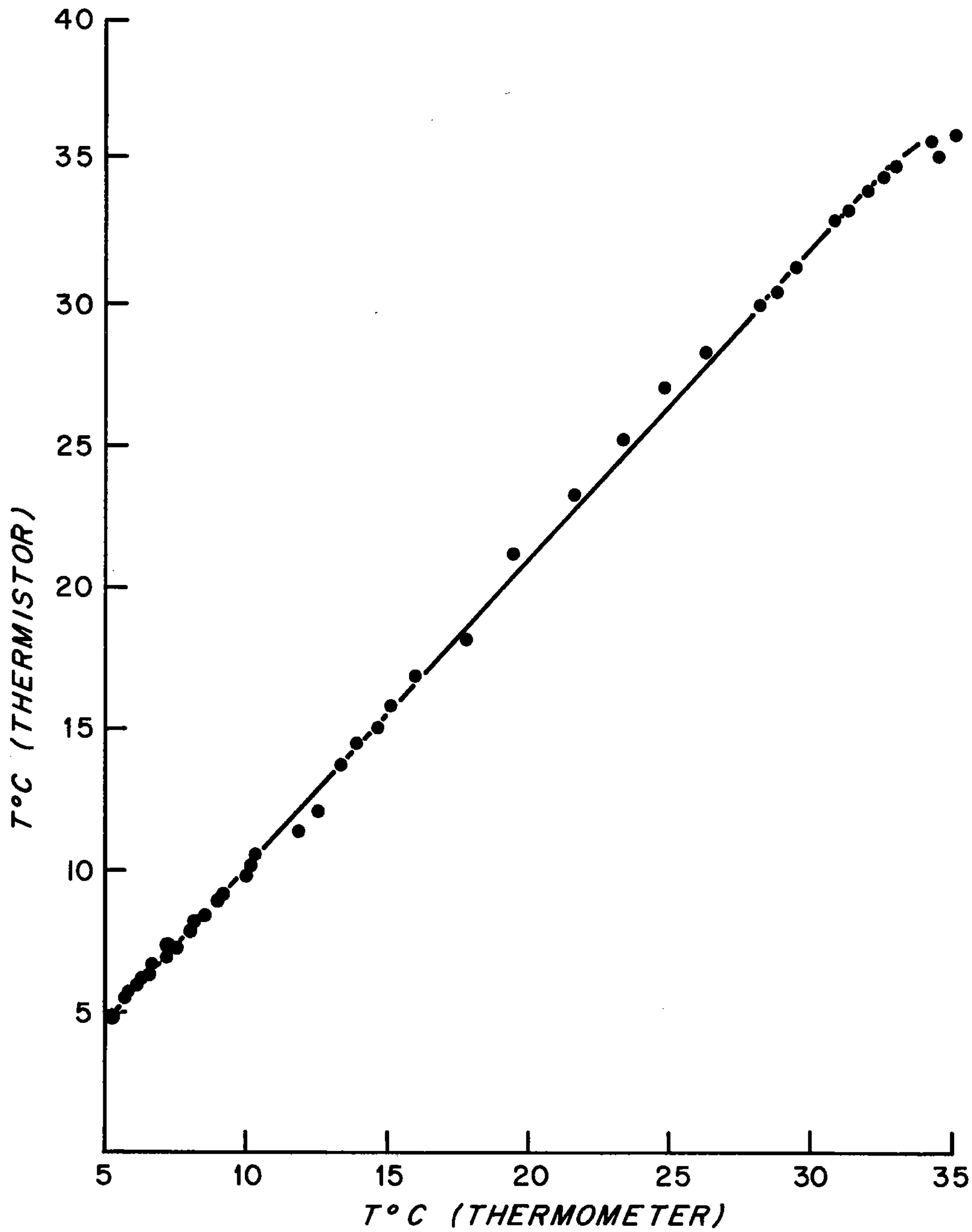

Figure 3. Calibration curve of the thermistor (versus a mercury laboratory thermometer).

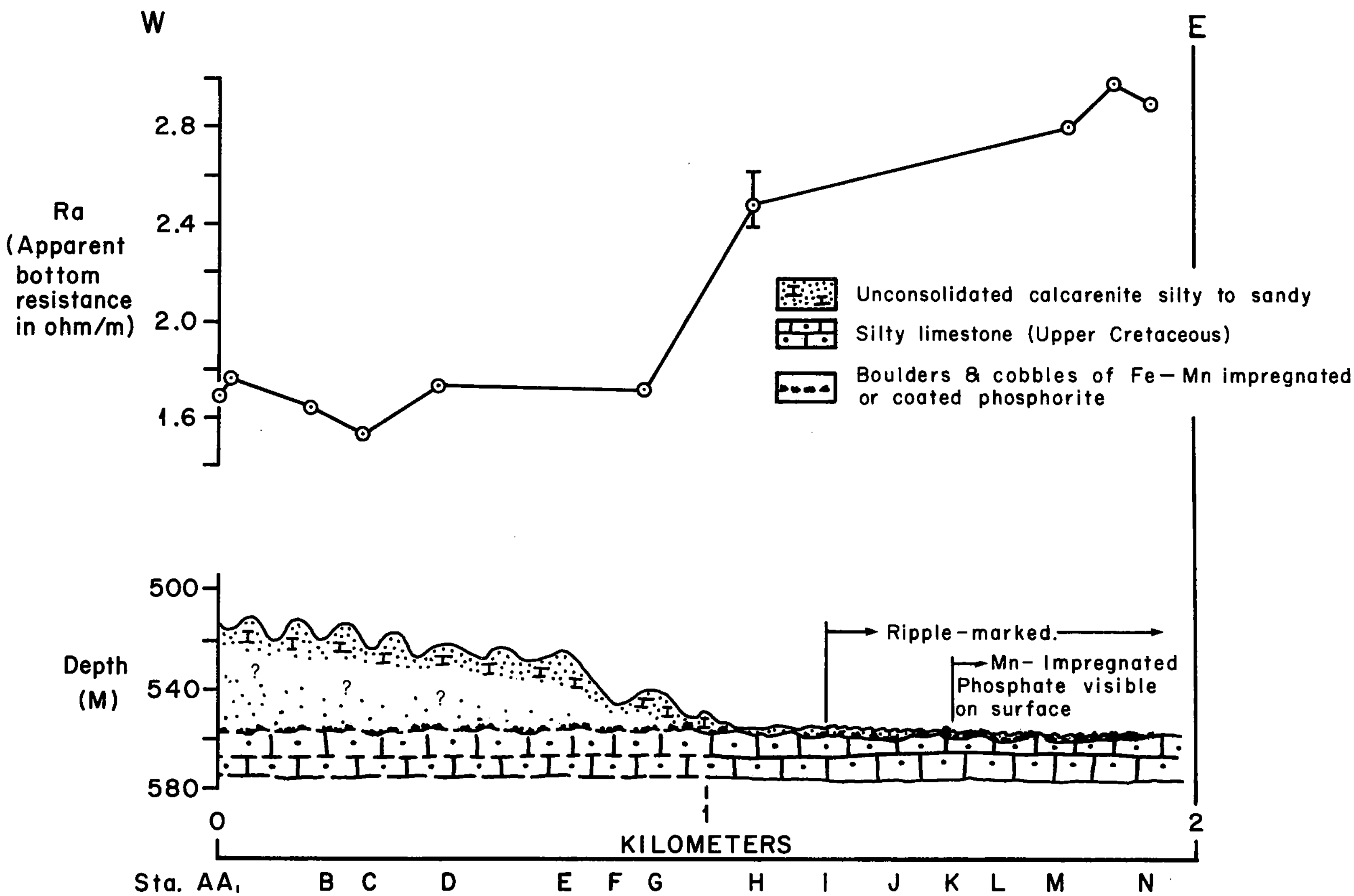

Figure 4. Bottom profile with corresponding resistivity measurements, made during Dive 201.

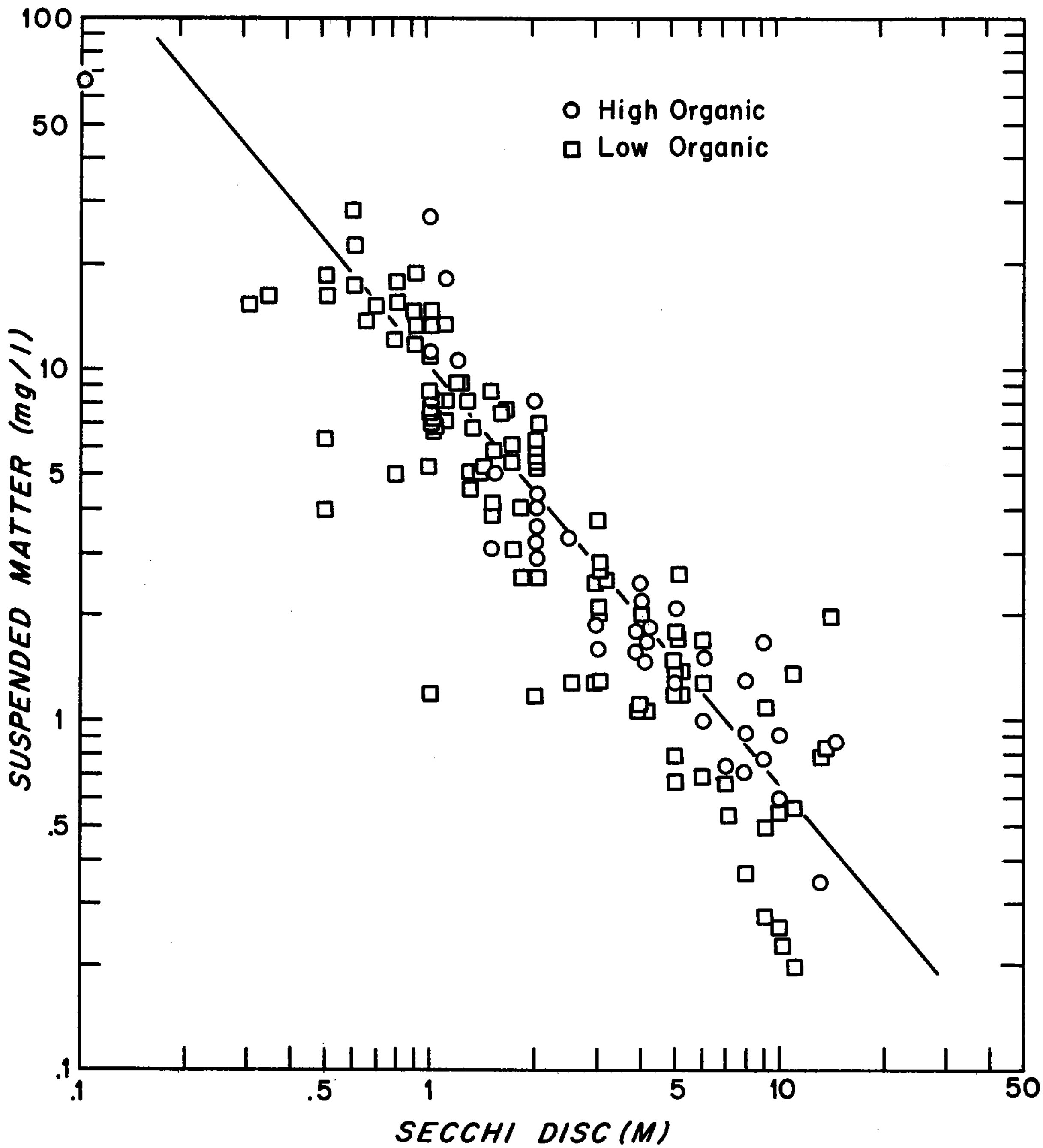

Figure 5. Suspended matter concentrations in waters along the Atlantic continental shelf.

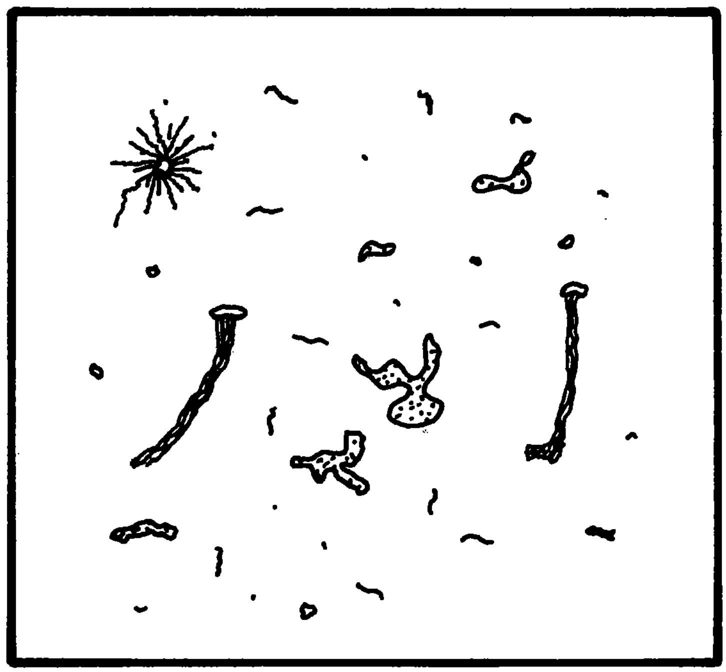

Figure 6. Sketches of filaments seen suspended in water column. Particles shown are an estimated three times natural size (including lens effect of viewing port, by Manheim).

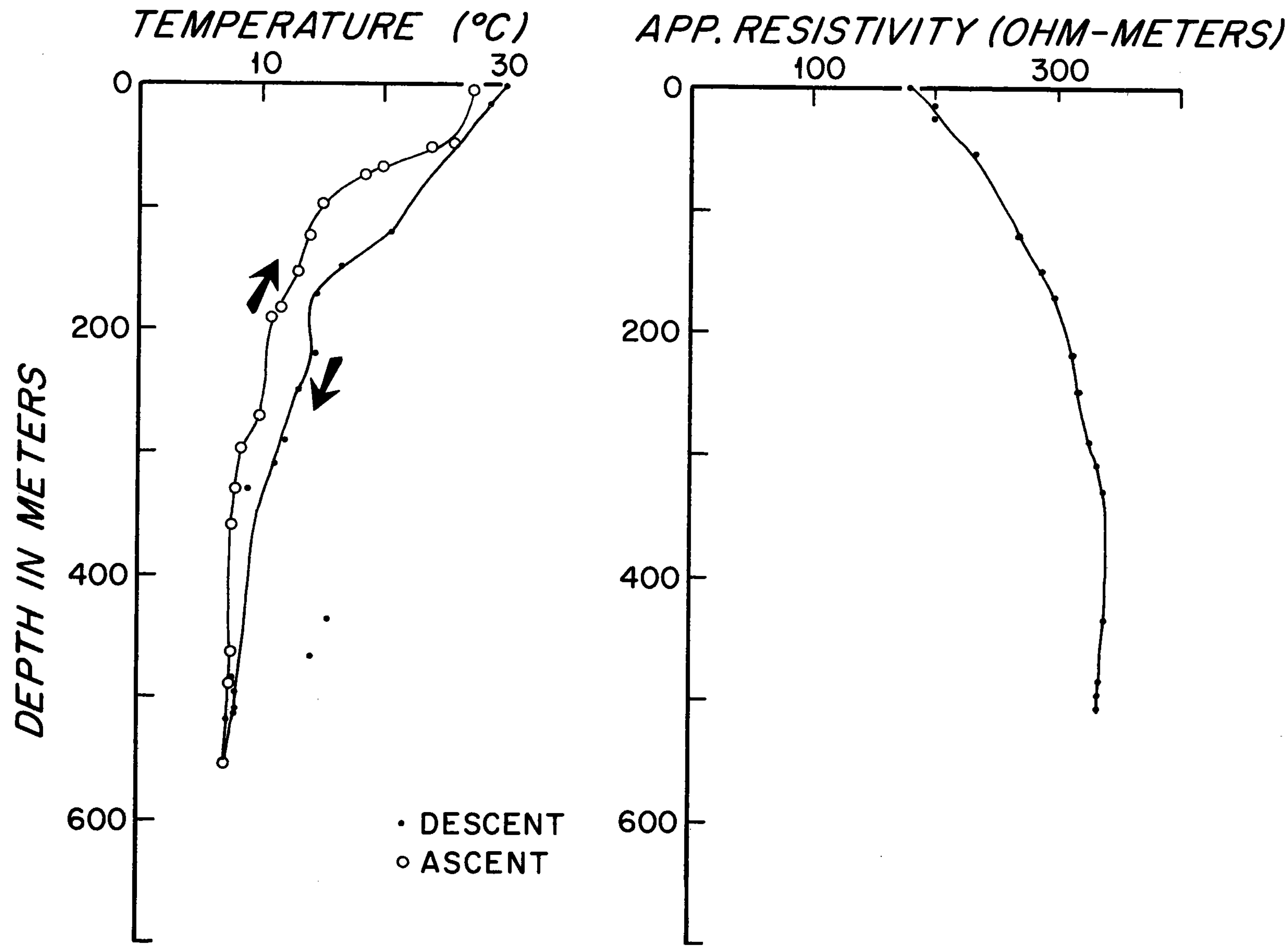

Figure 7. Temperature and resistivity results from Dive 201.

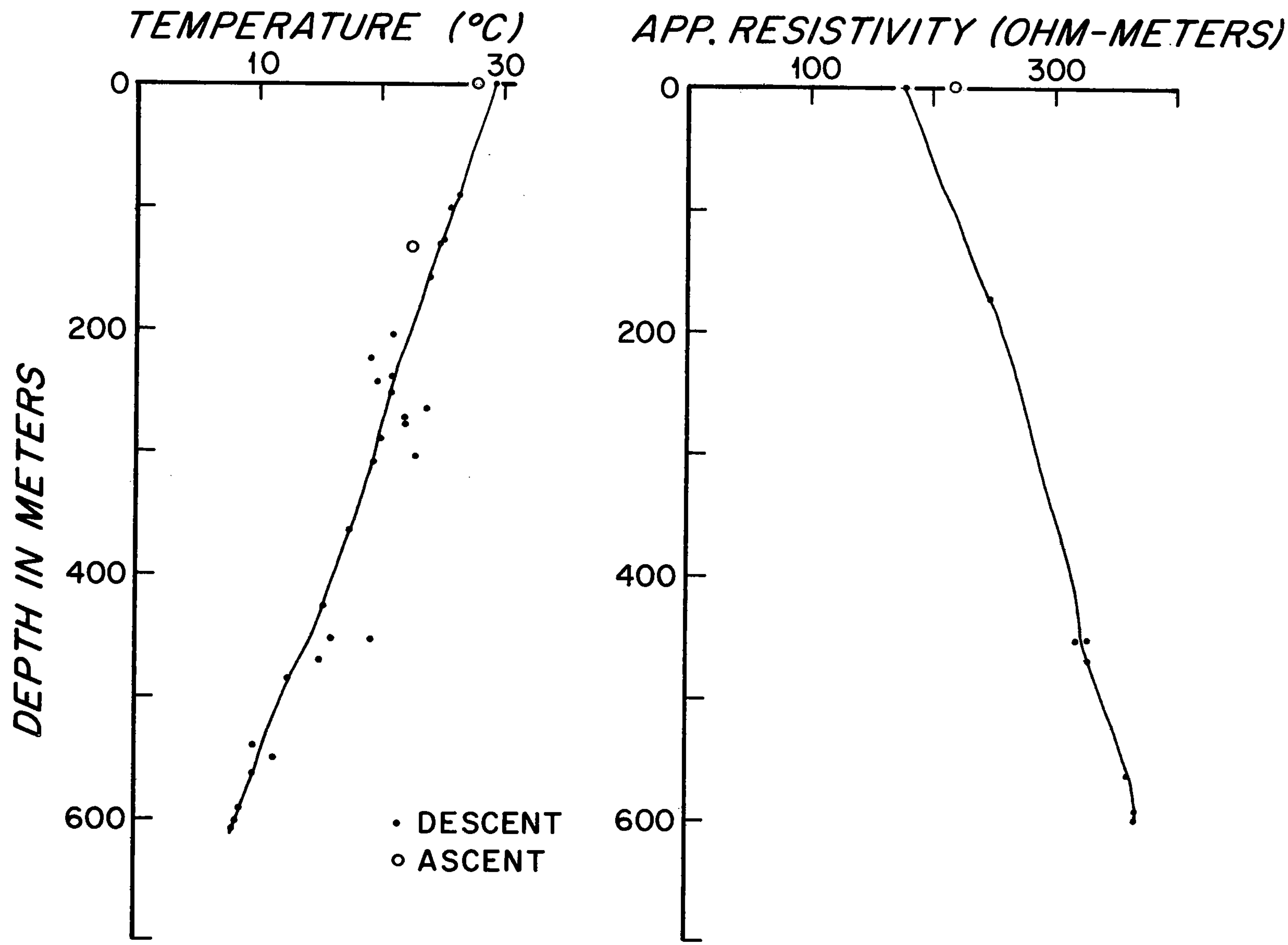

Figure 8. Temperature and resistivity results from Dive 202.

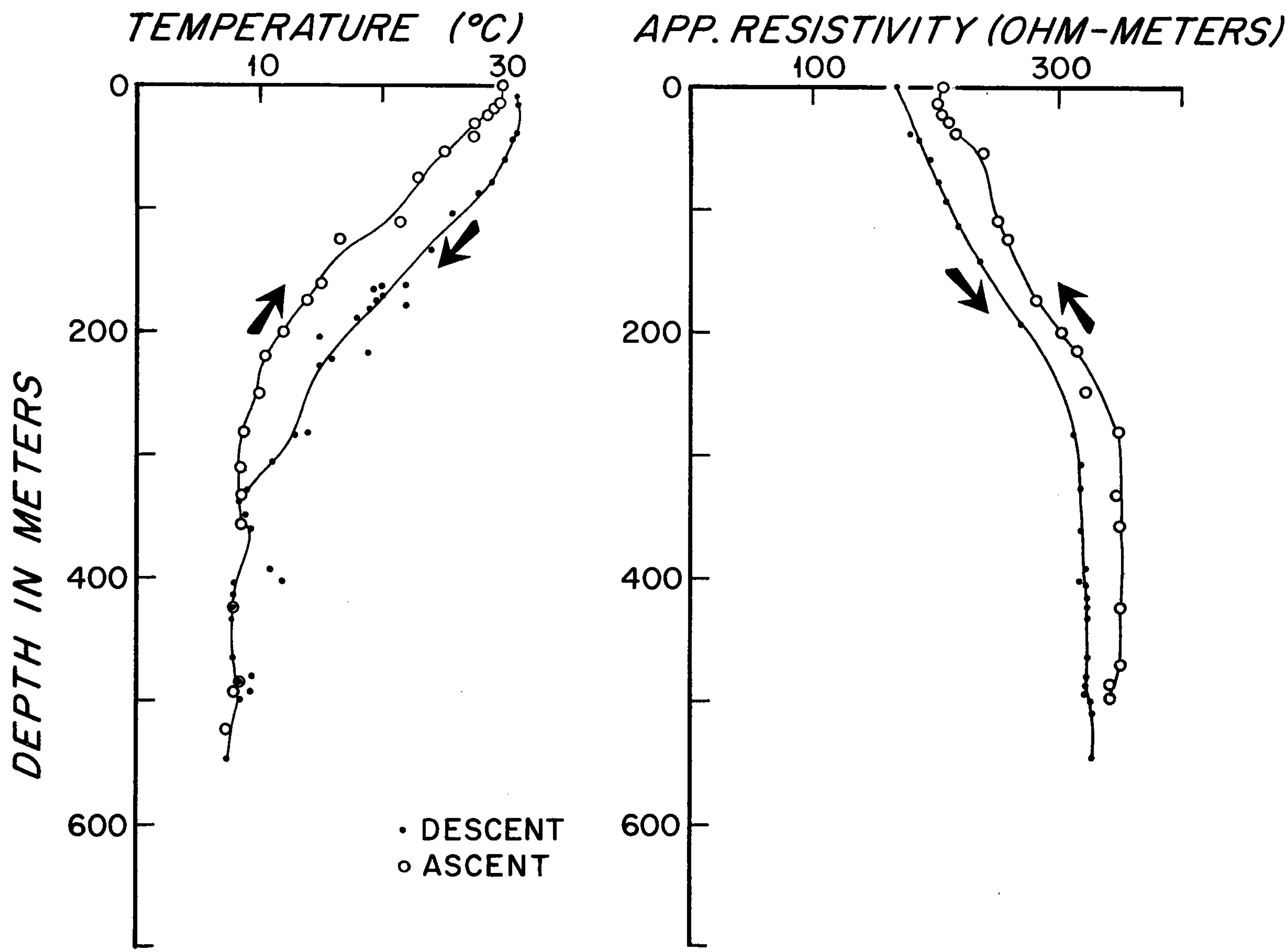

Figure 9. Temperature and resistivity results from Dive 203.

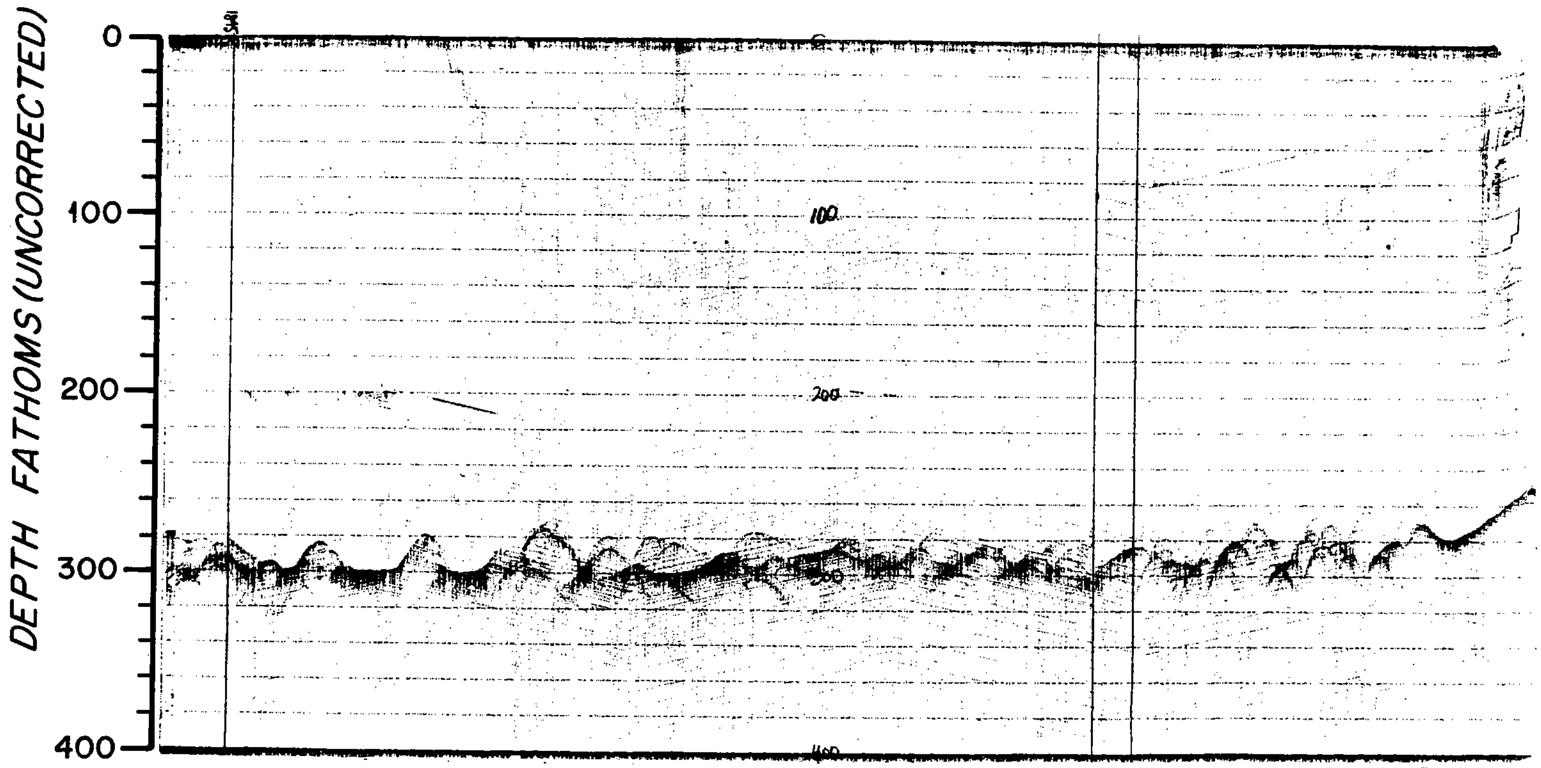

Figure 10. Echo soundings of coral "mounds" bordering the western edge of the Blake Plateau, near the Florida-Hatteras Slope. Depths are in fathoms, uncorrected.

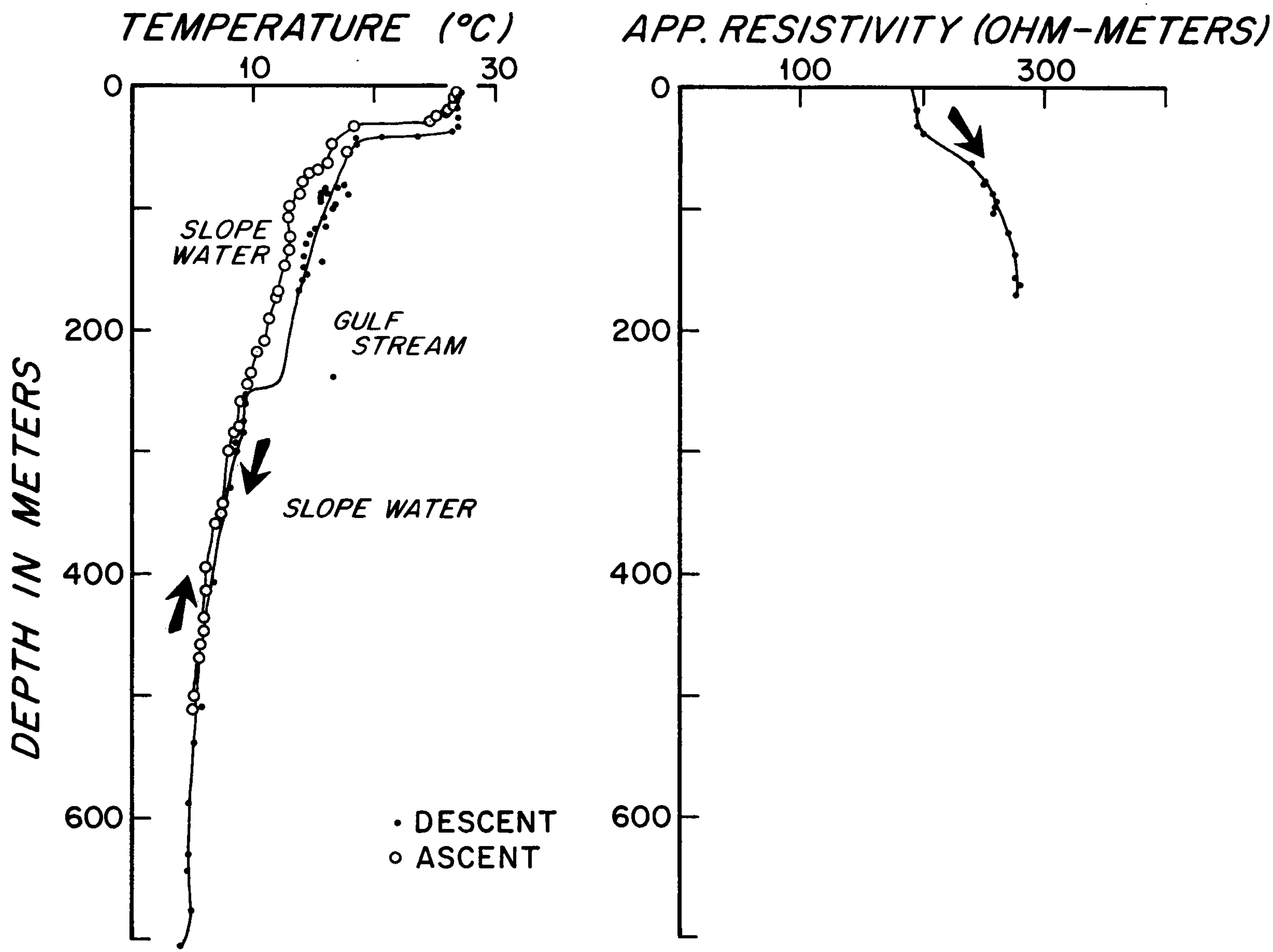

Figure 11. Temperature and resistivity results from Dive 204.

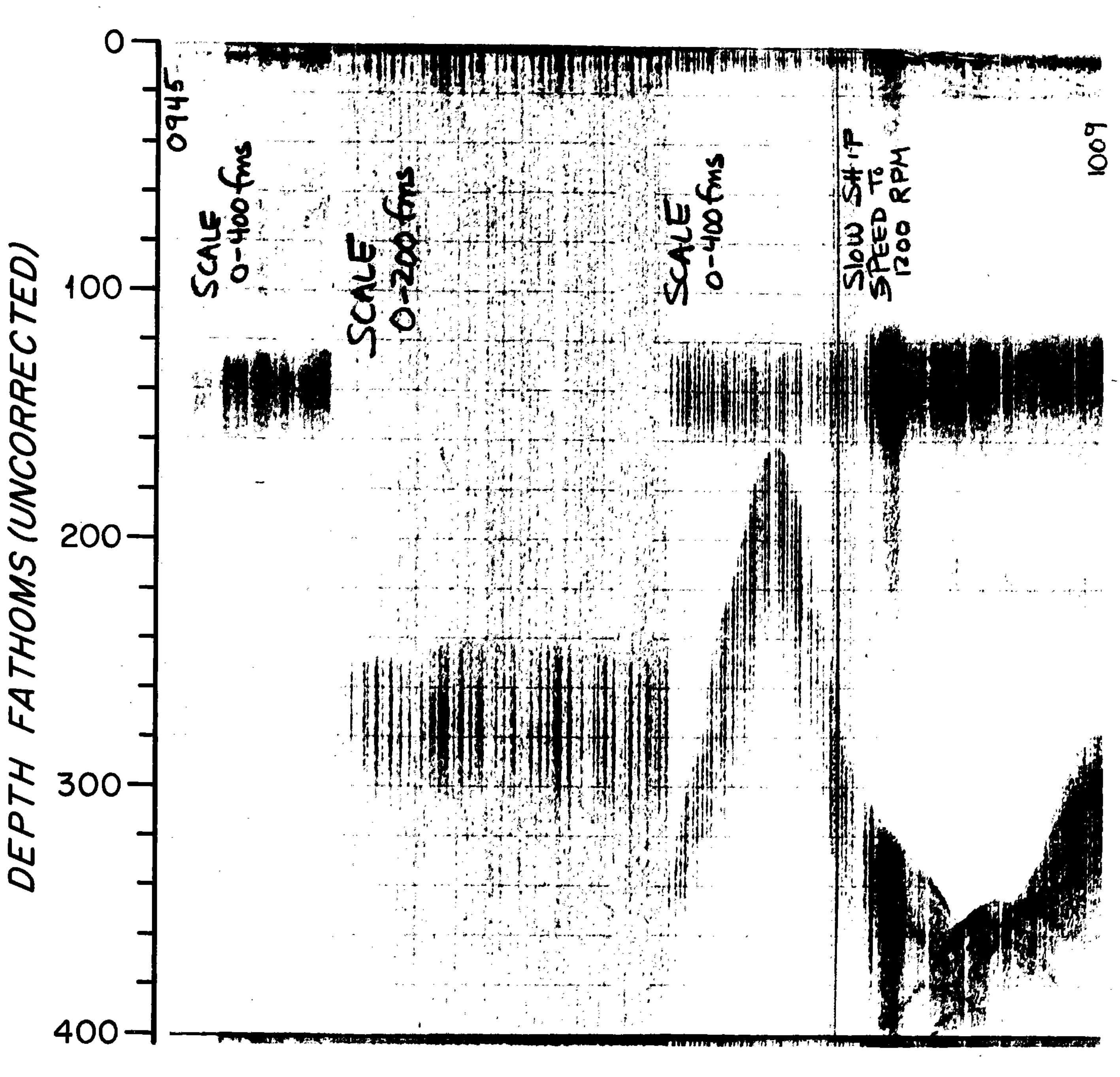

Figure 12. Echo tracing, showing Deep Scattering Layer. Depths are in fathoms, uncorrected; time is EST.

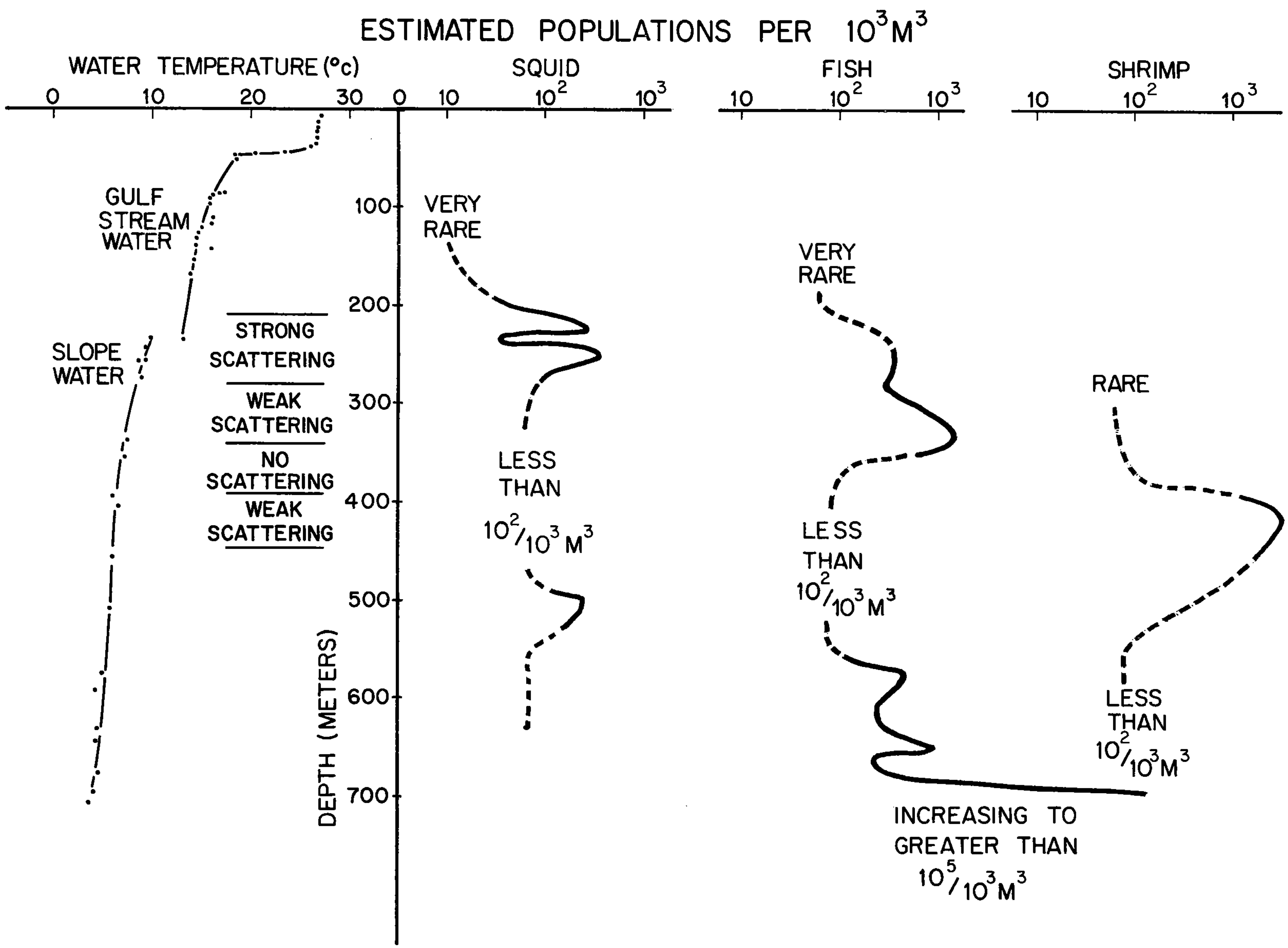

Figure 13. Distribution of mid-water organisms with depth in relation to the depth of the various scattering layers.

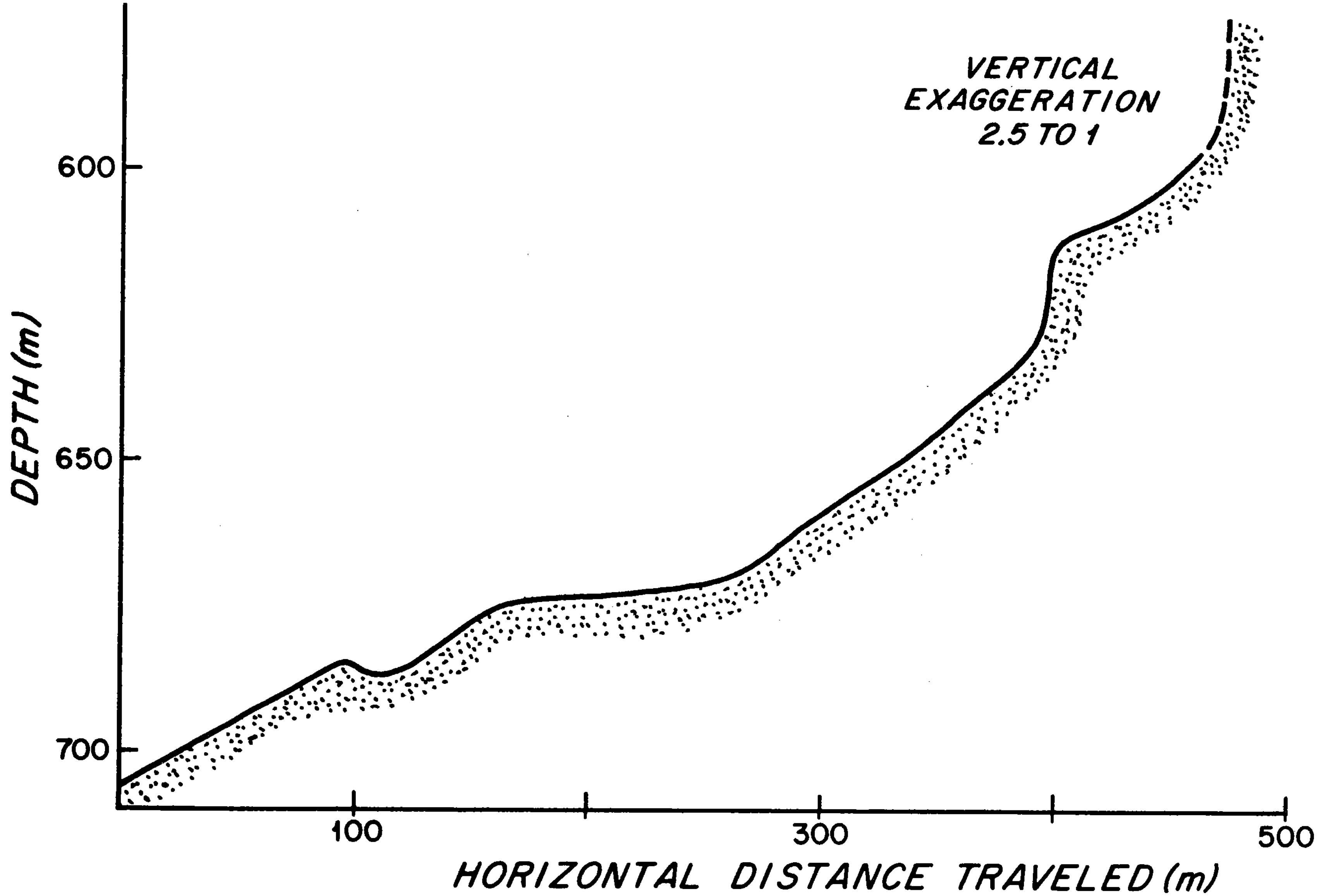

Figure 14. Bottom topography traversed during Dive 204. This profile was made by interpretation of times required to ascend up slope.

Appendix: Sediment Samples Collected

DIVE NO.	DATE	TIME	DEPTH (m)	LOCATION	LITHOLOGY	WHOI SAMPLE NO.
200	7/4/67	1635	542	Mn-phos pavement	manganese-phosphorite slab	2700
201	7/5/67	1416	542	station G	olive-black lutite	2701
201	7/5/67	1608	556	station L	plastic, buff-white silty lime-stone, hardened after storage	2702
201	7/5/67	1610	556	station L	black Mn-phosphatic nodule	2703
201	7/5/67	1644	555	station M_1	grey boulder, weathered to green on outside; fine-grained granite-syenite	2704
201	7/5/67	1647	556	station M_2	black Mn-phosphatic nodule	2705
201	7/5/67	1705	556	station N	whitish-buff calcareous silt-stone	2706
201	7/5/67	1705	556	on ALVIN'S skids when surfaced; assumed to be from last station, station N	blackish olive lutite	2706A
203	7/7/67	1530	505	on coral ridge	brown gravely and sandy mud, with predominance of coral fragments	2707
203	7/7/67	1611	546	in trough between two ridges	brown muddy sand, with predominance of coral fragments	2708

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Summary of observations made during ALVIN dives on the Blake Plateau. Water temperature and resistivity, bottom biology, geomorphology, and geology are discussed.

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2. Blake Plateau
3. East Coast Continental Margin

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