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GEOLOGICAL SURVEY

Seabed Assessment Studies: Application of Standard Marine Geologic Survey Techniques for OTEC Evaluation Studies in Samoan Test Area

By

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INTRODUCTION

The U.S. Geological Survey (USGS), as part of a cooperative research effort with the Marine Sciences Group (MSG) of the University of California at Berkeley, has conducted a multi-year program of marine geological assessment of oceanic island margins that represent potential sites for development of Ocean Thermal Energy Conversion (OTEC) systems. These studies include compilations of oceanographic data for both the Hawaiian and Puerto Rican island areas (Wilde et al, 1980; Trumbull et al, 1981) and a detailed survey of the submarine slope off the southwest coast of the island of Oahu, Hawaii (Normark et al, 1982).

The Oahu OTEC (O'OTEC) study, off the Kahe Point area of Oahu, used precision shore-based navigation to survey a grid of tracklines spaced at 1/2-km intervals. During the survey, 12 kHz echo-sounding profiles together with 3.5 kHz and mini-sparker high-resolution reflection profiles were collected. This site-specific data resulted in a detailed bathymetric map and an assessment of the type of sediment cover in the area (Normark et al, 1982). Geotechnical properties of the sediment were measured on subsamples from a set of gravity cores obtained during the survey (Winters and Lee, 1982).

The general siting and oceanographic conditions for development of an OTEC power plant on Tutuila Island were reviewed by Sigg and Heydt (1976). The present study involves a detailed survey of part of the steep submarine slope along the south side of the island of Tutuila, American Samoa (Fig. 1). The purpose of this investigation is to evaluate additional marine geologic techniques that might be applicable to site-specific surveys for OTEC development offshore of volcanic islands. Specifically, the survey was designed to provide: (1) a detailed bathymetric map; (2) a map of sediment distribution; (3) morphologic imaging using deep-towed side-scanning sonar; (4) seafloor photography and video to ground-truth the interpretations of acoustic records obtained for items 1 to 3 above; and (5) sediment samples, where appropriate, to evaluate depositional processes on the steep slopes in the survey area. In addition, a new shore-based positioning system was employed to provide a comparison with the system used in the Kahe Point survey in 1981 (Normark et al, 1982).

OPERATIONS AND DATA COLLECTION

The 5-day survey off American Samoa was conducted in December 1983 using the USGS vessel S.P. Lee. We collected approximately 750 trackline kilometers of 12 kHz echo-sounding and 3.5 kHz high-resolution reflection profiles (Figs. 1 to 4). Single-channel seismic reflection profiles using two small airguns (7 in^3 total volume) with the signal filtered to 100 to 300 kHz were collected over about 500 trackline kilometers in an effort to resolve sediment thickness in the area.

Four camera stations yielded 2600 color photographs over approximately 13 km of traverse (Fig. 5). Five gravity core samples were used to determine the sediment type and biostratigraphy in the area (Fig. 5). Six expendable bathythermographs (XBTs) were taken to determine the temperature/depth profile of the upper water column. No interpretable side-scanning sonar records were obtained, as a result of electronic malfunction.

The Del Norte Trisponder navigation system provided excellent position control, allowing good tracking of the ship during this study. Four shore-based beacons provided simultaneous range data for some 67,000 positions during the 109 hours of survey and sampling activities. The strikingly orthogonal nature of the trackline grid (Fig. 1) indicates the reliability of the real-time position control.

DATA REDUCTION AND PRESENTATION

Position Control and Trackline Plots

In post-processing, the raw navigation range data was desampled from every 5 seconds to every 30 seconds and converted into latitude/longitude positions. Three- and four-range positions generally described a smooth track, but two-range fixes commonly showed unacceptable scatter along the tracklines. The whole data set was therefore run through a smoothing program to remove the scatter. Some gaps in range data collection, especially very nearshore and in the western part of the survey area where line-of-sight between the ship and the transponders was blocked by the high mountains of Tutuila Island, required use of the ship's regular satellite navigation system. The satellite data was spliced into the gaps, producing a complete navigation data set.

Figures 1 to 4 present the trackline maps at two scales: 88.5"/°long. and 211.9"/°long., both on a Mercator projection. Figure 5 shows the tracklines for the camera traverses and the location of both gravity core and XBT stations.

Marine Topography

The detailed marine topography (bathymetry) derived from our survey is presented in Figures 6 through 9. These maps are based on the 12 kHz echo-sounding profiles, digitized at inflection points to give the most accurate shape of the seafloor. The depth data was corrected for the speed of sound through varying depths of sea water using new tables published by the United Kingdom Hydrographic Department (Carter, 1980). The corrected depths were then merged with position data on the basis of time and plotted by computer at the two map scales. The depth data were contoured by hand (TEC).

Much of the survey area covers steep and rough terrain that tends to give multiple side-echoes on a surface-ship echo-sounding record. The discrepancies in depth at track crossings that we encountered were caused primarily by the difficulty in digitizing the 'correct' bottom echo. Problems due to positioning errors were minimal where positions were determined by three or four transponder ranges. The maps presented are at two scales: the 'whole island' maps (Figs. 1 and 6) at 50 m contour interval are a convenient size, and the larger maps at 20 m contour interval (Figs. 2-4 and 7-9) enhance the bathymetric features shown.

Physiographic Maps

The physiographic diagrams (Figs. 10 to 12) are designed to be companion sheets to the topographic maps and to assist the user who may not be familiar with the interpretation of relief on the seafloor as portrayed by contours. They give a view from a point above and away from a direct overhead view. In this case the view is towards the north.

The diagram is prepared by making a grid of equally-spaced parallel lines, which are assigned some depth scaling factor, e.g. the distance between each line is equivalent to 50 m or 100 m. The grid is placed under the contours and oriented perpendicular to the desired direction of viewing. A new line is drawn where each contour and grid line of equivalent scaling intersects. This new line continues and crosses the next intersection of grid and contour lines, either up or down, depending on the slope direction. The result is a series of sloping lines, that give a feeling of perspective by presenting a view of the slope from a different angle. Shading is placed on one side of the sloping lines, usually the right-hand side, to enhance the depth perspective.

Changing the distance between the parallel lines of the grid, or changing the depth scaling value assigned to them, will result in a different vertical exaggeration of the final physiographic interpretation. In other words, with each data set it takes some practice to determine the spacing and value that will produce the most effective physiographic map.

Bottom Photography and Sediment Samples

Determination of sea floor sediment distribution and type from seismic data alone will not produce reliable results without 'ground-truth' information to help in the initial interpretation of that data. We chose to use an advanced seafloor photographic system and direct sediment sampling to gather the ground-truthing data.

Photography. We used a still-camera/video system developed by the U.S. Geological Survey (Chezar and Lee, in press). It consists of a video camera and recorder, a single-lens reflex camera modified to take a 400′ roll of film, associated pressure cases, and both flash and movie lights. Power is provided by batteries. This equipment is mounted in a sturdy aluminum frame and towed approximately 3 to 5 meters off the seafloor. A depth pinger mounted on the camera sled sends signals to a shipboard recorder, enabling the winch operator to control the sled's altitude off the bottom (Chezar and Lee, in press).

The video system failed during our cruise as a result of an electrical problem. We did, however, collect 2600 useful photographs during 4 stations with the still camera. These photos are the basis of our visual ground-truthing efforts. The primary use of the video would have been to review the camera traverses at sea, without requiring a dark room to develop film, and to provide visual continuity between the 35 mm photographs taken by the still camera. Nearly all scientific and engineering measurements, however, must still have come from examination of the higher-resolution photographs.

The first step in interpretation of the photos was to tape a voice-log commentary while reviewing the film of each camera station. The transcript of this first impression was then expanded in a frame-by-frame examination of the photos. The resulting photo log is presented in the Appendix. Where appropriate, photos are grouped under one description to avoid unnecessary repetition in a frame-by-frame description. Each description provides a general evaluation of the terrain adequate for most objectives of geologic mapping. Individual photos within a group may show additional details.

Six categories of bottom type are suggested by the photo descriptions. They are based on the apparent type of substrate (bedrock or rock talus), the degree of sediment cover on the substrate (none, some, or complete cover), and the presence of a relatively level, current-swept 'pavement' of unknown composition. There is also a category for black frames, whether caused by a strobe malfunction or by the camera flying too high for illumination of the seafloor.

These categories are represented along bathymetric profiles in the photo-geologic sections of Figure 13. Representative photos of the four major groups (bedrock, talus, sediment, 'pavement') are also shown in Figure 13.

Cores. High-resolution 3.5 kHz and single-channel seismic profiles taken in the survey area indicate limited sediment cover on the steep volcanic slopes of Tutuila Island. We made 13 attempts to collect gravity cores from 6 stations, chosen in areas thought to have some sediment cover, on the basis of the profile interpretations. Of these 13 attempts only 4 cores and 3 core catcher samples were recovered. The poor coring results support our initial interpretation of the seismic records.

Samples from sites 2GA, 3GA, 4GA, 7G, and 10G were examined by Charlotte Brunner. See Figure 14 for photographs of three of the cores, and a summary of results from study of the cores. Note that cores 2G and 2GA were taken from the same site. Both appear in the photograph, but only one was used by Brunner and therefore shown on the location map.

Water Column Temperature Profiles

Vertical temperature profiles of the water column are necessary to provide confirmation of the conditions assumed for calculation of sound velocity used for the marine topographic maps. In addition, the profiles indicate the temperature distribution with depth that is of prime interest for the development of OTEC systems. At selected sites during the cruise we deployed 6 XBTs (expendable bathythermographs). The locations of the XBTs are shown in Figure 5. Three were taken on the open slope (Fig. 15A), and 3 in a narrow, steeply-sloping canyon extending from Fagatele Bay (Fig. 15B). The XBTs have a 500 m depth limit; those deployed in the canyon hit the seafloor at depths less than 500 m. Though the temperature profiles are not identical at all 6 sites, they do show a consistent 20° C drop over 500 m at the 3 deep sites (Fig. 15).

EVALUATION AND CONCLUSIONS

The submarine slope south of Tutuila Island provides a clear contrast to the conditions mapped in the earlier study off Kahe Point, Oahu (Normark et al, 1982). The Samoan slope is steeper and relatively sediment-free in comparison. No effective map of sediment distribution can be made with the 3.5 kHz or airgun high-resolution reflection profiles collected in the present study. The few sediment cores and the photographic data show that coarse-grained basaltic and reef debris (sand and gravel size) are accumulating with biogenic carbonate in the low-lying areas within irregular surfaces of volcanic flows. Only the more gently sloping benches show a more complete sediment cover in photographs, but it is not thick enough to be resolved in the acoustic profiles. The following general evaluations can be made from the results of this investigation:

(1) The shore-based positioning system used in this study provided excellent real-time navigational control, and despite difficulties in reducing the data, it eventually resulted in a very acceptable record of tracklines run. The Del Norte system had the advantage of providing multiple simultaneous ranges; only 2 ranges were available for real-time navigation, but 4 were recorded for use in post-processing. During the O'OTEC survey of 1981, the Miniranger system used was not capable of collecting more than 2 ranges at a time, which severely hampered our post-processing effort, and degraded the accuracy of the final map products. It should be noted that this was a limitation of our equipment that doesn't necessarily apply to more advanced models which may now be available under the name Miniranger.

(2) Standard echo-sounding techniques (a surface vessel with wide-beam echo-sounder) are not adequate for producing fine-scale bathymetry in areas of deep water or steep slopes, such as offshore Tutuila Island. If surface vessels are to be used, multibeam or swath-sonar systems are highly recommended to obtain greater accuracy and detail. Even multibeam systems, however, cannot provide bathymetric accuracy comparable to deeply-towed seismic platforms (Theberge and Lonsdale, 1983). An assessment of current technology available for mapping steep slopes is in progress, as part of an on-going cooperative research project between the USGS and the MSG. Morphologic information from deep-towed side-scanning sonar instruments can aid siting studies, but such systems do not provide direct or detailed bathymetric data. Unfortunately, we were unable to obtain usable side-scan data during this study.

(3) In volcanic terrane with little sediment cover to sample and analyze, we suggest using photography and/or direct observations from submersibles to map specific sites for OTEC pipeline or anchor installations. Seismic reflection profiling techniques are of limited application in such terrane. Both deeply-towed cameras and manned submersibles equipped with pressure and/or acoustic sensors to accurately measure water depths would need to be individually navigated (i.e. separately from the ship) using ocean-bottom acoustic transponders to provide adequate resolution of depth and position.

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FIGURE CAPTIONS

Figure 1: Tracklines of USGS cruise L6-83-SP south of Tutuila Island, American Samoa. Bathymetry derived from the cruise data (see Fig. 6).

Figure 2: Expanded trackline plot of USGS cruise L6-83-SP for area off Steps Point (see location map). Bathymetry from Figure 7.

Figure 3: Expanded trackline plot of USGS cruise L6-83-SP for area off Pago Pago Harbor (see location map). Bathymetry from Figure 8.

Figure 4: Expanded trackline plot of USGS cruise L6-83-SP for slope area south of that shown in Figure 3 (see location map). Bathymetry from Figure 9.

Figure 5: Camera stations, core and XBT locations of USGS cruise L6-83-SP. Camera tracklines show the position of the vessel S.P. Lee, and are not corrected to show the position of the camera sled. Bathymetry from Figure 6.

Figure 6: Marine topography of offshore Tutuila Island. Map is of same area as Figure 1.

Figure 7: Expanded plot of marine topography of offshore Tutuila Island. Map is of same area as Figure 2.

Figure 8: Expanded plot of marine topography of offshore Tutuila Island. Map is of same area as Figure 3.

Figure 9: Expanded plot of marine topography of offshore Tutuila Island. Map is of same area as Figure 4.

Figure 10: Marine physiography of offshore Tutuila Island based on bathymetric data of Figure 6.

Figure 11: Marine physiography of offshore Tutuila Island based on bathymetric data of Figure 7.

Figure 12: Marine physiography of offshore Tutuila Island based on bathymetric data of Figure 8.

Figure 13: Sea floor profiles and summary photographic interpretations of 4 camera stations south of Tutuila Island. Twelve representative bottom photographs illustrating the type of sea floor are arranged into the 4 basic groups (bedrock, talus, sediment, and 'pavement') of 3 photos each.

Figure 14: Summary of gravity core data showing photographs of cores 2G, 2GA, and 3G with brief descriptions alongside. A description of sedimentary components in samples from the top of each gravity core is also presented.

Figure 15: (Text figure.) Summary diagrams showing temperature-depth profiles for 6 XBTs taken offshore of Tutuila Island. A) Stations 6X, 7X and 8X. B) Stations 9X, 9XA, and 9XB. Locations of XBT stations are shown in Figure 5.

APPENDIX

by C.E. Gutmacher

Introduction to Photo Logs

The following photo logs are an attempt to informally catalog the geological and biological information in the bottom photographs. Because positive identification of rock type and sediment grain-size is not possible from photographs alone, the reader should recognize that grain-size terms are used in a relative sense, and 'basalt' is used because the photographed areas are the underwater slopes of what is known to be an oceanic volcanic island. Similarly, a biological description should not be taken as an absolute statement of what the animal/plant is, but rather the type of animal/plant it resembles. For instance, in station 6 there are many photos of what appear to be multi-armed sea-pens. I guess they are some sort of stalked crinoid, which is how they appear in the log. The field of view in the photos is approximately 3 to 4 meters across; bottles or cans that can be used for scale appear in many photographs.

To a certain extent, photographs have been grouped by time, i.e. not every frame in a 'smooth sediment' section will show perfectly smooth sediment. For clarity in the bathymetric profiles of Figure 13 even further consolidation was necessary, and some very small groups were left out altogether.

The photo logs, therefore, are meant to give an idea of what the photos show. The readers must look at the films too before coming to their own conclusions about the content of the photos.

The location of a photograph can be determined by noting the time on the photo and keying to the same time along the appropriate trackline (Fig. 5). This is actually the location of the ship; on the cruise there was no way to independently track the camera sled.

Please note there are two time formats on the photos. At the start of each camera station the automatic clock in the camera failed to print the time on the film. In the photo logs these times are therefore approximate, accompanied by a frame count from the first frame showing the seafloor, and are in 24-hour Greenwich Mean Time (GMT, the same as times along the tracklines in Figs. 1-5.) Once the timer began imprinting on the film, the logs use a format such as 1221.1-1223.4 (equivalent to 0021.1-0023.4). This is GMT on a 12-hour basis, and the .1 and .4 represent not decimal minutes, but the first and fourth frame of their respective minutes. Due to irregularities in the triggering of the camera, there are between 2 and 5 frames per minute. The time format on the films is calendar day (Julian day equivalent), hours, minutes (ex. 7 12 09). December 7, 1983, is the same as JD 341.

Station 1 photo log, JD 341/2345-342/0118

GMT:

~ 2345-2355 (frames 1-41): light-colored sediment and small-scale rocky or talus surface. Some photos mostly sediment, some mostly rocky.

~ 2355-2358 (frames 42-53): water shots.

~ 2358-0002 (frames 54-71): going downslope. Thin dusting of sediment on rock substrate. Rock ranges from lumpy to almost smooth in appearance--not real rough or jagged, though there are a couple small steps or scarps. Rocks don't show the typical basalt texture, may have ferromanganese crust. Some areas that appear to be low-lying are filled with sediment. A couple of attached organisms in frame 54.

~ 0002-0017.4 (starts frame 72): smooth, apparently fine-grained sediment; local burrowing; local coarse sediment.

~ 0002 (frame 72): brittle star
~ 0006 (frame 86): first 'paw-print' burrow cluster
0011.1: attached organism
0013.1: sediment-covered pipe(?)
0017.2: 2 small rocks

Camera time from films (12 hour clock):

1218.1,2: small-scale roughness of bottom, with dusting of sediment.

1218.3-1219.2: smooth sediment as before.

1219.3-1221.4: dark semi-smooth rock with cracks and lumps, and lightest dusting of sediment. Some frames show sediment 'ponds' around rock outcrops, or sediment-filled troughs in rock outcrops. Last frames very dark, may be mostly sediment. Rocks look like basalt with ferromanganese crust.

1222.1-1223.4: water shots.

1224.1-1229.1: area of basalt(?) with generally more sediment cover than before--range from rock barely sticking through the sediment to a rocky outcrop and a blank space (scarp), as at 1225 and 1229. General downslope feeling.

1229.2-1236.1: water shots.

1236.2-1242.4: basalt(?) with generally still more sediment--some smooth bottom shots with burrows interspersed between shots of rocky 'islands' in sediment. A few mostly rocky shots, with sediment in the low areas.

1243.1-1249.1: smooth, coarse-sediment bottom changing rapidly to fine-grained sediment bottom. Couple of water shots (?, dark) at 1243 and 1244, and a couple shots of low relief rocks sticking through the sediment. Paw-print burrow clusters common locally.

1245.1: big sea anemone
1245.4: chiton(?)

1249.2-1250.1: hit rocky bottom that has sediment in low areas, followed by a couple of water shots. May be escarpment.

1250.2-1257.2: mostly smooth, fine-grained sediment with paw-print burrows. Very occasional rock sticking through.

1257.3-1258.4: more rocks visible through sediment. Scarp at last shot?

1259.1-1259.4: water shots.

0100.1-0112.1: mostly smooth, fine-grained sediment with paw-print burrows and occasional rock outcrops through sediment. Other notes:

0100.1: odd straight line of coarse sediment, and ripples in fine sediment
0100.4 & 0101.1: rock outcrop and scarp(?)
0102.1: animal in UL frame
0104.4: sea urchin LR frame
0105.1,3: rocky steep slope/scarp?
0107.5: chiton? CR frame
0108.1-0110.1: unusually large and open paw-print burrows

0112.2-0117.1: prolonged or serial bottom hit--most frames are black and those that aren't show clouds of sediment.

0117.2-0118.1: smooth, fine-grained sediment bottom with paw-print burrows.

Station 6 photo log, JD 342/2247-343/0300

GMT:

~ 2247-2257 (frames 1-28): bottom of coarse sediment with occasional low-relief rock outcrop. Rock looks like smoothed coral, nubbly and flat-topped. Several shots show attached plant-like organisms (look like big 'leaves' or a fan). Last two frames show a downhill trend.

~ 2257-2301 (frames 29-37): water shots.

~ 2301-2303 (frames 38-43): extreme downhill slope, nubbly low-relief outcrop with dusting of sediment. Last two shots show small scarps.

~ 2303-2306 (frames 44-51): water shots.

~ 2306-2314 (frames 52-72): gentle downslope, some steps, in large area of blocky rock outcrops. Surface of blocks is smooth lumps (i.e. not jagged). Outcrops ranging from sediment-covered (including burrows) to sediment- dusted. Rocks appear to be volcanic, with ferromanganese coating that smooths edges of the blocks. They look very similar to frames 54-71 of station 1.

~ 2314-2332.3 (starts frame 73): sequence begins with smooth, coarse-grained sediment bottom and occasional rock outcrops of the previous type. Rapid change to fine-grained sediment, very infrequent outcrops, numerous burrows (including paw-print burrows), occasional sea urchins (ex. 2319.2, 2326.2, 2327.2), glass bottle (2320.1), can (top of frame 74). At 2332.2 there is an unusual paw-print burrow, with many more than the normal number of holes in it.

Camera time from films (12 hour clock):

1132.4-1140.4: begin area of rock outcrops, and scarps followed by water shots. Rocks are blacker (basalt? or just no sediment on them?), in some places have a lumpy appearance and in others look very broken and angular. The occurrence ranges from a couple of rocks poking through sediment (though little or no sediment actually on the rocks) to what looks like a talus field with sediment between the chunks. There are three pairs of scarps followed by water shots; the water shots are at 1134.2&3, 1136.3-1137.3, and 1139.4-1140.4.

1140.5-1159.2: smooth, flat bottom of mostly fine-grained sediment; few burrows. Examples of infrequently occurring wildlife, and other things to note:

1147.2: fish
1149.3: sediment kicked up by camera hitting the bottom
1150.4 & 1152.1: sea spider (?)

1151.2: sea pen
1153.3: can
1158.2: crab(?) with banded legs.

1159.3-1202.1: gentle slope, and rock outcrops in sediment. Couple of all-sediment shots, and one all-rock outcrop and scarp shot (1201.2).
1159.5: star-shaped sea pen(?) - crinoid?
1200.1,2: fish with shovel-shaped head
1201.2: crinoid.

1202.2-1208.1: back to smooth sediment with occasional burrows and infrequent rocks sticking out of the sediment. Crinoid at 1202.3.

1208.2-1211.2: area of rocky scarp. Some shots far off bottom as the bottom falls away in a steep slope. Some shots of sediment and rubbly-type rocks. Sea pen at 1211.2.

1211.3-1230.2: back to smooth sediment bottom with occasional single or paw-print cluster burrows. Some paw-print burrows occur in most frames from 1222-1230. Several frames near the end have single sea pens. Other notes:
1214.1: group of single burrows
1215.3,4: can (same one)
1219.1: worm(?) trails
1219.3, 1220.3: crinoid
1220.4: holothurian? (creepy crawly)
1221.1,2: crinoid
1226: hit bottom
1227.3,4: can (same one).

1230.3-1235.1: outcrops start poking through the sediment. See some paw-print burrows and crinoids. Last few frames show mostly rock and extreme slope.

1235.2-1240.2: water shots.

1240.3-1248.4: mostly smooth bottom, and paw-print burrows.
1242.2,3: small-size rock rubble in half of these shots
1244.1: beer bottle and sea urchin
1246.2,3: true outcrop with sediment cover, and bottle
1248.4: sea urchin.

1249.1-1250.1: increasing lumpy rock outcrop, less sediment, till steep slope in last shot.

1250.2-1251.3: water shots.

1251.4-1255.2: coarser sediment cover, occurrence of burrows decreases until there appears to be either a smooth rock surface or coarse 'pavement' surface.

1255.3-˜ 0120: area appears to be scoured by currents. Bottom is either smoothed rock or close-packed, coarse-grained sediment 'pavement'. Pebbles or small local highs (or small depressions, hard to tell which) in the rock cause dark-colored lag deposits that look like U's or W's. In many shots linear, more resistant parts of the rock or sediment stand out as small steps in the outcrop. No wildlife. There is a fair overlap between some frames; camera/ship moving very slowly over the bottom - especially 0107-0111 where there are as many as four shots of the same thing. The overlap direction reveals quite a variation in the direction of camera travel; sometimes pretty straight ahead, sometimes sideways. (See navigation; ship is turning in a tight circle, and the camera is barely moving within that circle.)

˜ 0120-˜ 0143: less feeling of current scour in this section. Bottom looks more like coarse sediment pavement than like smoothed rock, though there is the occasional frame showing a small erosional step as described above. The dark 'lag' deposits now seem definitely to be around light-colored depressions (as opposed to high areas); perhaps are filled animal burrows? Some frames show pebbles and small rocky debris on the sediment pavement. Last several frames show small (erosional?) scarps in rocky outcrop.

0130.2: sea urchin
0132.1,2: can (same one)
0132.3: conical animal(?)
0136.3,4: good examples of lag?/burrows?
0140.2,3: partially buried (winch) wire.

˜ 0143-0151.4: more and finer-grained sediment on the bottom. Some scour/lag/burrow marks. Near end looks more like sediment on a nubbly rock surface.

0144.4: white plastic knife for scale
0146.1: fish
0147.2: fish and sediment puff from hitting the bottom.

0151.5-0153.1: water(?)/no strobe shots.

0153.2-0203.1: bottom now looks like fine-grained sediment with angular slabs of rock resting on the sediment surface, sometimes singly, sometimes in groups. Cans and other garbage occur commonly. Many frames show long skinny fish that swim by waving the last third of their body (these are the type seen most often in these camera runs).

0155.1: fish and very faint brittle star
0156.4: worm trails(?)
0159.1: long white fish? worm?
0159.3: good swimming fish and brittle star.

0203.2-0206.5: couple rounded rock outcrops or talus? in sediment, with light dusting of sediment on the rocks.

0204.3: large anemone on rock
0205: prominent ripples in the sediment.

0207.1-0218.4: bottom sediment now appears spotty, darker spots on lighter background; looks like small disorganized ripple crests with darker sediment on the tops. Very few talus blocks of varying sizes, and no sediment on them.

0212.4: can
0216.1,0217.3,0218.1&2: small fish
0217.4: big boulder with black pebble lag(?) deposit at base
0218.4: lobster-type creature.

0218.5-0235.1: rounded basaltic boulder rubble (some true outcrops of pillows?) in/on smooth sediment. Very little sediment on the rocks, and lots in between them. Long, thin fish in several frames. Last several shots show steep slope.

0222.3: lobster-type creature
0225.1: peculiar squished rectangular-shaped rock? bag?
0225.4: lovely anemone, side view
0226.4: fish among and anemone on rock(s)
0229.4: lobster-type creature
0233.5: strange thigh-bone shaped rock.

0235.2-0237.1: no strobe/water shots.

0237.2-0246.4: back to rounded basaltic outcrop/rubble in sediment bottom as before. Some frames all sediment, some all rubble in sediment, some sediment-dusted outcrop. There are the usual occasional fish and cans or debris.

0239.2: sea urchin and anemone
0242.1: brittle star in cleft of rock
0243.2: white plastic fork for scale
0245.3: 2 fish in fast motion (blurry)
0246.3,4: sponge? anemone? 2 views same one, on rock.

0247.1-0300.4: basically similar to above, except mostly sediment with infrequent rubble or outcrop. Several frames show usual long skinny fish.

0252.2: fish? or strange stalked thing in sediment?
0256.2,3: boulder, plus very long-legged shrimp in second shot
0257.2: can causing scour feature.

Station 8 photo log, JD 343/2253-344/0217

GMT:

~ 2253-2308 (frames 1-65): low-relief bottom. Dark plant-covered rocks and light-colored patches of sediment. From 2302 on green plants or maybe sea fans can be seen. In the lighter areas the bottom is nubbly in appearance.

~ 2255 (frames 9-12): several water shots (or bottom very faint)

~ 2300 (frames 32-36): several water shots (or bottom very faint)

~ 2301 (frame 37) on: get close enough to the bottom to think the light-colored nubbly texture may actually be groups of sea anemones. Some dark circles become common--sea urchins? dark anemones? Continue with plants and coarse-grained sediment to 2308

~ 2308 (frame 64): holothurian in center of frame.

~ 2308-2310 (frames 66-74): coarse sediment gives way to small rubble. Two frames show no sediment on the rubble, others show sediment mostly covering it. At 2310 (frame 74) there appears to be true rock outcrop, with sediment in its low-lying areas, some plants and some black incrustations(?).

~ 2310-2312 (frames 75-81): mostly light-colored, fine-grained sediment with occasional bit of plant material or rubble.

~ 2312-2314 (frames 82-90): small-size rubble surface, sediment dusted, some plants. At end slopes to right and bottom gets very faint (simultaneous strobe malfunction?).

~ 2314-2316 (frames 91-100): misfires and water shots.

~ 2316-2317 (frames 101-104): poor lighting--appears to be low-relief, hummocky rock outcrops with dusting of sediment.

~ 2317-2318 (frames 105-107): water shots.

~ 2318-2324 (frames 108-132): irregularly-shaped (lumpy, dissolved) rock outcrop with dusting of sediment, and sediment ponding in low areas. Strobe continues to act up so many shots are underexposed. Frame 112 has a couple of white-stalked organisms. Last few frames show very large blocks of rock.

~ 2324-2325 (frames 133-136): water shots.

~ 2325-2327.4 (start frame 137): sediment-dusted rubble sticking through sediment. Several frames show scarps, several at end may be water shots (or bad strobe). Last shot appears to be a sediment-dusted outcrop next to a void (a scarp).

Camera time from films (12 hour clock):

1127.5-1131.4: water shots and/or poor strobe.

1131.5-1134.3: large dark boulders partly or completely covered with light-colored sediment. Some are smooth, some lumpier in shape. Occasional views of sediment bottom in rear of boulder, or down a small scarp.

1134.2: shelf of rock with burrowed sediment on top (thin sediment, too).

1134.4-1135.5: basically smooth sediment bottom--still poor lighting. Some frames show suggestion of burrows, fecal strings, fish.

1136.1-1139.4: range from fairly smooth boulders, to rock 'shelves' sticking out of the sediment, to a couple shots of smooth sediment with burrows and tracks. General feeling of going downslope, ending with rock and scarp.

1140.1-1141.1: bad strobes/water shots.

1141.2-~ 1240: smooth sediment bottom with very occasional rock sticking through, and a few low-relief outcrops at the start. Fine-grained sediment gradually coarsens throughout this stretch. Due to strobe malfunctions some frames look like water shots--but often can discern cluster burrows so the bottom can be seen. Most frames have one or more of the following: cluster burrows, tracks, trails, sea urchins, fish, attached organisms, holothurians, human debris. Some examples:

1143.3,4: rock outcropping through sediment; small scarp followed by possible water shot at 1144.1
1151.2: fish with shovel-shaped head (saw one in station 6)
1153.1: large rattail fish
1156.2: holothurian
1201.4-1202.3: tracks and trails
1203.1,2: UC, C frame--shrimp? throws a shadow
1205.2: now think they are lobsters, see UC
1205.3: can, and burrow with occupant(?) or attached organism(?)
1205.4: good trail--entering 6-minute stretch of especially good trails
1205.5: well-lit picture shows bottom sediment to be getting coarser
1213.3: rock and two cans
1226.1: pair of rattail fish
1227.2: worm? wire?
1229.1: small tadpole-shaped fish (not a rattail)
1230.3: burrow with excavation pile (or occupant?)
1231.2: worm?
1234.3: fish and sea urchin
1232.1, 1233.2, 1235.1: lobsters?, camera far away from bottom

1236.3: worm?

~ 1240-~ 1250: transitional zone. Smooth to slightly lumpy sediment bottom; sediment coarser than before, with infrequent burrows, rocks, and occasional fish.

1242.2: UC 'feathery' animal? plant?
1242.5: tiny crab in center
1245.2: can
1247.1: few rocks, can
1247.4: another 'feathery' organism

~ 1250-0102.3: bottom looks like either fairly smoothed rock with coarser sediment in pockets, or, more likely, pock-marked (small-scale lumpy) coarse-sediment pavement as in station 6. Occasional rocks protrude above the general surface. Infrequent rattail fish, lobsters(?). Bottom has salt and pepper appearance, caused by circular mottles.

1253.4: lobster
1254.4: blocky rock outcrops through sediment
1256.4: fat fish (not rattail)
1259.2: sea urchin?
0100.2: horseshoe-shaped scours; or animal-made piles of debris in contrasting colors?
0102.3: thin rock or hard sediment outcrop, making small steps

0102.4-0116.4: bottom either smooth, fine-grained sediment or smoothed rock 'pavement'. Some frames show rubble sitting on or sticking through the surface. Bottom is less mottled than in previous section. Several shots have feeling of looking downslope.

0102.4: rock block in foreground, void behind
0103.1: water shot? bad strobe?
0105.1: step in sediment; steep slope?
0105.4, 0108.2: fat urchin
0109.2: white crab
0112.3,4: rock outcrop dusted with sediment, and sediment in a large hole in the rock. Enter area of more rubble than before.

0116.5-0139.1: back to mottled salt and pepper sediment/rock-type bottom of 1250-0102. Still unclear whether rock or sediment but there are some frames that are definitely one or the other. Mottles seem to be caused by coarser, dark material surrounding roughly circular areas of lighter-colored, finer-grained sediment. There are also some horseshoe-shaped scours.

0117.2: 2-1/2 bottles (one broken?)
0117.3: hit high point, see sediment cloud, edge of rock and void beyond
0118.1-0119.3: steep slope, many shots of smooth sediment
0121.1: close-up of rubble-studded bottom

0127.1: large block of rock on or protruding from mottled bottom
˜ 0131: steep slope
0135.1,2: rock outcrops and voids. Some rocks have a mottled appearance similar to the general bottom--bottom might be rock instead of sediment?-- very hard to tell.
0138.1: horseshoe-shaped scours; from here through 0139.1 there is a general feeling of slope.

0139.2-0149.1: still sediment 'pavement', or rock bottom, but few or different mottles. Mottles are light-colored on only slightly darker background, not salt and peppery as before. Lots of very coarse material or small rubble on the surface.
0144.4-0146.1: strobe misfires; mostly black with occasional hint of bottom as described above.
0146.2: high off the bottom, can only see large rock on one side
0148.1: talus block and scour behind it, center frame

0149.2-0153.4: bottom generally as in 0139-0149, but consistently lots of small-size basaltic rubble with little or no sediment dusting. Feeling of current.
0149.3: rock outcrop, sediment in low areas

0154.1-0158.2: bottom generally as in 0139-0149, but lots of dark-colored coarse material on the surface. Feeling of current.

0158.3-0206.3: smooth, light-colored sediment, some coarse concentrations of material (current winnowing) and some scattered small-size rubble.
0200.3: lobster
0202.2: bad strobes--light reflecting off bottle
0202.3,4: rocky steps or scarps? poor strobes
0203.1: water shot/bad strobes?

0206.4-0217.3: continue smooth light-colored sediment bottom. Much large-size rubble in nearly every shot--some may be outcrop, especially in the first few frames. Rubble is black, basaltic rock, some with pillow-like forms, some columnar shapes, with slight to heavy sediment coatings. Scattered cluster burrows occur in about 1/4 of the frames.
0207.1: stalked creature
0207.2: UL rattail fish
0208.1: cluster burrows, first in a long time
0208.3: 2 lobsters
0212.1: cluster burrows in sediment cover on a chunk of rubble (apparently not much sediment is needed for this type of burrow)
0212.4: stalked anemone(?) at left end of large rock
0213.2: rattail fish

Station 9 photo log, JD 344/0915-1009

GMT:

~ 0915-~ 0919 (frames 1-14): mostly dark-colored sediment bottom with white 'polka dots' (corals?). Some frames show coral bits and occasional rocks on the sediment surface.

~ 0916 (frame 5): fish? on the bottom

~ 0917 (frames 7,8): mound covered with plants or lacy corals(?)

~ 0919-~ 0924 (frames 15-37): dark, rocky bottom with white sand in patches. Rocks may also have some plant/coral incrustation; they look roughened in a manner not typical of rocks.

~ 0924-~ 0929 (frames 38-57): now predominately light-colored sediment bottom with patches of dark rock/incrusting growth. Sometimes the incrusting growth looks similar to a light-colored lichen on subaerial rocks.

~ 0928 (frame 53): fish(?) resting on sediment bottom

~ 0929-~ 0934 (frames 58-81): camera mostly too high above bottom, frequent strobe malfunction, and a generally light-colored bottom make it very difficult to tell much about the bottom in these frames. Squid following camera lights are photographed several times.

~ 0931 (frame 69): appears to be long white strings in the water--stalked organisms? Bottom barely discernible.

~ 0934-~ 0940 (frames 82-105): white sediment bottom, with occasional small rocks and/or dark organisms. Some frames show tiny fish(?) and squid. Bottom generally uneven, lumpy (burrowed?)

~ 0936 (frame 87): squid

~ 0937 (frame 94): gastropod? hermit crab? in small depression

~ 0938 (frame 97): several tiny fish? and perhaps burrows or hills

~ 0939 (frame 102): pair of squid

~ 0939 (frame 103): crater in top of small mound

~ 0940-~ 0946 (frames 106-130): light-colored sediment bottom is disturbed by trails and incipient ripples. The ripples gradually become more definite and organized. Some dark sediment patches; may be associated with mounds or other disturbance of the bottom. Also from ~ 0945 on ripples are edged in darker (heavier) sediment.

~ 0942 (frames 113, 115): examples of disorganized ripples/trails. Also small sponges(?) set into sediment--show as white, semi-spherical lump with opening in the top.

~ 0944 (frame 122): tiny white shell(?) fragments scattered on sediment surface.

~ 0946-~ 0949 (frames 131-145): bottom as above; darker sediment edging the ripples becomes drawn out by currents, making trails of dark material on the bottom.

~ 0949-~ 0953 (frames 146-161): light-colored sediment with some ripples and a few burrows. Otherwise featureless and bland.

~ 0953-~ 1001 (frames 162-195): light-colored sediment continues, with some ripples. Has occasional rocks, plant-like growths, and burrows. Some shots show many burrows that seem to be currently unused (beginning to be filled in). Some pebbles(?) are in craters in small sediment mounds.

~ 0953 (frame 162): white plastic bag among several rocks

~ 0953 (frame 163): tiny blue fish among plant-like material

~ 0957 (frame 177): rusty can, ripples, crater in sediment mound

~ 0957 (frame 180): sponge(?) on a rock in a sediment crater, and ripples in the sediment behind the crater

~ 0958 (frames 181,183,185): round terrestrial leaf? circular animal with tail? one in each of these shots

~ 0958-~ 0959 (frames 181-187): bottom covered with burrows, but they seem to be getting buried so they are not very obvious. Surface sediment becoming coarser with addition of white coralline(?) material.

~ 0959 (frame 187): anemone on rock in top of frame

~ 0959 (frame 188): terrestrial leaf

~ 0959 (frame 189): small mound with tracks on top?

~ 1000 (frame 193): couple large, open burrows

~ 1001 (frame 195): boulder and some rubble in half of frame (sediment in other half). Small blue fish near boulder.

~ 1001-1008.4 (starts frame 196): light-colored sediment featuring various amounts of burrows, trails, mounds, craters, etc. Occasional rock, terrestrial plant debris.

~ 1003 (frames 203,204): each have an anemone, 204 has a large plant as well (terrestrial palm frond?)

~ 1004 (frame 207): anemone

~ 1004-1005 (frame 208-214) incredible numbers of small open burrows; sediment more burrowed than not. In 212 a couple buried corals(?)--4 dark circles in a square, touching each other. In 214 half the frame shows intense burrowing, and barely any in the other half!

1008.4: last frame. Nice trails, burrows and circular mounds. Mounds are partly defined by the darker material around their edges.

1009: strobe died, off bottom at 1015.