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1978 Atlantic 3800-Meter Radioactive Waste Disposal Site Survey: Sedimentary, Micromorphologic and Geophysical Analyses

168

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1978 ATLANTIC 3800-METER RADIOACTIVE WASTE DISPOSAL SITE SURVEY: SEDIMENTARY, MICROMORPHOLOGIC AND GEOPHYSICAL ANALYSES

by

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FOREWORD

In response to the mandate of Public Law 92-532, The Marine Protection, Research, and Sanctuaries Act of 1972, as amended, the Environmental Protection Agency (EPA) has developed a program to promulgate regulations and criteria to control the ocean disposal of radioactive wastes. As part of that program, the EPA Office of Radiation Programs initiated feasibility studies in 1974 to learn whether present technologies could be used to determine the fate of radioactive wastes dumped in the past.

In 1978, the advanced technologies represented by the manned deep-submergence research vehicle (DSRV) ALVIN were employed to perform an on-bottom survey at the deepest of the previously-used United States low-level radioactive waste disposal sites. That site, located approximately 320 kilometers (200 miles) offshore in the Atlantic at a depth of approximately 3800 meters (12,500 feet), is situated in the axis of the Hudson Canyon channel. The objectives of this survey were to describe the biological, chemical, geological, and physical oceanographic characteristics of the dumpsite.

The present report provides a detailed description of the geological and topographical characteristics of the site. Two dives were made in two areas within the low-level radioactive waste dumpsite. The sediment deposits, bottom topography, biota, currents, and the differences in these parameters between the two areas within the dumpsite are discussed. The appearance of radioactive waste drums found in the dumpsite area is analyzed in terms of the localized geological and physical processes occurring at the site. The report concludes with a general discussion of the geologic stability of the area.

The Agency invites all readers of this report to send any comments or suggestions to Mr. David E. Janes, Director, Analysis and Support Division, Office of Radiation Programs (ANR-461), Environmental Protection Agency, Washington, D.C. 20460.

Glen L. Sjoblom

Glen L. Sjoblom, Director
Office of Radiation Programs

ABSTRACT

Five dives with the DSRV ALVIN in the extension of the Hudson Canyon Channel on the continental rise off Long Island were undertaken to investigate the physical, biological and chemical environment of an area formerly utilized as a radioactive waste disposal area. Observations within a depth range of 3985-3830 m revealed angular blocks and piles of displaced channel wall rock, boulder and cobble olistoliths of Eocene-age chalks derived from higher elevations on the slope, and bedforms such as ripples and scour marks which imply the existence of periodic strong currents. Local benthic fauna are sparse; bioturbation and burrows are uncommon. Three waste drums were located and one was subsequently recovered for analyses. Photographic and visual evidence suggest that downslope transport of objects such as talus blocks, olistoliths and waste drums has occurred in this area.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

INTRODUCTION

During the period July 22 to 28, 1978, a series of five dives with the DSRV ALVIN was made at the Atlantic 3800 meter Radioactive Waste Disposal Site. This site is located about 380 km off the coast of Long Island on the lower continental rise, 260 km seaward of the edge of the continental shelf, near the main channel of the Hudson submarine canyon system (Fig. 1). The waste consists of approximately 15,000 55-gallon drums that are filled with low-level radioactive waste and concrete. These are distributed over an area of a few tens of square kilometers in water depths of 3700 to 4100 m. The purpose of the diving program was to study the physical, chemical and geologic setting of the disposal site and the local biological conditions of the substrate in order to better assess the feasibility of future disposal of radioactive waste in the ocean.

The study was conducted in an area bounded by coordinates 37°40'N to 38°10'N and 70°24'W to 70°40'W, covering an area on the lower continental rise near the confluence of the main channels of the Hudson and Block submarine canyon systems (Fig. 2). In this region, the channel of the Hudson Canyon is characterized by an approximately 1 km wide canyon floor that contains a narrow, deeper, meandering thalweg or axis. The walls that bound the canyon floor exhibit slopes from gentle gradients of a few degrees to vertical and stand as high as 200 m (Fig. 3).

The primary mission of the project was to locate radioactive waste drums and to identify and recover a suitable drum for laboratory analysis. Secondary goals were to take sediment and water samples near the recovered drum. The geological work consisted of a description of bottom topography and sediments, the nature of bedrock exposures, and the sedimentary and erosional processes, including bioturbation, that affect the stability of the substrate. Geological samples were taken for laboratory analysis. Selected samples are listed and described in Table I and in Figure 13. The presentation and interpretation of these data are the basis of this report.

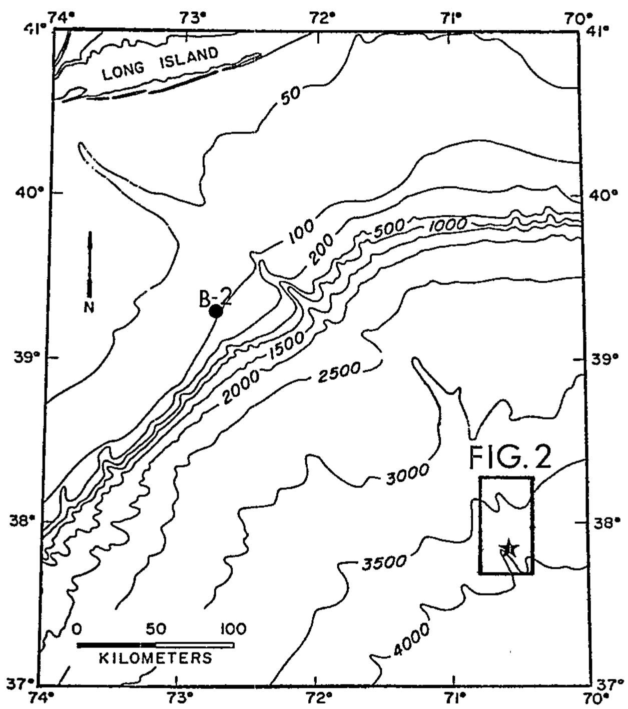

Figure 1

Regional bathymetric map of the continental shelf, slope and rise seaward of Long Island, New York. A star marks the 1978 dive positions within the 3800 meter Radioactive Waste Disposal Site, enlarged as text Figure 2. Stratigraphic control for the area is provided by the COST B-2 well, drilled in 1976 to a depth of approximately 5000 m. Contours in meters.

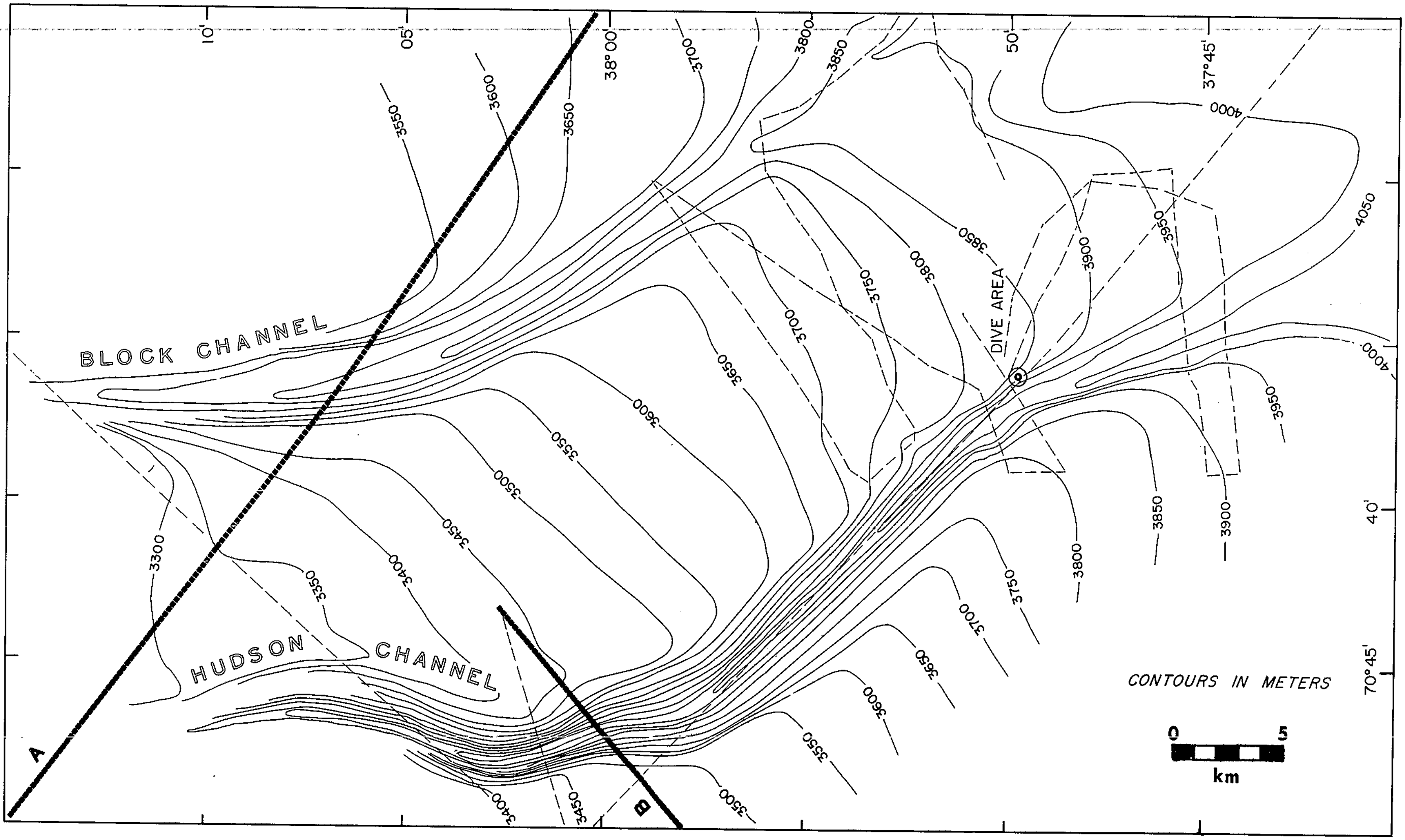

Fig. 2

Bathymetry of the 3800 meter Radioactive Waste Disposal Site, contoured in uncorrected meters (750 m = 1 sec. two-way reflection time). Solid line A indicates ship's track of the R/V Vema during seismic reflection (airgun) survey. Solid line B indicates locations of seismic reflection profile illustrated in Figure 18. Thin dashed lines are echosounding tracks of R/V Lulu.

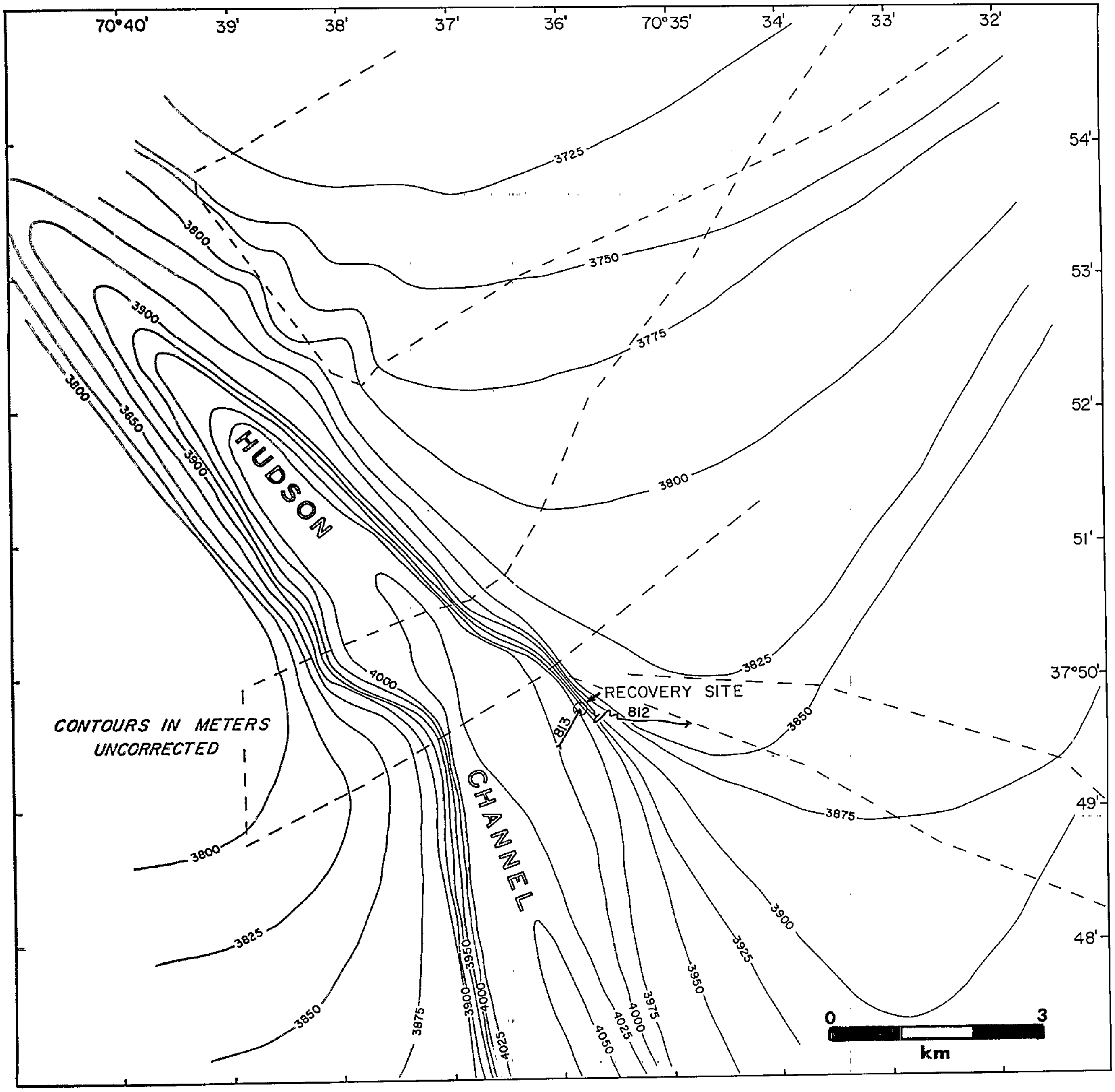

Figure 3

Detailed bathymetry in the vicinity of the 1978 ALVIN dives. Contour interval is 25 m. Dives 812 and 813 explored the eastern wall of Hudson Channel. Dive 814 surveyed and recovered a waste drum within the small circled region. Dashed lines are survey tracks of R/V Lulu.

TABLE I

Sample #	Description	Setting	Species *	Age
Alvin 812 Ski	Sandy mud	Ski sample	Cyclococcolithus leptoporus Coccolithus pelagious Helicopontosphaera kamptneri Helicopontosphaera inversa Rhabdosphaera clavigera Coccolithus doronocoides Gephyrocapsa sp. Thoracosphaera sp. Discoaster brouweri Discoaster asymmetricus	Pleistocene
Alvin 813 Ski-1	Greyish-tan mud w/iron staining non-calcareous	Ski sample	Barren No age determination possible	
Alvin 813 Ski 2	Mud	Ski sample	Same as in 812-ski	Pleistocene
Alvin 813 Chalk	white, consoli- dated chalk	Rounded boulder	Chiasmolithus solitus Zygrhablithus bijugatus Cyclicargolithus floridanus Sphenolithus moriformis Sphenolithus radians Discoaster barbadiensis Braarudosphaera rosa	Eocene, probably mid Eocene
Alvin 815 Ski	Mud	Ski sample	Similar as in 812-ski and 813-ski 2 Rare Emiliania huxleyi	Holocene(?) Quaternary
Alvin 679	White chalk collected in 1976	Boulder	Cyclicargolithus floridanus Chiasmolibus expansus Chiasmolithus solitus Discoaster barbadiensis Discoaster deflandrei Coccolithus pelagicus Zygrhablithus bijugatus Reticulofenestra umbilica Sphenolithus radians Helicopontosphaera seminulum Chiasmolithus gigas (?) Braarudosphaera bigelowi Braarudosphaera discula Zygolithus dubius Discolithus cf. segmenta Tribrachiatus orthostylus	Upper Middle Eocene
812-Core #1	Near Core #10	Core not available		
812-Core#10	Core taken into scarp face near bottom of face	Core not available		
813-Core #2	Corrosion product near first drum	Core not available		
813-Core #3	Taken in sediment build up downcur- rent from first drum, 8 cm long	Core not available		

*Species identification by Gretchen Blechschmidt, L-DGO

DIVE DESCRIPTIONS

Dive 812

Dive 812 on June 23, 1978, touched down at 1241 hours at a depth of 3924 m (Fig. 3). The submersible ALVIN then slid down a 10-30 degree mud slope to a depth of 3958 m. According to preliminary bathymetric mapping (Fig. 3) ALVIN's deepest position during this dive (3958 m) coincided with the base of the east wall of the Hudson Canyon channel. From this point an upslope traverse was initiated first in a northeasterly direction and later in a southeasterly direction. ALVIN left the bottom at a time of 1746 and a depth of 3827 m. No radioactive waste drums were located during this dive but many interesting and important geological observations were made.

The bottom topography around 3958 m is quite variable with slopes ranging from 0 to 20 degrees. Small angular mud-blocks lie on the sea bed and appear to have been derived from upslope sites (Fig. 4). Feeding trails and current lineations are common. The bottom here could best be described as blocky and lumpy.

Between 3950 and 3925 m, along the wall of the channel, small fluidized sediment flows were initiated by the submersible's contact with the sea bed. The associated mud clouds moved downslope at a rate estimated to be about 125 to 300 cm/second. The water was turbid and the visibility was poor. Southwesterly flowing bottom currents were persistent in the channel wall region as well as down in the channel floor. The velocity of the currents was estimated at about 25 cm/second. Such cross-channel flow is not unusual in submarine canyons (see Shepard, et al., 1979) and the presence of such currents and associated turbidity in the Hudson channel is attributed to flow associated with the Western Boundary Undercurrent (Heezen and Hollister, 1971; Eittreim and Ewing, 1972). In regions of smooth topography along the channel wall, a light tan sediment layer about 1 to 5 cm thick covers a firm, light tan, semiconsolidated marl or clay. Five to ten meter high marl or clay scarps are present (Fig. 5). These are separated by flat areas or

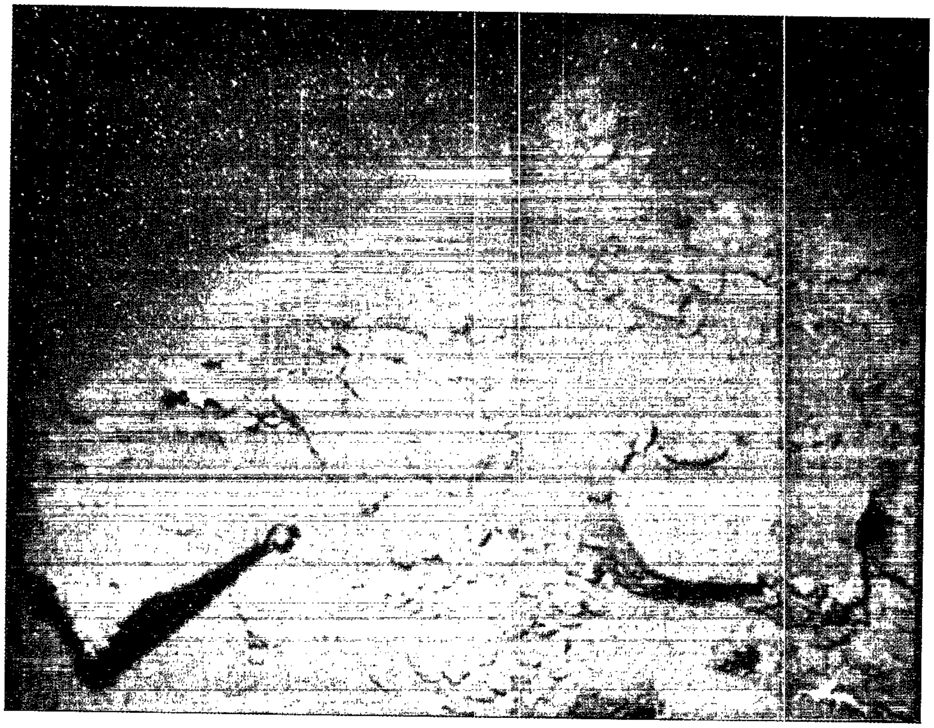

Figure 4

3830 m. Light tan marl or claystone angular talus blocks. These blocks appear to be locally derived by the slumping of adjacent wall rock. Planar surfaces are interpreted as joints produced in semiconsolidated strata. In this and other bottom photography the scale is approximately 2-3 m for the lower border of each frame.

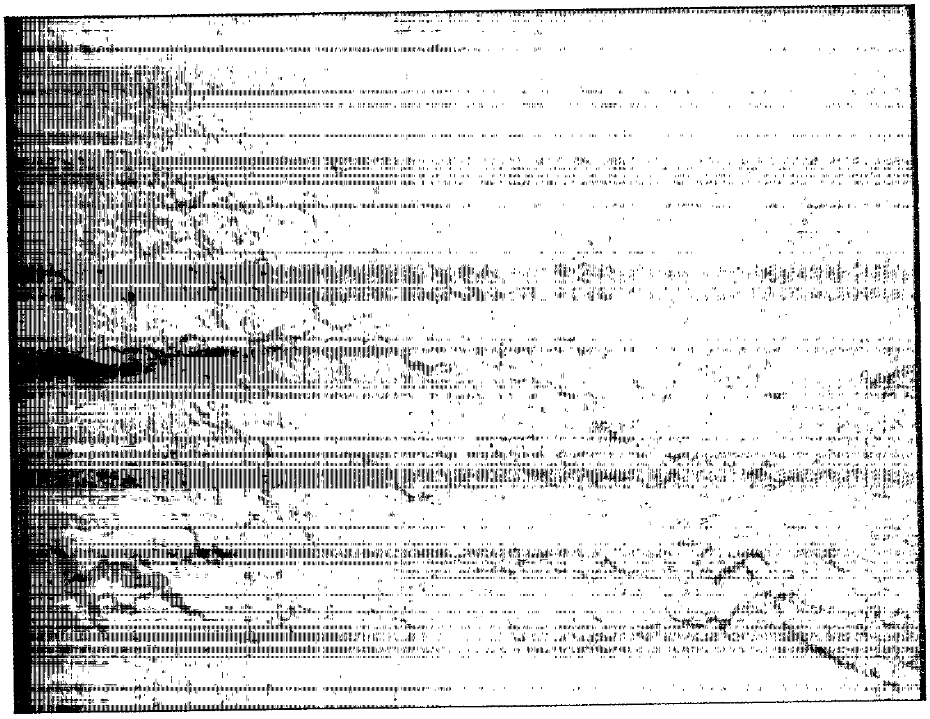

Figure 5

3870 m. Outcrop of semiconsolidated tan marl or claystone. This is a small slump scarp, bedding is indicated by horizontal ledge on left. This scarp is about 3 m high and is typical of the entire channel wall area. The flat bench begins at base of outcrop.

benches. Sediment ripples with a 10 cm wavelength are present on the current-swept flats. A possible boulder slide mark was observed and appeared to be very recent. In this region on the lower channel wall, a sparse brittle star population was observed along with plant debris and a few horizontal burrows.

From 3925 to 3900 m, further up the channel wall, small outcrops of soft, semiconsolidated marl or claystone were frequently observed. The outcrops have vertical faces 1 to 3 m in height, and are separated by flat current-swept benches. Symmetrical ripples with 15 to 20 cm wavelengths are present, suggesting the presence of oscillatory flow at this site. The flat bench areas often exhibit elongate tensional cracks, suggesting that the steep faces of the outcrops may have had their origin by slumping and thus the steep faces may represent slump scars. Subparallel crenulations just below the thin sediment drape suggest creep phenomena that may precede or be associated with slumping. In this depth interval, the brittle stars and the number of burrowers was seen to increase but the significance of this observation is not known.

Most of the outcrop faces between 3900 and 3875 m are covered with a thin sediment drape, but because of variable resistance to submarine weathering, layering or bedding is apparent beneath the cover (Fig. 5). Beds of marl or claystone are flaggy to massive, ranging from 10 to 30 cm thick. Occasional cut and fill structures are present. Ripples are again present at this depth and occur on the flat benches. A few ripples displaying wavelengths of 10 to 20 cm are oriented parallel to the slope and are also of symmetrical form. A small slump was observed in action, probably initiated by the ALVIN.

Similar scarp and bench topography occurs from 3875 to 3850 m. Lineations trend downslope on the faces of some of the marl or claystone outcrops. These appear to have been caused by small talus blocks sliding downslope. Numerous small to large angular talus blocks that appear to have fallen from higher outcrops litter the flat areas between scarps. Many of the talus blocks are plate-like slabs of marl that appear to have slid downslope, possibly on a mud or water cushion. These flat slabs are about 10 to 50 cm in diameter and several cm thick. Larger angular slumped blocks are also present. These vary greatly in size and are often bounded by smooth faces that may be joint planes (Fig. 4). Tool marks, believed to have been formed by small pebbles sliding downslope, are present in areas where the bottom is smooth but sloping. In this depth interval (3875-3850 m), so many of the scarp and bench features were observed that it is possible that this whole area is part of a very large slump complex. The small scarps and benches are believed to have formed as small dislocations and pullaparts and are the surface expression of much larger scale sliding and slumping along more extensive fault planes at depth (Fig. 5). The largest slump scarp observed was about 15 m in height and dipped 45 to 60 degrees. Angular talus blocks were present at the base of the scarp. As the submersible slid down the face of the scarp, observers noted that the plates and slabs of rock lying on the scarp itself seemed to be in a state of creep or instability. Scarps 1 to 5 m in height are the most common. Steep to vertical angles are the rule for the scarp faces and a smoothed 20-45 degree slope at the base of the scarps is common. A rough estimate of the spacing between scarps or the width of intervening benches is about 5 to 20 m. The scarps often seem to die out laterally. A 1 m high scarp, for instance, might decrease in height until it blends into a gentle slope over a distance of approximately 20 m. The megafauna between 3875 and 3850 m are generally sparse and there is a lack of burrowing activity. This region appears to be a biologically impoverished environment with only occasional ripples and a smooth to dimpled bottom.

The upper part of the channel wall from 3850 to 3828 m still exhibits slump features but the benches between slump scarps are wider and there is a general reduction in the average slope. A small basin-like feature occurs at about 3830 m and appears to be a bowl-shaped depression open on the downslope side (Fig. 6). ALVIN then slid down the wall which was about 10 m high and was covered with a light sediment drape. Currents appear to be stronger at this depth as evidenced by the formation of elongate sediment tails downcurrent from vertical burrows. These small sediment accumulations are dune-shaped, and are, on the average, 10 to 30 cm in length, 5 to 8 cm wide, and 2 to 4 cm in height. Long thin current lineations (grooves) are also present. Patches of pebbles and plant material of unknown origin are exposed in areas where the current has

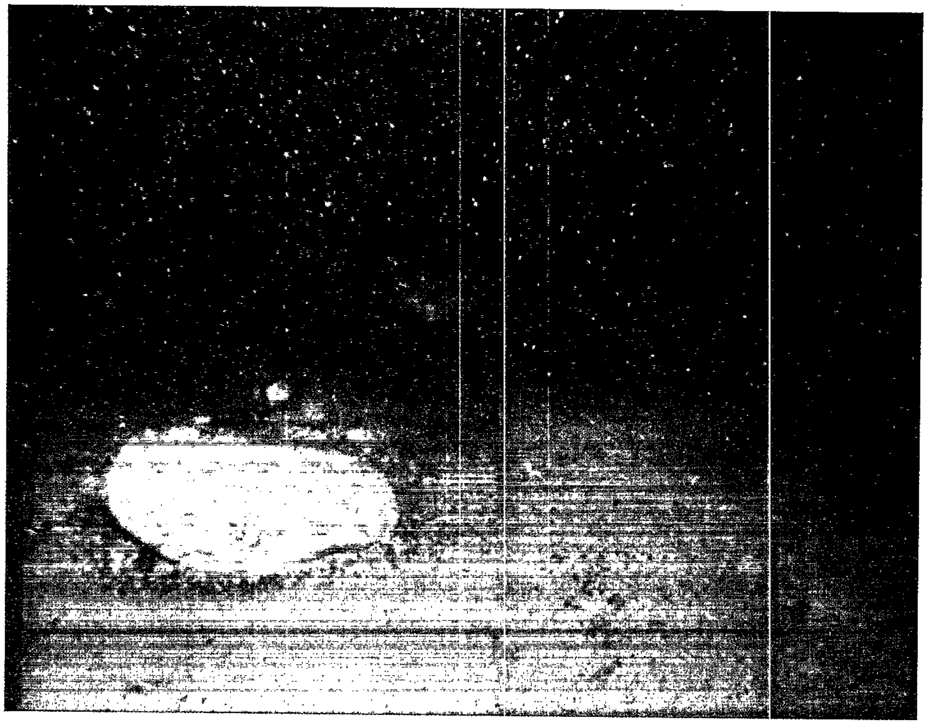

Figure 6

3964 m. Heavily bored, white Eocene (?) chalk boulder with a prominent scour moat exposing a gravel bottom.

swept away the top layer of sediment. Empty snail and clam shells are present but not abundant. The visibility is poor at these depths, 3 to 5 m being typical. Animal life is generally sparse along the canyon wall between 3850 and 3828 m. Brittle stars occur sporadically and increase slightly upslope. Occasional sea pens, sea whips, sponges, bryozoans, and ear-shaped sponges or Coelenterates form the rest of the sessile fauna. Cigar-shaped hollow tubes with an opening on one end were quite common on the bottom at depths of about 3850 m. Possibly these represent some kind of discarded egg case or molt. Occasional rattail fish and red shrimp are present but are not common. Small tan crabs occur on outcrops toward the upper part of the wall. Long sinuous horizontal burrows with impressive downcurrent dune-shaped sediment mounds are common where the currents are stronger. Small conical mounds are more common toward the upper part of the canyon wall.

At 3828 m, the shallowest point during this dive, brown talus blocks 30 by 15 by 3 cm were observed that were similar in appearance to brown siltstone lithologies observed in New England submarine canyons during previous dives (Ryan et al., 1978). Before terminating this dive, a short core (Core #10) was taken from the base of a small fault scarp. Another short core was taken for radioisotope analysis (Core #1). See Table I for core descriptions. All of the sediment encountered and cored during this dive was soft to semiconsolidated as compared to the abundance of hard rock encountered on the next day, June 24, 1978.

Dive 813

ALVIN dive 813 on June 24, 1978, in the same general area as Dive 812 (Fig. 3), reached bottom at 1305 hours at a depth of 3985 m. ALVIN touched down on a relatively flat terrain on the floor of the Hudson Canyon channel (Fig. 3). A 700 m long traverse was made in an easterly direction in search of waste drums. The course followed the break in slope between the generally flat floor of the canyon and a relatively steep (20 degrees to vertical) canyon wall. Radioactive waste drums were located at a depth of 3970 m and the dive was terminated from this depth at a time of 1733 hours.

Bottom topography in the region of this dive is characterized by irregular, boulder-strewn and hummocky areas separated by broad flat areas. This region is being swept by southwest-flowing currents similar to currents noted during Dive 812. The water was turbid but slightly clearer than the water higher on the channel wall. Slumped blocks of all sizes and shapes litter the bottom but seem to be concentrated in groups and piles (Fig. 7). These are separated by featureless broad flat areas that are 30 to 50 meters wide. The blocks and boulders can be grouped into three distinct classes. (1) Rounded cobbles and boulders of hard crystalline rock are common. These have been carried into deeper water by ice-rafting and have probably undergone some later concentration in the submarine canyon system. Quartzite, granitic and metamorphic rocks probably make up the bulk of these glacially derived cobbles (Fig. 8). (2) The most common pebble and cobble lithology is a soft tan marl or claystone. Tan marl blocks are very abundant and often occur in piles (Fig. 8). The blocks are very angular and seem to have been shaped by intersecting joint planes. These piles of blocks appear to be fresh and are generally not coated with sediment. Based on these observations and those of Dive 812, these blocks are interpreted to have been locally derived by slumping and sliding of semiconsolidated sediment from further up the canyon wall. Therefore, local gravitational instability along the canyon walls could easily explain the origin of this type of talus. (3) Rounded pebbles, cobbles and boulders of white chalk are abundant together with lesser occurrences of what appear to be blocks of brown siltstone. One boulder of apparently interbedded white chalk and probable brown siltstone was observed (Fig. 9). The average size of the white chalk boulders is smaller than the softer marl talus blocks, but 2-3 m diameter blocks were observed (Fig. 10). The chalk blocks exhibit a variety of shapes and sizes, but equant to cylindrical and tabular shapes are the most common. Relatively smooth surfaces are most common but some blocks, especially the larger boulders, are heavily bored (Fig. 6). Burrows are subparallel and probably occur parallel to original bedding in these rocks. The bored fabric appears to be a relict feature, and may have taken place in a different setting. The white chalk blocks look foreign to this environment, particularly since none of these were observed further up the channel wall during Dive 812, although blocks of the softer tan marl were common. The white chalk does not occur in the wall

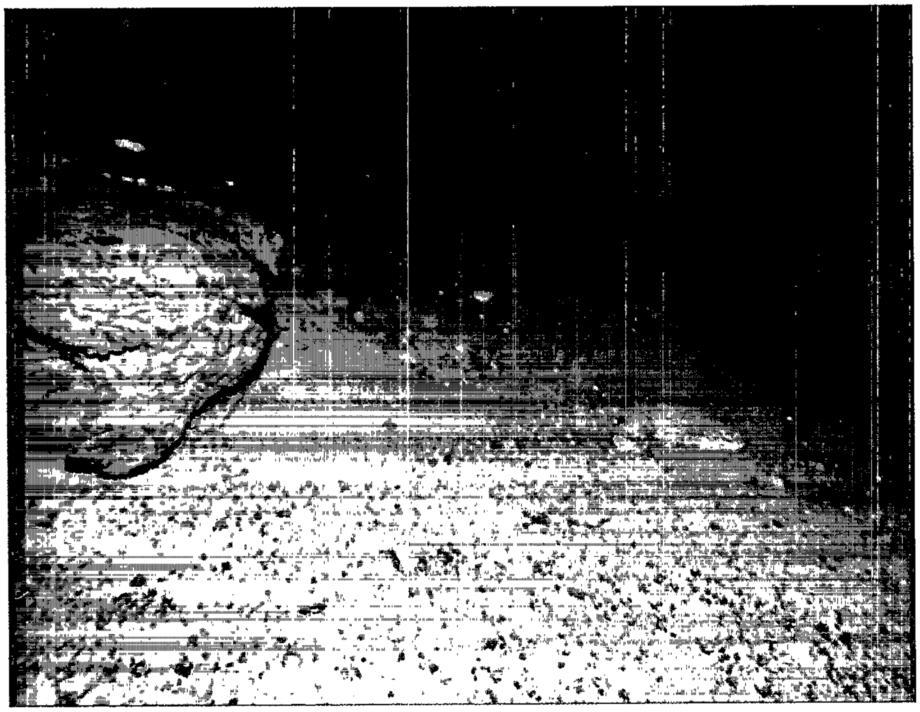

Figure 7

3960 m. Gravel and cobble bottom. Quartz pebbles with manganese coatings. White Eocene (?) chalk cobble protrudes from bottom at right center. Rounded marl or claystone talus is derived from the wall on the left.

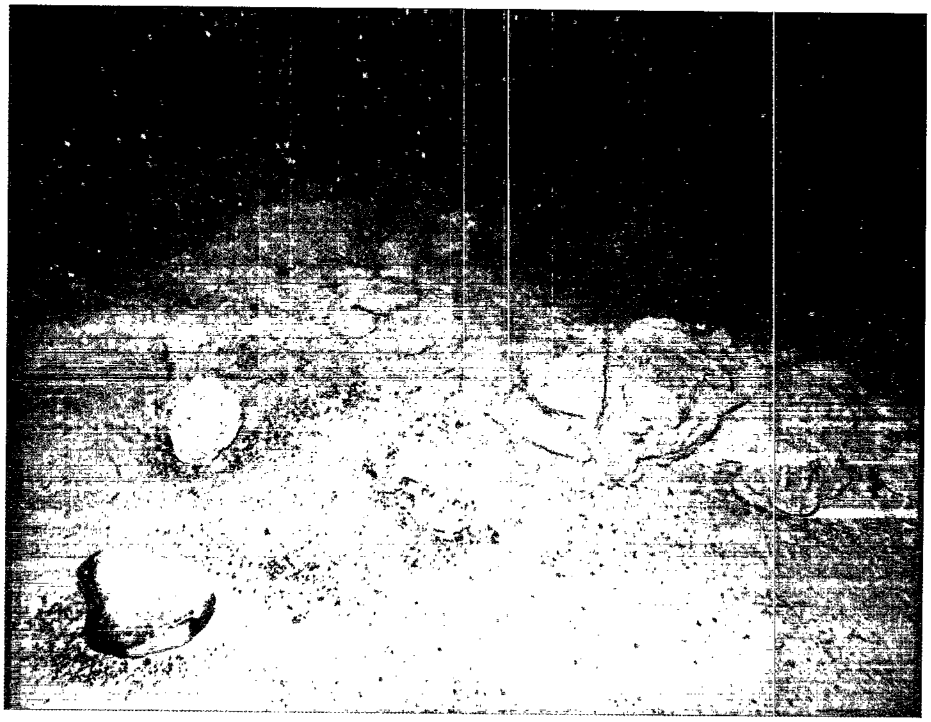

Figure 8

3967 m. Gravel and mud bottom. Currents in this region are 25 to 30 cm/sec. Rounded cobble in foreground is glacially derived. White Eocene (?) chalk boulder in background is believed to represent slumped material derived from exposures farther up the Hudson canyon or from the adjacent slope. Soft marl or claystone talus is derived from wall at left corner.

Figure 9

3960 m. Semiconsolidated marl or claystone talus derived from the wall at right front of photograph. White chalk and brown siltstone (?) boulder at center is embedded in soft marl or claystone. This material is thought to be derived from exposures at shallower depths in the canyon or on the slope.

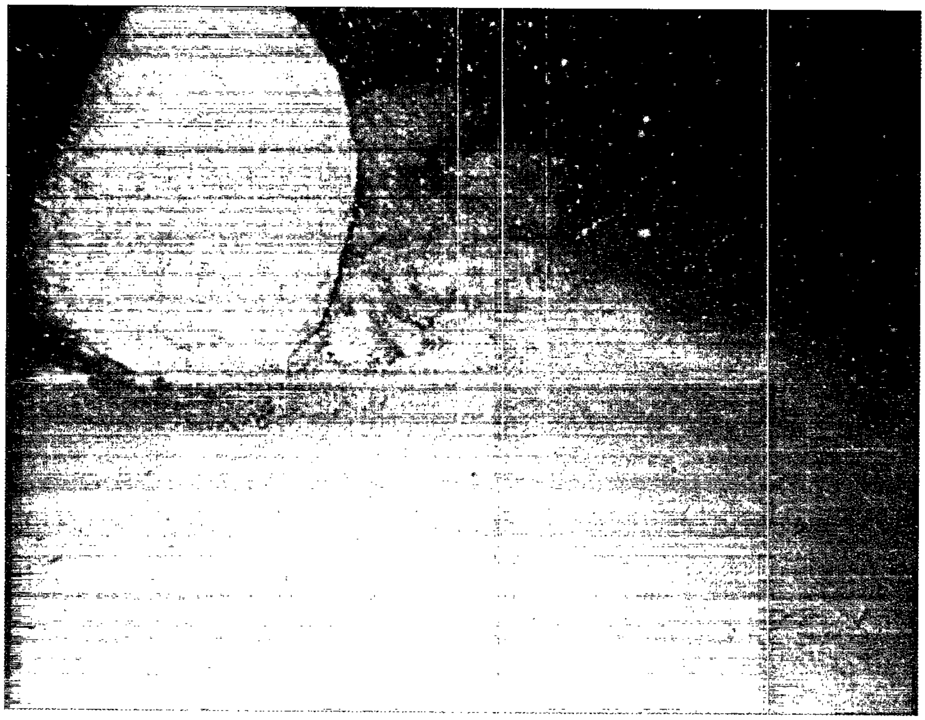

Figure 10

3961 m. Rounded chalk boulder 2-3 m long, resting upon a hard gravel bottom that is exposed in a prominent scour moat. Such excavations and the general absence of sediment dusting on boulders implies fairly strong and recent current activity at the site.

exposures either as bedded deposits or as resedimented clasts. The white chalk blocks were probably derived from further up the continental slope where similar rocks have been observed in place (Heezen and Dyer, 1977; Ryan et al., 1978; Musick, pers. comm., 1978). A sample of this rock type was collected at the drum recovery site and was determined to be of mid-Eocene age based on its contained microfauna (Table I). A sample of the same lithology was taken during investigation of the 2800 m dump site (Rawson and Ryan, 1978) and has also been dated as mid-Eocene (Sample 679, Table I). The white chalk appears to have originally accumulated in a shallower and more landward environment in water depths of 1500 to 2500 m (G. Blechschmidt, pers. comm.) and was redeposited at a later date in the Hudson Canyon system as blocks, boulders, cobbles and pebbles. Thus it is concluded that these rocks are not locally derived but have been transported down the canyon by some type of slide or mudflow mechanism.

Scour moats are generally present around the bases of boulders in this region of the Hudson channel. These current scours are present on the upcurrent side of the boulders and a sediment buildup or drift is usually present on the downcurrent side. Scour moats (Fig. 10) have a variety of sizes and shapes but are 5 to 10 cm deep on the average. A large quartzite boulder of glacial origin was observed that was surrounded by an impressive scour moat. An older mud burial line was still visible on the boulder about 30 cm above the exposed base of the boulder. This provides a good example of recent erosion.

RADIOACTIVE WASTE DRUM SITE AT 3970 METERS DEPTH

Description of Site

The first radioactive waste drum was spotted during Dive 813 at 1540 hours and a depth of 3970 m (Fig. 11). This drum was lying on a hummocky, irregular sea bottom. The three types of talus blocks described above surrounded the drum. Although these blocks varied greatly in size many of them were about the size of the drum (Fig. 11). A prominent scour moat was present on the upcurrent side of the drum, and a mound of granule-sized sediment had been built up on the downcurrent side of the drum (Fig. 12). The drum was intact, but highly

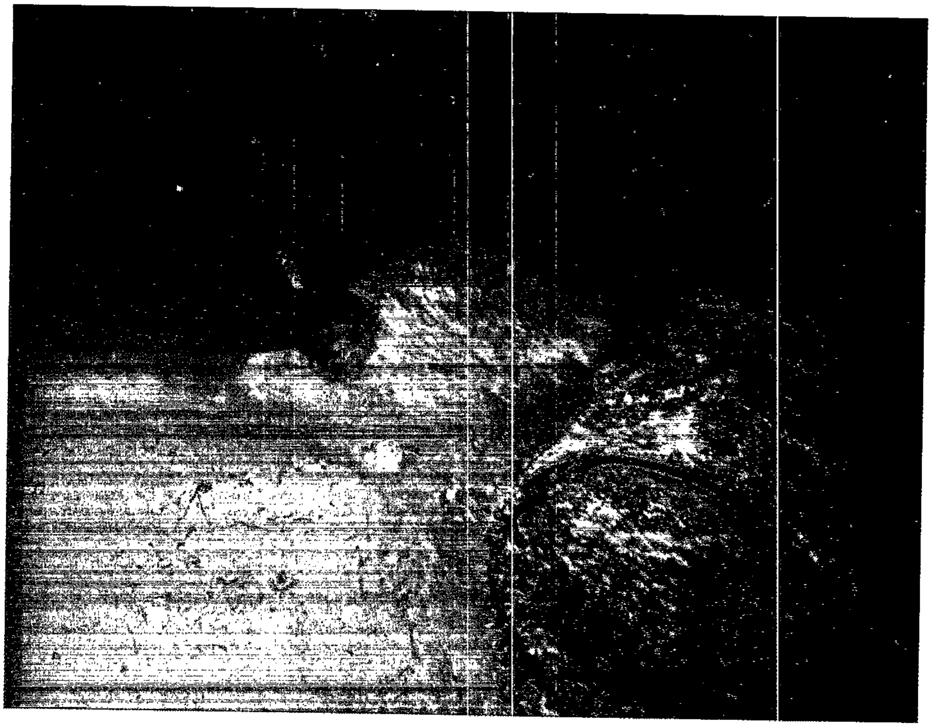

Figure 11

3970 m. Photograph of the first drum located during Dive 813. Currents have kept the upper surface of this heavily corroded drum free of sediment accumulation. Soft marl talus litters the local area of this drum. Corrosion has obliterated identification markings.

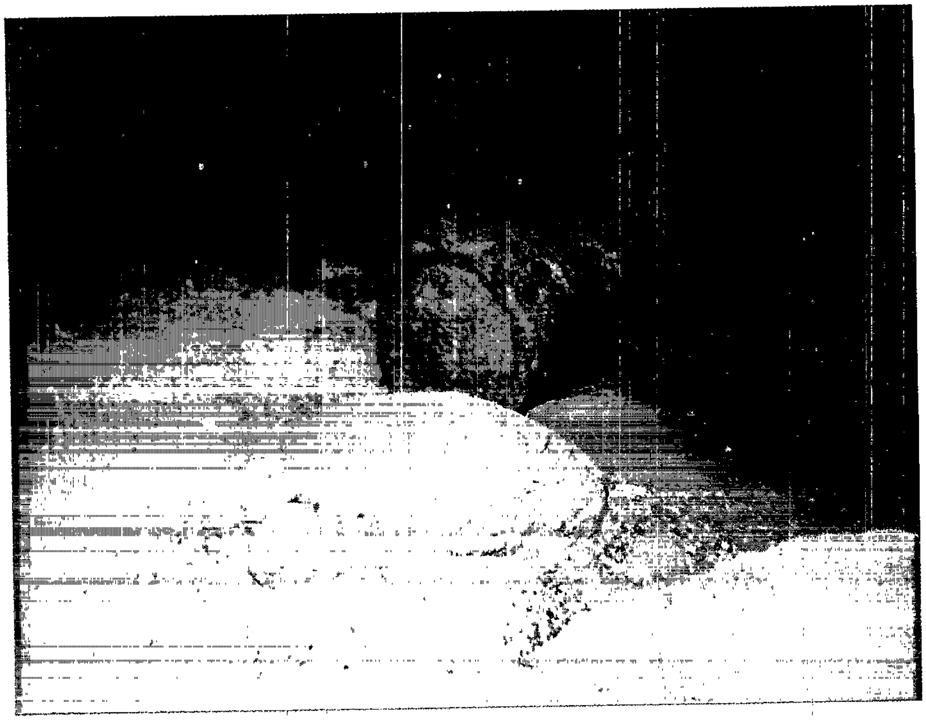

Figure 12

Photograph of first drum located on Dive 813. This drum is resting on a hard substrate. Corrosion of the drum has streaked the sediment surface in a downcurrent direction. The corrosion products are coming from the upper right hand corner of the drum. Note large marl or claystone talus blocks lying about.

corroded and blistered. Trails of corroding material were observed coming from the drum (Fig. 12). A core was taken in the corrosion-rich sediment and another in the sediment buildup on the downcurrent side of the drum (Table I). The sediment drift consisted of foraminiferal sand. The core only penetrated about 8 cm and a hard light tan clay or marl substrate was observed. Thus the bottom in this area does not appear to be a product of recent deposition, but instead probably represents an erosional surface covered with a thin biogenic or hemipelagic sediment layer (Fig. 13).

Another waste drum (No. 953) was located nearby (Fig. 14). This drum was surrounded by a well-defined scour moat similar to that around the first drum. One end of the drum had a wedge of sediment sloping away from it. This wedge appears to have formed when the drum slid into its final resting position, plowing the sediment as it moved (Fig. 14). Various sizes, shapes, and types of talus were lying around drum No. 953. Abundant rounded white and brown pebbles were present in the drum area (Fig. 7). These gravelly deposits appear to have been sorted by currents and are exposed in patches. Elsewhere the gravels are obscured by thin, hemipelagic surface deposits. These gravels are probably glacial in origin and were later concentrated by currents flowing in the canyon channel. Small white anemones were attached to larger rocks near the drum and it is interesting to note that these organisms, which favor hard substrates, were absent from the drum surface. Brittle stars and a few small scorpion-like crabs and large rattail fish were the dominant inhabitants of the drum area. As noted, no organisms were observed on the drum itself. The currents seemed to be stronger at this drum site than those of the previous site, Dive 812. The velocity was estimated at 25 to 30 cm/sec. When the mud bottom was disturbed by the submersible, the sediment was quickly swept away downcurrent after a few minutes. The largest and deepest scour moats were observed around the large talus blocks in this area (Fig. 10). The site of this drum is characterized by a highly variable, complex depositional and erosional topography. Thirteen sediment cores, a water sample and a box core containing a brittle star were taken from this site for various geochemical and radiochemical laboratory analyses (Fig. 13).

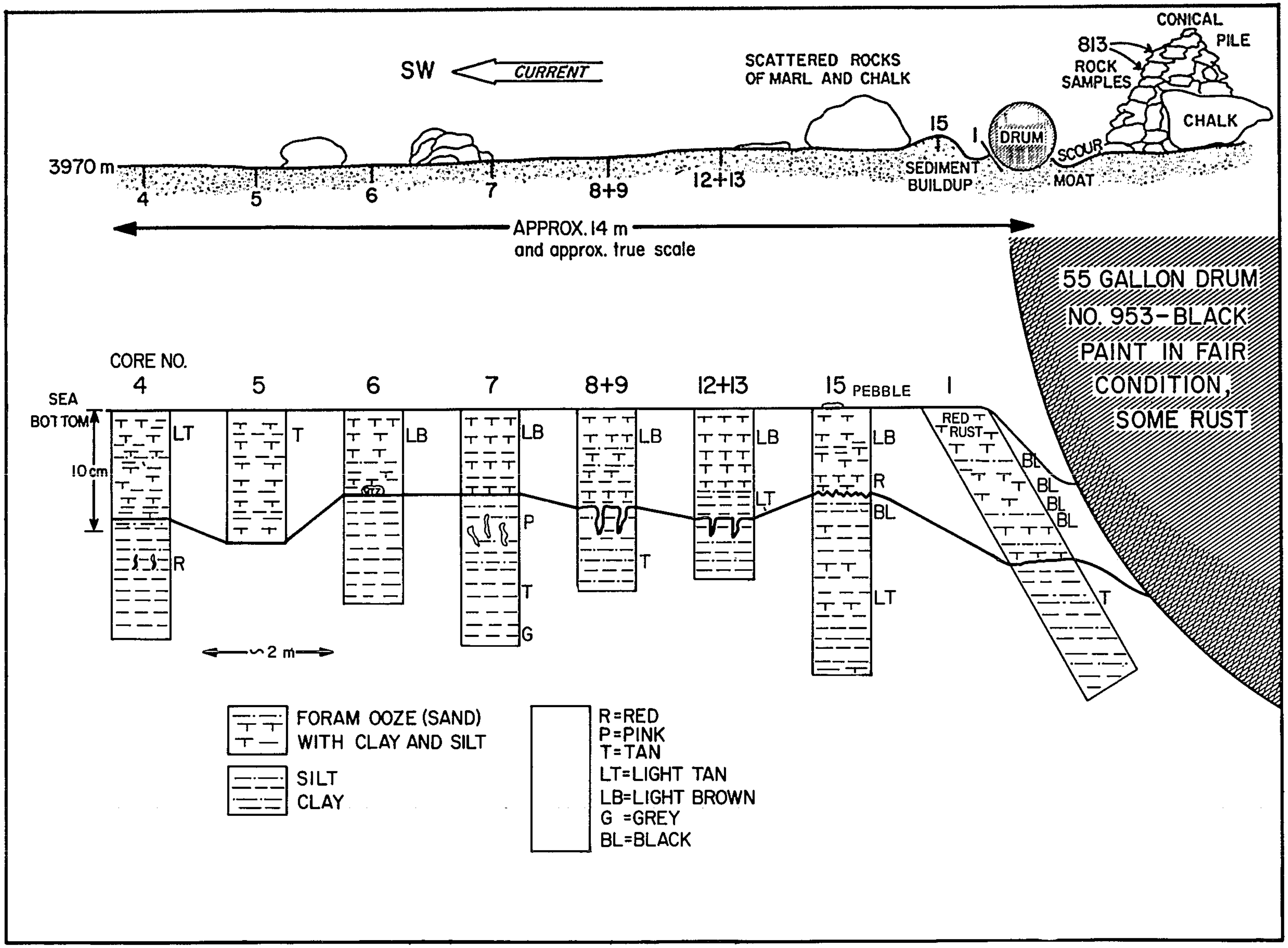

Figure 13

Position and field descriptions of tube cores taken downcurrent from Drum 953.

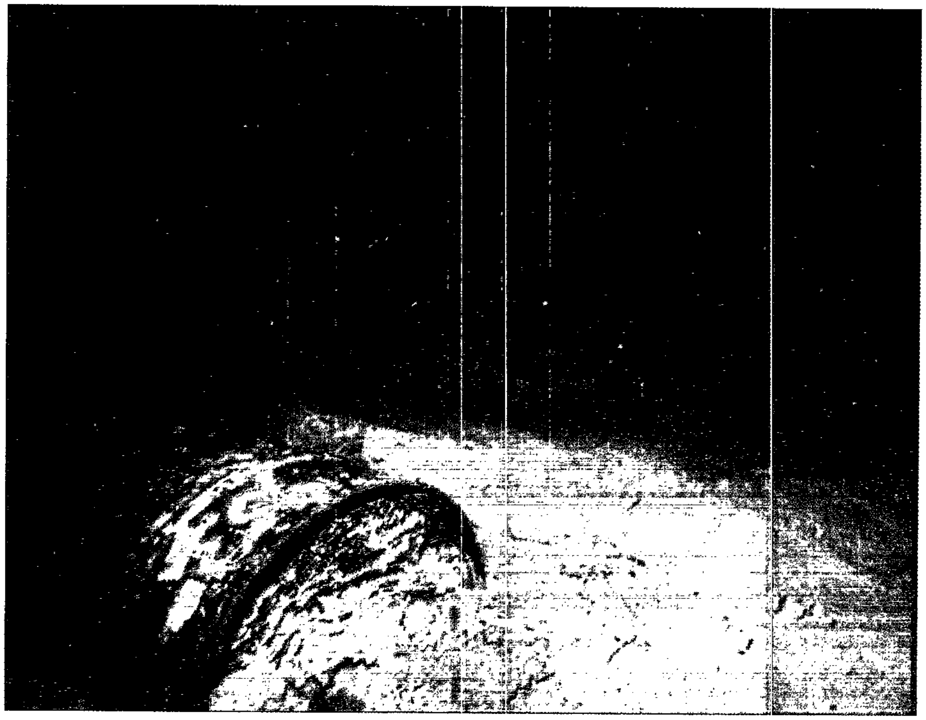

Figure 14

3970 m. Photograph of second drum (953) located. Soft mud bottom is disturbed by ALVIN. Sediment wedge at the end of the drum may have been plowed up when the drum slid into its present position.

Before leaving the bottom, rock specimens were taken from a conical pile of unsorted rubble near the drum. This rock pile is about 3 to 5 m high and consists of rounded white cobbles and boulders of chalk, glacial cobbles and locally derived tan marl talus blocks (Fig. 13, Fig. 15). This mound of rocks was like others observed while searching for the waste drums. Two samples were taken from this pile. The white cobbles (ALVIN 813 chalk) here are believed to be representative of all the white blocks of boulder to cobble size encountered along the bottom during Dive 813. The mode of origin of these piles is unclear at this point. Perhaps these represent the toe of a circular slump that has pushed this rock mixture to the surface, forming a small cone that has had its fine-grained sedimentary component stripped away by recent currents.

Coring Program and Field Description of Cores

The first waste drum discovered was a 55-gallon drum. A scour moat was present on the upcurrent side of the drum and a sediment buildup occurred on the downcurrent side. The drum was sitting on a firm bottom as evidenced by its lack of burial (Fig. 11). Two cores (Table I) were taken with 40 cm-long plastic core tubes, but because of the hard bottom only a few inches of sediment were recovered in each core. One core (Core #2) was taken in the area stained by the corrosion from the barrel near the east corner of the drum and the other core (Core #3) was taken in the sediment buildup on the downcurrent side of the drum.

A series of 13 tube cores, 10 of which are discussed here, were taken at the recovery drum site (No. 953). The 10 cores were taken at approximately 2 m intervals starting at a distance of about 14 m on the downcurrent side of the drum (Fig. 13). These cores were to be used for various radiochemical and geochemical analyses and only the field description made through the plastic core tubes is available for this report. These cores sampled two distinct lithologies, or sedimentary layers. The first layer consists of a 4 to 10 cm thick foraminiferal rich marl. The percentage of clay and silt increases downward within this unit. This layer is soft and porous and is tan to light brown in color. Near the drum and in the sediment buildup on the downcurrent side of the drum a significant amount of corrosion products (rust)

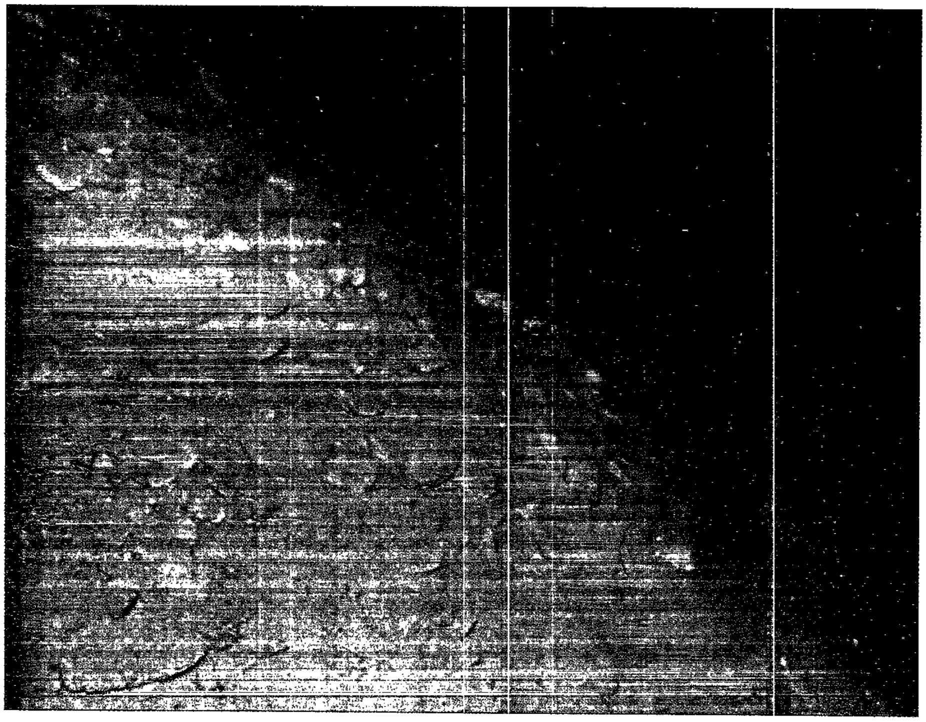

Figure 15

3970 m. Conical rock pile near drum 953. Two cobbles were sampled from this pile. One is a glacial erratic, the other is Eocene-age chalk (Table I.)

from the drum is mixed into this layer, creating a reddish discoloration of the sediment (Fig. 13, Core #1). The upper layer is generally in sharp contact with the lower layer which consists of semiconsolidated light tan, silty marl or claystone. This layer is quite hard as evidenced by the lack of core penetration. This layer is mottled in some of the cores and vertical burrows exist in others. The surface sediment has filtered down into the burrows. A pebble assumed to be quartz was noted along the contact between these two units in Core 6 and probably represents a lag deposit formed during a period of strong currents. Core #1 was taken at an angle under the drum to test the oxidation state of the sediments under the drum. This core contained considerable black colored sediment, the cause of which is uncertain but may be due to the formation of sulfides under anoxic conditions. This was the longest core taken from this series and was 28 cm long. Average penetration of the cores was about 15 cm.

The contact between these two lithologic units probably represents an erosional surface or a local unconformity. This erosional surface or unconformity is probably still forming in some parts of the channel, while in other parts of the channel foraminifera-rich surface sediments accumulate above it, particularly behind rocks or other topographic obstructions that break up the constant southwesterly current flow and possible tidal (and/or inertial) current flow which may be present.

INTERPRETATION AND DISCUSSION

The radioactive waste dump site studied encompasses an area of a few tens of square kilometers centered around 70°35'W to 37°50'N. According to available records, about 15,000 55-gallon drums of low-level radioactive waste embedded in concrete are reported to make up the contents of the dump site (Dyer, 1976). Only three drums were located during Dives 812 and 813 and one drum (No. 953) was recovered on Dive 814. The drums located on these dives appear to be lying near the base of the eastern side of the Hudson submarine canyon channel on the lower continental rise at a depth of 3970 m (Fig. 3). The main axis or thalweg of the channel appears to lie about 1 km to the west based on a limited bathymetric survey (Fig. 3). There is some evidence that this deeper axis meanders across a relatively flat channel floor (Fig. 3). Where the channel thalweg hugs the channel wall, tidal and/or contour currents may be concentrated to produce higher velocity currents than those observed on the channel flats (15-30 cm/sec). Higher velocity currents might cause the thalweg to cut laterally into the soft marl or claystone bedrock thus oversteepening the slope. Oversteepening or undercutting at the base of the slope would allow slumps or gravity slides to occur. Based on the observations made during Dives 812 and 813, there seems to be little doubt that this is a region characterized by major slumping and that the oversteepening mechanism could account for the observed scarp and bench topography. The scale of this slumping is difficult to assess. Small slumped blocks and scarps are easily observed, but larger features are difficult to assess from a submersible. It is most probable that the smaller features observed indicate that slumping on a much larger scale is taking place (Fig. 16). These data indicate that the canyon axis is presently being filled along its margins through the process of slumping from the walls.

A possible model for the earlier incision and later partial filling of the Hudson Canyon channel is suggested below and illustrated in Figure 16. During the last low sea level stand some 15 to 20,000 years ago, a much deeper, steep walled canyon was cut into the deposits of the continental rise. Many previous workers have both suggested and documented that the submarine canyons of the continental slope were deeply incised during this period (Shepard, 1952; Stetson, 1936, 1949). The Pleistocene age Hudson Canyon channel or seaward extension of the Hudson Canyon may have been a deep vee-shaped valley cut or formed by the action of sediment-laden turbidity currents or submarine debris flows as they passed seaward through this region towards the Hudson Fan Complex. As the Wisconsin-age glaciers receded, sea level rose and the sediment supply to the continental shelf, slope, rise and abyssal plain was diminished. At this time, the Hudson Canyon channel began to backfill from the seaward side. Two possible mechanisms, operating together, could account for this backfilling:

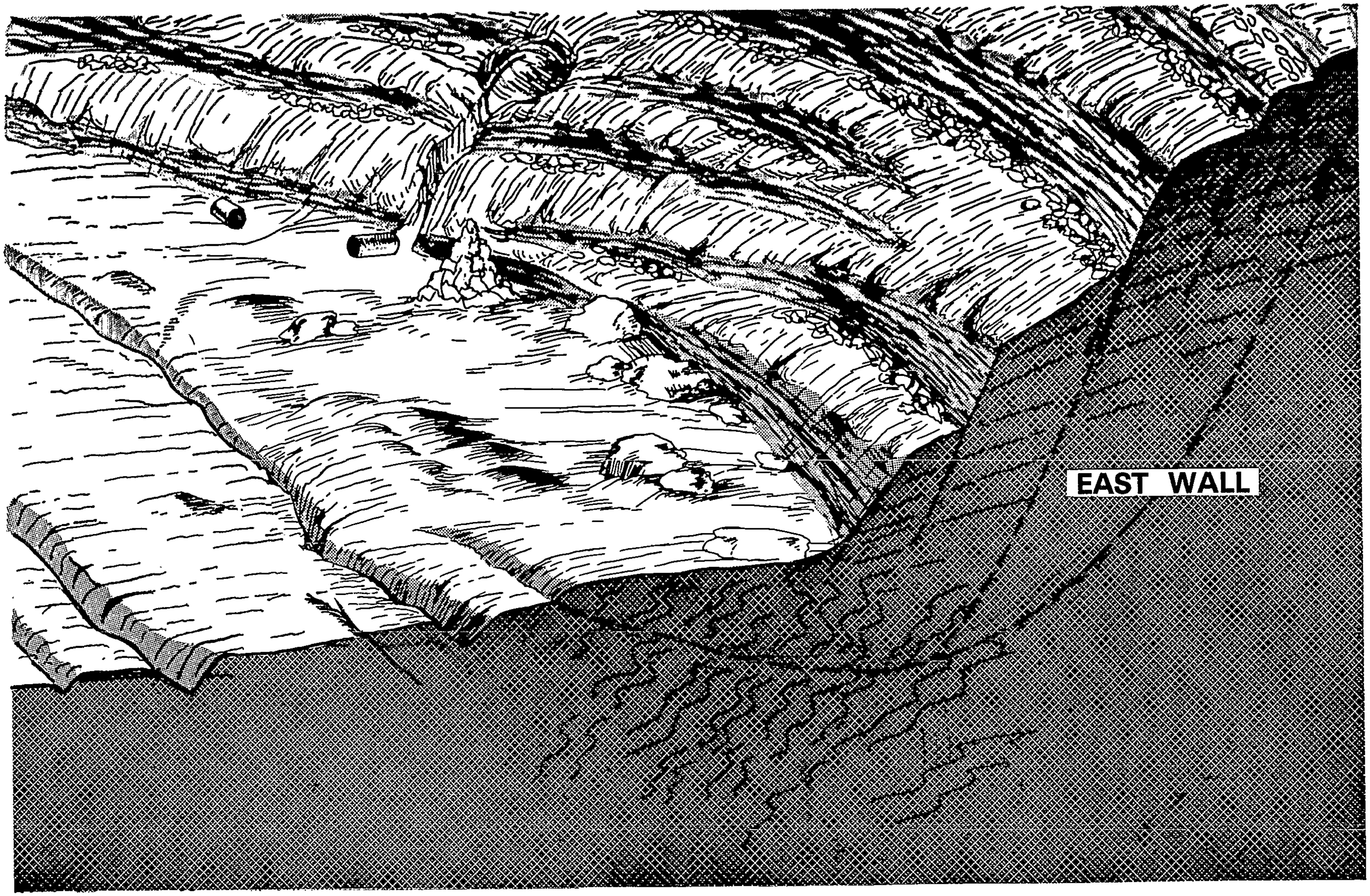

Figure 16

Hypothetical model for large scale slumps as a canyon filling mechanism.

with the many documented slump scarps along the channel walls, indicate that the channel floor is a site of net accumulation.

If these postulated geologic processes are indeed operating in this area, some geologic recommendations in terms of waste disposal can be made. First, it is clear that this is a very unstable area as indicated by slump scarps, avalanche deposits, and a lack of biological activity. Concrete filled drums, once introduced into the canyon system might behave as any other sedimentary particle, that is, these drums may move down the channel just as the chalk and siltstone cobbles and boulders have moved. The barrels observed on Dive 813 were probably in their original dumped position but some evidence of movement was indicated (plowed sediment) (Fig. 14). It is also possible that these drums may have slid down the channel walls to their present position, which would account for their position at the base of the channel. Any drums present on the channel floor could be subsequently moved or buried by slides or slumps from the channel walls which may plow into the channel area with great force.

Many speculations and assumptions have been presented in this report, but these are considered reasonable based on the available data. Further study is needed to support, alter or disprove the suggested geologic processes operating in the lower reaches of the Hudson submarine canyon. Based on this study, this area is classified as a dynamic deepsea environment whose agents and processes are presently poorly understood. With respect to future waste disposal activities in this and other canyon environments, material dumped on the flat divides between channels may eventually be displaced or buried if the interpretation of successive slumping and filling of channels is correct (Fig. 16). If low-level radioactive waste material is to be dumped in the North Atlantic, the flat and featureless abyssal plain areas to the northeast would be a geologically more stable area to consider for the possibility of future dumping.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

During the period of 22-28 July 1978, five dives were made in the manned submersible ALVIN into the Atlantic Ocean 3800-meter depth radioactive waste disposal site located in the Hudson Canyon channel approximately 320 kilometers from the Maryland-Delaware coast. A geological description of the site was made by direct examination of the bottom topography, bedrock exposures, sedimentary and erosional processes, and sediment cores collected from the dumpsite area. Observations within a depth range of 3985-3830 meters revealed angular blocks and piles of displaced channel wall rock, boulder and cobble olistoliths of Eocene-age chalks derived from higher elevations on the slope, and bedforms such as ripples and scour marks which imply the existence of periodic strong currents. Local benthic fauna were sparse. Three low-level radioactive waste drums were examined from the submersible, and one was subsequently recovered for corrosion and concrete deterioration analyses. Photographic and visual evidence suggest that downslope transport of objects such as talus blocks, olistoliths, and radioactive waste drums has occurred in this area.

17. KEY WORDS AND DOCUMENT ANALYSIS

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