HAMILTON BANK, LABRADOR

PART I

SURFICIAL SEDIMENTS

FOR

DEPARTMENT OF ENERGY, MINES & RESOURCES
ATLANTIC GEOSCIENCE CENTRE
BEDFORD INSTITUTE OF OCEANOGRAPHY
DARTMOUTH, NOVA SCOTIA

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CONTENTS

FIGURES

PLATES

ENCLOSURES

ACKNOWLEDGEMENTS

We gratefully acknowledge the assistance of Dr. W. van der Linden and Mr. A. Jackson of the Atlantic Geoscience Centre, Bedford Institute of Oceanography throughout the period of this study. The Photographic Section at the Bedford Institute, under Mr. N. Fenerty kindly supplied copies of typical seafloor photographs. Discussions with Dr. van der Linden and Dr. R. Fillon were helpful.

ABSTRACT

Results of size analysis of sediment samples from Hamilton Bank and the adjacent Cartwright and Hawke Basins are reported. Maps of percentage gravel, sand, silt, clay and mud, and a summarizing map illustrating gross sediment distribution are presented. Hamilton Bank sediments consist of a central area of muddy sand and a peripheral area of sand. The bank edge and upper slopes are characterized by a series of circumscribing sediment bands. In sequence from shallow to deep, these are gravel/sand and gravel/sand/mud. The gravel common to these two bands is restricted to the bank edge. The floors of Cartwright and Hawke Basins are composed of mud with silt predominating over clay. These mud-filled basins appear to be acting as sediment sinks for fine clastics winnowed from adjacent slopes and banks. Seafloor photographs further supplement the characterization of Hamilton Bank surficial sediments, while generally confirming the conclusions on sediment distribution based on grab samples.

SECTION 1. INTRODUCTION

This report considers the interpretation of size analysis data and seafloor photographs from Hamilton Bank and the flanking Cartwright and Hawke Saddles. As such, the study represents one segment of a multifaceted examination of the surficial geology of the region.

Hamilton Bank (Plate.1), has been selected by the Atlantic Geoscience Centre as apparently typical of the series of banks which constitute the outer continental shelf off the Labrador coast. It is considered that the study of this bank will lead to an understanding which can be extended to the other banks off Labrador. The outer shelf off Labrador is the site of increasingly intensive petroleum exploration with two wells now drilled and abandoned; one of which encountered significant oil shows. Apart from academic interest then, there is a practical requirement for an early understanding of such aspects as surficial geology, iceberg scouring, bathymetry and sub-bottom stratigraphy and structure as these relate to exploitation of offshore resources.

The data from Hamilton Bank collected to date includes bathymetry, potential field and gravity profiles, shallow and intermediate-depth seismic reflection profiles, sediment grab samples, gravity cores and long piston cores. Most of the data from the Hamilton Bank area was collected from the C.F.A.V.

SACKVILLE in 1972 and from C.S.S. DAWSON and C.F.A.V. SACKVILLE in 1973. Survey positioning was carried out by Satellite Navigation and Loran C. Positional accuracy of 250 m or less was obtained (van der Linden, 1974). The examination of most of this scientific data has yet to be completed and reported on.

A number of gravity cores and longer (6 to 12 m) piston cores were recovered from Cartwright and Hawke Basins and from the Continental Slope east of Hamilton Bank. These will shortly be reported on by Dr. G. Vilks of the Bedford Institute. Of particular relevance are the presently published, regional intermediate-depth seismic sections described by Grant (1972) and a regional bathymetric map, Canadian Hydrographic Service Chart 813 (1:1,500,000). A detailed bathymetric chart of the Hamilton Bank area is currently in the process of development and will incorporate all reliable data, and hopefully justify a scale of 1:500,000. An undrafted bathymetry map of the northern half of Hamilton Bank and Cartwright Saddle, drawn by Dr. W. van der Linden (van der Linden, 1973), presently constitutes the only detailed map in the area. Considering the lack of a detailed bathymetric map for southern Hamilton Bank and Hawke Saddle, and our conclusion that surficial sediment distribution in the Hamilton Bank area is closely related to seafloor topography, the sediment distribution maps of this report must be held as interim representations. These may require modification when the detailed bathymetry compilation becomes available.

PLATE 1

LOCATION MAP AND REGIONAL BATHYMETRY

HAMILTON BANK

(Bathymetry Contours in Metres)

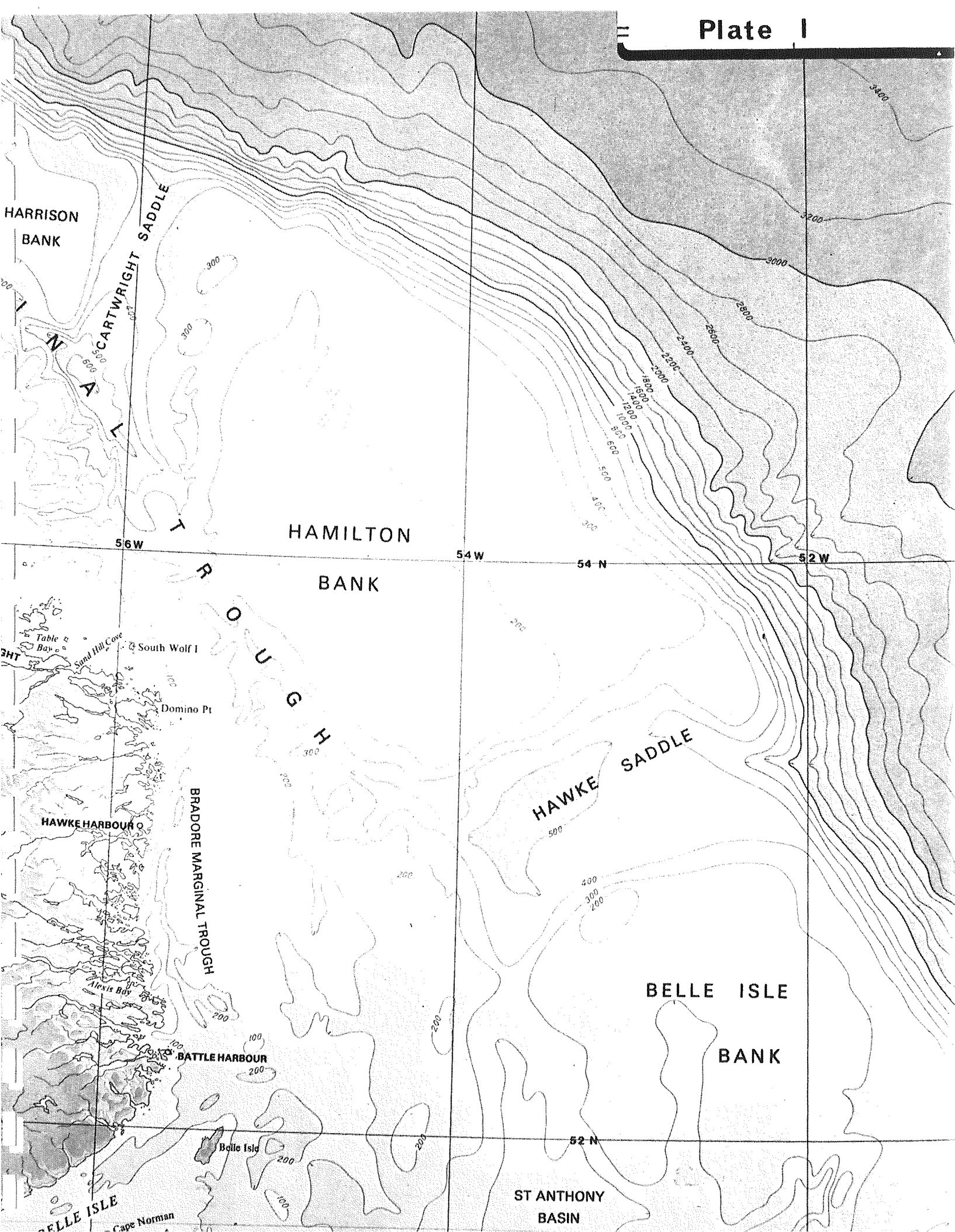


Plate I
HARRISON BANK
CARTWRIGHT SADDLE
HAMILTON BANK
TROUGH
56 W
54 W
54 N
52 W
52 N
Table Bay
Sand Hill Cove
South Wolf I
Domino Pt
HAWKE HARBOUR
BRADORE MARGINAL TROUGH
HAWKE SADDLE
Alexis Bay
BATTLE HARBOUR
Belle Isle
BELLE ISLE BANK
ST ANTHONY BASIN
Cape Norman

SECTION 2. REGIONAL AND TEMPORAL SETTING

The continental shelf in the Hamilton Bank area (Plate 1) may be subdivided into three major physiographic zones as follows:

Inner Shelf

Marginal Trough

Outer Shelf

The Inner Shelf is topographically complicated and acoustically impenetrable. This reflects the presence of complexly eroded Precambrian rocks at or very near the seafloor.

By analogy with the Precambrian Shield of the Labrador coast, these are expected to be crystalline and metasedimentary rocks. The Inner Shelf is essentially devoid of sedimentary cover although unconsolidated sediments occur in pockets. Notable in this zone are presumed glacially modified ancient drainage channels, extending from the entrance to Lake Melville (Cartwright) to the Marginal Trough. Such incised valleys are common along the eastern edge of the Inner Shelf. The seaward limit of the Inner Shelf may be taken as the 100 metre contour.

The Marginal Trough is an erosional feature which essentially defines the shoreward edge of a coastal plain sequence of Quaternary, Tertiary and Mesozoic sediments; all, presumably more susceptible to erosion than the Precambrian

basement rocks. The trough is a continuous feature which in detail consists of a series of basins, 300 to 500 metres deep, and linking saddles with minimum depths of 200-300 metres. The eastern margin of the trough is formed by the relatively steep face of the Outer Shelf.

Grant (1972), Figures 1 and 2 (this paper), has shown that south of Hamilton Inlet, smooth surfaced but seismically opaque strata, correlated as Lower Palaeozoic sediments, overlie the Precambrian and form the floor of the Marginal Trough. Beneath the eastern side of the Marginal Trough, at the southern end of Hamilton Bank, an inlier of seismically transparent and folded strata, presumed to be Upper Palaeozoic or Mesozoic by Grant, occurs under a cover of Quaternary sediments. The surface of these strata can be seismically traced a short distance beneath the gently eastward-dipping, Mesozoic to Cenozoic, coastal plain succession of Hamilton Bank.

North of Hamilton Inlet, the Palaeozoic strata are absent and Precambrian rocks form the base of the Marginal Channel beneath a cover of glacial till. The Mesozoic to Cenozoic coastal plain sequence lies directly on the Precambrian basement.

A detailed bathymetric map of the northern part of the Marginal Trough adjacent Hamilton Bank (van der Linden, 1973) reveals the presence of a narrow ridge, defined by the 250 metre contour, with relief of about 50 metres, which parallels

the western edge of Hamilton Bank. The ridge creates a sub-basin within the main Cartwright Basin. Grant (1972) interprets the ridge to be a glacial moraine. The linearity of the ridge invites speculation as to whether it may be a terminal moraine, or a lateral moraine. If a lateral moraine, a similar feature may exist around the southern end of Harrison Bank to the north.

The Outer Shelf consists of a series of banks, 150-250 metres deep, e.g. Makkovik, Harrison, Hamilton and Belle Isle Banks, and intervening transverse troughs termed "saddles" on published charts, e.g. Cartwright and Hawke Saddles; 300-400 metres deep. The internal structure of the banks, derived from seismic reflection records, reveals them to be large cuestas with strata gently inclined toward the east and abruptly terminated by erosion at the Marginal Trough. Application of the term "saddle" to the transverse troughs north and south of Hamilton Bank has proven rather restrictive in describing the distribution of surficial sediments. It is apparent that the sills which occur at the seaward end of these transverse troughs, and truly fit the definition of "saddle," have coarser sediments than the mud-filled basins shoreward which they limit. Both morphologically and sedimentologically, it seems desirable to restrict the term "saddle" to the sill which links the offshore banks, e.g. "Cartwright Saddle." The term "basin," e.g. "Cartwright Basin" would then apply to the basinal part of the

transverse and marginal troughs. These expressions have been adopted for the purposes of this report.

The surface of Hamilton Bank is inclined at a very low angle toward the east and is relatively, very smooth, excepting a complex micro-relief imposed by the many iceberg scours as revealed by sidescan sonar. The slope break, marking the transition to the continental slope, occurs at a depth of about 250 metres.

During the Pleistocene glacial epoch, ice sheets advanced onto the present continental shelf from highlands in Labrador. Ives (1957) has shown that the Wisconsin Ice Sheet at its maximum development attained thicknesses exceeding 1,500 metres in Labrador. Ives calculated from theoretical slope expectations, that its eastern margin at this time would have reached the edge of the continental shelf. Grant (op. cit.) has identified, seismically, a number of moraines in the Marginal Trough and on the banks of the Outer Shelf. Glacial drift is interpreted by Grant to blanket Hamilton Bank and the erosional edge of the coastal plain strata.

It seems probable that present physiography, including incised drainage patterns of the Precambrian Inner Shelf, the Marginal Trough, the termination of the Mesozoic-Cenozoic coastal plain succession as a cuesta and the inter-bank, transverse troughs, is to a large extent, a product of

Tertiary sub-aerial exposure and erosion. The immature topography of the new coastal plain was consequently dissected along the western margin of the sedimentary wedge, initiating development of the Marginal Trough. Periodic incising or partial breeching of the coastal plain by transverse fluvial valley systems resulted in the initial development of the present transverse troughs. The subsequent modification of this eroded terrain by Pleistocene glaciation is undoubted. However, the relative degrees of influence of fluvial and glacial erosion in the evolution of the present morphology remains to be determined. The role of regional tectonic events in this evolution is unclear.

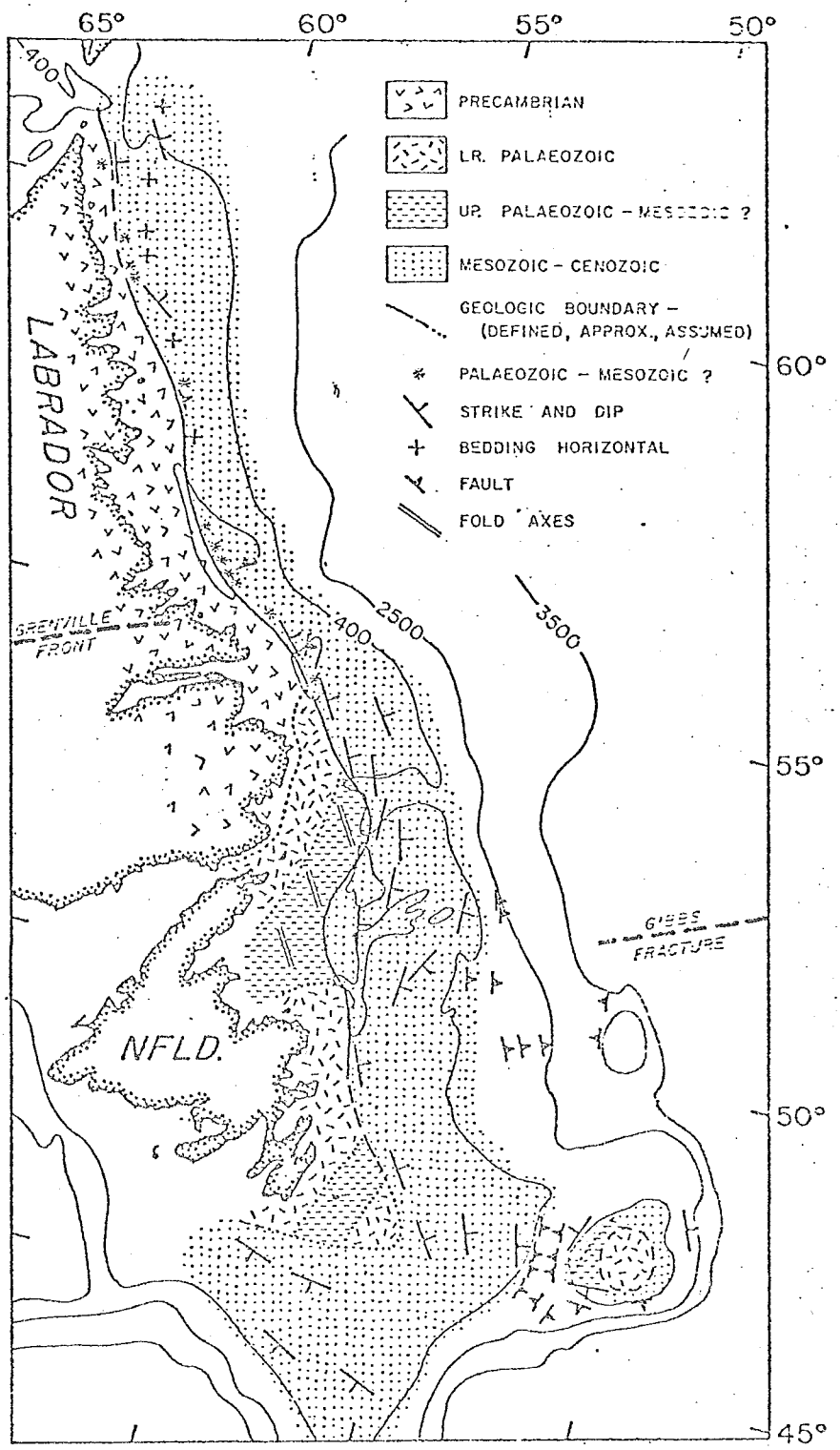


Figure 1 (after Grant, 1972)

Bedrock geology. Strike and dip determinations were plotted at seismic line intersections or course alterations.

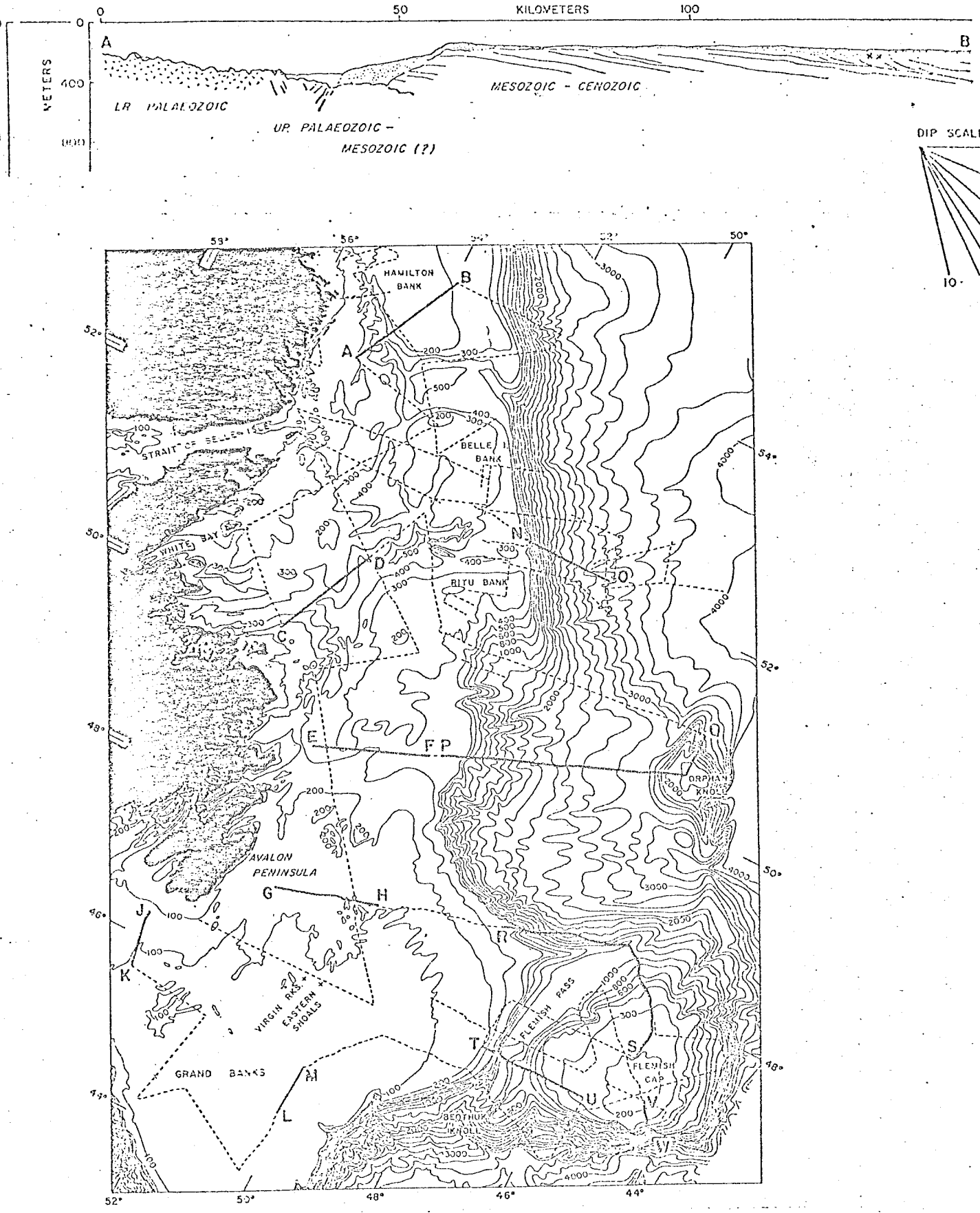


Figure 2 (after Grant, 1972)
Seismic cross section of Hamilton Bank and Marginal Trough. Note that the cross section depth scale is based on an assumed seismic velocity of 1500 m/s for water and sediments. Surficial deposits, except mud, are stippled and morainal accumulations are denoted by x's. Bathymetric contours on the location map are drawn at 100 metre intervals on the Continental Shelf.

SECTION 3. SAMPLING AND ANALYTICAL PROCEDURES

Sediment sampling was carried out with a standard Van Veen grab (Plate 2). This device will in the absence of gravel, take a relatively undisturbed sample of approximately the upper 15 cm of sediment on the seafloor. Where a grab recovered only gravel, the representativeness of the sample was suspected. That is, it was considered that fine sediment may have been washed out through jaws of the grab held partially open by a pebble. The value of such a sample thus is diminished though of course it is a qualitative affirmation of the presence of gravel in an area. From undisturbed grab samples, a quantity representative of the whole sample, was collected in plastic buckets and sealed until analysis was begun.

Seafloor photographs were obtained with an E.G. & G. utility camera system, mounted in a frame developed by the Bedford Institute of Oceanography (Plate 3).

Standard procedures in the size analysis of sediments were followed by the Sedimentology Laboratory at the Bedford Institute. Briefly, the still moist samples were disaggregated and wet-sieved on a 63 micron sieve. The +63 micron fraction (sand and gravel) was oven-dried, weighed and dry-sieved on a nest of ten sieves, representing 1 ϕ intervals between 63 microns and 32 millimeters. Each sieve fraction was weighed and its percentage of the whole sample calculated. Pipette analysis was performed on the -63 micron fraction to obtain gross percentages of silt and clay, and thus of mud.

PLATE 2

VAN VEEN GRAB SAMPLER

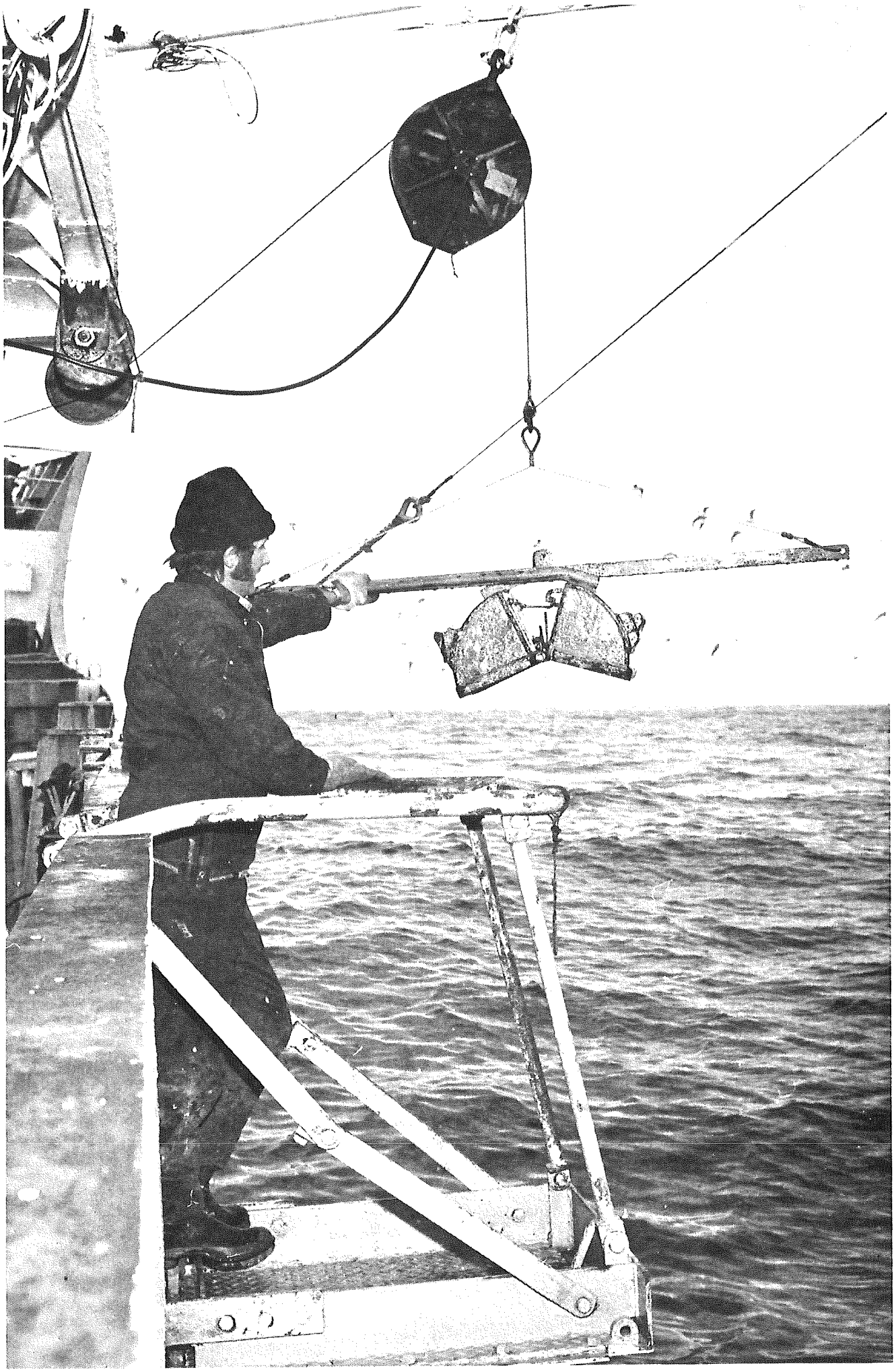
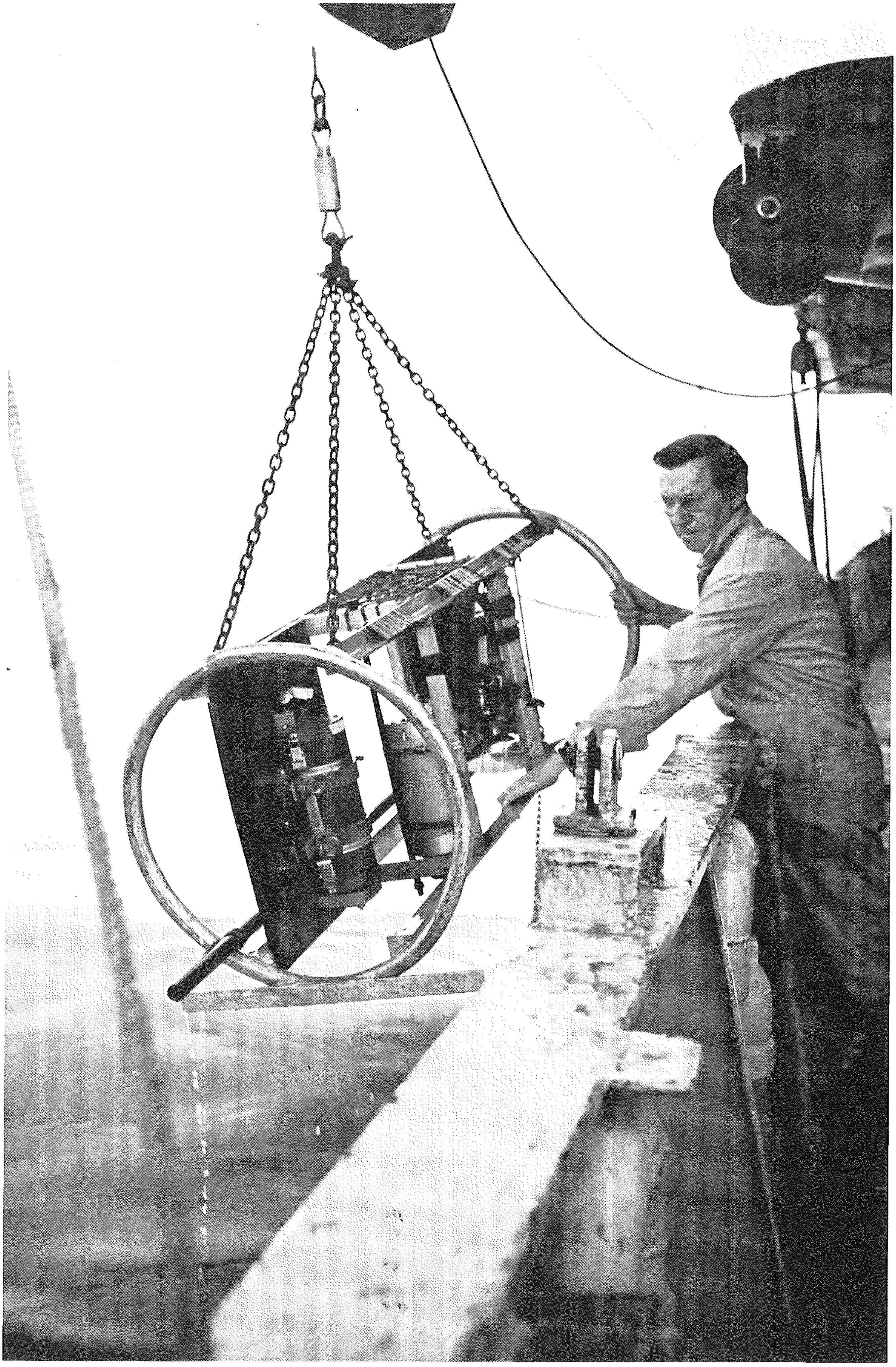


PLATE 3

E.G.&G. UTILITY CAMERA SYSTEM

MOUNTED ON BEDFORD INSTITUTE FRAME



SECTION 4. SURFICIAL SEDIMENT GRAIN-SIZE DISTRIBUTION

Surficial sediment grain-size distribution has been characterized through size analysis, and illustrated in a series of maps of percentage gravel, sand, silt, clay, and clay and silt combined; mud (Enclosures 3, 4, 5, 6, and 7). Finally, the gross sediment grain-size zonation of Hamilton Bank is summarized and illustrated by a single map (Enclosure 8).

The iso-percentage maps of gravel, sand, silt, clay, and mud illustrate separately, the major sediment grain-size distributional trends in the study area.

For gravel (Enclosure 3), high concentrations are restricted to the bank edges of Hamilton Bank, Harrison Bank and Belle Isle Bank, and to the morainal ridge within Cartwright Basin. Size-frequency histograms for the gravel fraction of samples with considerable quantities of gravel were plotted. These are illustrated in Enclosure 9. No obvious geographic trends of size-frequency distributions are apparent. The histograms do illustrate the fact that essentially two distributions exist: normally distributed gravel, and a distribution which is markedly skewed toward the coarsest gravel classes. The latter may reflect an inordinately large influence of coarse and very coarse pebbles (greater than 16 mm and 32 mm in diameter respectively) on weight percentage determinations. The gravel fractions of these highly skewed samples should be

re-examined and judgement passed on the sample's representativeness.

In general, the distribution pattern of gravel closely follows bottom morphology. Where the slope of the bank edge is relatively great, e.g. the eastern edge, the gravel exposures form a narrow band. Where the slope diminishes as at the southeastern corner of the bank, the band of gravel is much broader though it still parallels the morphology of the bank edge. This sympathetic relationship suggests that the gravel or till constitutes an horizon which outcrops at the bank edge in a narrow band where the slope is greatest and in a broad band where the slope is least.

Sand (Enclosure 4) is the major constituent of Hamilton Bank surficial sediments. Over most of the bank, it is diluted with less than 20 percent mud. The highest concentrations of sand (95%) occur in the shallowest area of the bank (150 metres) along the western edge. The sand content of sediments appears to diminish gradually from the banks into the basins where mud finally dominates. Similarly, sand content decreases away from the axis of the morainal ridge in Cartwright Basin.

Considering the silt and clay content of sediments in the study area (Enclosures 5 and 6), it is observed that silt generally dominates clay. In the area of "muddy sand"

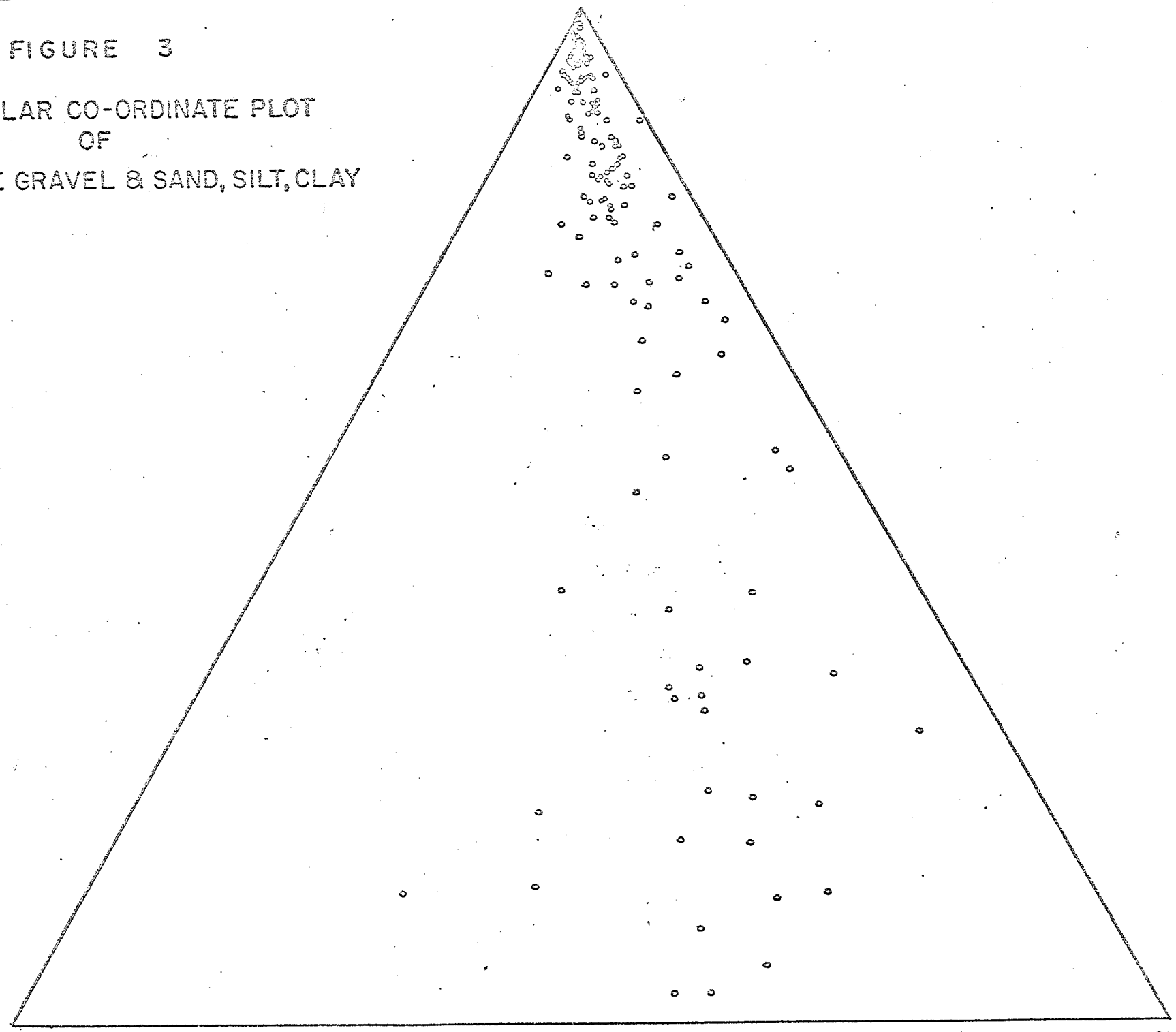
(Unit 1a of Enclosure 8) on central Hamilton Bank, with mud concentrations as high as 50 percent, the clay content is between 5 and 10 percent. In the mud of Hawke and Cartwright Basins (Units 5a and 5b), the silt content again dominates that of clay, though less markedly. There the composition is approximately 60 percent silt and 40 percent clay. On the slopes of Hamilton Bank, a normal gradation from low silt and clay concentrations at the top, to higher concentrations at the bottom occurs.

Mud (Enclosure 7), representing silt and clay content combined, naturally reflects the distributional trends of its components but is a useful summarizing illustration of the distribution of fine-grained clastics. In the study area, mud either dominates or is present as a major constituent in the sediments of low hydraulic energy regimes; the basin floors and deeper zones of the bank edge slopes. It remains to be seen, however, whether central Hamilton Bank with its muddy sand is truly a low energy regime as suggested by its poorly sorted sediments.

A triangular co-ordinate plot of grain size class percentages using gravel and sand, silt, clay as end members (Figure 3) illustrates the strong preponderance of sand and gravel in surficial sediments of the study area. The general domination of silt over clay in the fine sediment fraction is further illustrated.

FIGURE 3

TRIANGULAR CO-ORDINATE PLOT
OF
PERCENTAGE GRAVEL & SAND, SILT, CLAY



Following is a general consideration of the surficial sediment distribution pattern in the study area. These generalizations are illustrated in Enclosure 8.

HAMILTON BANK

Sand is the major component of Hamilton Bank surficial sediments. A division into "Sand" (Unit 2a) and "Muddy Sand" (Unit 1a) has been made. The "Sand" averages 93% sand and 7% mud. "Muddy Sand" averages 75% sand and 24% mud. The existence of the mud and sand mixture (Unit 1a) in central Hamilton Bank, surrounded by a well-sorted sand, is problematical. No evidence of bottom currents of sufficient speed to develop ripple marks at any point on the bank was found in photographs. If varying flow regimes over the bank are responsible for the observed sediment distribution patterns, it suggests that the highest aspect of Hamilton Bank, 150 metres deep, with the highest degree of sorting, protrudes into a relatively high energy water mass. The central area of poor sorting may be indicative of a relatively low level of hydraulic energy. The down-slope well-sorted sands peripheral to the central muddy sand zone may reflect a relatively high energy regime; the product of upwelling and associated boundary effects at the bank edge. The popularity of parts of Hamilton Bank for foreign fishing fleets may be indirect evidence of such unpredicted current activity. Clearly the logical explanation of Hamilton Bank's sediment distribution patterns must await in

situ measurements of bottom current velocities, consideration of the effects of long-period ocean surface waves, internal waves, etc. and temperature and salinity structure of the surrounding water mass.

Note that some seafloor photographs of Hamilton Bank (Stations 39, 40, 49, 51, 52, 53, and 54) suggest that gravel is more extensive on the bank than the present grab samples indicate. These photographs were however, obtained in areas of intense iceberg scouring as revealed by sidescan sonar. Thus the seemingly anomalous gravel may be a shallow sub-bottom horizon which has been exhumed by scouring. If this situation exists, it is also relevant to the interpretation of sidescan sonar records. These records commonly display poorly defined "iceberg scours" which do not yield distinct topographic reflections and associated acoustic shadows. These are in notable contrast with scours that display these features distinctly. It may be then, that the indistinct reflections are from exhumed gravel, plowed aside by grounding icebergs. Smoothing of the resultant micro-topography would be accomplished by filling depressions with sand, leaving gravel on the surface. Differential reflection by sand and gravel would then produce the ill-defined lineations of the sidescan sonograms. Comparison of precision depth recordings obtained from the Nova Scotia Research Foundation

V-Fin system and corresponding sidescan sonograms would resolve this question. The filling of iceberg scour depressions would occur over a period of time related to the hydraulic energy level of bottom waters. This period of time would, if it could be estimated, reveal the approximate minimum age of scouring. Some of the observed cobbles or boulders on Hamilton Bank may have been ice-rafted. Their scarcity and size would preclude this being sampled in a Van Veen sediment grab.

HAMILTON BANK EDGE

The slopes marking the edge of Hamilton Bank are characterized by sediments having gravel as a major component (Enclosure 8). Toward the top of this slope, gravel is mixed with sand (Unit 3a) in a circumscribing band which averages 44% gravel, 51% sand, and 5% mud. Down-slope, the mud content increases in significance at the expense of sand and gravel which nonetheless remain as major constituents of the sediment. Here the surficial deposits are a mixture of sand, gravel and mud (Unit 4a). Grain-size distribution averages for this band are: gravel - 34%, sand - 44%, and mud - 22%. The observed gravel concentration and attendant sand and mud around the bank edge suggests that the gravel unit is either a clean gravel, subject to the spillover and admixing of sand and finer clastics from Hamilton Bank, or

is itself a very poorly sorted sediment, i.e. glacial till. Presumably the same spillover sediments from Hamilton Bank may be mixed with the unsorted sediments of the till.

As discussed in the previous consideration of gravel distribution, these circumscribing bands of gravelly sand and gravelly muddy sand, reflect seafloor topography in their areal distribution. That is, the areal distribution is suggestive of a planar horizon which outcrops along the bank edge slope with the area of exposure related to the inclination of the slope. The implication of this relationship, if real, is that the gravel horizon is an essentially planar unit which is continuous across Hamilton Bank (though superficially covered by finer clastics), and which outcrops around the bank periphery at the intersection of its dip plane and the plane of the bank edge slope.

HAWKE BASIN

Toward the base of the Hamilton Bank slope in Hawke Basin (Unit 1b, sandy mud), gravel ceases to be a major component of the surficial sediments whereas sand, presumably more mobile in its down-slope progression than gravel, remains a major contributor. Mud is the dominant constituent. Average grain-size distribution is 33% sand and 66% mud.

Toward the deeper part of Hawke Basin, mud increases as sand content diminishes and in the central area of the basin, mud occurs in excess of 90% (Unit 5a, Enclosure 8).

The muds of Hawke Basin are easily penetrated by a piston corer and cores 12 metres long were repeatedly obtained. Acoustical transparency, equated with the fine-grained and unconsolidated nature of the sediments in the basin is attested to by the presence of sub-bottom reflections on Presicion Depth Recordings.

CARTWRIGHT BASIN

Cartwright Basin sediments are influenced by the proximity of adjacent banks, Hamilton to the south, Harrison to the north and the Inner Shelf to the west. Additional to these major features is the linear ridge which parallels the western edge of Hamilton Bank and creates an elongate sub-basin between it and Hamilton Bank. This narrow ridge within the Cartwright Basin, identified by Grant (1972) as a moraine by its seismic characteristics, has surficial gravel concentrations. Seafloor photographs (Station 59) further confirm the composition of the ridge as an unsorted mixture of sand, gravel and boulders, and support Grant's inference.

The common progression occurs of coarse sediments on adjacent bank edge slopes or morainal ridge slopes, to mud in the basin. Photographs from Station 38 reveal the floor of Cartwright Basin to be fine-grained, smooth and supporting numerous, burrowing animals. As in Hawke Basin, the easy penetration of surficial sediments by 12 metre long piston cores and their acoustic penetration by the 12 kH_z Precision Depth Recording system, reveal the shallow sub-bottom sediments to be predominantly fine-grained and unconsolidated. Preliminary studies of the cores from Cartwright Basin indicate that significant volumes of methane are being generated in this shallow sedimentary section (Vilks, personal communication).

SECTION 5. RECOMMENDATIONS

Following are suggestions for further studies of the surficial sediments in the Hamilton Bank area.

1. The interpreted sediment grain-size distribution patterns in the Hamilton Bank area should be re-examined in the light of the finalized bathymetry map when available. This suggestion stems from the apparently strong relationship between seafloor morphology and sediment distribution.

2. Further quantification of the grain-size distribution of sediments should be carried out. Statistical measures of grain-size distribution e.g. median or modal diameters, sorting coefficients, etc. could readily be plotted on the present base map once computed. Because a detailed pipette analysis was not performed on samples, the statistical measures, Mean, Median and Mode, can only be accurately calculated for those samples mainly composed of sand or gravel (most samples).

3. An examination of coarse fraction lithologies might be revealing of till sources. McMillan (1971) related pebble lithology in ground moraines on the continental shelf, to bedrock lithology. The relatively high density of sampling on Hamilton Bank suggests it as a test of McMillan's thesis.

4. Examine P.D.R. records from Hawke and Cartwright Basins for sub-bottom penetration. Map continuous reflections in terms of structure or depth and compare shallow reflections with core stratigraphy. The question of whether the methane in sediments of Cartwright Basin forms an acoustically reflecting horizon should be examined.

5. The examination of V-Fin, shallow seismic reflection records should be made. Though little penetration of sediments on Hamilton Bank was recorded, the records contain excellent measurement of micro-topography which may be related to sediment distribution patterns. Of high priority should be the task of relating these precision seismic recordings to the iceberg scours observed with sidescan sonar. As suggested previously (page 19), the distribution and nature of iceberg scours may be important to the understanding of surficial deposits on Hamilton Bank.

6. Give consideration to the genesis of surficial sediments in the study area in the light of conclusions from core studies. Core analyses might reveal temporal trends in climate and water depth which may be related to the evolution of present surficial deposits.

7. A study of seafloor photographs and maps of sediment distribution by a marine biologist might reveal significant relationships between benthonic fauna and seafloor sediment types. Faunal distributions may in turn, reveal something of the hydrodynamic regime in the area.

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MAP REFERENCES

Canadian Hydrographic Service, 1972.

Bathymetric Chart No. 813, Labrador Continental Margin. Scale - 1:1,500,000., Canadian Hydrographic Service, Ottawa, Ontario.

van der Linden, W.J.M. 1973.

Bathymetry of Makkovik, Harrison and northern half of Hamilton Bank, Labrador. Unpublished preliminary map. Scale - 1:500,000. Atlantic Geoscience Centre, Bedford Institute of Oceanography, Dartmouth, Nova Scotia.

APPENDIX A

SEAFLOOR PHOTOGRAPHS AND ANNOTATIONS

INDEX OF CAMERA STATION ANNOTATIONS

(Typical Photograph follows Annotation)

CAMERA STATION 28

4 FRAMES (all out of focus)

Poor prints suggestive of fine-grained sediment.

Granular surface produced by biogenic processes.

One Brittle Starfish present.

FRAME NUMBER None

CAMERA STATION 38

30 FRAMES

VARIATION: Very little

GRAIN SIZE: Apparently fine-grained; mud or muddy sand.

SURFACE TEXTURE: Generally smooth, with minor irregularities produced by biogenic churning. Burrow-orifaces common.

FAUNA: Anemone, common; shell fragments; worm tubes, common.

FRAME NUMBER: 6

STATION 39

12 FRAMES

VARIATION: Very little

GRAIN SIZE: Fine, except for few cobbles

SURFACE TEXTURE: Highly marked with burrow-oriface mounds and depressions; few animal trails.

FAUNA: Holothurian (?), several; Coelenterates (?), Ascidians (?) attached to cobbles, several; crab, one.

FRAME NUMBER: 13

STATION 40

12 FRAMES

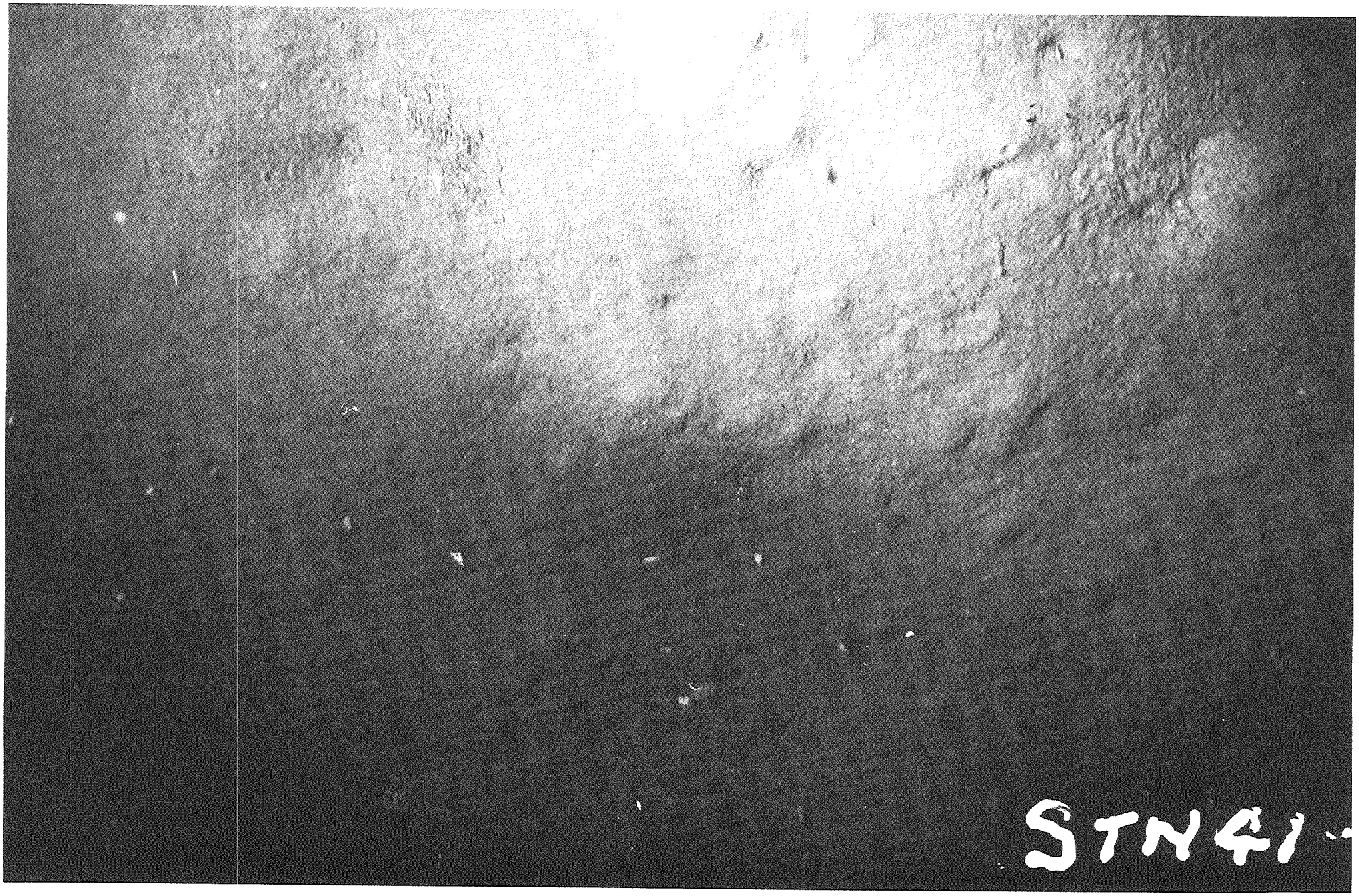
VARIATION: Moderate

GRAIN SIZE: Fine (sand?) excepting two frames which display concentrations of gravel with some cobbles.

SURFACE TEXTURE: Hummocky, due probably to burrowing; few trails.

FAUNA: Crab (2); shell fragments, few; coniform gastropod, several; starfish; worm tubes.

FRAME NUMBER: 7


STN41

STATION 41

1 FRAME

VARIATION:

GRAIN SIZE: Fine (sand)

SURFACE TEXTURE: Hummocky, no open burrow holes.

FAUNA: Few specimens, unidentified.

FRAME NUMBER: 1

STATION 48

21 FRAMES

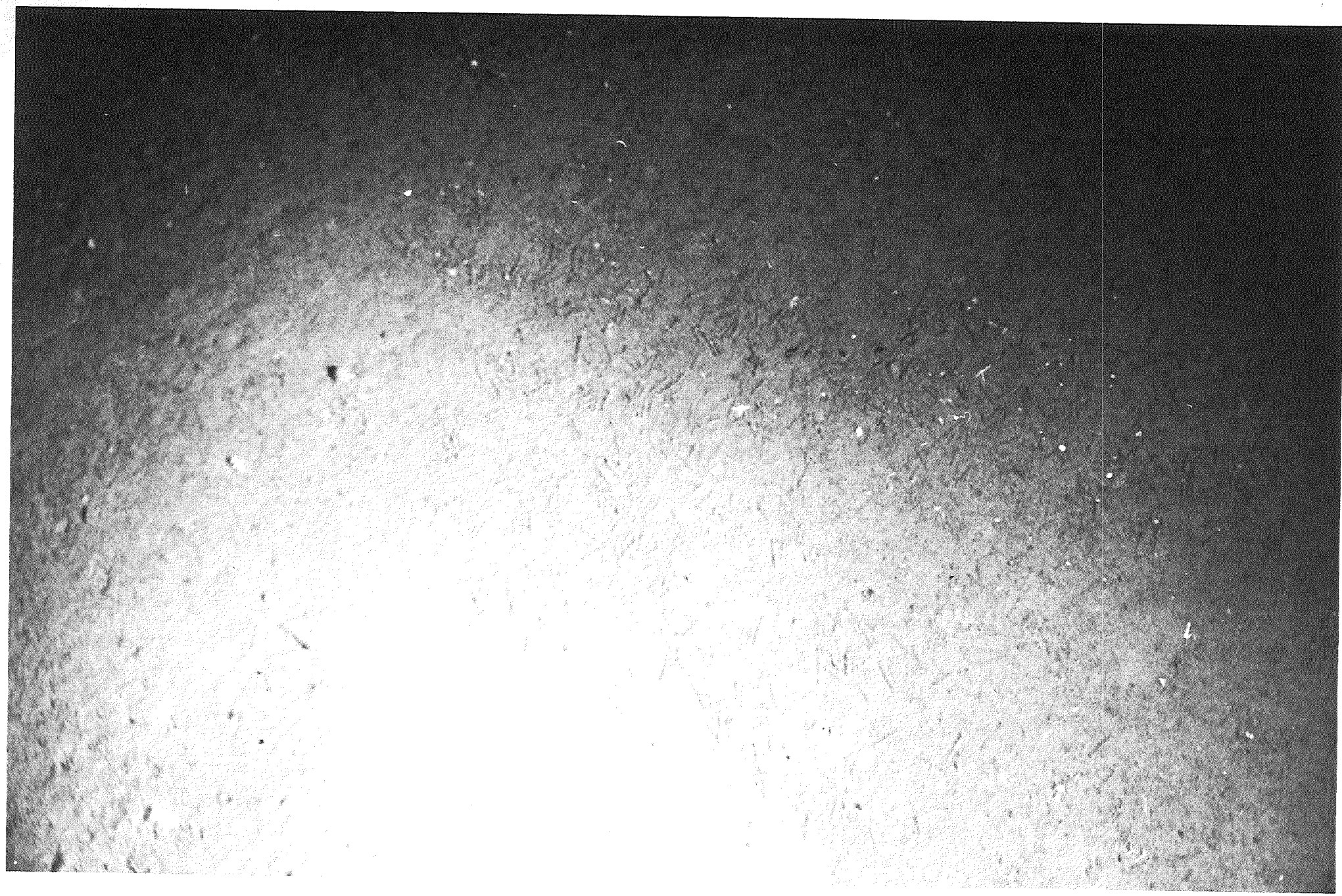
VARIATION: Little variation excepting the presence of scattered boulders.

GRAIN SIZE: Sand

SURFACE TEXTURE: Slightly hummocky; few trails; many worm tubes lying on seafloor in some areas and protruding from seafloor in others.

FAUNA: Worm tubes; small starfish; numerous Ascidians (?) attached to boulders.

FRAME NUMBER: 3



STATION 49

25 FRAMES

VARIATION: Moderately high

GRAIN SIZE: Bimodal; small to medium (well-rounded) boulders, and sand.

SURFACE TEXTURE: Hummocky where bottom consists of boulders, smooth where bottom consists of fine sediment. Boulders are commonly, partially covered by fine sediment. The general impression is of a thin veneer of fine sediment mantling a rock fragment and boulder horizon. Elongate worm tubes are abundant in patches; burrow-oriface mounds and depressions are common.

FAUNA: Anemones, common; Ascidians; fish (one); worm tubes, ubiquitous.

FRAME NUMBERS: 9 and 18

STATION 51

20 FRAMES

VARIATION: Moderate

GRAIN SIZE: Fine to coarse sand, some fine gravel. Large angular or sub-angular rocks occur frequently, these support an attached benthonic fauna. Photos commonly suggest the presence of rock fragments buried beneath a veneer or fine sediment.

SURFACE TEXTURE: Generally smooth except where thinly covered rocks produce surface irregularity. Surface exhibits frequent trails and burrows.

FAUNA: Fish (one); Anemones, common; Brittle Starfish, common; Ascidians (?), common (attached to rocks); Mollusc shells, Pelecypod, Gastropod, few.

FRAME NUMBER: 6

STATION 52

19 FRAMES (Generally similar to Station 50)

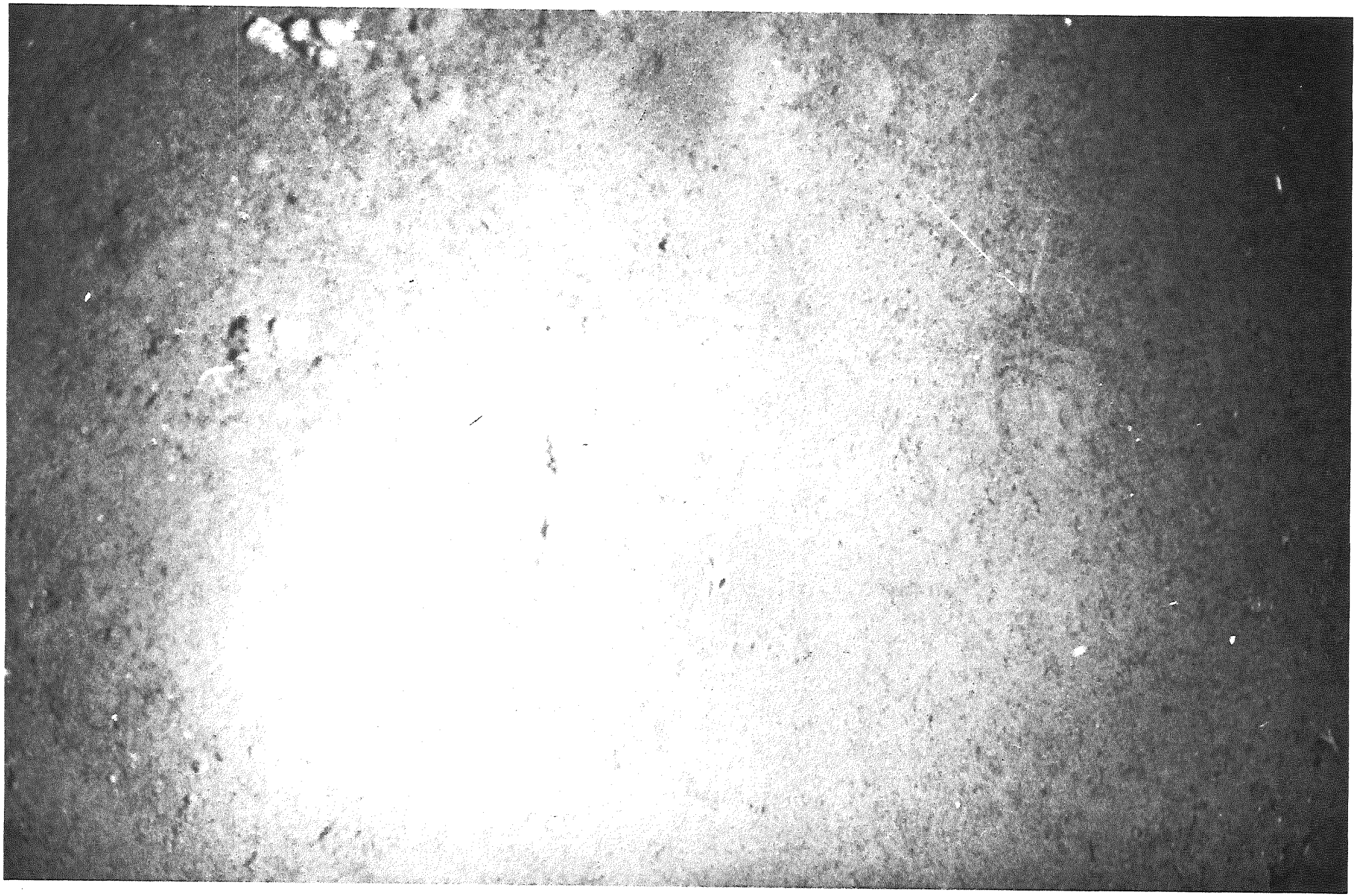
VARIATION: Moderate

GRAIN SIZE: Mainly sand, some fine gravel with scattered subangular boulders (less than one per frame), infrequent suggestion of partially buried boulders.

SURFACE TEXTURE: Generally smooth with only minor, hummocky relief. Some burrow-oriface mounds and depressions.

FAUNA: Starfish, common; Ascidians, commonly attached to scattered boulders; coniform Gastropods; Anemones, few.

FRAME NUMBER: 8



STATION 53

16 FRAMES

VARIATION: Little

GRAIN SIZE: Sand with occasional boulders.

SURFACE TEXTURE: Minor hummocky relief due possibly to burrowing. Few animal trails.

FAUNA: Crab (1); starfish, common; Ascidians (?) attached to pebbles or cobbles.

FRAME NUMBER: 11

STATION 54

25 FRAMES

VARIATION: Very little

GRAIN SIZE: Muddy sand with several cobbles observed in the last frame.

SURFACE TEXTURE: Generally smooth with frequent burrow-oriface mounds and depressions. Numerous agglutinated (?) worm tubes are scattered on the seafloor. Animal tracks discernable in some frames.

FAUNA: Starfish, common; worms, inhabitants of agglutinated worm tubes, ubiquitous; numerous small swimming animals, pteropods (?), shrimp (?) occur in all frames; Ascidians (?), few, attached to the several boulders present.

FRAME NUMBER: 15

STATION 59

6 FRAMES

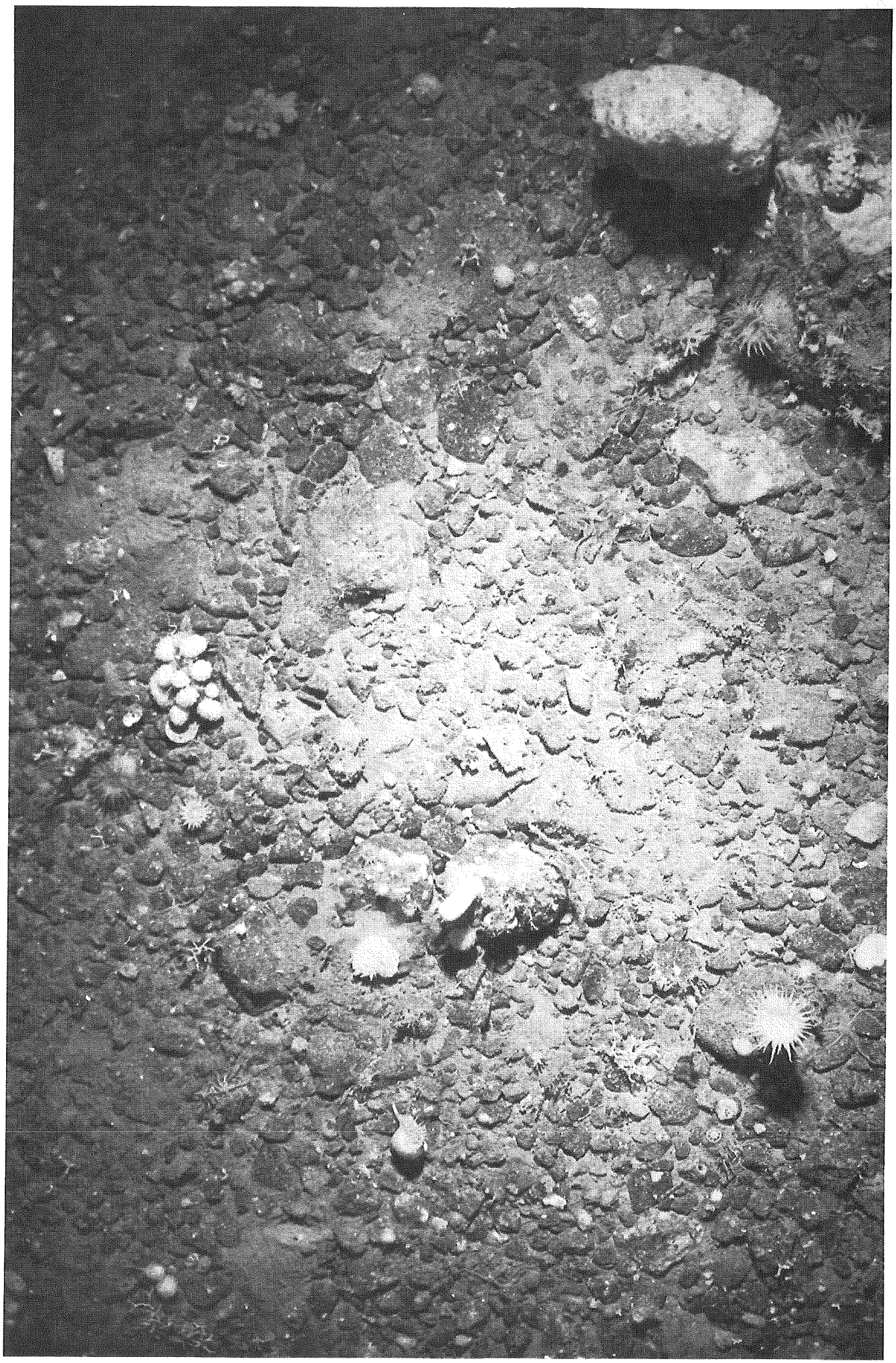
VARIATION: Moderate

GRAIN SIZE: Sand, gravel, boulders. General impression is of a cobble and boulder pavement partially covered by sand. Largest boulders are sub-rounded while smaller cobbles of the pavement are subangular.

SURFACE TEXTURE: Rough

FAUNA: Anemones; Ascidians (?), attached; starfish; deep-sea sponges (?).

FRAME NUMBER: 3



STATION 61

21 FRAMES

VARIATION: Very little

GRAIN SIZE: Muddy sand

SURFACE TEXTURE: Very smooth, except for frequent burrow-oriface mounds and depressions.

FAUNA: Numerous agglutinated (?) worm tubes are scattered on the seafloor. Holothurians (?) common; other fauna unidentified.

FRAME NUMBER: 19

STATION 64

20 FRAMES

VARIATION: Very little

GRAIN SIZE: Sand with fine gravel

SURFACE TEXTURE: Smooth, with occasional burrow-oriface mounds and depressions. Few discernible animal trails.

FAUNA: Brittle Starfish, numerous; Anemones, few; coniform Gastropod shells, few; burrowing worms, few.

FRAME NUMBER: 13

STATION 73

9 FRAMES

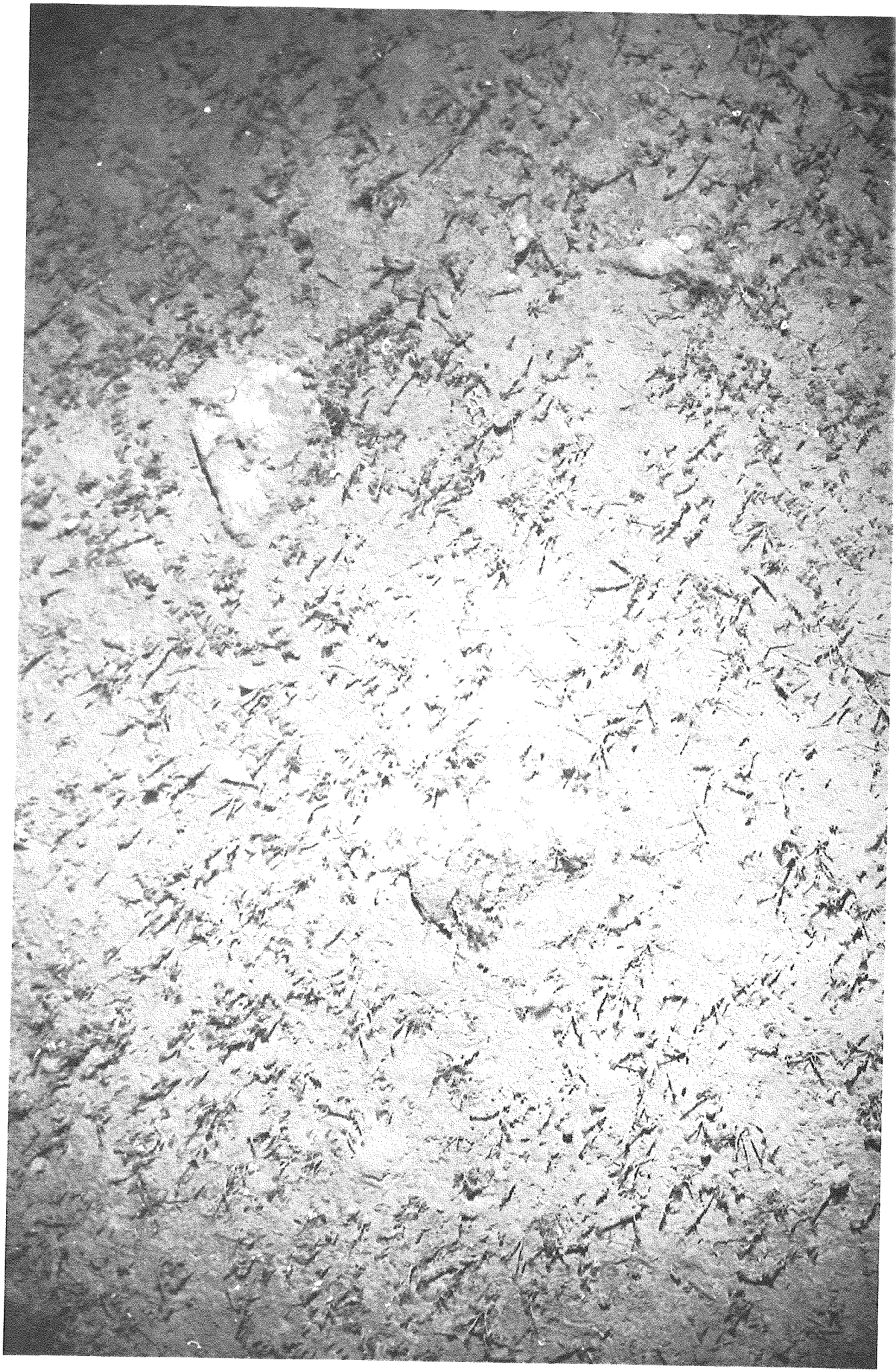
VARIATION: Little

GRAIN SIZE: Fine sand. One frame displays three large rock fragments or boulders.

SURFACE TEXTURE: Smooth, with occasional burrow-oriface mounds or depressions. A multitude of agglutinated worm tubes protrude from the seafloor.

FAUNA: Worms, with agglutinated (?) tubes, abundant; Ascidians (?), few.

FRAME NUMBER: 2



STATION 91

8 FRAMES

VARIATION: Little

GRAIN SIZE: Dominantly gravel with infilling sand and occasional large boulders.

SURFACE TEXTURE: First six frames exhibit a pebble pavement partially covered by sand or fine sediment and supporting abundant fauna. The last two frames exhibit a pebble pavement with little or no fine sediment cover, and supporting fewer fauna.

FAUNA: Anemones; Coelenterates (?) or Ascidians (?); unidentified branching animal; coniform Gastropod shells; Pelecypod shells.

FRAME NUMBERS: 2 and 8

STATION 92

10 FRAMES

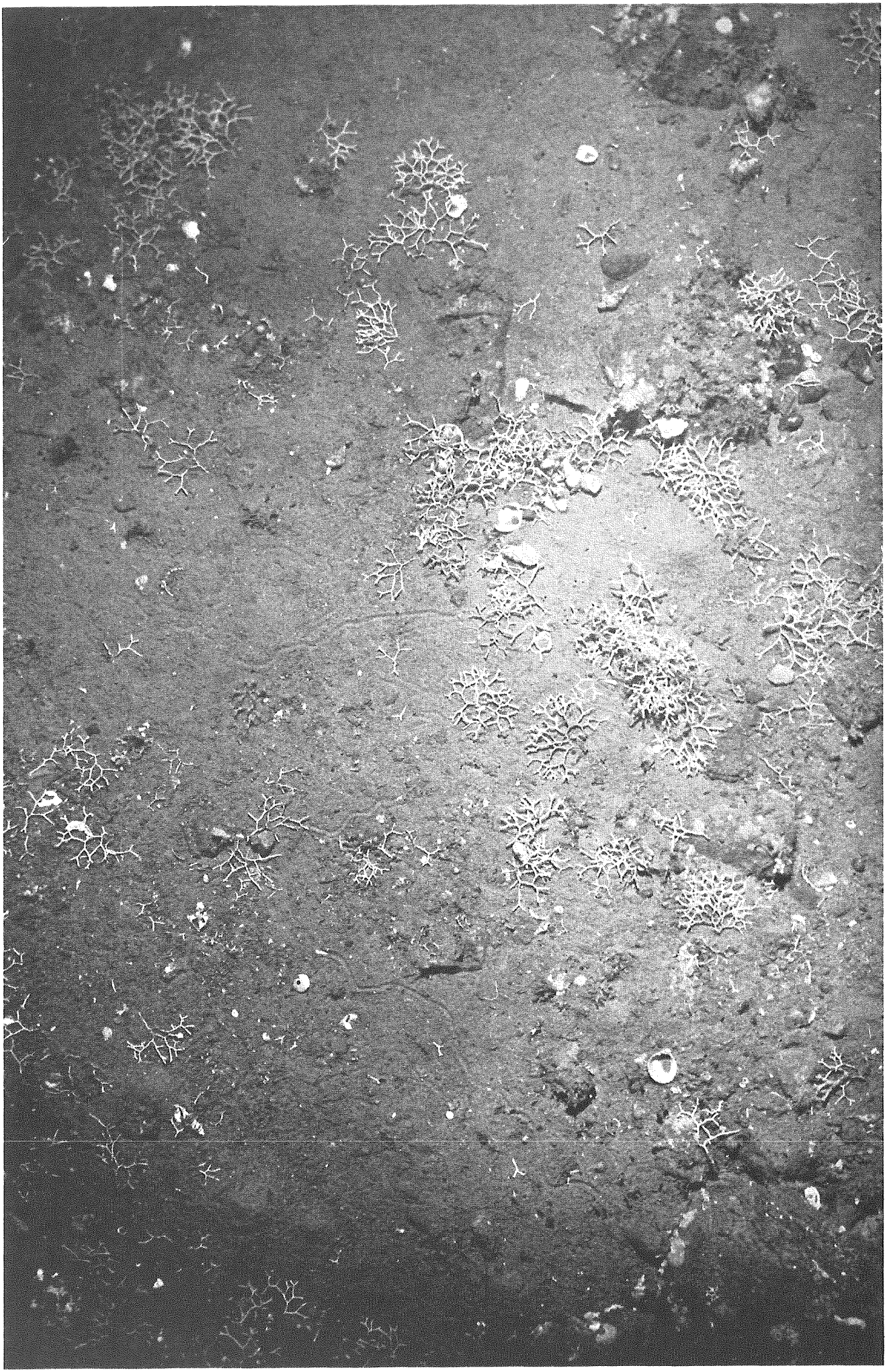
VARIATION: Moderate

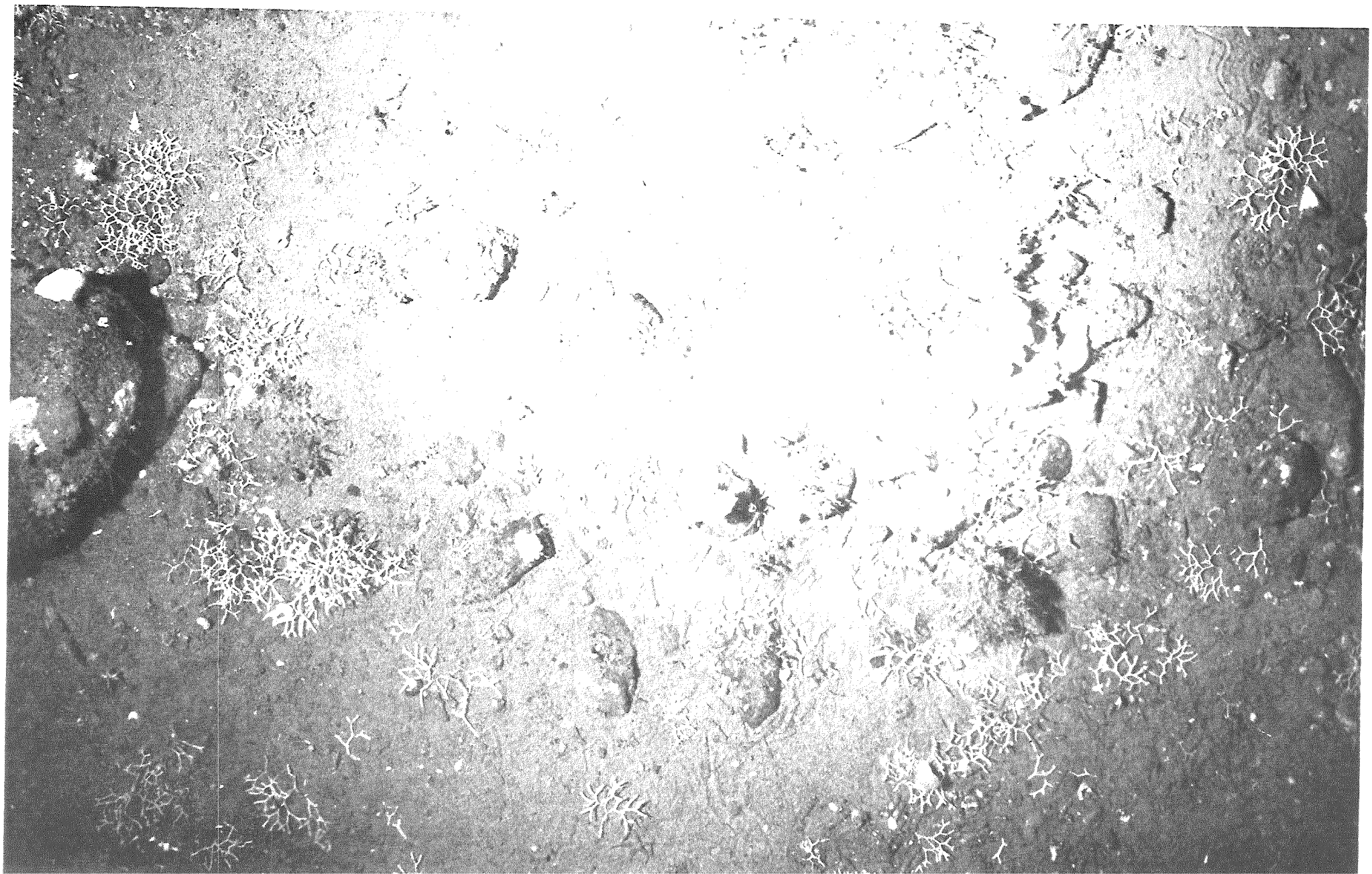
GRAIN SIZE: Sand, with cobbles and large boulders common in some frames.

SURFACE TEXTURE: Smooth except where boulders or cobbles exposed. The general impression is that a cobble pavement, occasionally exposed, underlies the area and is largely covered by a veneer of finer sediment. There is no evidence of sediment scouring by currents. Agglutinated (?) worm tubes are commonly scattered on the seafloor. Animal trails are common.

FAUNA: Unidentified attached, branching animal, ubiquitous; agglutinated (?) worm tubes, abundant; coniform Gastropods, common; Pelecypod shells, common; unidentified Coelenterates or Ascidians.

FRAME NUMBERS: 7 and 9





STATION 98

17 FRAMES

VARIATION: Moderate

GRAIN SIZE: Sixteen frames exhibit only sand while the last frame exhibits a substantial amount of gravel.

SURFACE TEXTURE: Smooth with low-relief, burrow-oriface mounds and depressions. Agglutinated worm tubes are scattered in abundance on the seafloor. A preferred orientation of these tubes may exist. Animal trails are common.

FAUNA: Agglutinated worm tubes, abundant; coniform Gastropod shells, common; Pelecypod shells; unidentified, branching tubular animal as observed at Stations 91 and 92, few; starfish, large, short-armed, one.

FRAME NUMBER: 7

STATION 101

19 FRAMES

VARIATION: Little

GRAIN SIZE: Dominantly coarse gravel and cobbles with frequently large boulders. Finer sediment lies between the pebbles. Several frames exhibit partial covering of the coarse sediment by the finer sediment. Boulders are rounded while the cobbles and pebbles range from angular to sub-rounded.

SURFACE TEXTURE: Rough

FAUNA: Agglutinated (?) worm tubes, common; Ascidians and/or Coelenterates, attached to boulders; Pelecypod shells; starfish, few; Gastropods, coniform, few; crab, one.

FRAME NUMBER: 9

STATION 102

10 FRAMES

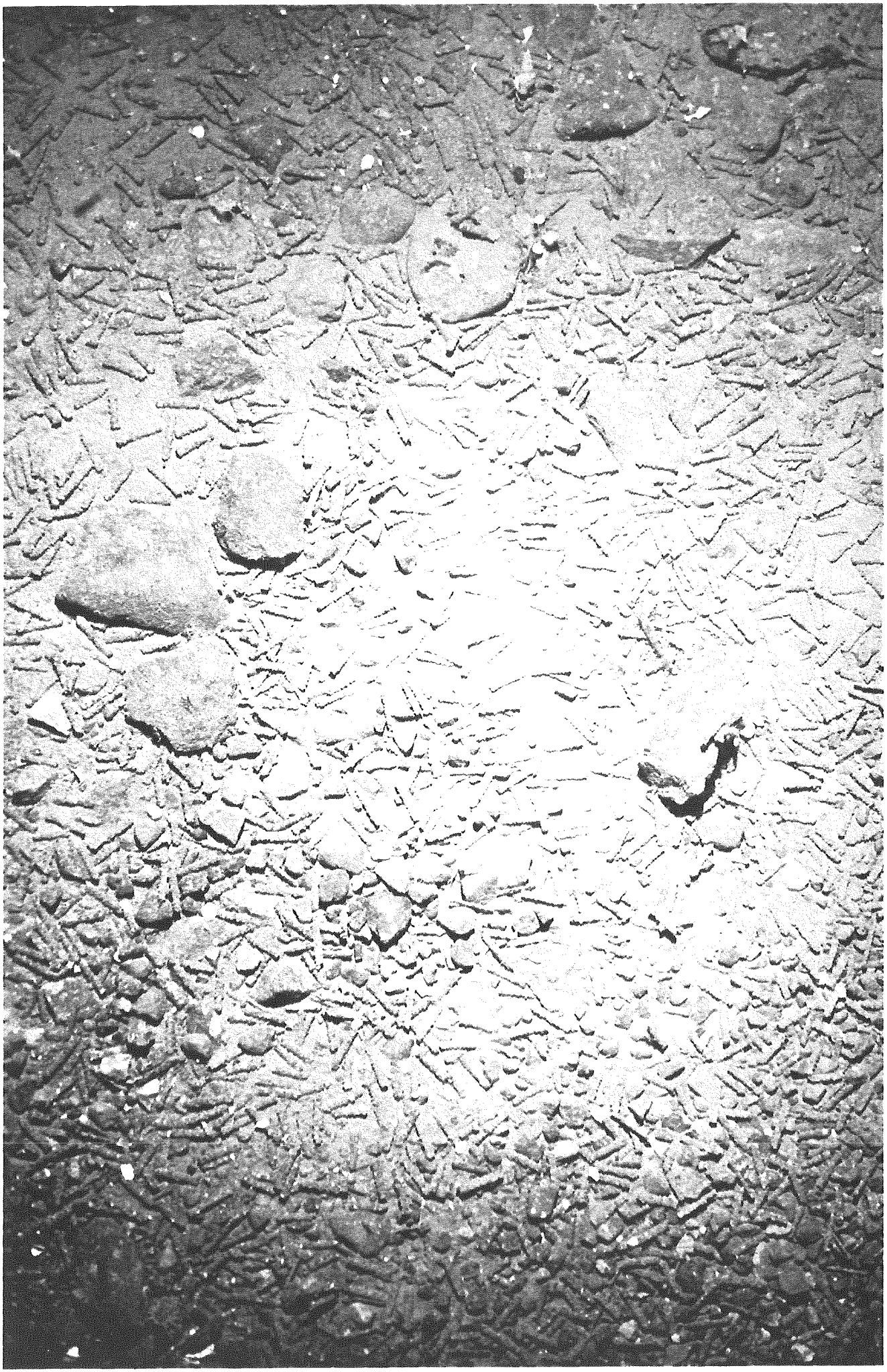
VARIATION: Moderate

GRAIN SIZE: Seemingly bimodal; pebbles and small cobbles with sand surrounding or partially covering these. Several large cobbles or small boulders.

SURFACE TEXTURE: Moderately rough due to pebbles and cobbles and a profusion of agglutinated worm tubes.

FAUNA: Worm tubes, agglutinated, abundant; starfish, short-armed, one; Pelecypod valves, few; Gastropod shells, coniform, few; Coelenterates, including Anemone, few.

FRAME NUMBER: 1



STATION 103

18 FRAMES

VARIATION: Moderate

GRAIN SIZE: Fine sand with isolated large boulders and cobbles; sub-rounded to subangular.

SURFACE TEXTURE: Generally smooth with numerous low-relief, burrow-oriface mounds and depressions. Numerous animal trails.

FAUNA: Pelecypod valves; crab, two; starfish, few; sea urchin, one.

FRAME NUMBER: 2