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SURFICIAL GEOLOGY OF THE UPPER SCOTIAN SLOPE WEST OF VERRILL CANYON

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PREFACE

This open file consists of a report and accompanying figures. Figures 14-26 reproduce poorly by xerography and originals have been deposited for examination at the G.S.C. open-file libraries in Dartmouth and Calgary.

ABSTRACT

Piston cores and high-resolution seismic-reflection profiles have been studied from an area 50 x 50 km square on the Scotian Slope, west of Verrill Canyon, in water depths of 200 to 1000 m. Apart from Verrill Canyon, no major valleys incise the slope in this area. Sand and gravel extend from the continental shelf to water depths of 400-500 m. Below this a series of shallow gullies (200-500 m wide, 5-25 m deep) lead to two large debris flows in water depths of 500-1000 m. The flows are 5-15 ms thick in seismic-reflection profiles, and there is another horizon of debris flows visible about 50 ms subbottom. Otherwise, slope sediment is acoustically well stratified and draped over topographic irregularities.

Piston cores have been collected from both the debris flows and undisturbed sediment sequences between the flows. Four lithostratigraphic units are recognized in the undisturbed section. A carbon-14 date of 12,000 years B.P. has been obtained near the base of this sequence, and is consistent with the palynological and foraminiferal stratigraphies. The debris flows are overlain by a thin sediment sequence, and are estimated to date from between 5000 and 12,000 B.P.

INTRODUCTION

The work reported here is part of project 6.1.3.2, Seabed Stability on the Continental Slope, within the Department of Energy, Mines and Resources, Energy Research and Development program. The objective of this project is to identify and where possible alleviate geological constraints to production of hydrocarbons from the offshore.

Under the objectives of this project, detailed studies are being made in areas of present hydrocarbon exploration and areas of demonstrable seabed instability. One such area is the Scotian Slope (Fig. 1) between 61° and 62°W, in which the exploratory wells Acadia K-62, and Shubenacadie H-100 have been drilled.

Upper continental slopes off eastern Canada are morphologically highly variable, as a result of great variety in Quaternary sedimentation processes. Many of these sedimentation processes are related to glacial events on the continental shelf, and have no present-day mid-latitude analogues (Stanley et al., 1972). Mass movement of sediment and canyon incision are two erosional processes that have shaped the continental slope (Stanley and Silverberg, 1969). At times in the past, sedimentation may have been very rapid in proximity to ice margins. Such processes can result in potentially hazardous seabed stability conditions.

This study is part of a larger project to investigate sediment instability, sedimentation processes, and the Quaternary history of continental slopes off eastern Canada. Several areas, each with different morphological and sedimentological characteristics, are being investigated in detail (Hill, 1981, 1983, 1984a,b; Piper and Normark, 1982; Piper et al., 1983).

In this study we describe the upper continental slope (200 to

1000 m water depth) from Verrill Canyon (longitude 61°10'W) westwards to longitude 62°W (Fig. 1). The study area includes the Acadia K-62 and Shubenacadie H-100 well sites. On small-scale bathymetric maps, this area appears to have a simple smooth morphology, not cut by canyons. In contrast, to the east of the area the Scotian Slope is highly dissected by canyons, the largest being the Gully (Marlowe, 1968). Stanley and Silverberg (1969) have described near-surface sediments in one area of this dissected slope. To the west of the study area, canyons are generally absent. Hill (1981, 1983, 1984a,b; Hill et al., 1983) has shown that one small part of the area (B in Fig. 1) has an extremely irregular morphology and complex sedimentation history.

Most of the data used in this study were collected from CSS Dawson in March 1982 on Cruise 82-004 (Fig. 2), and include 300 km of 3.5 kHz profiles, 200 km of high resolution deep-towed sparker profiles, obtained using the Nova Scotia Research Foundation Corporation V-fin system (Bidgood, 1964), and 11 piston cores. An additional 200 km of 3.5 kHz profiles from cruise 81-044 have also been used. In compiling the bathymetric map (Fig. 3), 12 kHz profiles from several other cruises have been used. Interpretations of a Sea MARC I side-scan survey of the mid-slope area at the same longitude on cruise 82-014 (Piper et al., 1983) have been incorporated where appropriate.

METHODS

Navigation was by hyperbolic Loran-C: most cross-over checks show little variation from one survey to another, but occasional discrepancies of up to 500 m occur.

The 3.5 kHz profiles were collected using an ORE system with a hull-mounted transducer array. The V-fin sparker system was towed at a depth of around 100 m, and operated at 250 joules. No useful information was obtained using the V-fin system in water depths greater than 800 m.

Cores were collected with a Benthos split piston corer device. Considerable difficulty was experienced with the split piston and, in some cores, several decimetres of sediment were extruded on deck. Thus the absence of a stratigraphic marker in some cores may be an artifact. Comparison with trigger-weight cores also suggests that the upper 50 cm of the sediment column may not have been sampled in the piston cores.

BATHYMETRY

The bathymetry of the study area is shown in Fig. 3. The area can be divided into two morphologic regions. In the east, Dawson and Verrill Canyons sharply indent the shelf break and are deeply incised into the continental slope. A large proportion of bathymetric records comprise hyperbolic reflectors, so that any bathymetric representation is imprecise.

In the western part of the study area, the seabed is generally smooth, cut by two shallow valleys, the East and West Acadia valleys. The shelf break occurs at about 250 m, and the upper slope down to about 700 m is steepest (≈5°) and cut by short gullies, 1-2 km wide and 10-50 m deep.

ACOUSTIC INTERPRETATION OF SEABED MORPHOLOGY

Seven types of seabed are distinguished in 3.5 kHz profiles, on the basis of reflectivity and meso-scale roughness of the seabed as illustrated in figure 4. The mapped extent of these surficial acoustic units (Fig. 5) can be tentatively extended using V-fin sparker and Sea MARC I 4.5 kHz records.

Type A (Fig. 4a) consists of smooth seabed with substantial acoustic penetration showing parallel reflectors. It is interpreted as representing undisturbed muddy seabed conditions.

Type B1 (Fig. 4a) consists of rather rough seabed, with vertical roughness on a scale of 2-5 m and a horizontal scale of hundreds of metres.

Type B2 (Fig. 4a) consists of very rough seabed, with irregularities on a vertical scale of 10 m and a horizontal scale of a few hundred metres. The type of roughness of both B1 and B2 is characteristic of debris flows (Embley, 1976, 1982), and corresponds to areas with surface lineations that are typical of debris flows in Sea MARC I sidescan sonar records.

Type C (Fig. 4a) consists of relatively smooth seabed that is neither highly reflective, nor particularly well stratified. Its character appears transitional between types A and D, and may thus indicate a sandy-mud bottom.

Type D (Fig. 4b) consists of smooth highly reflective seabed, apparently sand and gravel that is typical of continental shelf and slope deposits to water depths of about 400 m in this area. (Note that the small scale roughness in Fig. 4b is due to ship motion).

Type E (Fig. 4a) consists of small areas within type A in which the upper few metres of surficial sediment is missing.

Type H (not illustrated) consists predominantly of hyperbolic reflections, so that the acoustic character of the true seabed is indeterminate.

DISTRIBUTION OF SEABED MORPHOLOGY TYPES

Type D seabed of sand or gravel extends from the continental shelf to depths of 400-500 m throughout the survey area except locally in the canyons. Dawson and Verrill Canyons are generally characterised by hyperbolic reflectors (type H). In the western half of the survey area, two major debris flows (type B2) were mapped in water depths between approximately 500 and 1000 m. The debris flows appear to originate in water depths of less than 700 m in a series of shallow gullies, 200-500 m wide and 5-25 m deep. The eastern flow is some 5 km wide and extends downslope towards Verrill Canyon. It is flanked by narrower zones of somewhat disturbed seabed (types B1 and C). A 5-km wide zone of undisturbed, stratified sediment separates the eastern from the western debris flow. The western flow is some 15 km wide and, at its western margin, partly fills East Acadia Valley (Piper et al., 1983). To the west of East Acadia Valley is a zone of undisturbed stratified sediment cut by two valleys some 25-75 metres deep (Mid and West Acadia Valleys), with an acoustically distinct sediment fill (Fig. 4a).

INTERPRETATION OF SEISMIC REFLECTION PROFILES

Area west of Verrill Canyon

Over much of the area west of Verrill Canyon, near-surface sediments are relatively transparent and evenly stratified, with as much as 100 ms sub-bottom penetration. Individual reflectors can be correlated throughout the area over distances of tens of kilometers (Figs. 6, 7). Sediment thickness decreases downslope, with a 50% decrease in thickness from 500 m to 1300 m water depth.

The debris flows show characteristic surface roughness and generally lack internal reflectors (Figs. 6,7). They are typically 5-15 ms thick. Along the western margin of the eastern debris flow, there appears to be a small older flow overlain by about 5 ms of stratified sediment (Fig. 6). There also appear to have been large debris flows similar in size and location to the eastern and western debris flow about 50 ms sub-bottom (Fig. 7). A thin, surface, acoustically transparent sediment layer overlying debris flow in the valley is interpreted as recent sediment fill of Holocene age.

The sediment both cut by and underlying the debris flows is well stratified, and has a draped configuration, maintaining almost constant thickness over topographic highs and lows (Figs. 7 and 8). The gently undulating character of these reflectors (Fig. 7) appears to be inherited from the surface of the buried debris flow at 50 ms sub-bottom, or an even deeper horizon. Piper et al. (1983; their fig. 8) show that these undulations suggest the former existence of a series of slope gullies a few hundred metres wide with an average spacing of 3 km.

On the upper slope, in less than 800 m water depth, seismic profiles show an apparently erosional seafloor, with a relief of 1-3 m (Figs. 9, 10), corresponding to seabed types B1 and C in 3.5 kHz profiles. Larger depressions apparently interconnect to form straight gullies. It often is difficult, both in seismic reflection profiles and sidescan images, to distinguish between thin debris flows and eroded seabed of the upper slope. Neither is it possible to define the style or cause of the erosion. However, it is clear that the present seabed is rougher now than at the time that most of the upper 50 ms of sediment accumulated.

Because of steep slopes and hyperbolic reflections, there is little useful seismic data from Verrill and Dawson canyons. The slopes of Verrill Canyon have 5-10 ms of acoustically transparent material (?debris flow) over >20 ms evenly stratified, draped sediment. Similar draped, stratified sediment occurs at the seafloor in Dawson Canyon, in water depths of the order of 650 m.

Continental shelf north of survey area

On the continental shelf immediately north of the study area, V-fin sparker profiles show up to 40 msec of sediment (Fig. 11) overlying a basement reflector inferred to be Tertiary bedrock. The lower 20-25 ms has the acoustical characteristics of till. It is overlain by about 10 ms of laterally heterogenous, very poorly stratified material that might be either sand and gravel or till. The uppermost 2-7 ms of sediment rests unconformably on the underlying sequence, and shows discontinuous stratification, including prograding channel fill. This acoustic configuration may have developed during the progradation of a barrier beach system (c.f. Amos, 1983).

In general, there is little acoustic penetration on the upper slope: a hard unstratified bottom is seen to a water depth of about 450 m, beyond which penetration increases to reveal well stratified sediments similar to those on the middle slope. However, at the head of Dawson Canyon, in water depths of 200 to 140 m, up to 15 ms of well stratified sediment directly overlie till (Fig. 12). The stratified sediments are cut unconformably by the present seafloor.

CORE STRATIGRAPHY

Introduction

Eleven piston cores, between 3 and 10 m in length, have been collected (Table 1, Figs. 2 and 13). Cores 2, 5, and 9 are from acoustically undisturbed areas (Fig. 5), and therefore should represent continuous stratigraphic sequences. Cores 1, 3, 6, and 7 are from acoustic seabed type C. Cores 4 and 8 are from debris flows of acoustic seabed type B2. Cores 10 and 11 are from within Mid Acadia Valley in the western part of the study area (Fig. 8).

Lithofacies

Eight lithofacies are distinguished on the basis of sediment grain size, colour, and sedimentary structures, identified from visual examination of cores and study of x-radiographs and smear slides (Table 2) .

Lithofacies 1. This consists of olive grey mud (Table 3), mostly 5Y4/2 in colour, but with some 5Y3/2 and 2.5Y4/2, particularly near the core top. Sand content is less than 20% and clay greater than 30%. Mollusc shells are common. X-radiographs generally show only indistinct bedding (Fig. 14) and commonly a faintly mottled bioturbated character. Rarely, graded beds of laminated silt (similar to those described by Kontopoulos and Piper, 1982) are seen (Fig. 15).

Lithofacies 2 is similar to lithofacies 1, but is coarser, comprising olive grey silty mud with less than 20% clay. It has faint bedding and a mottled appearance in x-radiographs (Fig. 16).

Lithofacies 3 occurs as thin beds within lithofacies 1 and consists of red-brown and grey-brown sandy gravelly mud, with colours including 5YR4/3, 10YR3/3, 10YR5/1 and 10YR4/2. The beds have sharp bases, gradual tops, and are in places graded or laminated (Fig. 17).

Lithofacies 4 consists of a very distinctive red-brown mud (the "brick-red mud" of Stow, 1977), entirely 5YR4/4 in colour, that frequently occurs as in sharp-based laminated beds (Fig. 18), which may be sandy or even gravelly (Fig. 19).

Lithofacies 5 is a dark red brown mud that is often sandy. Colours are 5YR4/3 and 5YR3/3. X-radiographs show indistinct bedding and scattered granules (Fig. 20).

Lithofacies 6 of dark brown mud is similar to lithofacies 5, but the colour is less red, and includes 10YR4/2, 10YR3/2 and 7.5YR4/2. X-radiographs show indistinct bedding and scattered granules (Fig. 21), and occasional graded beds (Fig. 22).

Lithofacies 7 is a dark olive-grey mud, with colours 5Y3/2, 5Y3/1, 5Y4/1, 5Y5/2 and 2.5Y3/2. It is frequently finely laminated (Figs. 23,24), but in places includes sand and scattered granules. Dark laminae and mottles, believed to be of fine iron sulphides, are common. A similar feature is seen in the uppermost part of the Emerald Silt on the Scotian Shelf (Macdonald, 1982).

Lithofacies 8 is similar to lithofacies 7, but is strongly mottled, with the mottling enhanced by concentrations of dark iron sulphides. In places, there are scattered granules (Fig. 25). Only remnants of bedding are visible in x-radiographs (Fig. 26).

Lithostratigraphic Units

Four lithostratigraphic units (Fig. 13) can be distinguished in the cores. Core 5 is taken as the lithostratigraphic type section.

Unit 1. This unit occurs at the top of all cores and consists predominantly of olive-grey mud (or silty mud in upper slope cores), with interbedded red brown mud and sandy gravelly mud (lithofacies 3) in some cores. Mollusc shell fragments are common, and the muds are bioturbated. The base of the unit is at 95 cm depth in Core 5. The maximum thickness of the unit is 3.9 m in Core 9.

Unit 2. Beneath Unit 1 in all cores is a very variable sequence of muds and sandy muds of red-brown or dark red-brown colours (lithofacies 4 and 5), with some beds of lithofacies 6. Dispersed pebbles occur at some horizons. These muds are referred to as Unit 2. The unit is 2-3 m thick.

Unit 3. This unit consists of rather monotonous dark brown mud (lithofacies 6), with occasional beds of lithofacies 5 and 7. Dispersed sand and gravel occur at some horizons, and in core 2 there is an apparent slump horizon.

Unit 4. In Cores 2, 5, 9 and 10, a thick sequence of dark olive-grey mud (lithofacies 7 and 8), locally with scattered granules, underlies Unit 3, and is termed Unit 4. In addition, similar sediment occurs beneath a thin sequence of unit 2 in cores 4 and 8 from the debris flows, and is interpreted as slide blocks.

Foraminifera (by G. Vilks)

Foraminifera were counted in the > 125 µm fraction from 35 cc samples in Cores 1 and 4 (Table 4). Results are summarized in Figure 27. Planktonic foraminifera make up between 10 and 70% of the total individuals present. Variations in planktonic foraminifera can be used to divide the sequence into three planktonic foraminiferal zones which correspond to lithostratigraphic units 1, 2 plus 3, and 4 respectively.

1. A zone with 25 to 50% of the *Neogloboquadrina pachyderma* being dextral, and *Globigerina quinqueloba* and *G. bulloides* together making up 15 to 25% of the total planktonic foraminifera. Since this zone occurs at the top of the cores, it is interpreted as post-glacial.
2. A zone in which the sinistral form of *N. pachyderma* predominates, making up 65 to 90% of the planktonic foraminifera.
3. A zone found only in core 4 in which *G. quinqueloba* and *G. bulloides* together make up 20 to 60% of the total planktonic foraminifera, with 10 to 35% of the *N. pachyderma* being dextral.

The foraminiferal distribution data of Bé and Tolderlund (1971) suggest that Zone 1 represents the least 'polar' conditions and Zone 2 the most 'polar', with Zone 3 intermediate between 1 and 2.

The variations in benthonic foraminifera are less pronounced (Table 4). The dominant species in Zone 1 are *Islandiella helenae, Cassidulina reniforme, Oridorsalis umbonatus, Globobulimina auriculata,* and *Nonionella labradorica*. In Zone 2, *Cassidulina reniforme* predominates, with some *Elphidium excavatum* f. *clavata, Islandiella helenae, Nonionella labradorica,* and *N. turgida.* In Zone 3, species diversity is lower and *C. reniforme* and *E. excavatum* f. *clavata* are co-dominant with lesser *N. labradorica, N. turgida,* and *I. helenae.*

Mollusca (by F. Wagner)

Mollusca found in the cores are listed in Table 5. Identifiable mollusca are most common in lithostratigraphic units 1 to 3. All species recorded are within their present geographic range, except for *Macoma brevifrons* (for which the identification is doubtful), which ranges from South Carolina to Brazil. However, southern species are also known from late-glacial cores in Emerald Basin (Wagner, pers. comm. 1983). Three species occur beyond their normal depth range: *Macoma brevifrons* (9 to 24 m), *Astarte undata* (9 to 190 m), and *Macoma calcarea* (1 to 360 m). The *M. brevifrons* specimen occurs in a sandy bed and was probably resedimented.

Palynomorphs (by P.J. Mudie)

Palynomorphs (Tables 6 and 7) have been examined from some of the same horizons as foraminifera. Samples of 5 cc volume were processed using the method of Mudie (1982). Despite long heating in 52% HF, all samples except the 5-6 cm level in Core 1 contained large amounts of undigested silt-sized mineral grains, the presence of which is often associated with counting biases towards fewer, larger palynomorphs and low species diversity. However, Tables 6 and 7 show that there is a large degree of similarity between the fine-grained sample from 5-6 cm and the coarse-grained sample from 55-56 cm in Core 1. If these two samples represent approximately the same time interval, namely pollen zone C3-c of Deevey and Livingstone (Livingstone 1968), then it may be valid to interpret all the samples relative to the youngest coarse-grained sample from 55-56 cm in Core 1.

Core 82-004-1/5-6 cm: Pollen concentration is high and is dominated by small Pinus banksiana-type grains (40%), with small but ecologically significant amounts of thermophilous deciduous species (Quercus, Acer, Tilia, Juglans) and relatively high % herbs (NAP), including Ambrosia and Rumex acetosella. This assemblage is typical of surface samples from the Scotian Slope and the Fogo Seamount (Mudie 1980) and is assigned to the European weed zone, C3-c. Dinoflagellate concentration and diversity is very high, with Operculodinium centrocarpum dominant and Piperodinium perplexum n. gen. sp. (Mudie 1980; Mudie and Deonarine,, in prep.) subdominant, and with boreal-subarctic Spiniferites spp. well represented. Small but ecologically significant numbers of subtropical taxa are present, e.g. Hemicystodinium, Lingulodinium and Leptodinium aculeatum. The ratio of % Operculodinium centrocarpum to Multispinula minuta is very high. Overall, the assemblage is typical of deep slope to seamount coretops south of the Grand Banks. The dinocyst-pollen ratio is high, indicating an outer continental margin-deep sea environment.

55-56 cm: Pollen and spores are lower in taxonomic diversity although total numbers per gram are almost the same as for 5-6 cm. Higher percentages of Sphagnum and fern spores may indicate redeposition of nearshore Holocene sediment since pre-Quaternary palynomorphs are rare. Picea & Pinus % are similar to the surface sample, as are Betula & Quercus %. High % NAP, including Gramineae, Rumex and Pteridium, suggest that this sample also represents Zone C3-c.

Dinoflagellate species are mostly very similar to the 5-6 cm sample, although Piperodinium is poorly represented and there is a correspondingly higher % of Brigantedinium. The low % Piperodinium probably reflects the coarse sediment texture which also accounts for the higher %

of *Brigantedinium* cysts. Overall, the high Dinocyst ratio and % of subarctic taxa indicate an assemblage very similar to the 5-6 cm sample.

405-406 cm: Pollen concentrations are an order of magnitude lower than the near-surface samples, suggesting a late glacial environment. The dinocyst: pollen ratio of 0.7 indicates a large influx of terrigenous sediment, or possibly, a more nearshore environment. High *Picea* %, in conjunction with low pollen concentration, suggests a woodland environment, which may be correlated with Zone A (≈10 Ka) although the presence of *Quercus* and *Acer* is anomalous. Dinoflagellates show a large change in the % ratio of *Operculodinium* to *M. minuta*, implying a cold water (boreal) environment. High % *Brigantedinium* may indicate redeposition of shelf sediment.

493-494 cm: Quaternary palynomorph concentrations are anomalously high relative to the overlying and underlying samples and contain species indicating a cold climate. Many pre-Quaternary pollen and dinocysts are also present, indicating substantial erosion and redeposition of shelf bedrock strata. High % *Betula nana*-type pollen, *Artemisia* and % NAP suggest a tundra-shrub environment (Zone L, ca 10-12 Ka) although the pollen concentrations are very high for offshore marine sediments (Mudie and Short, in press). The % ratio of *Operculodinium* to *M. minuta* clearly indicates subarctic conditions.

555-556 cm: Palynomorph concentrations are low, with relatively large numbers of pre-Quaternary taxa present. Relatively high % *B. nana*, *Artemisia* and high % NAP suggest a tundra-shrub environment (Zone L). The dinocyst ratio and % subarctic dinoflagellates suggest a subarctic environment similar to the previous sample.

605-606 cm: This preparation contains less mineral debris than those from 55-555 cm, and the pollen composition is probably better representative of the paleoenvironment. *Betula nana*, *Pinus bankiana*-type and Gramineae pollen dominate; % NAP is high, including the tundra species, *Dryas* cf. *octopetala*. Pollen % is most similar to that found in modern central Baffin Bay sediment (Mudie and Short, in press). The presence of *Tsuga* and *Acer* is anomalous but it might indicate long-distance transport by southerly air or ocean currents. The high ratio of dinocysts: pollen indicates a depositional environment similar to the top of the core. Pre-Quaternary palynomorphs are not present.

Dinoflagellates are somewhat similar to the surface sample although the lower dinocyst ratio and absence of subtropical taxa probably indicates significantly cooler water. There is a notable increase in % *Bitectatodinium* which is a marker species for late glacial pelagic sediments in the eastern N. Atlantic (Turon 1980) and relatively high % *Multispinula quanta* and *Zygobikadinium* suggest a strong influx of fresh water. *Leiosphaera* sp. A is also present which normally indicates nearshore ice pack (Mudie and Short, in press). Overall, the dinoflagellate assemblage indicates a deep water subarctic environment similar to that presently found in eastern Baffin Bay (Mudie and Short, in press). It is notable that the higher dinocyst concentration and increased ratio of subarctic to arctic dinoflagellates corresponds to an increase in subarctic planktonic foram. Similar late Wisconsinan dinoflagellate peaks are found in ^{14}C dated cores from the Fogo Seamounts (Mudie and Keen, 1982) although there they are not accompanied by increased numbers of subarctic foraminifera.

Core 82-004-4: Samples from 125, 150, 175 and 200 cm all contained abundant undigested coarse silt despite prolonged HF treatment. This made it impossible to get a good palynomorph count. Palynomorphs also appeared thermally altered which may be due to the severe HF treatment, or to penetration of a much older Neogene section (say upper Late Miocene-early Pleistocene).

The most notable features are:

(a) very low dinoflagellate concentrations, with occasional Miocene-Pliocene species present, and no taxa diagnostic of Pleistocene-Recent sediments.

(b) predominance of pollen and wood fagments, suggesting a terrestrial deposit. The pollen are dominated by bisaccates (excluding *Tsuga*) and hardwood species e.g. *Quercus* are strongly represented.

Lithologic correlation of cores

Within Unit 1, many cores contain a red-brown mud bed about two-thirds of the way down the unit (Fig. 13). Individual beds within Units 2 and 3 of cores 1, 2, 5 and possibly 3 can be correlated. In particularly, there are two red-brown muds near the top of Unit 2 found in all these cores (Fig. 13). The dark olive-grey mud at about 5 m in core 5 is also recognised in core 1, but appears to be absent in core 2 (Fig. 13).

Relationship of cores to acoustic stratigraphy

Cores 1, 2 and 5, from the area of undisturbed stratified sediments between the two debris flows, contain individual beds that can be correlated from one core to another, confirming the acoustic interpretation. Furthermore, a general correlation with core 9 (from an undisturbed area 20 km to the west) can be established, with core 9 having a higher sedimentation rate in unit 1, but very similar in units 2 and 3.

Core 3, located in about 5 ms of stratified sediment overlying possible old debris flow appears to have penetrated only the stratified sediment sequence. Cores 5, 6 and 7 from the eastern debris flows recovered less than 3.5 m of Unit 1, and apparently did not sample debris-flow material.

Core 4, also from the eastern debris flow, penetrated about 1 m of Unit 1, 0.8 m of Unit 2, and over 2 m of Unit 4. Unit 4 is interpreted as a block carried in the debris flow; Unit 2 as turbidites associated with or following the debris flow; and Unit 1 as subsequent sedimentation. A similar sequence is seen in core 8 from the western debris flow.

Core stratigraphy: synthesis

One C-14 date is available from the cores. Apparently resedimented (sand-filled) fragments of *Aporrhais occidentalis* at 495 cm in core 1 gave a date of about 12000 years B.P. (Table 8). Although this represents a maximum age for this horizon, the palynological observations also suggest an age of 10,000-12,000 yrs B.P. for this horizon. If the sedimentation rate was constant above this horizon, this date would indicate on age of only about 3000 yrs B.P. for the base of Unit 1.

In the slope area south of the Scotian Gulf, Hill (1981) recognised the distinct down-core change in foraminiferal assemblages that is similar to the change from zone 1 to zone 2 at the boundary between Units 1 and 2 in core 1 of this study. Hill (1981) obtained three C-14 dates at or close to this zonal boundary. A small mollusc shell gave a date of 5050 yrs B.P. (but this date is suspect because of the small size of the sample). The other two dates were of total organic carbon, which gave ages, corrected for old (non-radioactive) detrital carbon, of 8400 and 6800 yrs B.P.

These data taken together suggest that the age of the base of Unit 1 probably lies between 5000 and 8500 yrs B.P.; more carbon-14 dating will be needed to obtain a more precise age. The age of the base of Unit 1 places a minimum age on the large debris flows.

Sedimentologic interpretation of cores

The bioturbated olive-grey muds of Unit 1 represent contemporary accumulation processes, particularly fall-out from suspension following meteorologically-forced strong current events on the upper slope (Hill and Bowen, 1983). The sediment is presumably derived from reworking of the uppermost slope and outer-shelf banks. The interbedded red-brown muds appear to have a different source, and lack bioturbation. They occur in sharp-based beds of the type that Hill (1983b) has interpreted as resedimented (either turbidites or debris flow), and those with fine laminations (Fig. 17) are presumably of turbidite origin.

The correlated red-brown mud beds in the upper part of Unit 2 in the apparently continuous-sedimentation cores 1, 2, 5 and 9 are similar to the red-brown mud beds in Unit 1, and to those immediately overlying the major debris flows in cores 4 and 8. The resedimentation process is likely related to the major debris flows. Alternatively, since the debris flows were accompanied by widespread slumping (Piper et al., 1983), it could be argued that they are equivalent to the slumped bed at 5.5 m depth in core 2 and the resedimented mollusc shells at 5 m depth in core 1. More cores from the debris flows themselves will be needed to resolve this interpretation. In either case, the major debris flows must be younger than the mollusc shell in Unit 3 of core 1, dated at about 12000 y.B.P.

The mode of deposition of much of units 2, 3 and 4 is unclear. The acoustic profiles suggest a draped depositional configuration, and this is confirmed by the approximately constant thickness of units 2, 3 and 4 in cores, in contrast to the more ponded configuration of unit 1. The draped configuration suggests deposition principally from suspension. On the shelf edge, this draped sediment overlies till, and acoustically resembles the Emerald Silt of King (1970); like the Emerald Silt, it may therefore be a periglacial deposit. Lithofacies 7 and 8 lithologically resemble the upper part of the Emerald Silt. Some sharp-based graded beds are present, in units 2 and 3, suggesting that resedimentation processes have also occurred. Lithostratigraphic units 2 and 3 contain common pinkish quartz and red sandstone clasts (Table 9) which are characteristic of the widespread red tills of Nova Scotia and the Scotia Shelf (Grant and King, 1983).

DISCUSSION AND CONCLUSIONS

Data from this study and the Sea MARC survey of the same area (Piper et al., 1983) suggest that there are occasional widespread events of surficial slumping and debris flow movement. Within unit 1, correlatable red-brown muds representing a small sedimentation event occur along at least 30 km of the slope. This widespread event must have been fed by different slumps within each valley system.

The Sea MARC I survey (Piper et al., 1983) shows that the main debris flows are approximately synchronous with a widespread surficial sliding event, during which the top 5-20 m of sediment was removed over an area of at least 2500 km^2. Again, the debris flows and slumping are not restricted to areas of steep topography and occur within several valley systems. The lower debris flows (about 50 msec sub-bottom) recognised in the v-fin profiles also appear approximately synchronous over a wide area.

The synchronous occurrence of bedding-pla~~c~~ne slides and mass flow over a wide area, not closely related to topography, is observed in the area affected by groundshaking in the 1929 earthquake on the continental slope off St. Pierre Bank (Piper and Normark, 1982). It is difficult to conceive of a non-seismic triggering mechanism which would produce such widespread events. Cyclic loading during a major storm might initiate extensive sediment failure at the shelf-break, but could not account for the slumping of sediment in 2500 m water depth (Piper et al., 1983). Valley wall undercutting and steepening, or sediment overloading, would produce only local slump and mass-flow effects.

We thus conclude that the widespread slump and mass-flow features in the study area west of Verrill Canyon are seismically triggered. Within the last 12000 years there was one major seismic event affecting an area at least 50 km wide. There may have been a later, much smaller event affecting at least 30 km, that produced the correlatable resedimented beds in Unit 1.

CONSTRAINTS ON HYDROCARBON EXPLOITATION

1. This study provides a regional framework within which specific site surveys for wells can be evaluated.
2. Even though the regional slope is less than 2.5°, some 40% of the seabed between Verrill Canyon and 62°W, in water depths of 500-1000 m, consists of debris flows, and much of the rest of the area shows signs of disturbance.

3. The large debris flows were emplaced within the last 12000 years.
4. Small debris flows younger than the large flows have also occurred.
5. The episodic nature of large debris flows, and the widespread occurrence of the small debris flows suggests both were seismically triggered.

ACKNOWLEDGEMENTS

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LIST OF TABLES

Table 1. Core locations and water depths

Core	Lat. °N	Long.°W	Water depth (m)
1	42°56.7'	61°40.8'	570
2	42°56.7'	61°38.9'	624
3	42°57.0'	61°36.9'	651
4	42°56.0'	61°35.5'	786
5	42°54.7'	61°38.7'	827
6	42°58.8'	61°39.9'	413
7	42°57.8'	61°37.9'	570
8	42°54.4'	61°43.4'	413
9	42°52.9'	61°56.2'	730
10	42°53.8'	61°54.4'	693
11	42°53.8'	61°53.9'	704

Table 2. Summary of lithofacies

1. Olive grey mud, mostly 5Y4/2, some 5Y3/2 and 2.5Y4/2, particularly near core top. Sand <20%, clay >30%. X-radiographs show bioturbation. Mollusc shells common.

2. Olive grey silty mud, mostly 5Y4/2. Similar to "olive grey mud", but coarser: clay <20%.

3. Red brown and grey brown sandy gravelly mud, occurring within unit 1. Colours vary, including 10YR3/3, 5YR4/3, 10YR5/1 and 10YR4/2.

4. Red brown mud, usually in thin beds, often sandy. Entirely 5YR 4/4.

5. Dark red brown mud, often sandy. Colour 5YR4/3 and 5YR3/3. X-radiographs show graded beds.

6. Dark brown mud, often sandy. Colour typically 10YR3/3, but includes 10YR4/2, 10YR3/2, 7.5YR4/2.

7. Dark olive grey mud, often sandy or with granules. Colours include 5Y3/2 5Y3/1, 5Y4/1, 5Y5/2, and 2.5Y3/2.

8. Mottled grey mud. This is similar to "dark olive grey mud", but is prominently mottled.

Table 3. Summary grain size statistics

Core	Depth (cm)	Lithostratigraphic unit	Lithofacies	%gr	%sd	%si	%cl
2	10-12	1	2	0	46.3	44.7	9.0
	70-72	2	5	0	14.0	51.3	34.7
9	40-42	1	1	0	19.8	48.6	31.6
	210-212	1	1	0	7.8	45.8	46.4
	320-322	1	2	0	39.2	42.7	18.1
	405-407	2	4	0.6	32.3	35.0	32.1
	470-472	2	5	0	10.9	37.7	51.4
	550-552	2	5	0	11.3	37.7	48.4
	800-802	3	6	0	10.5	38.5	51.0
	885-887	3	6	0	16.2	41.7	42.1
	1010-1012	4	7	0	13.7	2.3	44.0

Table 4. Foraminifera from cores 82-004-1 and 4. Determinations by G. Vilks on the > 125 µm fraction of 35 cc samples.

```
     CRUISE: 82-04          STATION: 001            SAMPLE TYPE:                    PAGE:    1

        LATITUDE:    0.0000                 LONGITUDE:      0.0000          WATER DEPTH:  570


          INTERVAL DEPTH(CM)                 0          50          100         150          199
          INTERVAL WIDTH(CM)                 5           5            5           5            5
          SPLIT NUMBER                      32          16           16          32            4


      BENTHONIC FORAMINIFERA
          TOTAL                            233         309          230         135          178
          DIVERSITY                       1.87        1.93         1.96        2.07         2.05

          GENUS / SPECIES                                     COUNTS
ISLANDIELLA           CF.HELENAE                       120           75          10           21
CASSIDULINA           CF.TERETIS                         1                        7            6
ASTRONONION           GALLOWAYI              9           3            1
BUCCELLA              FRIGIDA                1           3            6           8
CASSIDULINA           RENIFORME             51          21           56           2           46
CIBICIDES             LOBATULUS                          4                        3            1
ELPHIDIUM             EXCAVATUM CLA          1          17           28          35           36
ELPHIDIUM             SUBARCTICUM            1           3            1                        1
ORIDORSALIS           UMBONATUS             44          36            3           1
FISSURINA             MARGINATA              1                        1
GLOBOBULIMINA         AURICULATA            20          28           14          21           14
ISLANDIELLA           HELENAE               77
ISLANDIELLA           NORCROSSI              5
INDET                 SPP                    3           8           13           8            5
LAGENA                MOLLIS                             1                                     1
MELONIS               ZAANDAMAE              3           2            1                        2
NONION                GRATELOUPI                                     10          11            7
NONIONELLA            LABRADORICA           18          56           17          28           33
PULLENIA              OSLOENSIS                          2            2
PYRGO                 SUBSPHAERICA                                                             1
QUINQUELOCULINA       SEMINULUM                                                                1
TRILOCULINA           TRIHEDRA                                                                 1
VIRGULINA             LOEBLICHI                          4            2           1            2


      FORAMS
          TOTAL                            174         323           94         270          131
          DIVERSITY                       1.31        1.37         1.16         .59          .88

          GENUS / SPECIES                                     COUNTS
GLOBIGERINA           BULLOIDES              8          43            5          21           18
GLOBIGERINA           QUINQUELOBA           24          18           20          11            2
GLOBIGERINITA         GLUTINATA              3           4            1           1            2
GLOBIGERINOIDES       RUBER                              1
GLOBOQUADRINA         DUTERTREI              1           1
GLOBOROTALIA          INFLATA                7          11                                     1
NEOGLOBOQUADRINA      PACHYDERMA ST         93         119           52         229           96
NEOGLOBOQUADRINA      PACHYDERMA DE         39         126           16           8           12
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         CRUISE: 82034        STATION: 001              SAMPLE TYPE:                 PAGE:   2

         LATITUDE:   0.0000                 LONGITUDE:     0.0000      WATER DEPTH:  570


    INTERVAL DEPTH(CM)                    252      300      351      400      450
    INTERVAL WIDTH(CM)                      5        5        5        5        5
    SPLIT NUMBER                           16       16       16        8        8


  BENTHONIC FORAMINIFERA
      TOTAL                               242      330      129      144      257
      DIVERSITY                          1.30     1.86     1.53     1.73     1.89

    GENUS / SPECIES                                      COUNTS
ISLANDIELLA       CF.HELENAE               22       36        6       11       60
CASSIDULINA       CF.TERETIS                3        2        1
ASTRONONION       GALLOWAYI                          5        7                 3
BUCCELLA          FRIGIDA                            3        1        1        6
CASSIDULINA       RENIFORME               151      160       77       77       99
CIBICIDES         LOBATULUS                 2        2        1        2        2
ELPHIDIELLA       GROENLANDICA                                         1
ELPHIDIUM         EXCAVATUM CLA            36       14       18       17       38
ELPHIDIUM         SUBARCTICUM               1        2        2
ORIDORSALIS       UMBONATUS                          3                          1
FISSURINA         MARGINATA                                                     1
GLOBOBULIMINA     AURICULATA                1       20                 3        5
ISLANDIELLA       HELENAE                                     3        6       12
ISLANDIELLA       NORCROSSI                          3                          3
INDET             SPP                       2       13        4       12        2
LAGENA            LAEVIS                                                        1
MELONIS           ZAANDAMAE                                                     2
MILIOLINELLA      CHUKCHIENSIS                                         1
NONION            GRATELOUPI               10
NONIONELLA        AURICULA                           2        2                 3
NONIONELLA        TURGIDA                           38        4        5       14
NONIONELLINA      LABRADORICA              11       19        2        1        2
PROTELPHIDIUM     ORBICULARE                                                    1
PYRGO             SUBSPHAERICA                                         2
QUINQUELOCULINA   SEMINULUM                                            3
TRILOCULINA       TRIHEDRA                           5                 1
VIRGULINA         FUSIFORMIS                                           1        1
VIRGULINA         LOEBLICHI                 3        3        1                 1


  FORAM2
      TOTAL                               267      466      283      231      192
      DIVERSITY                           .71     1.21      .65      .46     1.02

    GENUS / SPECIES                                      COUNTS
GLOBIGERINA       BULLOIDES                11       42       11        6       30
GLOBIGERINA       QUINQUELOBA               3       38       11        6       11
GLOBIGERINITA     GLUTINATA                 9        7        2        2        4
GLOBOQUADRINA     DUTERTREI                          1
GLOBOROTALIA      INFLATA                   2        1        1
GLOBOROTALIA      SCITULA                           17        4        2        1
NEOGLOBOQUADRINA  PACHYDERMA SI           219      292      241      209      131
NEOGLOBOQUADRINA  PACHYDERMA DE            23       68       13        6       15
```

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          CRUISE: 82004          STATION: 001                 SAMPLE TYPE:                       PAGE:   3

        LATITUDE:     0.0000                  LONGITUDE:      0.0000       WATER DEPTH:   570


        INTERVAL DEPTH(CM)                 488          550         600
        INTERVAL WIDTH(CM)                   5            5           5
        SPLIT NUMBER                        32            8          16


    BENTHONIC FORAMINIFERA
       TOTAL                               188          243         282
       DIVERSITY                          2.32         2.14        1.74

       GENUS / SPECIES                                          COUNTS
ISLANDIELLA         CF.HELENAE              16           25          30
ASTRONONION         GALLOWAYI               11           12           4
BUCCELLA            FRIGIDA                               3          11
CASSIDULINA         RENIFORME               55           64         140
CIBICIDES           LOBATULUS                9           14
ELPHIDIELLA         GROENLANDICA             1
ELPHIDIUM           EXCAVATUM CLA           24           33          52
ELPHIDIUM           SUBARCTICUM              2
ORIDORSALIS         UMBONATUS                2                        1
FISSURINA           MARGINATA                1            1           4
GLOBOBULIMINA       AURICULATA               6            4           2
ISLANDIELLA         HELENAE                  2            2           4
INDET               SPP                      2            9          10
LAGENA              SUBSTRIATA                            1
MELONIS             ZAANDAMAE                1            1           2
NONIONELLA          AURICULA                 5            2           3
NONIONELLA          TURGIDA                 28           57           5
NONIONELLINA        LABRADORICA             14            8           8
OOLINA              HEXAGONA                 1
PATELLINA           CORRUGATA                1
PYRGO               SUBSPHAERICA                          4           1
QUINQUELOCULINA     SEMINULUM                3
SACCAMMINA          ATLANTICA                             1
TRILOCULINA         TRIHEDRA                 1                        4
VIRGULINA           FUSIFORMIS               1                        1
VIRGULINA           LOEBLICHI                1            2


    FORAM2
       TOTAL                               281          125          50
       DIVERSITY                           .34          .77        1.01

       GENUS / SPECIES                                          COUNTS
GLOBIGERINA         BULLOIDES                7            3           4
GLOBIGERINA         QUINQUELOBA              4           12           9
GLOBIGERINITA       GLUTINATA                                         1
GLOBOROTALIA        SCITULA                               1           1
NEOGLOBOQUADRINA    PACHYDERMA ST          260           97          34
NEOGLOBOQUADRINA    PACHYDERMA DE           10           12           1
```

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          CRUISE: 92.04        STATION: 034              SAMPLE TYPE:                  PAGE:    1

          LATITUDE:    0.0000                  LONGITUDE:     0.0000        WATER DEPTH:     0


          INTERVAL DEPTH(CM)                 120        170        250        283        330
          INTERVAL WIDTH(CM)                   5          5          5          5          5
          SPLIT NUMBER                         2          4          2         64          8


      BENTHONIC FORAMINIFERA
          TOTAL                              243        325        193        227        321
          DIVERSITY                         2.11       1.77       1.30       2.16       1.41

          GENUS / SPECIES                                    COUNTS
ISLANDIELLA         CF.HELENAE                23         30                     3          5
ASTRONONION         GALLOWAYI                                                   3
BUCCELLA            FRIGIDA                                                     3          1
CASSIDULINA         RENIFORME                 34        108         85         23         47
CIBICIDES           LOBATULUS                             1                    10
CRIBROSTOMOIDES     CRASSIMARGO                                                            1
ELPHIDIUM           EXCAVATUM CLA             78         99         76         19        192
ELPHIDIUM           SUBARCTICUM                                                 1
ORIDORSALIS         UMBONATUS                  1          5                    14
FISSURINA           MARGINATA                                                   1
GLOBOBULIMINA       AURICULATA                 5          7          1         80          1
ISLANDIELLA         HELENAE                   33         38          2          1         15
ISLANDIELLA         NORCROSSI                  1
INDET               SPP                       13          8          5         25          8
LAGENA              LAEVIS                                                      1
NONIONELLA          AURICULA                   6          2          1          3          7
NONIONELLA          TURGIDA                   16          4          1         21          9
NONIONELLINA        LABRADORICA               19         19         14         14         32
PROTELPHIDIUM       ORBICULARE                                       1
PULLENIA            OSLOENSIS                                                   5
PYRGO               SUBSPHAERICA               9          1
QUINQUELOCULINA     SEMINULUM                  2                     1                     1
TRILOCULINA         TRIHEDRA                   1
VIRGULINA           FUSIFORMIS                 2          1          6
VIRGULINA           LOEBLICHI                             2                                2


      FORAM2
          TOTAL                              155         40        133        306        122
          DIVERSITY                         1.20       1.13       1.33       1.29       1.41

          GENUS / SPECIES                                    COUNTS
GLOBIGERINA         BULLOIDES                  4          4         16         49         62
GLOBIGERINA         QUINQUELOBA               35          4         32         58         14
GLOBIGERINITA       UVULA                                                                  1
GLOBIGERINITA       GLUTINATA                  2          3          4          6          4
GLOBOROTALIA        INFLATA                                                     2          4
GLOBOROTALIA        SCITULA                                                     2
NEOGLOBOQUADRINA    PACHYDERMA ST             70         26         63        164         25
NEOGLOBOQUADRINA    PACHYDERMA DE             45          3         18         25         12
```

Table 5. Mollusca. Determinations by F.J.E. Wagner.

Core	Depth	Lithostratigraphic Unit	Molluscs
1	145	2	Taxodont pelecypod-indet. 6 fragments
	188	2	*Bathyacea* sp. 1 fragment
	395	3	?*Propebela* sp. 1 fragment
	490-495	3*	*Aporrhais occidentalis* Beck 3 fragments
2	84	2	*Propebela turricula* (Montagu) 1 complete specimen
	221	2*	*Macoma* cf. *M. brevifrons* (Say) 1 complete shell
	320	3	*Astarte undata* Gould 1 complete shell
	659	3-4 boundary	?*Colus* sp. 1 fragment
4	67-74	2	*Natica clausa* Broderip & Sowerby 1 complete specimen
			Macoma calcarea (Gmelin) 1 single valve
	93	2	*Bathyarca* sp. 1 fragment
7	31	1	Barnacles. Several fragments
9	45	1	*Yoldia* *(Megayoldia)* *thraciaeformis* Storer 1 fragment
			Gastropod-indet. 1 fragment
10	100	1	*Dentalium* sp. 1 fragment

* In sand bed or filled with sand, probably resedimented.

Table 6. Core 82-004-1: Pollen & spore percentages

Sample depth (cm)	5-6	55-56	405-406	493-494	555-556	605-606
Picea	15	11	27	17	18	8
Pinus	40	45	37	32	24	23
Abies	3	4	6	2	2	4
Tsuga	1	-	-	-	-	8
Betula	5	5	6	15	10	15
Quercus	3	5	2	-	-	-
Acer	7	2	2	-	-	4
Tilia	1	-	-	-	-	-
Juglans	1	-	-	-	-	-
Salix	1	-	-	-	4	-
Ericaceae	1	-	2	-	2	-
Alnus	1	2	-	-	2	-
Rosaceae	1	-	9	-	2	4
Cyperaceae	2	-	2	5	-	-
Gramineae	4	5	-	2	6	12
Ambrosia-type	1	-	-	-	-	-
Rumex	5	5	-	-	2	-
Dryas	0	-	-	-	1	8
Artemisia	0	-	-	2	1	-
Other herbs	3	-	-	4	6	4
Pteridium	3	2	-	-	1	-
Lycopodium	1	4	4	2	5	8
Other ferns	0	2	-	2	1	-
Sphagnum	4	7	2	2	5	-
Other moss	0	-	-	-	5	-
% NAP	25	23	19	31	36	36
total number per cc	16,250	15,326	3,958	26,650	7,107	4,225

Table 7. Core 82-004-1: Dinoflagellate percentages. Determinations by P.J. Mudie.

Sample depth (cm)	5-6	55-56	405-406	493-494	555-556	605-606
Operculodinium centrocarpum	38	31	15	6	19	81
Multispinula minuta	2.5	2.2	9	7	9	7
M. quanta	0.5	3	-	-	-	7
Brigantedinium simplex	8	19	29	31	35	15
B. cariacoensis	3	8	6	3	2	3
B. spp. (*B. major* & indet.)	10	12	12	28	13	10
Bitectatodinium tepikiense	1.5	4	3	3	2	8
Tectatodinium pellitum	1.5	3	3	1.5	-	1
Spiniferites elongatus	3	5	-	1.5	-	3
S. ramosus	3	0.7	6	7	-	-
Other *Spiniferites* spp.	3.5	4	15	4.5	10	0.5
Leptodinium aculeatum	0.5	-	-	-	-	
Hemicystodinium zoharyi	1.0	-	3	1.5	4	-
Lingulodinium machaerophorum	0.5	0.7	-	-	-	-
Pterosperma species 1	0.5	-	-	1.5	-	-
Piperodinium perplexum	20	0.7	-	-	-	7
Zygobikadinium lenticulatum	4	4	-	3	7	7
Votadinium calvum	0	1.5	-	-	-	1
Leiosphaera sp. A	-	-	-	-	-	1
Protoperidinium A						0.5
Dinocyst ratio*	94	93	63	44	67	81
% subarctic	51	48	27	18	12	19
% subtropical	2	0.7	3	1.5	4	-
Total #/cc	5,217	36,674	2,639	43,550	4,680	27,462
Total species	17	15	10	13	9	14
Dinocyst: Pollen	3.3	2.4	0.7	1.6	0.7	6.5

*Ratio of *O. centrocarpum* to *M. minuta*

Table 8. Carbon-14 dates from Scotian Slope cores

This study

Beta-6283	82-004-1-490/495	Carbonate	12020 ± 1320

Dates from Scotian Gulf area (Hill, 1981)

GX 7737	78-005-77-58 (top of unit 2)	Carbonate	5050 ± 300 (small sample: caution)
GX 7766	80-004-16G-35/37 (base of unit 1)	TOC	9920 ± 310 (8400 corrected)
GX 7767	80-004-16-18/39 (base of unit 1)	TOC	8280 ± 270 6800 corrected)

Table 9. Selected petrographic characteristics of the sand fraction of sediment samples

Core	Depth	Size	Pink qz	Dark grains	Red sst	Pyrite tubes	Forams %
2	10-12	vf-f	Tr	R			<1
	70-72	vf-f	Tr	F		F	<1
9	40-42	vf-f	Tr	R			1
	210-212	vf-f	Tr	R			1
	320-322	vf-f	Tr	C			1
	405-407	vf-fc	C	C			-
	470-472	vf-vc	C	C	C		-
	550-552	vf-fc	C	C			Tr
	800-802	vf-fc	C	C		F	Tr
	885-887	vf-c	F	F			0.5
	1010-1012	vf-f	Tr	R			1

Tr = trace; R = rare; F = few; C = common.

LIST OF FIGURES

Figure 9. V-fin deep towed sparker profile across upper slope above western debris flow, showing small gullies and the generally eroded character of the seabed. (82-004; 072/0730)

Figure 10. V-fin deep towed sparker profile, showing one large gully and generally eroded seabed on upper slope. (83-012; 127/0855)

Figure 11. V-fin deep towed sparker profile from outer continental shelf, showing two sand units overlying till and bedrock. (For further discussion, see text.)

Figure 12. V-fin deep-towed sparker profile from the head of Dawson Canyon showing truncated stratified sediment sequence overlying till (N.B. this profile is not corrected for tow fish depth; surface irregularity is an artefact of tow-fish movement).

Figure 13. Summary lithostratigraphic core logs for cores 1-11, showing division into units 1, 2, 3 and 4.

Figure 14. X-radiograph of lithofacies 1, core 2, 60-80 cm, showing generally structureless character with occasional bedding. (N.B. all X-radiographs are original scale)

Figure 15. X-radiograph of lithofacies 1, core 10, 40-60 cm, showing bed of laminated silt.

Figure 16. X-radiograph of lithofacies 2, core 10, 60-80 cm, showing mottled silty appearance.

Figure 17. X-radiograph of lithofacies 3, core 2, 80-100 cm. Bed of red-brown mud, grading up into very dark grey-brown mud, showing sharp base and presence of lamination.

Figure 18. X-radiograph of facies 4, core 4, 80-100 cm, showing sharp-based laminated bed of red-brown mud.

Figure 19. X-radiograph of lithofacies 4, core 10, 280-300 cm, showing gravelly character of red-brown mud.

Figure 20. X-radiograph of lithofacies 5, core 2, 210-236 cm, showing sandy mud.

Figure 21. X-radiograph of lithofacies 6, core 2, 236-256 cm, showing bedding.

Figure 22. X-radiograph of lithofacies 6, core 2, 150-170 cm, showing graded bed with abundant granules.

Figure 23. X-radiograph of lithofacies 7, core 4, 281-301 cm showing fine laminae and iron sulphide mottles.

Figure 24. X-radiograph of lithofacies 7, core 10, 399-419 cm, showing lamination.

Figure 25. X-radiograph of lithofacies 8, core 2, 624-644 cm, showing mottling and granules.

Figure 26. X-radiograph of lithofacies 8, core 4, 190-210 cm, showing characteristic mottled appearance with only remnants of bedding.

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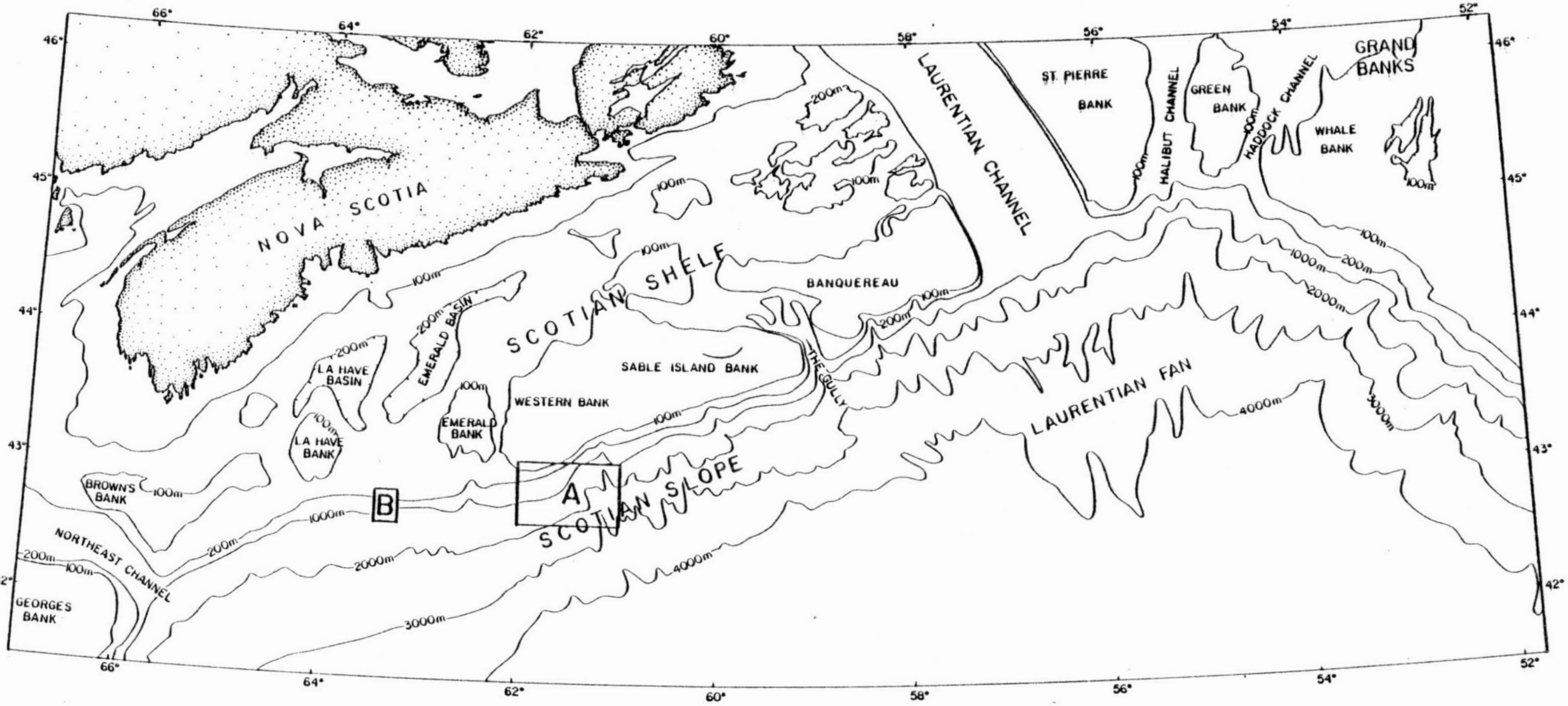


Figure 1. Location of study area (A). B indicates area studied in detail by Hill (1981).

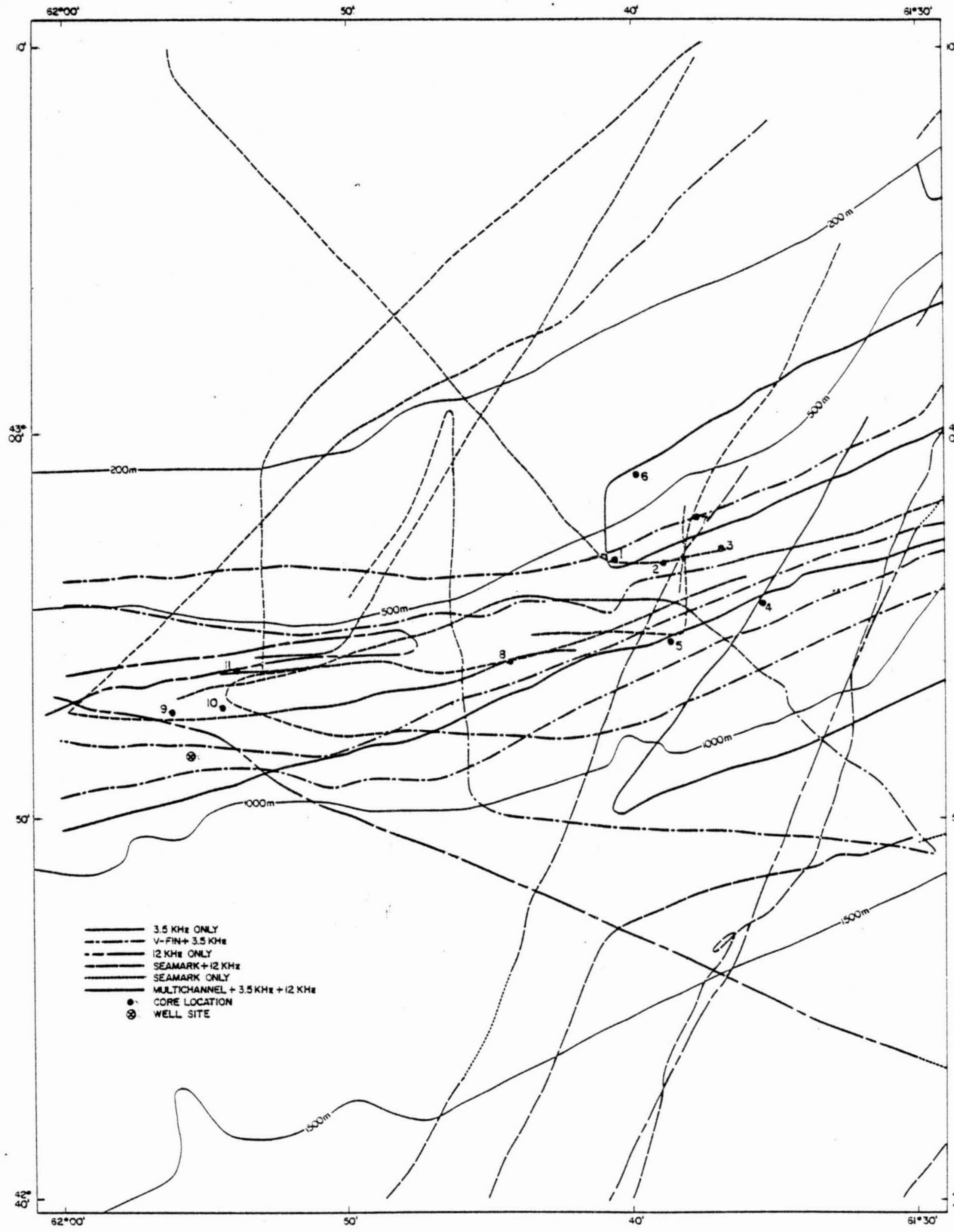


Figure 2. Key map showing data available in the study area. Seismic reflection profiles that are illustrated in Figs. 4 and 6-11 are located in Fig. 28.

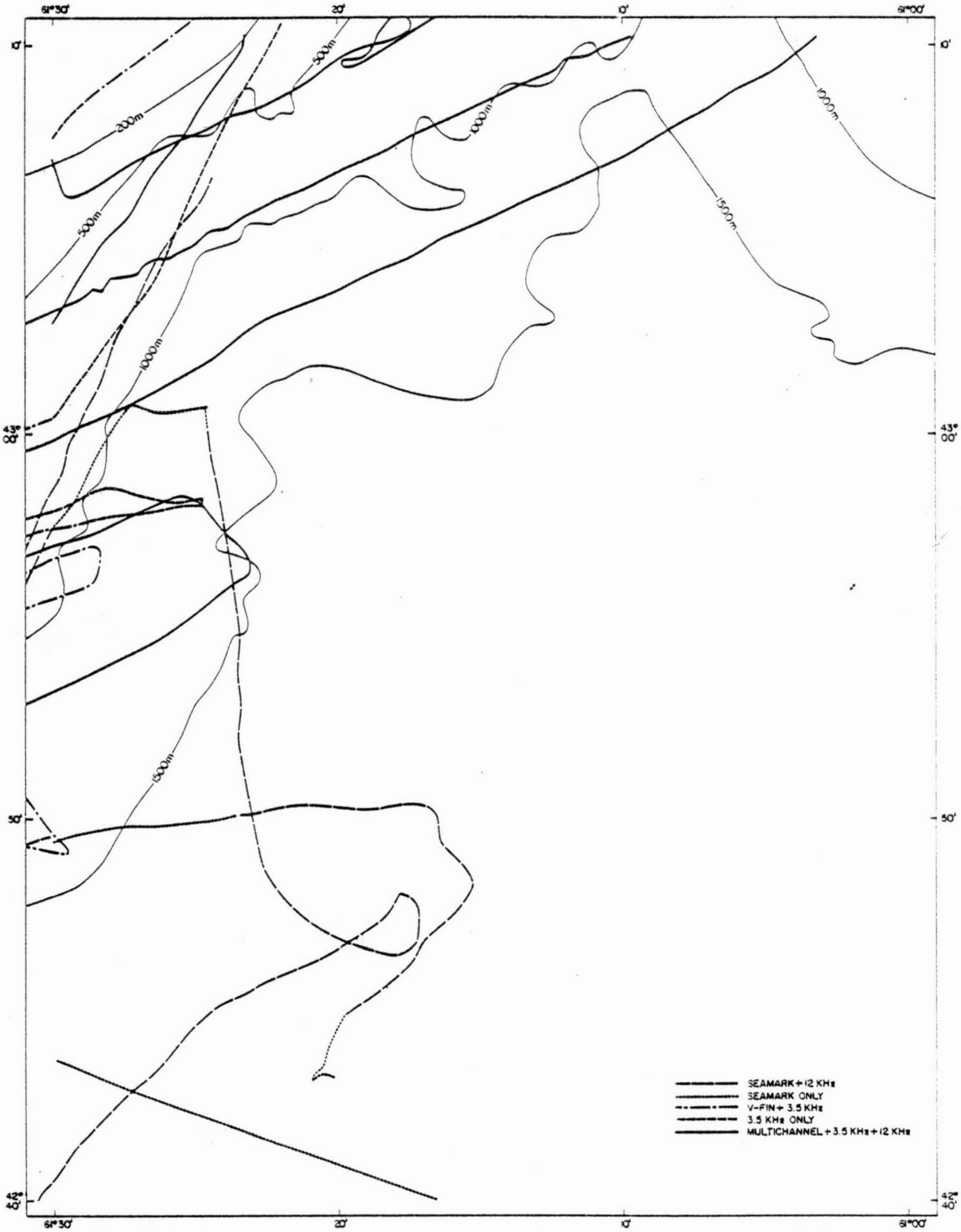


Figure 2 (continued)

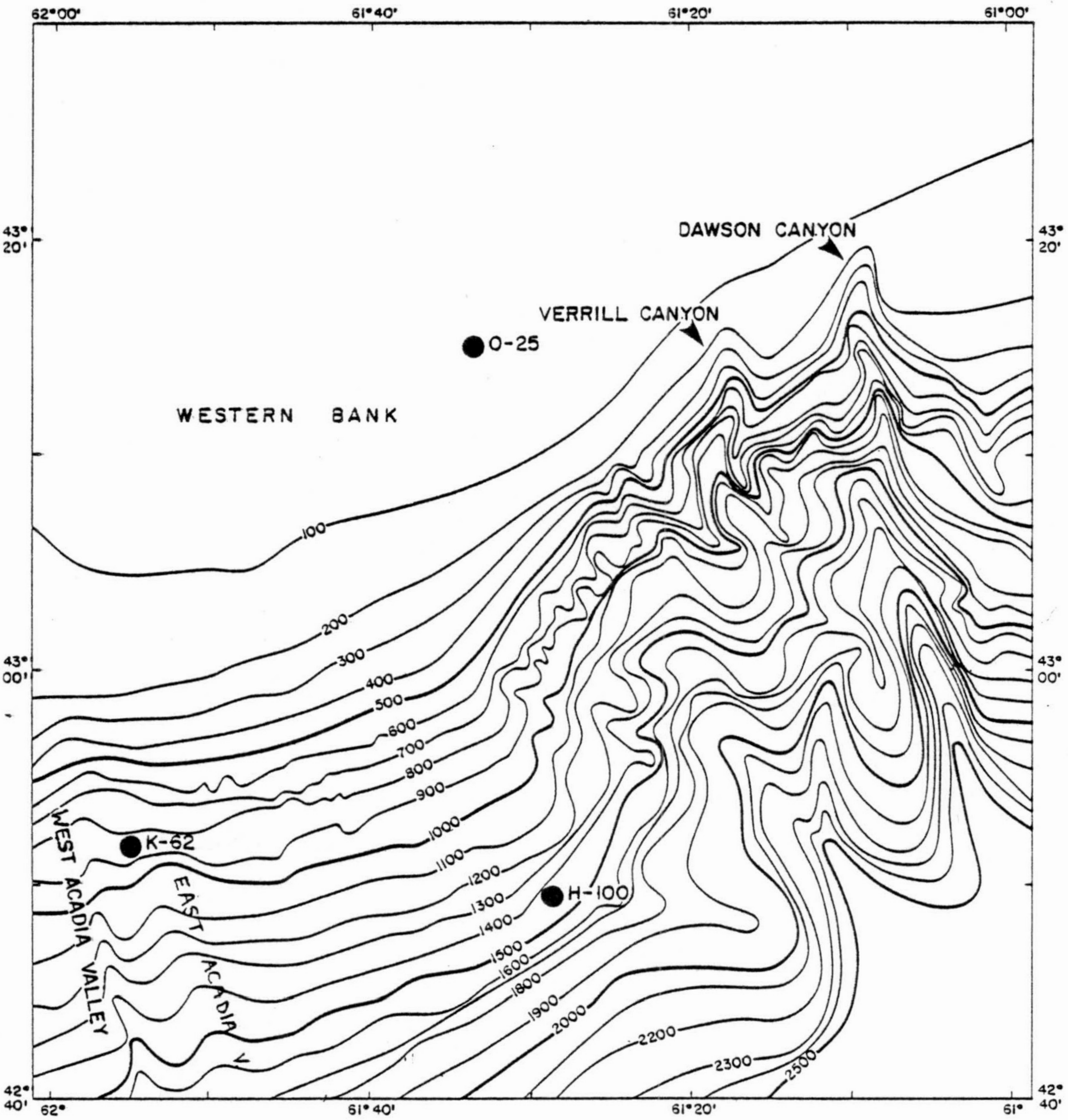


Figure 3. Bathymetry of the study area based on National Resource Series 1:250,000 charts and Piper et al. (1983), also showing location of exploratory wells.

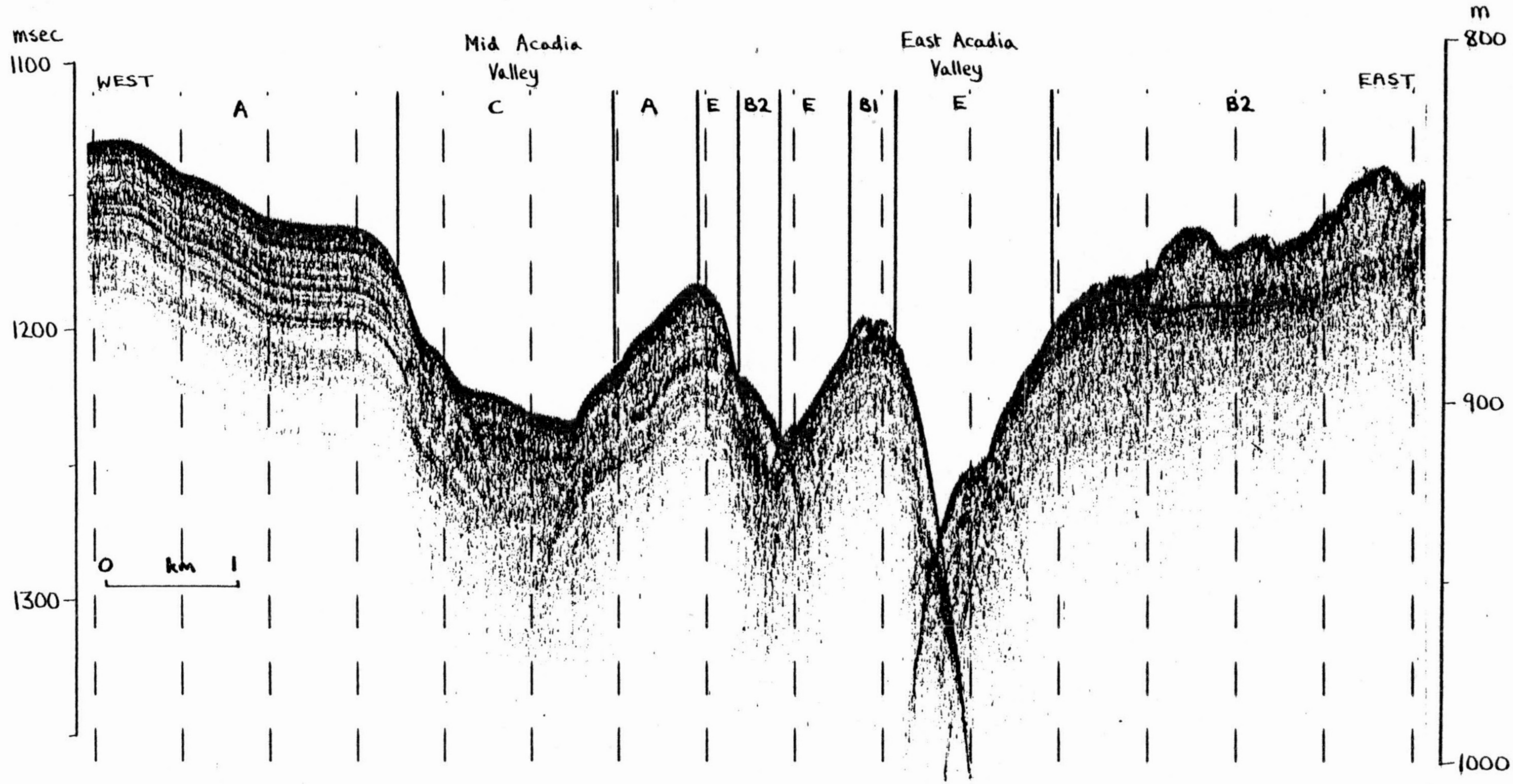


Figure 4. Examples of types of seabed acoustic character seen on 3.5 kHz profiles.

(a) types A, B1, B2, C and E near East Acadia valley.
(82-004; 70/0900)

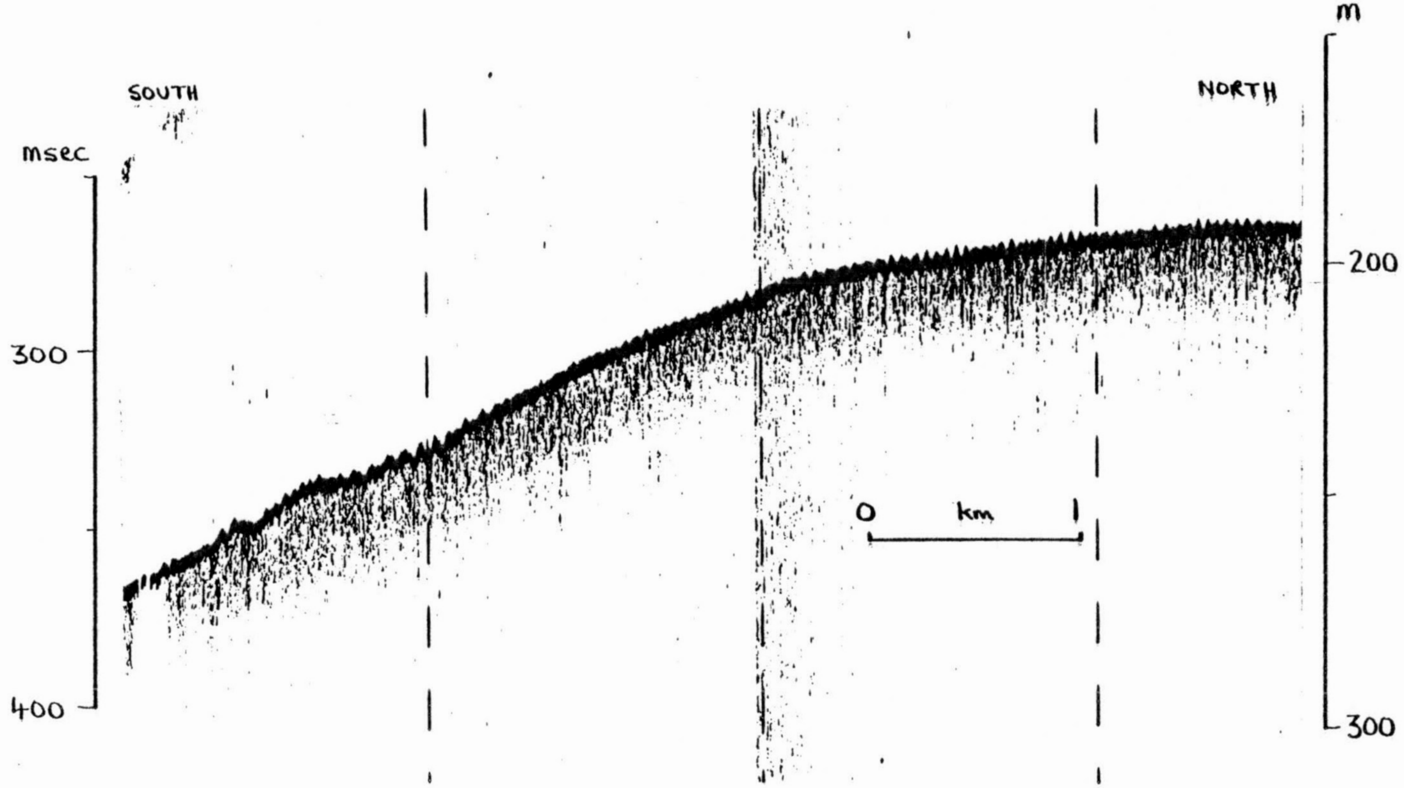


Figure 4 (b): type D seabed on upper slope
(fine scale roughness due to ship motion)

(82-004; 69/0130)

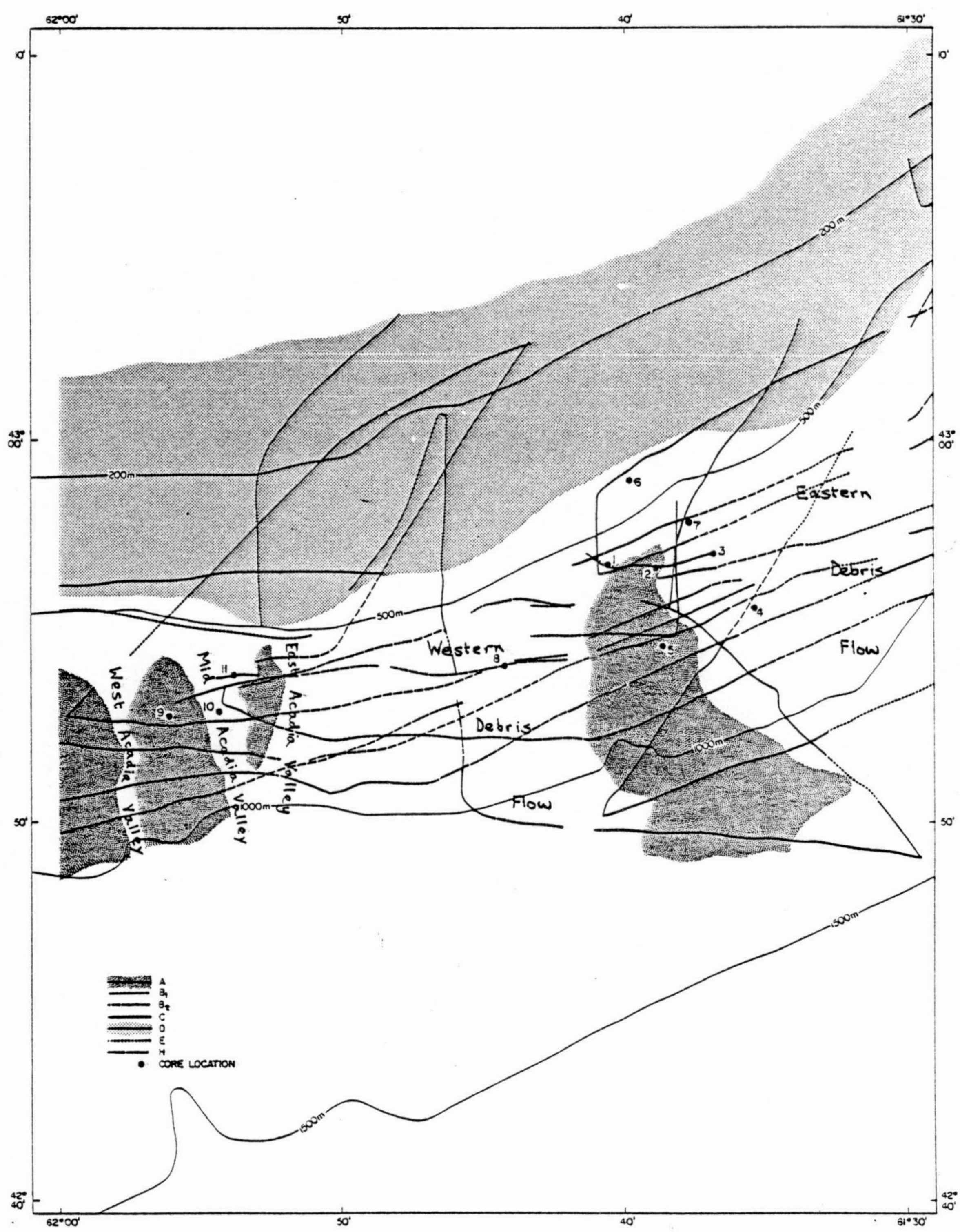


Figure 5. Map showing distribution of seabed acoustic types based on 3.5 kHz profiles.

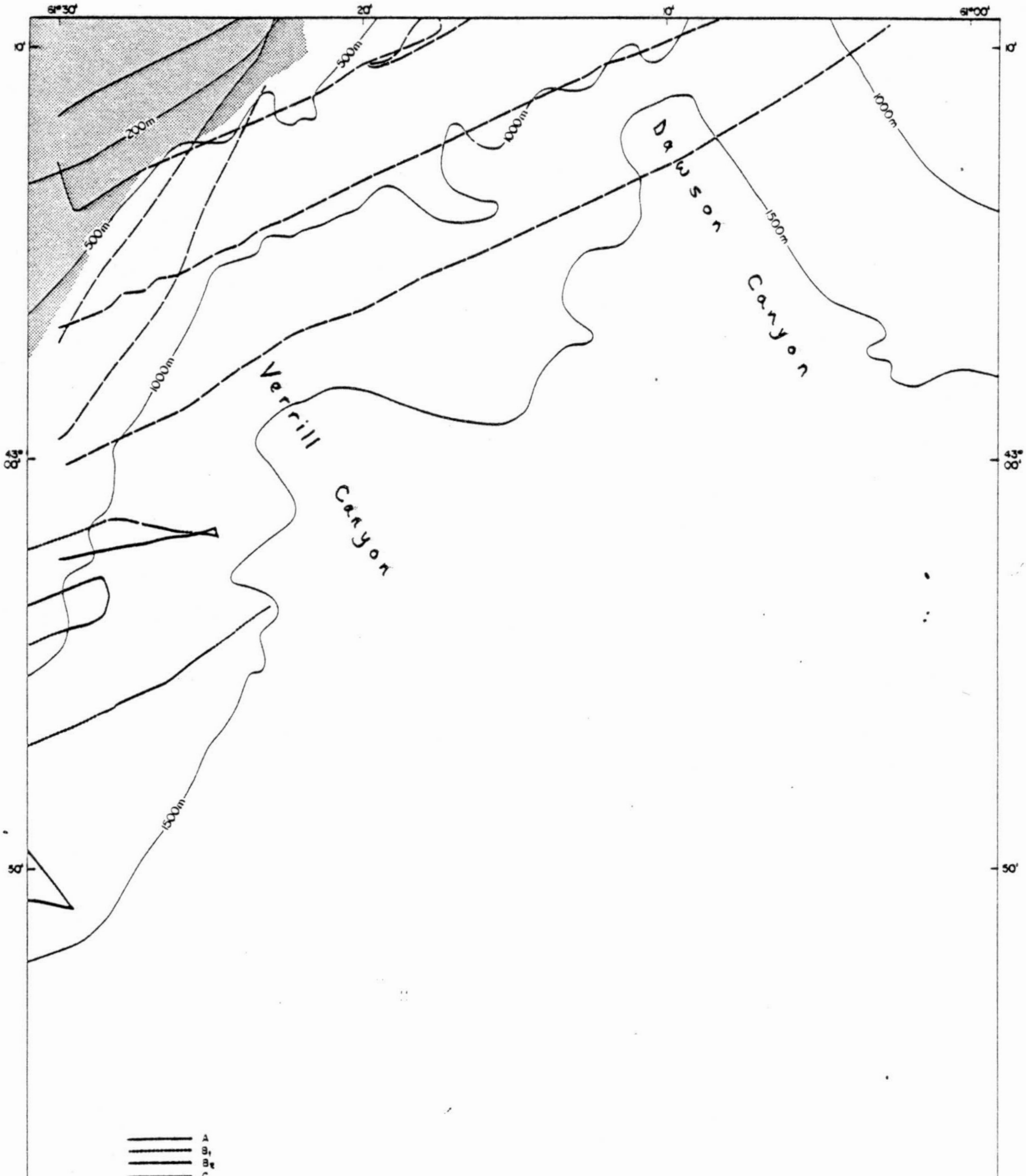


Figure 5 (continued)

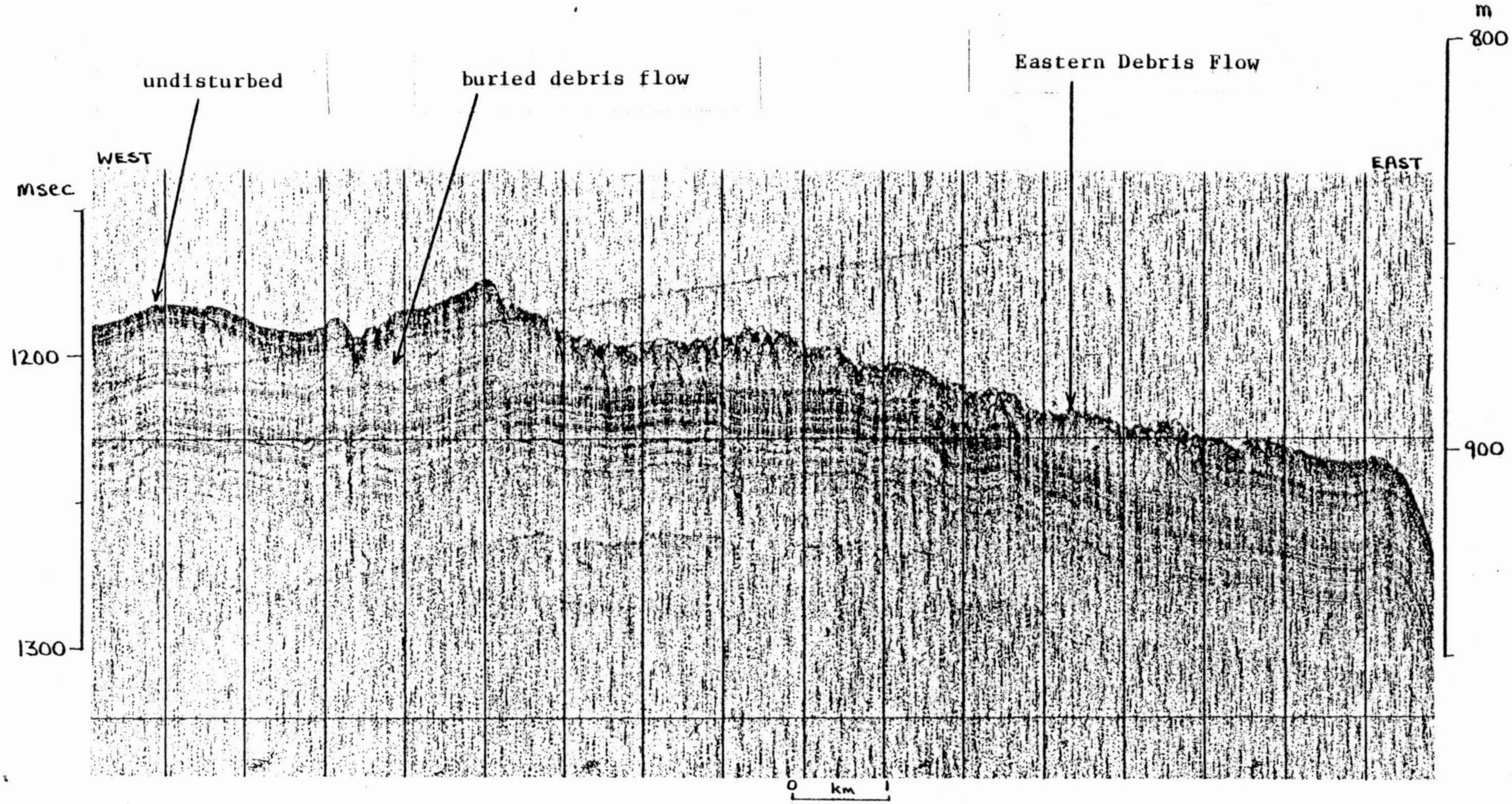


Figure 6. V-fin deep towed sparker profile across eastern debris flow, also showing buried debris flow and area of undisturbed sediment. (82-004; 70/0245)

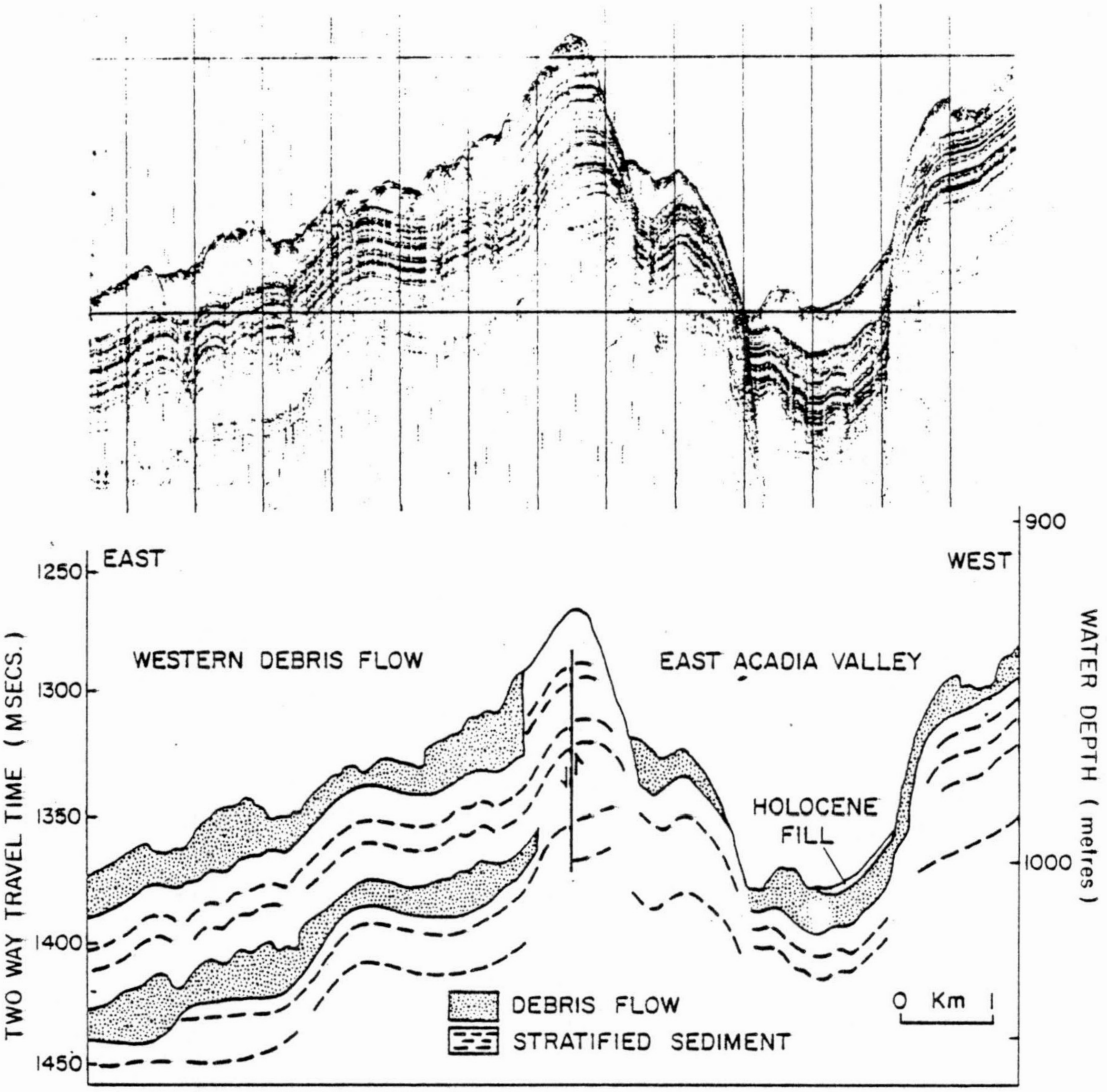


Figure 7. V-fin deep towed sparker profile across East Acadia valley, showing Holocene fill in valley overlying debris flow, the rough surface of the western debris flow east of the valley, the draped configuration of sediments beneath the surface debris flow, and a probable debris flow about 50 m sec sub-bottom. (83-012; 128/2110)

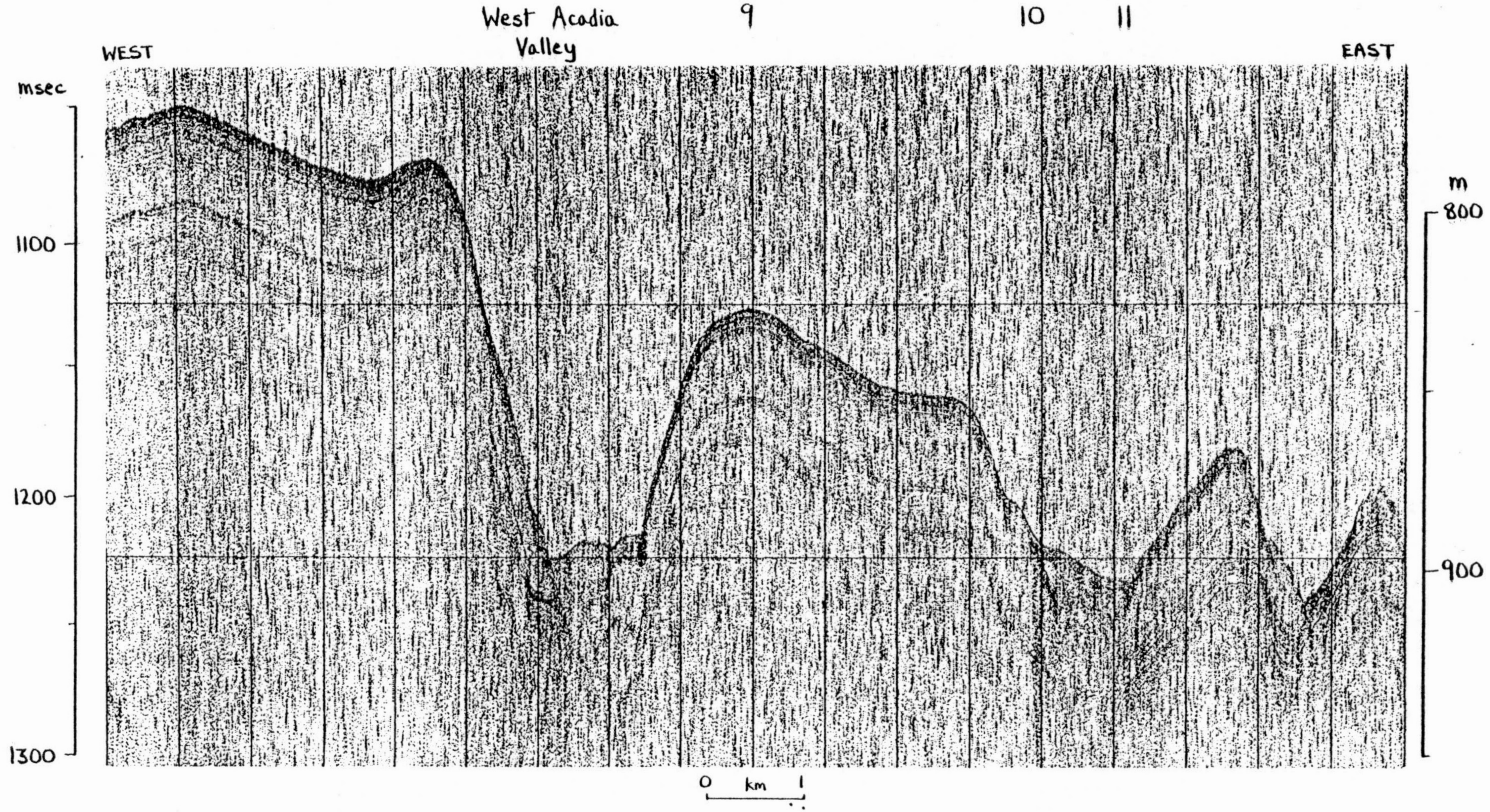
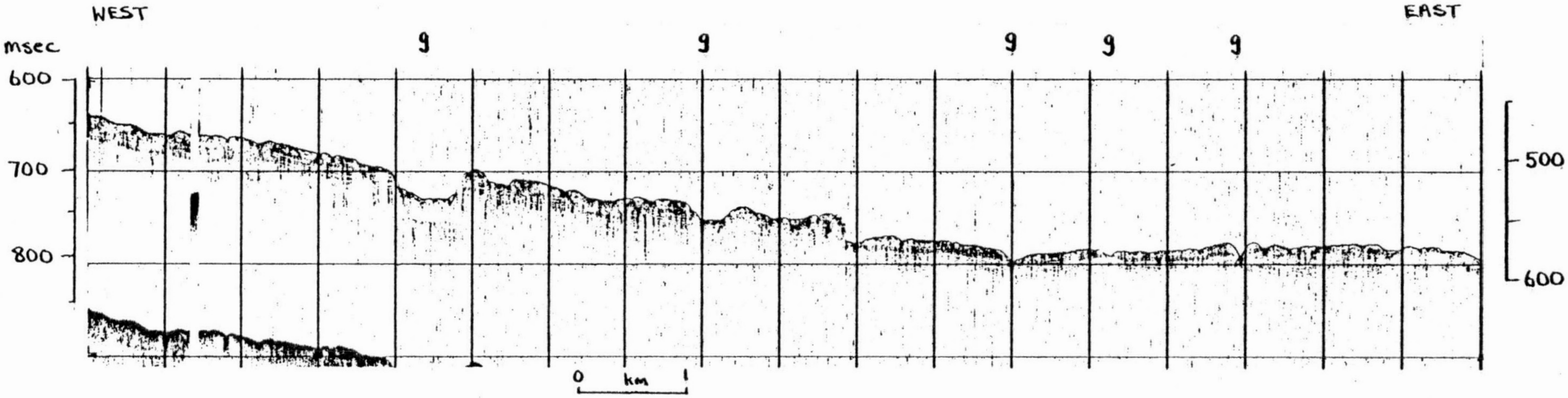


Figure 8. V-fin deep towed sparker profile, showing West and Mid Acadia valleys and location of cores 9, 10 and 11. (82-004; 070/0800)



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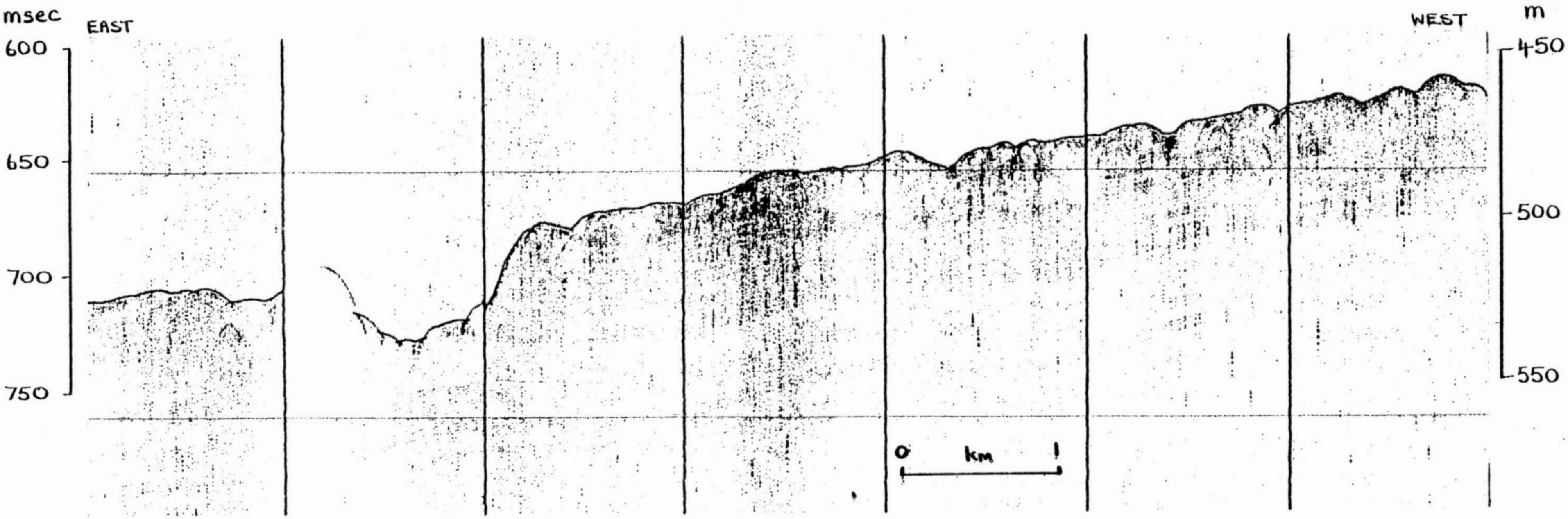

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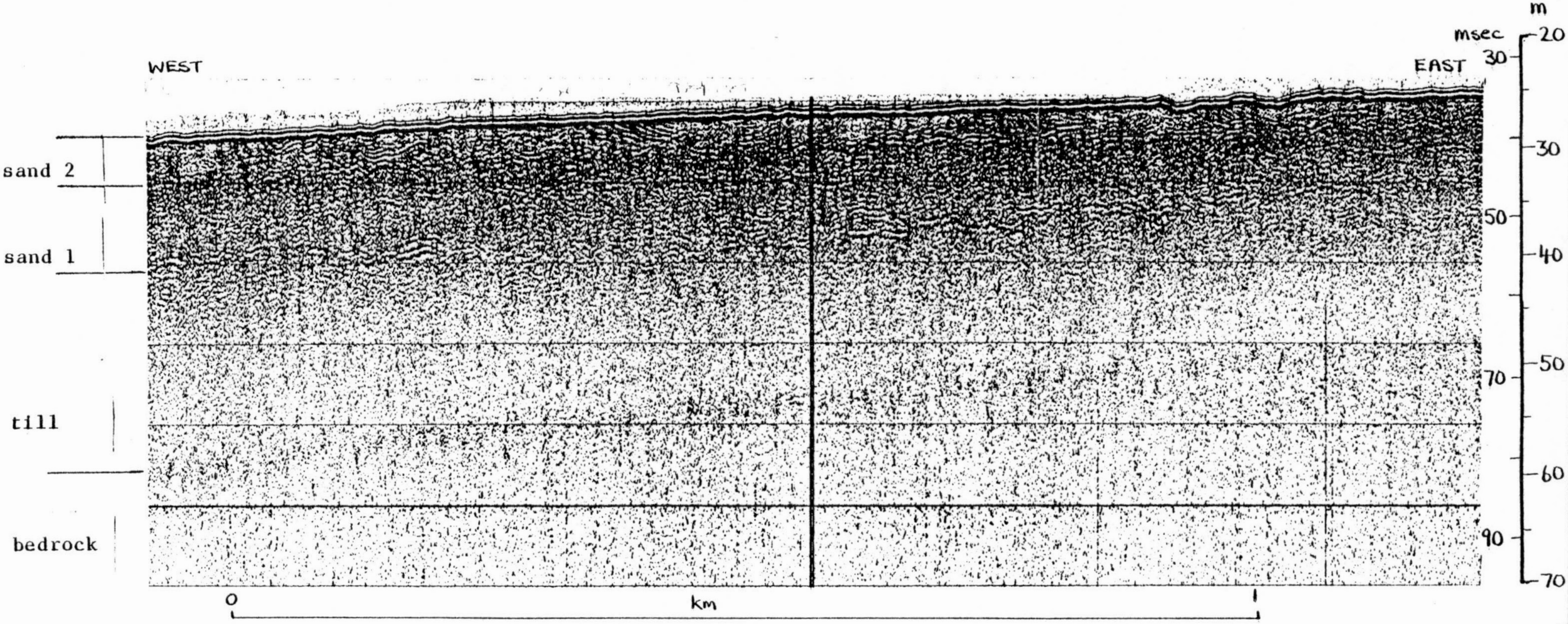

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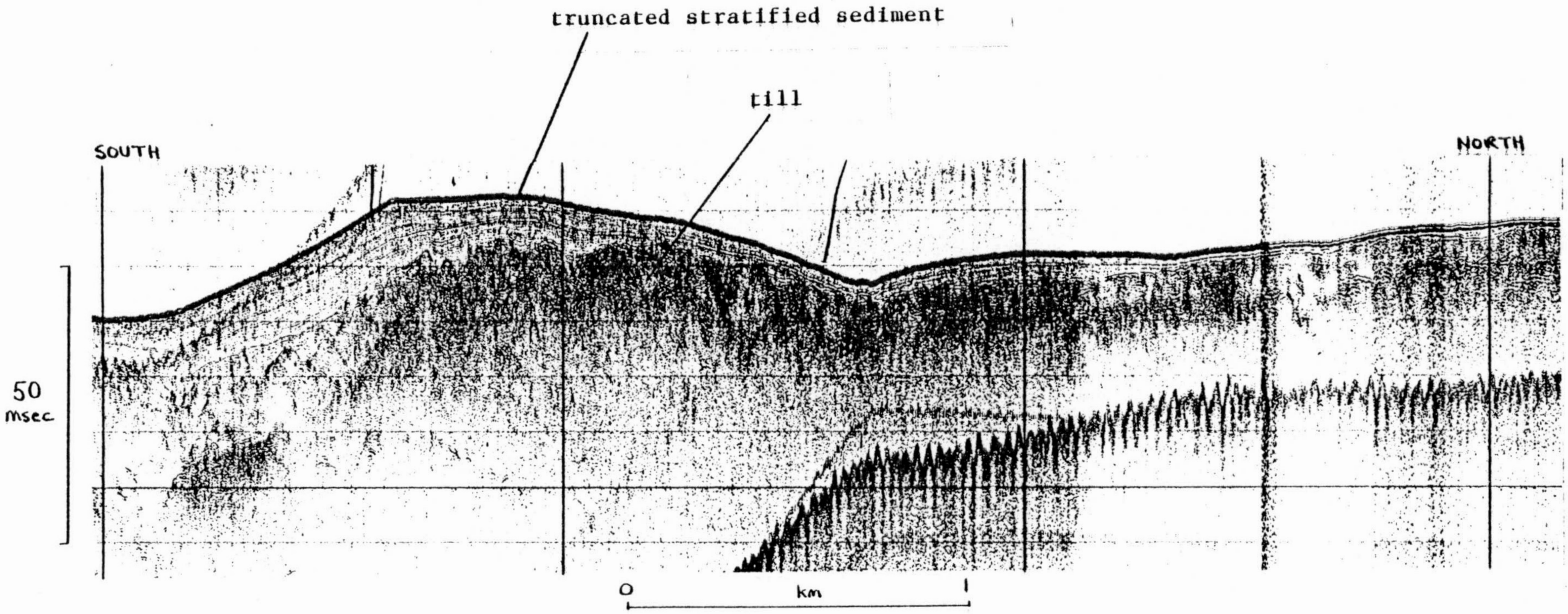

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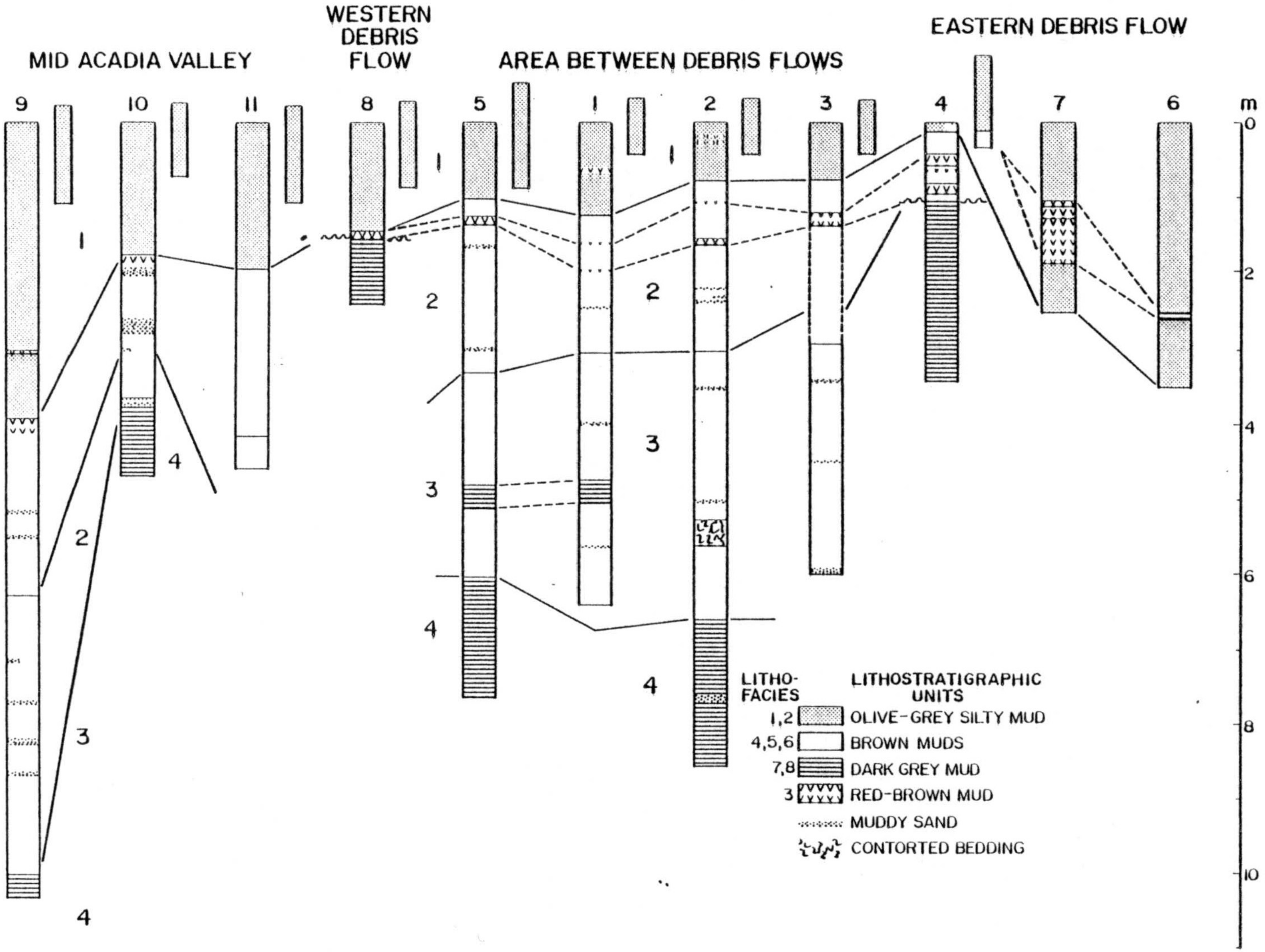

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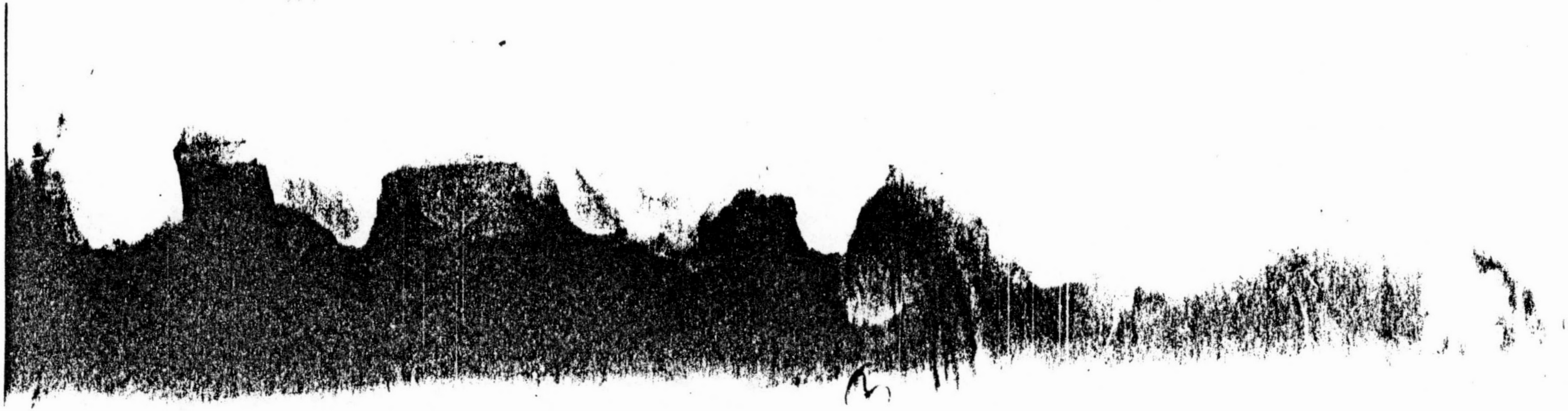

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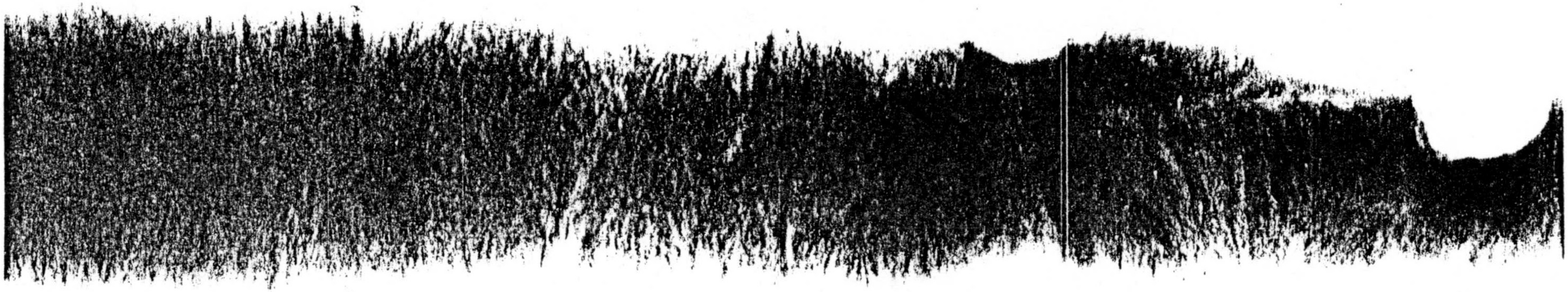

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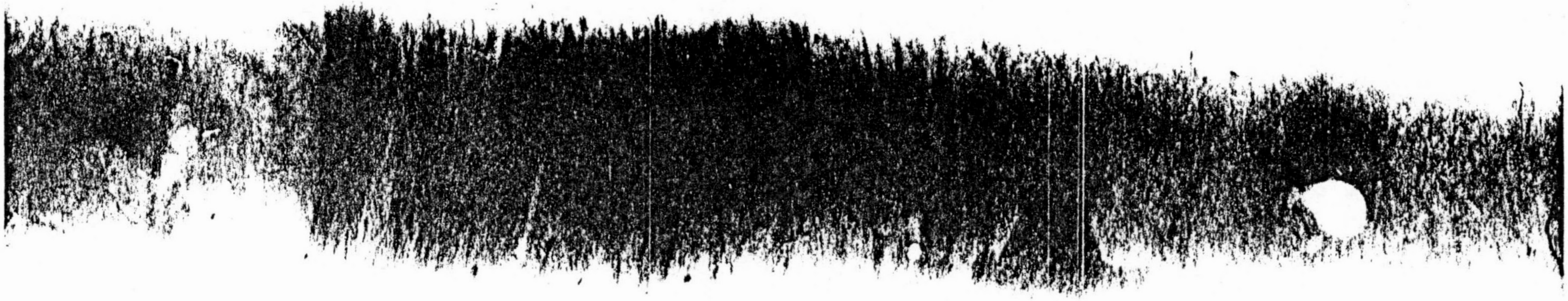

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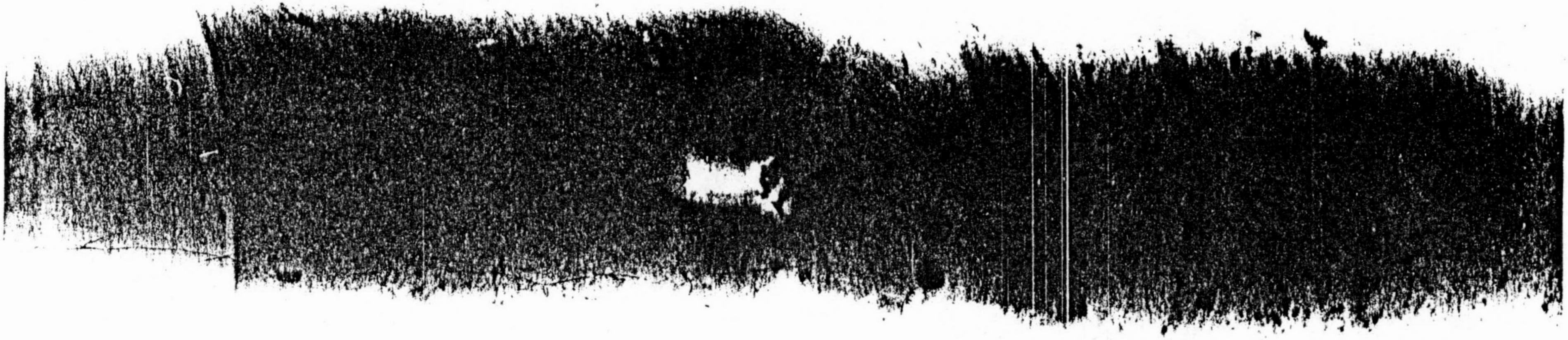

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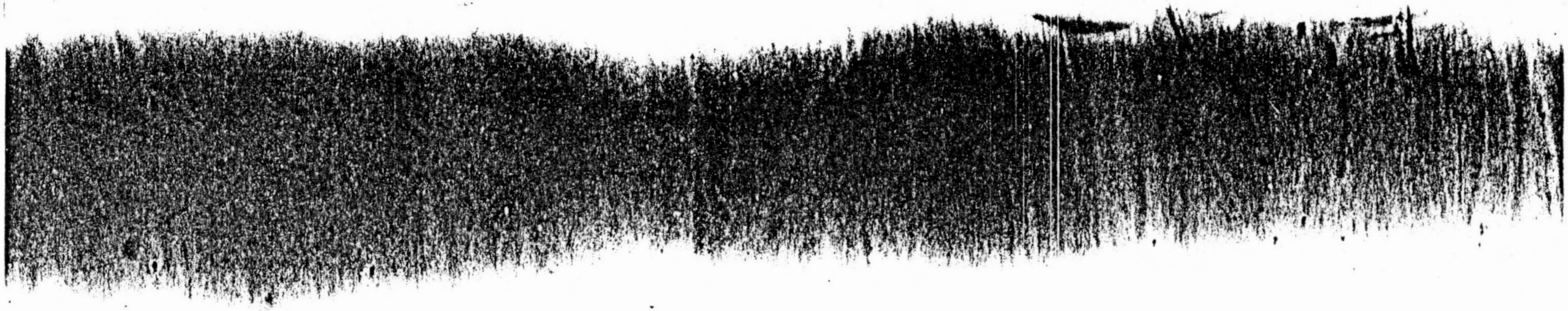

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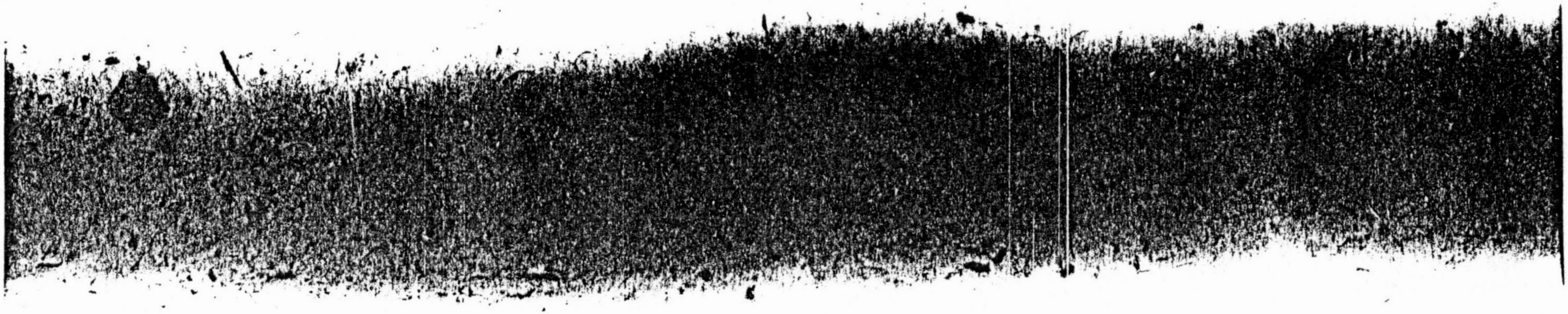

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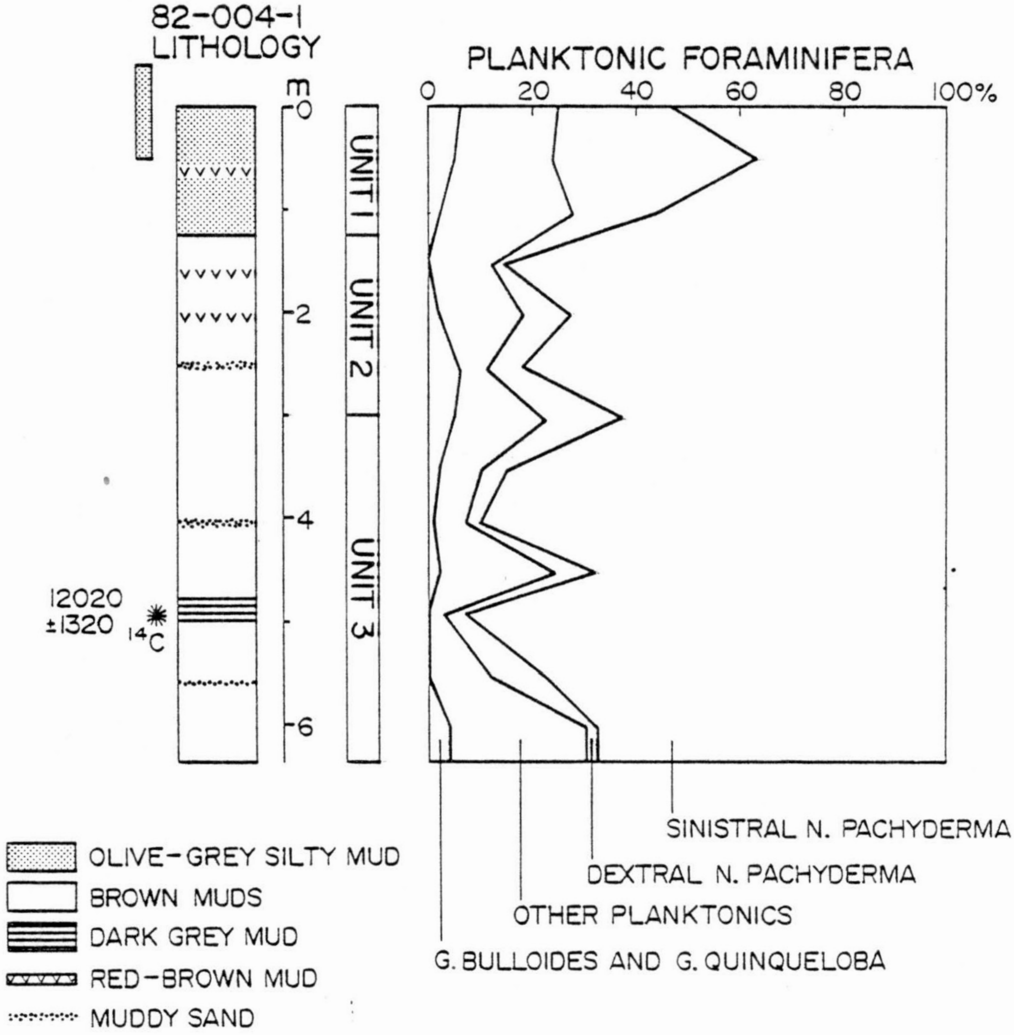

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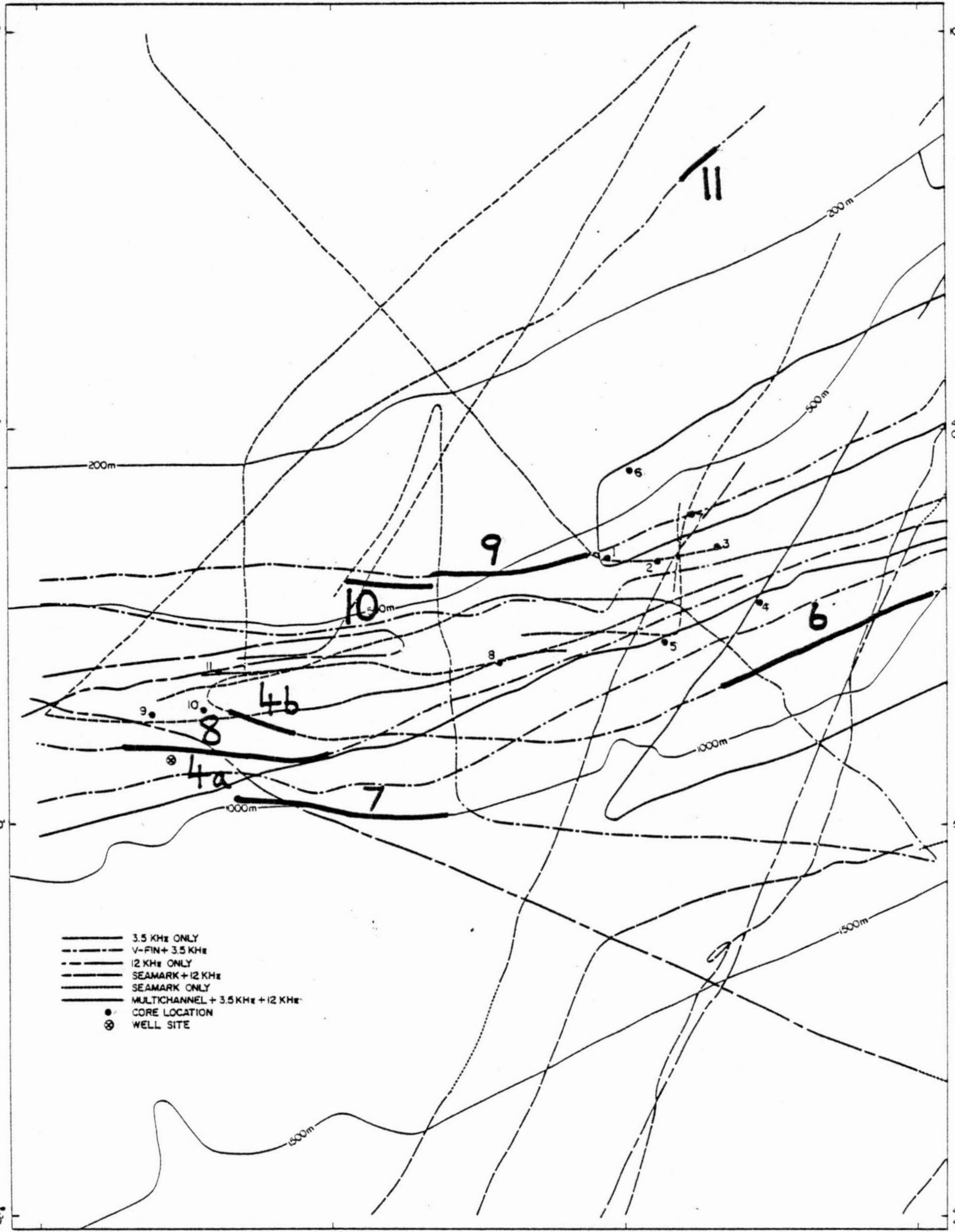

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