3. MARINE GEOLOGICAL-GEOPHYSICAL INVESTIGATIONS IN 1977 OF THE SCOTT INLET AND CAPE DYER – FROBISHER BAY AREAS OF THE BAFFIN ISLAND CONTINENTAL SHELF

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Abstract

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*Geological-geophysical investigations were undertaken from **C.S.S. Hudson** in 1977 in the Scott Inlet and the Cape Dyer – Frobisher Bay areas of the Baffin Island shelf.*

The walls of the Scott Inlet submarine trough consist mainly of more or less flat lying strata, whereas strata forming its floor have been folded and faulted. A structural high appears to underlie the outer part of the south wall. A calcareous concretion of late Eocene age was recovered by dredging across benches on the trough wall. A persistent oil slick in the area may be caused by seepage from the rock formations.

Bedrock geology of the southeastern Baffin Island shelf was further defined by geophysical profiling and the recovery between Cumberland Sound and Frobisher Bay of shallow drill cores of Precambrian gneiss and limestone of probable Ordovician age.

Introduction

Geological and geophysical investigations of the bedrock underlying the continental shelf adjacent to the east coast of Baffin Island were concentrated in 1977 in the vicinity of Scott Inlet, where an oil slick possibly from a natural seep was reported by Loncarevic and Falconer (1977), and at various localities between Cape Dyer and Frobisher Bay. The cruise tracks and stations occupied are indicated in Figures 3.1 and 3.2. This work was undertaken from **CSS Hudson** during cruise 77-027 as part of an on-going program to determine the extent, age, physical properties, and structural framework of the main bedrock units of the continental shelf in this region. Reconnaissance data on the surficial sediments of the shelf, and underway geophysical data and soft sediment samples en route across Baffin Bay from Thule, Greenland, and on two tracks across Davis Strait, were also obtained. This report deals with the bedrock studies on the Baffin Island shelf which were the primary objectives of the cruise.

The studies of the continental shelf geology were carried out by means of continuous seismic reflection (655 cm^3 air gun source), Huntec deep tow high resolution seismic, magnetic and gravity profiling in conjunction with collection of bedrock samples principally by shallow corehole drilling, and to a lesser extent, by dredging. The drilling was done with the Bedford Institute of Oceanography underwater electric rock core drill (Fowler and Kingston, 1975), which cuts a 25 mm diameter core and penetrates to a maximum of 6 m below the seafloor. The drilling procedure was similar to that used in this area (MacLean et al., 1977; in press).

Samples of consolidated and semiconsolidated rock considered representative of the underlying material were recovered at six localities, five by drilling, and one by dredging (Fig. 3.2; Table 3.1). Rock fragments obtained at other localities were all judged to be from erratics in the overburden. Failure to obtain bedrock cores at other drill sites resulted from several factors: (1) numerous electrical and mechanical problems with the drill that limited both penetration and number of drilling attempts at several stations; (2) difficulty in retaining cores of semiconsolidated material; (3) limited bedrock penetration at some localities due to fragments jamming in the core barrel; and (4) generally fairly thick overburden and the inherent difficulties in positioning the drill on the prime target area.

Table 3.1

1977 bedrock sample station* data

Station	Location lat.	Location long.	Water depth (m)	Seafloor penetration (cm)	Results
9	71°19.5'N	70°22.1'W	dredged interval 658-475 m		calcareous concretion recovered
25	64°01.4'N	63°55.9'W	197	414	370 cm biotite gneiss core
26A	63°39.5'N	63°38.1'W	373	354	83 cm limestone core
27	63°35.5'N	63°47.3'W	219	113	15 cm semiconsolidated sandstone core
28	63°11.8'N	63°00.9'W	179	277	100 cm limestone core
29	62°58.3'N	63°00.8'W	182	544	108 cm garnet gneiss core

* Drill stations, except No. 9 which was a dredge station.

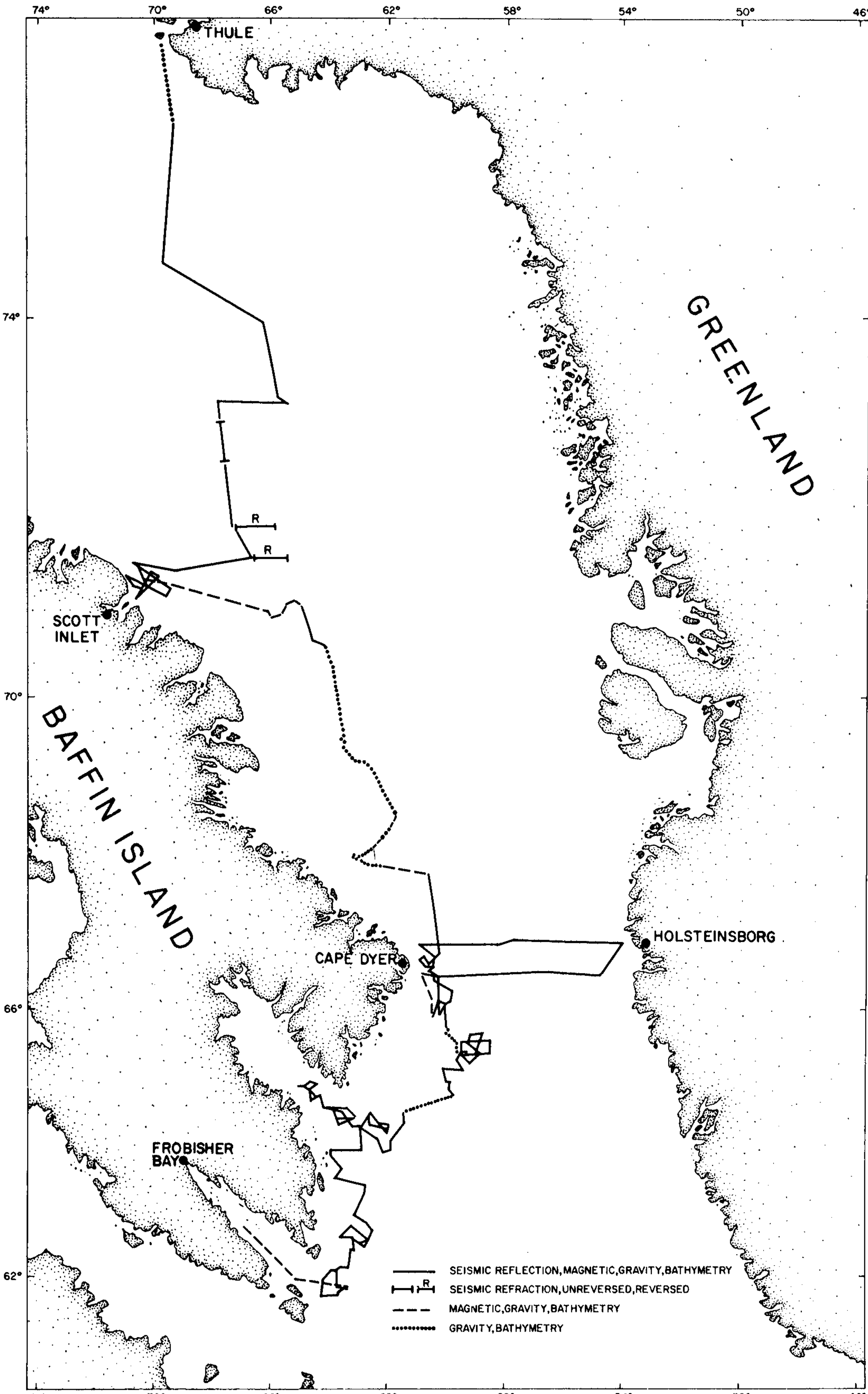

Figure 3.1. Tracks along which data were collected on cruise 77-027, **CSS Hudson** September 18 – October 13, 1977.

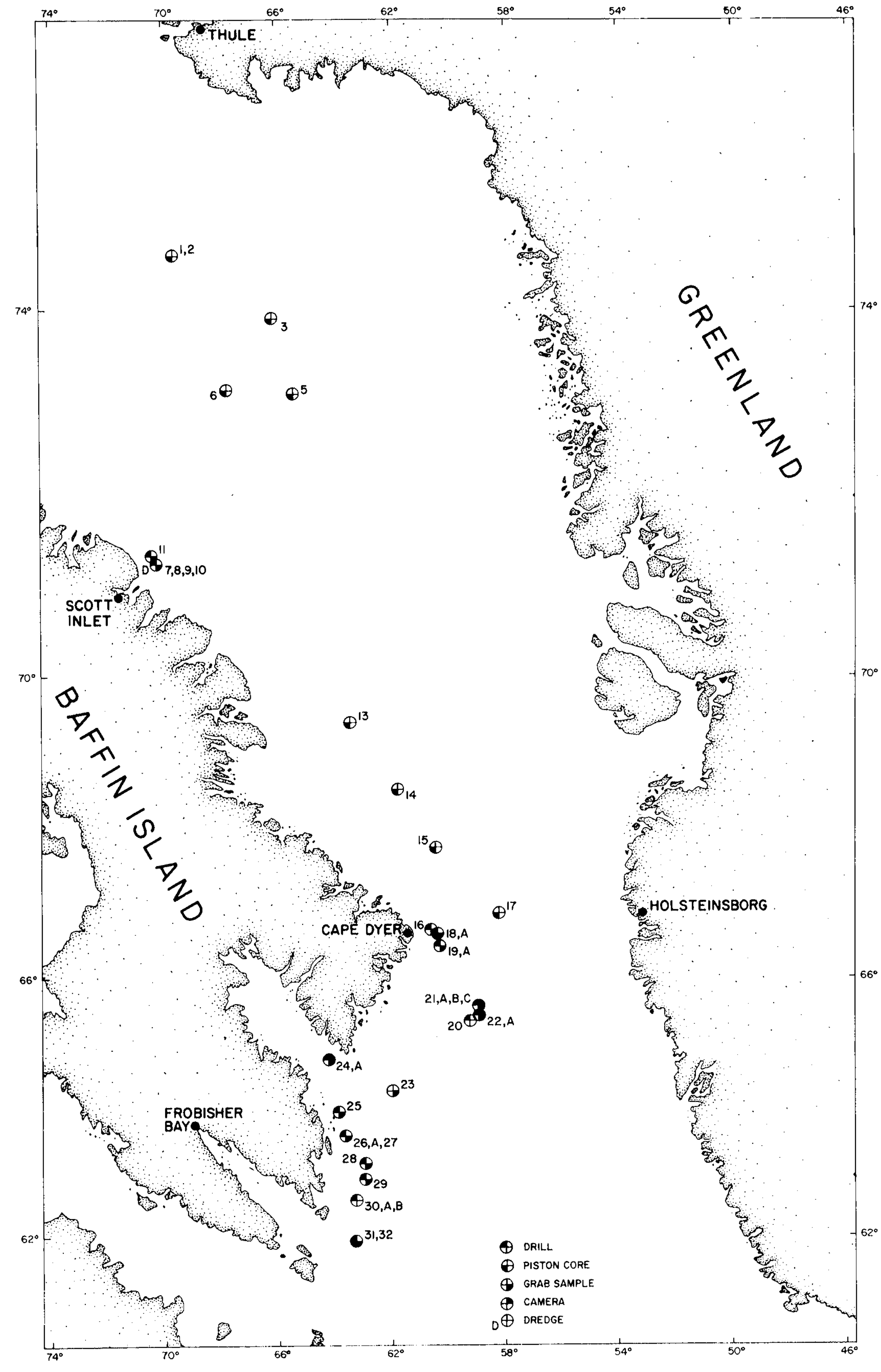

Figure 3.2. Geological stations occupied during cruise 77-027.

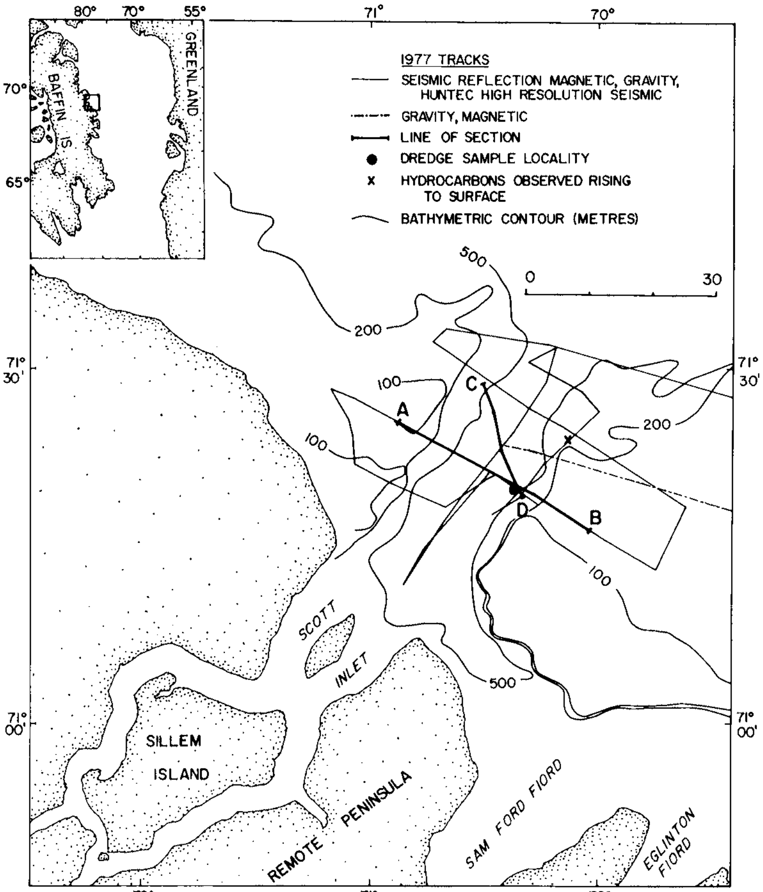

Figure 3.3. Index map of Scott Inlet area showing bathymetry, tracks along which geophysical data were collected in 1977, dredge sample location, and locality where hydrocarbon particles were seen coming to surface.

Strong currents, particularly between Cape Dyer and Frobisher Bay caused the ship to lose station and drilling to be terminated on two occasions. Unusually severe ice conditions prevented carrying out a planned reconnaissance of parts of the shelf between Scott Inlet and Cape Dyer and seriously hampered work from Cape Dyer to Cumberland Sound where drilling and towing of geophysical equipment were impractical in an ice-bound area that in places extended seaward for nearly 110 km from the coast.

Satellite navigation and Loran-C systems were used for navigational positioning.

Scott Inlet area

The occurrence of an oil slick in the vicinity of the submarine trough seaward from Scott Inlet was observed on two occasions in 1976 (Loncarevic and Falconer, 1977) and again in 1977 on September 5, 6, and 22. More extensive traversing of the area in 1977 revealed that the extent of the slick was greater than the limited observations in 1976 had indicated. Its observed extent on September 5 and 6 is shown by Levy (1978), who gives results of chemical studies of the hydrocarbon material. The slick was recognizable from a vessel only during calm sea conditions. Its persistence in time and space indicates that it originates from a source in this area and observations of hydrocarbon particles and gas bubbles rising to the surface (Loncarevic and Falconer, 1977; Levy, 1978) support this. The composition of the slick, its wide extent and the lack of known man-made causes suggest it may be caused by natural seepage of hydrocarbons from strata exposed at the seafloor. Work in this area in 1977 was directed to obtaining additional data on geological conditions as a prelude to more extensive studies planned for 1978.

The Scott Inlet submarine trough extends across the shelf in a northeasterly direction and represents a seaward continuation of Scott Inlet fiord (Fig. 3.3). Water depths in the trough reach more than 800 m, and it has some 700 m relief. The shores of Scott Inlet consist principally of precipitous cliffs rising several hundred metres from the sea. Løken and Hodgson (1971) reported and discussed the morphology of Scott Inlet and the submarine trough. The Scott Inlet fiord (and trough) are considered to have been carved by glacial erosion possibly along a pre-existing drainage system as suggested by Fortier and Morley (1956) and Ives and Andrews (1963).

Scott Island and the cliffs that form the shores of Scott Inlet are composed of a gneissic complex of Archean or Aphebian age (G.D. Jackson, pers. comm., 1978). Quaternary marine sediments form a narrow coastal lowland fringe to the north of Scott Inlet and less extensively to the south. Offshore, the walls of the submarine trough consist mainly of truncated beds of a more of less flat lying sedimentary sequence (Fig. 3.4 and 3.5) except the outer 15 km of the south wall where a structural high with associated positive gravity and magnetic anomalies occurs. A 100 milligal (F.A.) gravity low occurs over the central and inner part of the trough. Hood and Bower (1973) and Jackson et al. (1977) identified a sedimentary basin at least 6 km deep, and probably structurally controlled, along this section of the shelf on the basis of aeromagnetic and seismic refraction data. Strata forming the floor of the trough are folded and contain faults (Fig. 3.5). Data from a few profiles suggest that disturbed strata possibly extend beneath the younger flat lying strata of the walls, as for example along the northern part of profile C-D (Fig. 3.5) where an angular unconformity appears to exist between the beds of the lower part of the wall and flat lying strata higher in the section. Regionally, however, these relationships have not yet been well identified.

Dredging of the south wall between 658 m and 475 m water depth (Fig. 3.4) yielded a boulder sized dark grey calcareous concretion composed mainly of fine grained calcite together with some angular silt-to-sand sized quartz grains and minor other detrital components. Some sponge and a few other fossil fragments are present, mainly replaced by sparry calcite, but in general the rock contains few macrofossils. L.F. Jansa (pers. comm., 1978) believes the presence of ferroan sparry calcite replacing skeletal grains indicates that the concretionary material was influenced in later diagenetic stages by formation waters derived from argillaceous strata. The sample material might therefore be associated with a shaly sequence.

Examination of seismic profiles suggests that lithological variations among the strata forming the walls of the trough may be expected. For example, the rocks of the lower portion of the south wall on profile A-B (Fig. 3.4) give rise to stronger reflections of seismic energy than those higher in the sequence and also form benches on the trough wall. This suggests that harder and more resistant rocks occur along the lower section of the wall in this area with apparently softer (and possibly thinner bedded) material higher in the section. Petrologic inferences drawn by Jansa relating to the possibility of the limestone being in association with shale appear compatible with this tentative interpretation from the seismic data.

On the basis of a study of dinoflagellates in the sample, G.L. Williams (pers. comm., 1978) considers the rock to be of late Eocene age. Some Senonian species also were identified but their presence is attributed to reworking of material from older strata.

The lithological and faunal composition of the rock suggest that deposition took place in a neritic environment.

The nearest known occurrence of Eocene strata on the adjacent land is some 330 km to the north on Bylot Island at the northern end of Baffin Island where a thin sequence of molasse type sediments is preserved in northwest-southeast trending grabens (Jackson et al., 1975; Jackson and Davidson, 1975).

The locality some 15 km from the seaward end of the south wall where Loncarevic and Falconer (1977) and Levy (1978) observed blobs and bubbles coming to surface (Fig. 3.3) is approximately coincident with the flank of the structural high. This suggests that this area is a source of the slick material, but if as suspected, the hydrocarbons originate through natural seepage from seabottom strata, other source areas may exist. The truncated beds forming the trough walls and the folded and apparently faulted strata of the floor present numerous opportunities for escape of fluids or gasses should these be present in the rock formations. Possible deflections due to tidal currents acting on a stream of particles rising through the water column must also be considered in attempting to relate sea surface observations with seabed geology.

Occurrence of the slick north of the Scott Inlet trough (Levy, 1978) is also significant because water currents along the coast are southbound. Sources of the slick therefore may also exist elsewhere on the shelf, for example, seaward from Buchan Gulf where a submarine trough is cut into the shelf 87 km northwest of Scott Inlet.

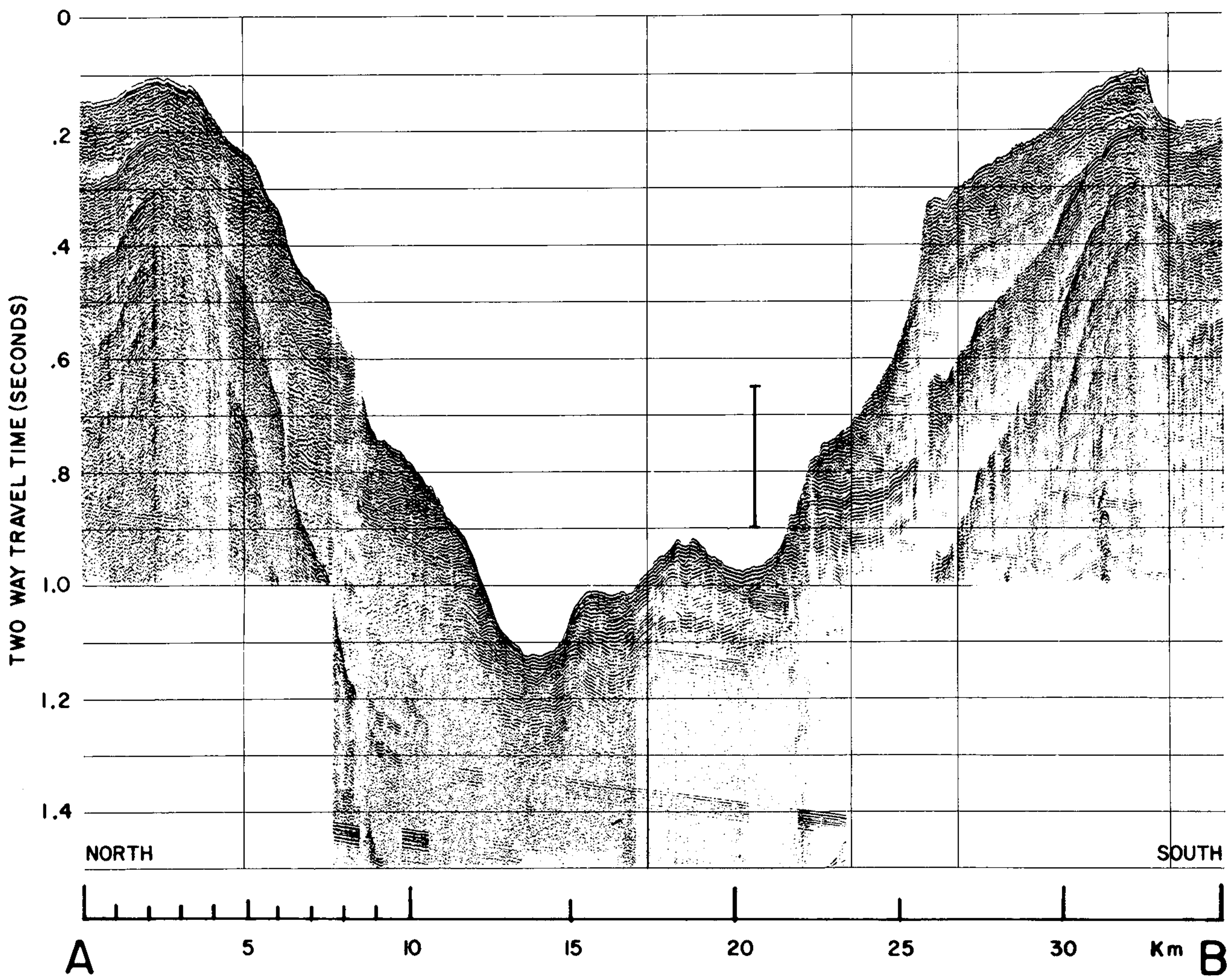

Figure 3.4. Profile A-B (see Fig. 3.3 for location). Seismic reflection record across Scott Inlet submarine trough illustrating the shape of the trough and the stratigraphic sequence through which it has been cut. The strong seismic reflectors in the lower part of the south wall approximately 22-26 km along the profile apparently are associated with more resistant strata that form benches on the trough wall at this locality. The vertical bar slightly to the right of centre indicates the approximate interval dredged. The seismic reflection data appear to support Løken and Hodgson's (1971) interpretation that the narrow ridge at the top of the south wall is a lateral moraine. The vertical exaggeration is approximately 23 times.

Cape Dyer – Frobisher Bay area

Volcanic rocks occur in a narrow discontinuous belt that extends northwestward from Cape Dyer for 85 km along the coast of eastern Baffin Island (Clarke and Upton, 1971). MacLean et al. (1978) reported on offshore basalt occurrences southeast of Cape Dyer on the basis of a petrological study of core samples, and seismic and magnetic data. Existence of basalt offshore in this area previously had been inferred by Grant (1975) and Hood and Bower (1973, 1975). Additional geophysical data acquired in 1977 further define the contact between the volcanics and the sediments adjoining them to seaward. A 12.5 cm core of dark grey, fine grained basalt was recovered at a locality 152 km southeast of Cape Dyer (Fig. 3.2, Stn. 21B) where the presence of basalt was inferred from geophysical data, but it is not clear whether or not the sample was in situ. The rock units closer to shore between Cape Dyer and Cumberland Sound were inaccessible for sampling and geophysical profiling due to ice.

Additional corehole drilling and geophysical profiling were carried out on the shelf between Cumberland Sound and Frobisher Bay to further define the rock units underlying that area and results from these studies are incorporated in the geological map (Fig. 3.6). The new data extend and refine information presented earlier on this area by MacLean et al. (1977). Table 3.1 summarizes the drill station data.

Drill station 25, where a 370 cm core of biotite gneiss was recovered, is situated just west of the boundary with Paleozoic strata at the south side of the entrance to Cumberland Sound. On the eastern side of the boundary and 44 km to the south, station 26-A yielded an 83 cm core of grey limestone composed of fine crystalline calcite. A core of dark brown micritic limestone was obtained at station 28 just north of the boundary with the Precambrian gneisses of the basement high (Fig. 3.6). This rock contains radiolariacasts and finely disseminated organic material and closely resembles rocks sampled previously 22 km to the west described by Jansa (1976) and MacLean et al. (1977). On the basis of lithologic, seismic and magnetic similarities the limestone rocks from stations 26A and 28 are considered part of the middle – late Ordovician sequence cored previously east and southeast of Cape Murchison (MacLean et al., 1977). Ordovician strata are also thought to occur in two small structural depressions in the basement southeast of Lady Franklin Island on the basis of seismic and magnetic data.

The Precambrian rocks of the basement high extending through Monumental and Lady Franklin islands are now considered, on the basis of a core of garnet-biotite gneiss recovered at station 29 and complementary seismic and magnetic data, to constitute the bedrock eastward to the boundary with the Mesozoic-Cenozoic strata that lap on them

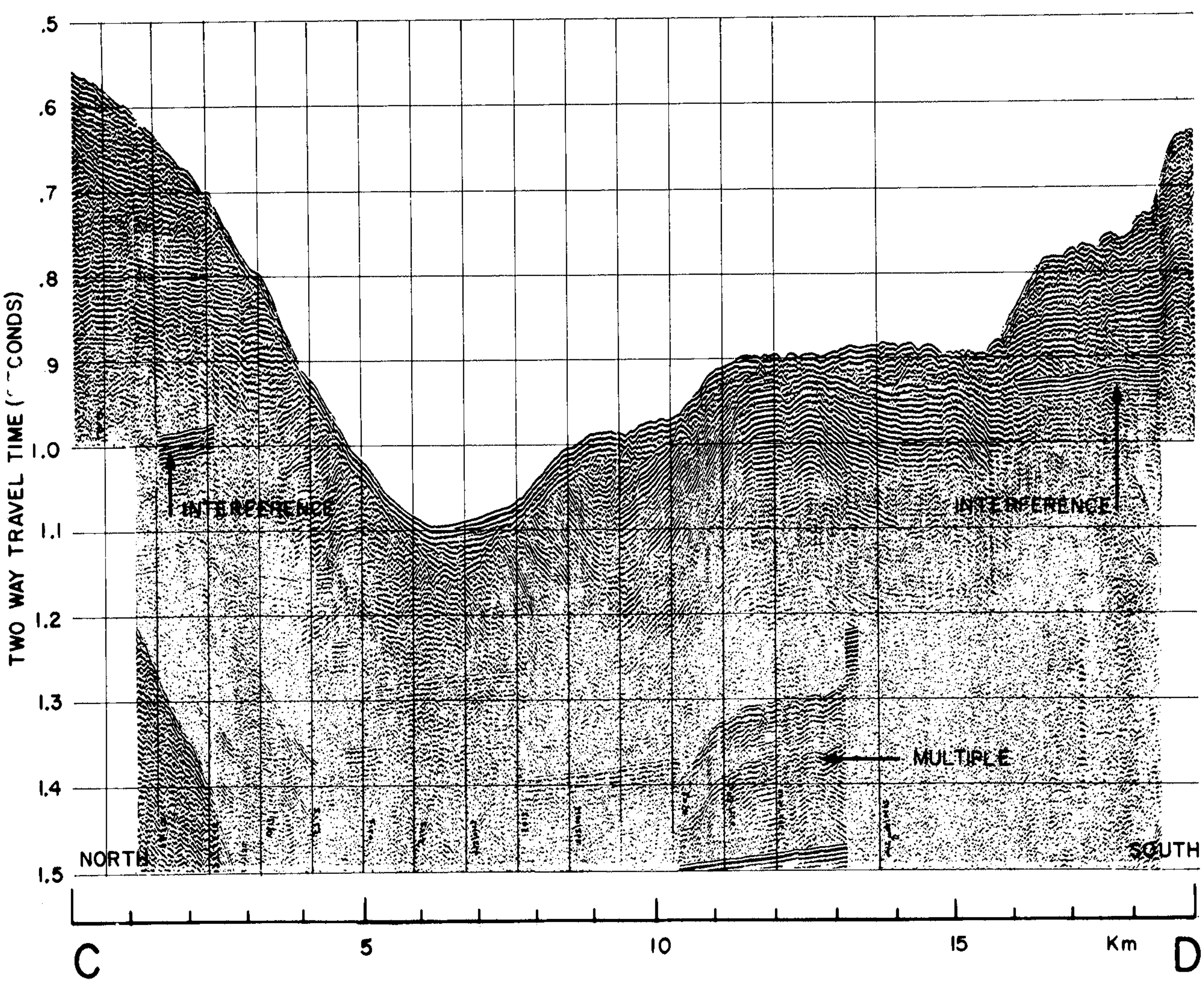

Figure 3.5. Profile C-D (see Fig. 3.3 for location). Seismic reflection record across part of Scott Inlet submarine trough illustrating folded and probably faulted strata in the floor of the trough and flatter lying strata higher on the walls. The vertical exaggeration is approximately 19 times.

to seaward. Lacking sample control MacLean et al. (1977) previously had tentatively mapped the eastern part of this Precambrian area simply as Ordovician or earlier.

A small sample of semiconsolidated sandstone with scattered gravel fragments was recovered from the cutting head of a piston corer at station 32 (Fig. 3.2) off the etrance to Frobisher Bay, 59 km southwest of a locality where similar sediment was drilled in 1976 (MacLean and Falconer, 1977). Foraminifera in the sample were studied by F.M. Gradstein who (pers. comm. 1978) considers the material to be of Pliocene-Quaternary age and deposition to have occurred in a normal salinity open marine environment. Gradstein correlates the foraminiferal assemblage in the sample with the uppermost assemblage in wells drilled on the Labrador Shelf (Gradstein and Williams, 1976). The sample locality is underlain by a sequence of apparently regularly bedded strata that dip gently seaward at an angle of about 2° and attain a thickness of 600 m or more at the core station. Difficulty has been experienced in obtaining satisfactory samples of this material with the drill and this has been attributed mainly to the strata being poorly lithified, though the thickness of surficial cover is also a factor. As a consequence, it is uncertain whether or not the material recovered by the piston corer is representative of the strata seen on the seismic records to underlie that locality.

In view of the foregoing, as well as analogies drawn with lithological and paleontological data from the Labrador Shelf (McWhae and Michel, 1975; Gradstein and Williams, 1976; Gradstein, pers. comm. 1978) and a sample of late Albian-Cenomanian age recovered at a drill station off Cumberland Sound (MacLean and Falconer, 1977), the sequence of sedimentary rocks on the outer part of the southeastern Baffin Island shelf (Fig. 3.6) is thought to be mainly of Cenozoic age and occurrences of Mesozoic strata at the bedrock surface are thought to be more localized.

A short core of semiconsolidated sandstone similar to material in the bottom of the piston core from station 32 was recovered from a thin layer covering the older rocks at station 27 east of Brevoort Island.

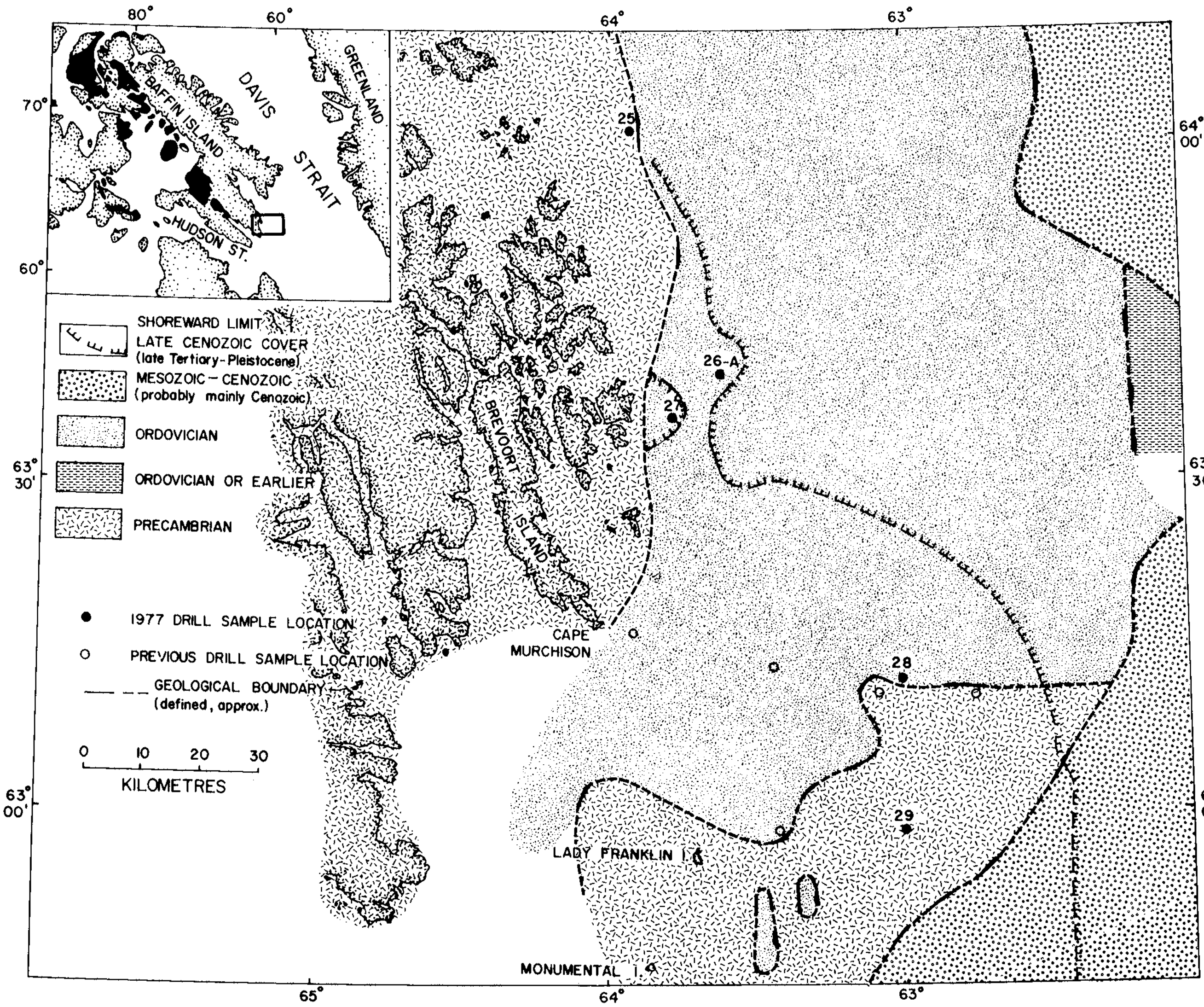

Figure 3.6. Geological map of the continental shelf seaward from Hall Peninsula, southeastern Baffin Island. This extends and updates information in Figure 3 of MacLean et al. (1977). Solid dark areas on inset map indicate known on-shore occurrences of Ordovician rocks (including undivided Ordovician-Silurian strata) in the Baffin Island region.

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References

Clarke, D.B. and Upton, B.G.J.
1971: Tertiary basalts of Baffin Island: field relations and tectonic setting; Can. J. Earth Sci., v. 8, p. 248-258.

Fortier, Y.O. and Morley, L.W.
1956: Geological unity of the Arctic Islands; Trans. Roy. Soc. Can., ser. 3, p. 3-12.

Fowler, G.A. and Kingston, P.F.
1975: An underwater drill for continental shelf exploration; Soc. Underwater Technol., v. 1, no. 4, p. 18-22.

Gradstein, F.M. and Williams, G.L.
1976: Biostratigraphy of the Labrador Shelf, Part 1; Geol. Surv. Can., Open File 349, 39 p.

Grant, A.C.
1975: Geophysical results from the continental margin off southern Baffin Island, **in** Canada's Continental Margins and Offshore Petroleum Exploration, C.J. Yorath, E.R. Parker and D.J. Glass, eds., Can. Soc. Pet. Geol., Mem. 4, p. 411-431.

Hood, P.J. and Bower, M.E.
1973: Low-level aeromagnetic surveys of the continental shelves bordering Baffin Bay and the Labrador Sea; **in** Earth Science Symposium on Offshore Eastern Canada, P.J. Hood, ed.; Geol. Surv. Can. Paper 71-23, p. 573-598.

1975: Aeromagnetic reconnaissance of Davis Strait and adjacent areas; **in** Canada's Continental Margins and Offshore Petroleum Exploration, C.J. Yorath, E.R. Parker, and D.J. Glass, eds.; Can. Soc. Pet. Geol., Mem. 4, p. 433-450.

Ives, J.D. and Andrews, J.T.
1963: Studies in the physical geography of north-central Baffin Island, N.W.T.; Geogr. Bull. no. 19, p. 5-48.

Jackson, G.D. and Davidson, A.
1975: Bylot Island map-area, District of Franklin; Geol. Surv. Can., Paper 74-29, 12 p.

Jackson, G.D., Davidson, A., and Morgan W.C.
1975: Geology of the Pond Inlet map-area Baffin Island, District of Franklin; Geol. Surv. Can., Paper 74-25, 33 p.

Jackson, H.R., Keen, C.E., and Barrett, D.L.
1977: Geophysical studies of the eastern continental margin of Baffin Bay and in Lancaster Sound; Can. J. Earth Sci., v. 14, p. 1991-2001.

Jansá, L.F.
1976: Lower Paleozoic radiolaria-bearing limestones from the Baffin Island shelf; in Report of Activities, Part B, Geol. Surv. Can., Paper 76-1B, p. 99-105.

Levy, E.M.
1978: Visual and chemical evidence for a natural seep at Scott Inlet, Baffin Island; in Current Research, Part B, Geol. Surv. Can., Paper 78-1B, rep. 4.

Løken, O.H. and Hodgson, D.A.
1971: On the submarine geomorphology along the east coast of Baffin Island; Can. J. Earth Sci., v. 8, p. 185-195.

Loncarevic, B.D. and Falconer, R.K.H.
1977: An oil slick occurrence off Baffin Island; in Report of Activities, Part A, Geol. Surv. Can., Paper 77-1A, p. 523-524.

MacLean, B. and Falconer, R.K.H.
1977: Baffin Island Shelf – Shallow corehole drilling, 1976; in Report of Activities, Part B, Geol. Surv. Can., Paper 77-1B, p. 125-127.

MacLean, B., Falconer, R.K.H., and Clarke, D.B.
1978: Tertiary basalts of western Davis Strait: bedrock core samples and geophysical data; Can. J. Earth Sci., v. 15, no. 5.

MacLean, B., Jansa, L.F., Falconer, R.K.H., and Srivastava, S.P.
1977: Ordovician strata on the southeastern Baffin Island shelf revealed by shallow drilling; Can. J. Earth Sci., v. 14, p. 1925-1939.

McWhae, J.R.H. and Michel, W.F.E.
1975: Stratigraphy of Bjarni H-81 and Leif M-48, Labrador Shelf; Bull. Can. Pet. Geol., v. 23, p. 361-382.