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# Reports

## Distributional Trends in the Recent Marine Sediments of Northern Baffin Bay*

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### Introduction

### Purpose of the Study:

The purpose of this investigation was to determine the nature of the Recent sediments in northern Baffin Bay, and to examine their textural properties relative to water depth, bottom configuration, and the agents responsible for their transport.

Baffin Bay is that body of water lying between Greenland, on the east, and Baffin Island on the west (Fig. 1). It connects with the Atlantic Ocean to the south through Davis Strait, and with the Arctic Ocean to the north by way of Lancaster, Jones, and Smith Sounds. It is about 800 miles long and 280 miles in width. The arctic Circle is approximately coincident with its southern limit at Davis Strait.

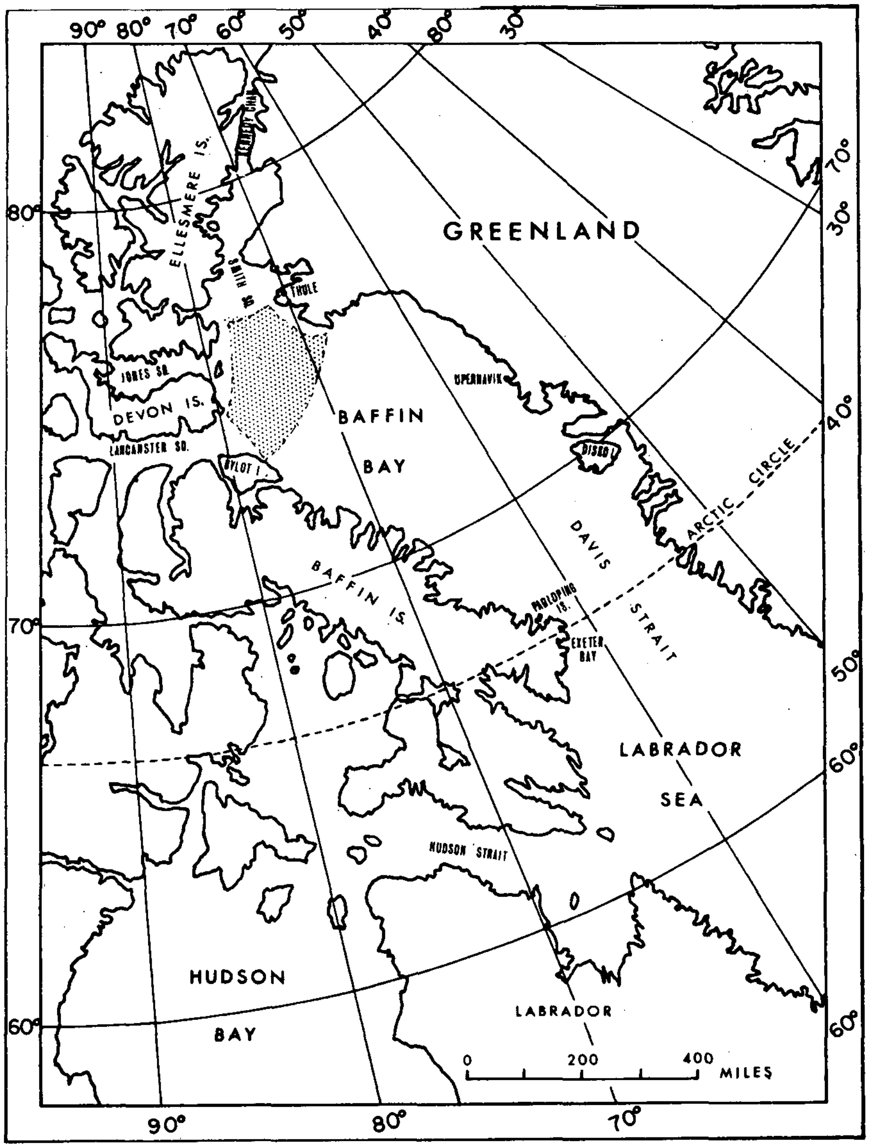

Figure 1 - Location map. Study area shaded.

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* Manuscript received

Although recent sediments have been studied in some detail at several localities within the Canadian Eastern Arctic region, the bottom material of Baffin Bay was described from a relatively few spot samplings only. It appeared that a sediment sampling program providing cross-sectional coverage of Baffin Bay, on one or more selected transects, could contribute considerably towards definition of the general sedimentary regime in Baffin Bay, and toward unification of extant data. It was on these considerations that this study was proposed.

## Nature of the Study:

The primal basis of this investigation was mechanical size analyses of 69 snapper samples of bottom sediment, collected within the study area outlined in Figure 1. Auxiliary lines of research included determination of the organic matter and calcium carbonate content of the sediment, and evaluation of the lithology and abrasion of the gravel-size material.

The samples for this study were collected during September and October, 1964, as one phase of an oceanographic cruise on board CCGS LABRADOR. An account of the cruise and a complete description of program and equipments is contained in "Bedford Institute of Oceanography Cruise Report No. 054" (Collin, 1964).

## Previous Work

One of the earliest descriptions of bottom sediments in the Baffin Bay region is contained in the reports of the Danish "Ingolf" expedition of 1895 and 1896. On the basis of a number of samples collected in Davis Strait and the Labrador Sea, Boeggild (1900) suggested that grey "deep sea" clay probably covered the entire bottom of Baffin Bay.

Kiaer (1909) has described samples collected by the second Norwegian expedition in the "Fram". Several samples from shallow water in fiords off Jones Sound were classed as "soft brown clay", with mention of contained pebbles, plant detritus, and molluscan shells.

The "Godthaab" expedition of 1928 (Riis-Carstensen, 1931) recorded the nature of the bottom deposits at each sounding station in Baffin Bay, but no samples were retained for special study. Grey clays were the predominant sediment type, with occasional brown or yellow clay. Gravel, shells, and sand were of common occurrence, particularly at stations nearest shore.

Trask (1932) reported on the analysis of sediment samples collected in Davis Strait by the "Marion" expedition of 1928. The deposits sampled were described as containing considerable ice-rafted material, with gneiss, quartzite, and aphanitic limestone as the predominant lithologies of the rock fragments. Sediment texture was noted to vary with the configuration of the sea bottom and with surface currents and tides. A calcium carbonate content of from 20 to 40 percent in the finer sediment was considered related to ice-rafted limestone fragments in the coarser material.

Vibe (1939) reported gravel, sand, sandy clay, and clay from shallow waters (10 to 64 metres) in the Upernavik and Thule districts in northwest Greenland. Coarse sediments nearshore graded outward into finer material.

Perry (1961) investigated marine sediment from the Canadian Eastern Archipelago, and described it as mainly poorly sorted olive grey material, with particles of all sizes from clay to cobbles. A number of the samples studied were collected in Lancaster Jones, and Smith Sounds. The coarser material was generally most abundant in zones extending several miles offshore. Sediments in deeper water, farther from shore, were predominantly silts.

Kranck (1964) reported medium to fine sand as the dominant inshore sediment type in the area of Exeter Bay, with coarse gravel occurring on the continental shelf. Current transport appeared to be the most important factor in determining inshore sedimentary characteristics, while textural and compositional characteristics of sediment on the offshore shelf and slope are related to ice-rafting.

Sediment samples have been collected in the Eastern Canadian Arctic by the United States Hydrographic Office, but the results of these studies are not presently available.

The importance of ice as an agent of sediment transport, and the processes which may operate in this regard, are well documented. Tarr (1897) discussed sediment pick-up and the abrading action of sea-ice and glacial ice grounded in shallow water, and also referred to the loading of shore-ice by debouching streams and windblown material. Sverdrup (1938) described the entrapment of sediment in sea-ice by bottom freezing and surface thawing, with the sediment eventually finding exposure on the upper surface of the ice. Emery (1949) has discussed mechanisms of ice-rafting as related to sedimentation in the Arctic Basin. Campbell and Collin (1958) have proposed a suspension-freezing process as important in ice-transport of fine sediment.

The bathymetric configuration of Baffin Bay is now reasonably well defined by published hydrographic charts. Dunbar (1951) has compared fiord development on the Greenland coast with that on the Baffin Island coast. The bottom physiography of Baffin Bay has been classified and analyzed by Pelletier (1966). A number of workers have examined the influence of regional bathymetric relationships on oceanographic processes. These latter studies, and all other contributions in the field of physical oceanography in Arctic Canada, have been reviewed by Collin and Dunbar (1964).

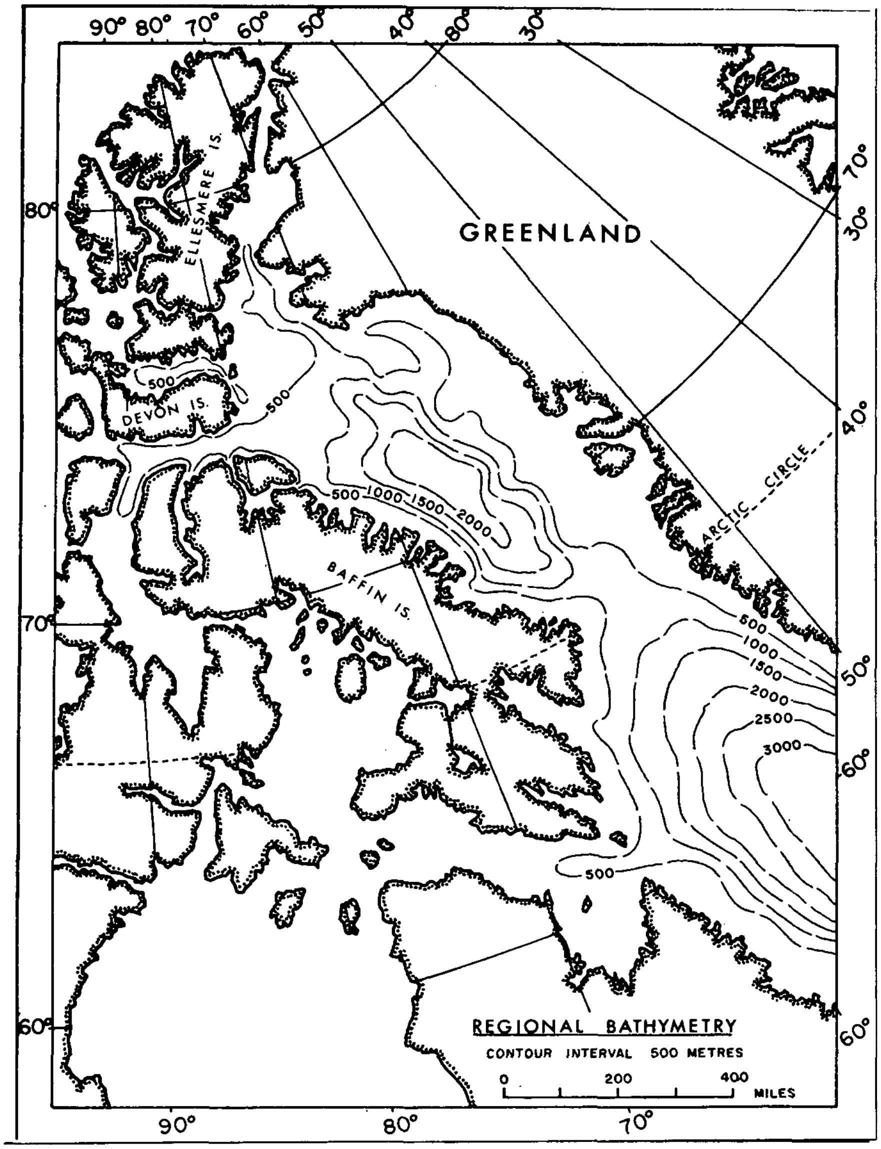


Figure 2 - Regional bathymetry.

## Physical Setting

### Topography and Regional Geology:

The topography of the land masses surrounding Baffin Bay is rugged and mountainous. Precambrian crystalline rocks compose almost the entire eastern coast of Baffin Island, and are predominant on the Greenland coast as well. Tertiary basalts and Cretaceous sediments occur on the Greenland side in the Disko Island region, and volcanic rocks are found in the area of Padloping Island, on the east coast of Baffin Island. Palaeozoic and younger strata are encountered in the three northern exits from Baffin Bay.

### Climate:

Polar climatic conditions support the permanent ice cap on Greenland, and smaller ice caps on Baffin, Bylot, Devon, and Ellesmere Islands. The glaciers draining these ice accumulations

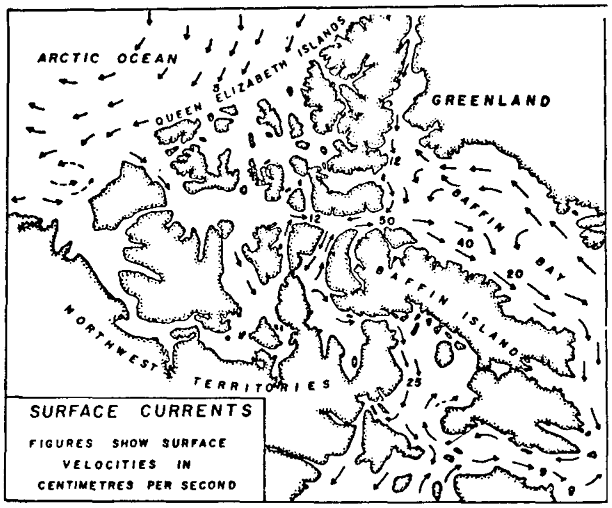


Figure 3 - Surface water circulation in the Baffin Bay region. (After Collin and Dunbar, 1964).

release numerous icebergs during the summer "breakup" period, particularly along the Greenland coast. Sea-ice forms on Baffin Bay during the winter months, attaining almost complete coverage by mid-January, and melting away by mid-August. Clearance of sea-ice from the region progresses southward from centres of weak accumulation in Smith Sound and Lancaster Sound (Schule and Wittman, 1958).

Oceanography:

Bathymetry - The general bathymetric form of Baffin Bay is that of a deep, enclosed basin (Fig. 2). The maximum depth in central Baffin Bay is 2,400 metres, while the limiting "sill" depth for exchange of water to the south, through Davis Strait, is 600 metres. The effective sill depth through the two main channels connecting with the Arctic Ocean is 200 metres in Smith Sound - Kennedy Channel to the north, and 175 metres in Lancaster Sound - Barrow Strait to the west (Hachey, Lauzier and Bailey, 1956).

The continental shelf separating Greenland from the deep, central portion of Baffin Bay is about 140 miles (225 km) wide, but is much narrower off Baffin Island on the western side (Fig. 2). The continental slope along both the east and west sides of the deep central zone is steep and narrow, as opposed to the gradual shallowing to the north. In the northern region the sea floor of Baffin Bay is continuous with that of Smith Sound, and over a large area resembles a submerged headland previously exposed to weathering (Pelletier, 1966).

Water Circulation - Figure 3, after Collin and Dunbar (1964), illustrates the general anti-clockwise pattern of surface water circulation within Baffin Bay. The Baffin Current transports cold Arctic water southward along the east coast of Baffin Island, through Davis Strait. Warm Atlantic water from the West Greenland Current enters Baffin Bay via Davis Strait, and flows parallel to the west coast of Greenland, undergoing fairly rapid cooling as it progresses northward (Sverdrup, Johnson and Fleming, 1946).

Deep water circulation within Baffin Bay is apparently somewhat restricted, inasmuch as dissolved oxygen content in the deep water has been found to reach a minimum of 3.2 ml/litre at a depth of 2,300 metres, with surface oxygen content at about 10 ml/litre (Collin, 1964).

Smith (1941) has reported the West Greenland Current as effecting the movement of icebergs northward along the Greenland coast, and westward to the south-moving Baffin Current. The southward movement of sea-ice and icebergs in Baffin Bay is confined to the path of the latter current (Dunbar, 1954).

## A Sedimentary Model

The more recent studies of bottom sediments in the Baffin Bay region indicate somewhat greater textural variability than suggested by earliest references. Ice-rafted material has been recognized as a major constituent of the bottom sediment, and bottom configuration and surface currents have been defined as further control relative to textural characteristics.

The bottom topography of Baffin Bay is now reasonably well charted, and water circulation is at least resolved on a regional scale. As a working hypothesis in evaluating the results of this study it appears feasible, therefore, to postulate a sedimentary model for Baffin Bay, in the general sense of the "model" approach developed by Potter and Pettijohn (1963).

Baffin Bay constitutes a dynamic sedimentary basin. Assuming ice-rafting to be the most important factor in sediment transport, and that ice movement is controlled mainly by the circulation of surface water within Baffin Bay (Fig. 3), it may be inferred that detritus-laden ice moves mainly in a zone peripheral to the central deep water area. Further, since ice movement is initiated by melting conditions attending warmer weather, much of the sediment load carried by the icebergs and sea-ice will be released within this zone of movement.

Considering the indicated velocities of surface currents (Fig. 3) as the extreme upper limit of current velocities at depth, only sand-size particles, and finer, would undergo appreciable lateral transport in settling from ice to bottom. Finest particles would be most affected in this respect, while gravel and boulders would deposit almost directly beneath their point of release. The finest fraction of the sediment in suspension will not deposit where there is any significant movement of the bottom water (Hjulström, 1939). Presumably this material will favor deposition in the central deep water zone.

The general distributional pattern of bottom sediment in Baffin Bay, therefore, might be expected to show clays as centrally predominant, grading laterally into silts and sands, with gravel and larger fragments dominant in the marginal zone of surface currents. It must be assumed that ice-rafted detritus is completely heterogeneous in size. Where water movement affects the bottom, however, sorting of this material will occur by virtue of non-deposition of fine particles. The latter fraction (clays, for example) will constitute a sorted sediment in itself, at its site of deposition.

The location of sampling stations within the study area is shown in Figure 4, and Figure 5 locates these sampling sites with respect to bathymetry. Depth of water at sampling stations ranged from 269 metres to 1,940 metres. Although the latter sounding is short of the maximum depth recorded in Baffin Bay (2,400 metres), approximately one-third of the samples were collected from depths greater than the maximum sill depth for exchange of water (600 metres). On this basis the study area is considered a representative sampling of Baffin Bay as a sedimentary basin.

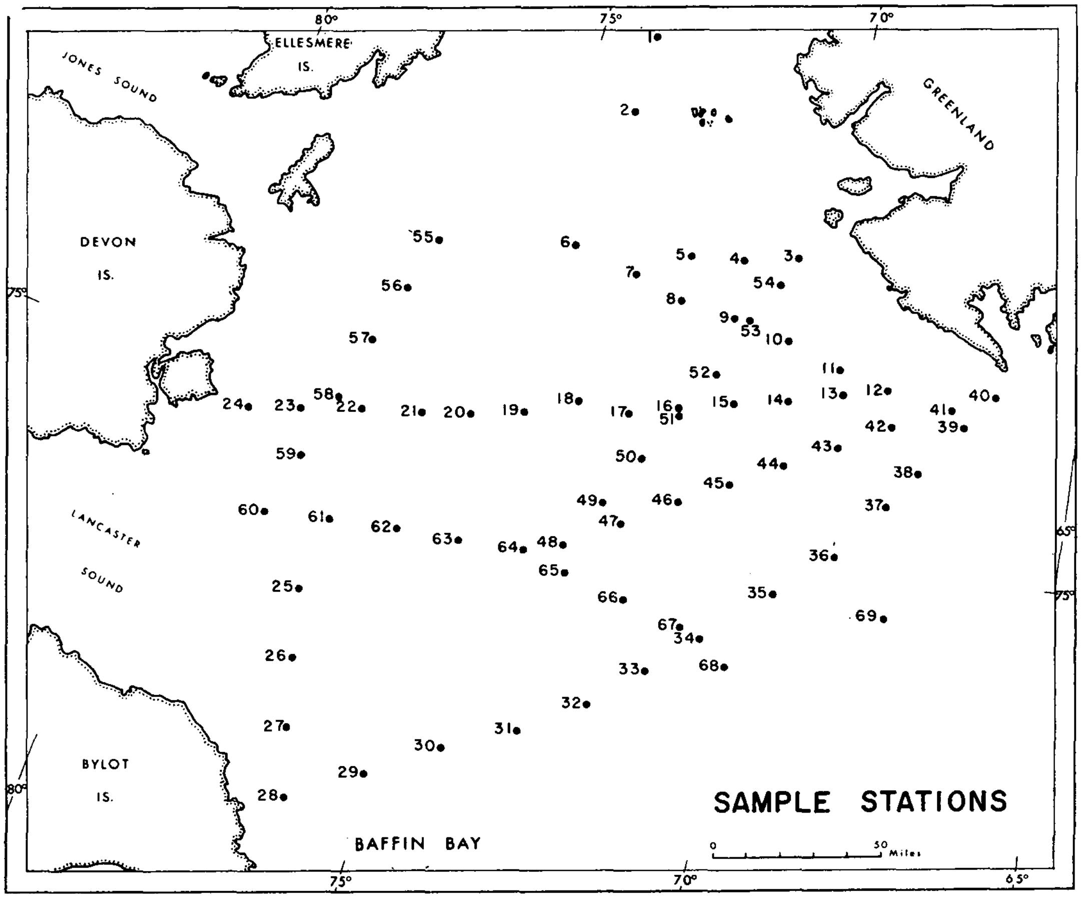


Figure 4 - Sample station locations.

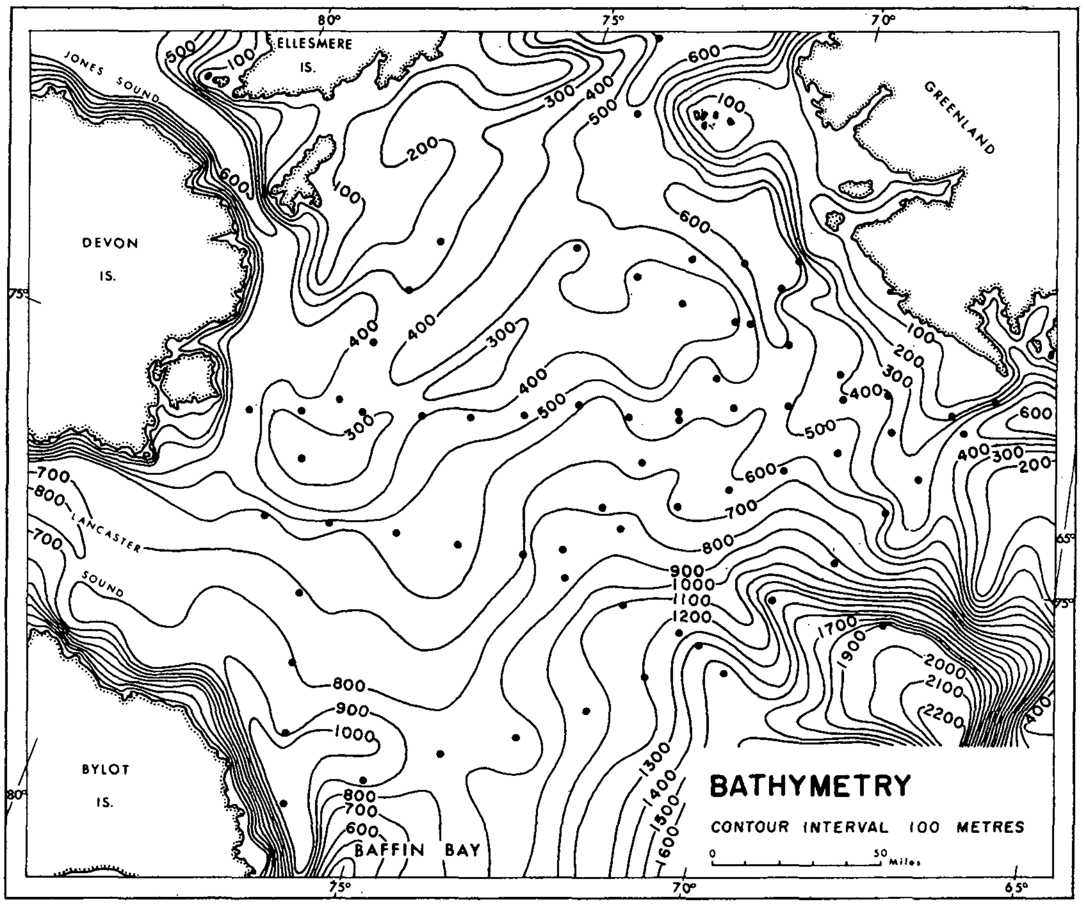


Figure 5 - Detailed bathymetry of the study area.

## The Bottom Sediments

### Sampling:

The samples comprising the material for this study were recovered with a Dietz-LaFond bottom sampler (LaFond and Dietz, 1948). At those stations where coring of the bottom sediment was attempted, this sampler was employed as the tripping weight for the coring apparatus. This practice effected some economy of time, and supplied a sample check on the upper portion of the core. When coring was not included in the station program the Dietz-LaFond sampler was lowered alone. In areas of deeper water the sampler was sometimes weighted to ensure an observable slackening of the line when the sampler reached bottom.

On retrieval of the sampler following a successful lowering, the material recovered was removed and placed in a polythene bag. The bag was sealed and numbered, and placed in a correspondingly identified one-pint cardboard ice-cream container. The sample number, depth, position, and general description were recorded in a notebook. Sediment samples were stored in an unheated vegetable locker on board ship until the end of the cruise.

The average wet weight of the samples recovered was about 800 grams. Clay-size material was predominant in most samples, with a greater or lesser admixture of silt, sand, gravel, and cobbles. Several samples contained numerous shell fragments; some contained annelids and/or faecal pellets; a few were rich in siliceous spicules and diatoms. Pebbles sometimes fouled in the jaws of the sampler, preventing the jaws from closing tightly. Such occurrences were noted as cases where "washing" of the sample might have taken place during the trip to surface.

On completion of the cruise the samples were transported to the University of New Brunswick for laboratory analysis.

### Size Distribution:

The particle size distribution of all samples, according to the grade scale of Wentworth (1922), was evaluated by mechanical analysis. Material in the silt and clay range (less than .063 mm in diameter) was analyzed by the pipette method as described by Krumbein and Pettijohn (1938). The size distribution of coarser particles was determined by dry-sieving.

Gravel - Particles greater than 2 mm in diameter are here classified as gravel. This fraction of the sample was excluded from the main computation of particle size distribution according to weight, as it was considered that material in this size range was ice-rafted, and that its distribution following release from the ice would be essentially independent of hydraulic conditions. Also, at this larger size range it is questionable whether the samples were of sufficient weight to be representative. According to Wentworth (Krumbein and Pettijohn, 1938, p. 32) at least one kilogram of sample is required for accurate mechanical analysis of particles in the 2 to 4 mm size range. In consequence, any numerical description of the coarse fraction must be recognized as approximate.

The method used to quantify the coarse fraction was simply to express its weight percent in terms of the wet weight of the total sample. While no allowance was made in these calculations for moisture content, which could be expected to vary somewhat from sample to sample, it did not appear that this was overly critical to the results obtained.

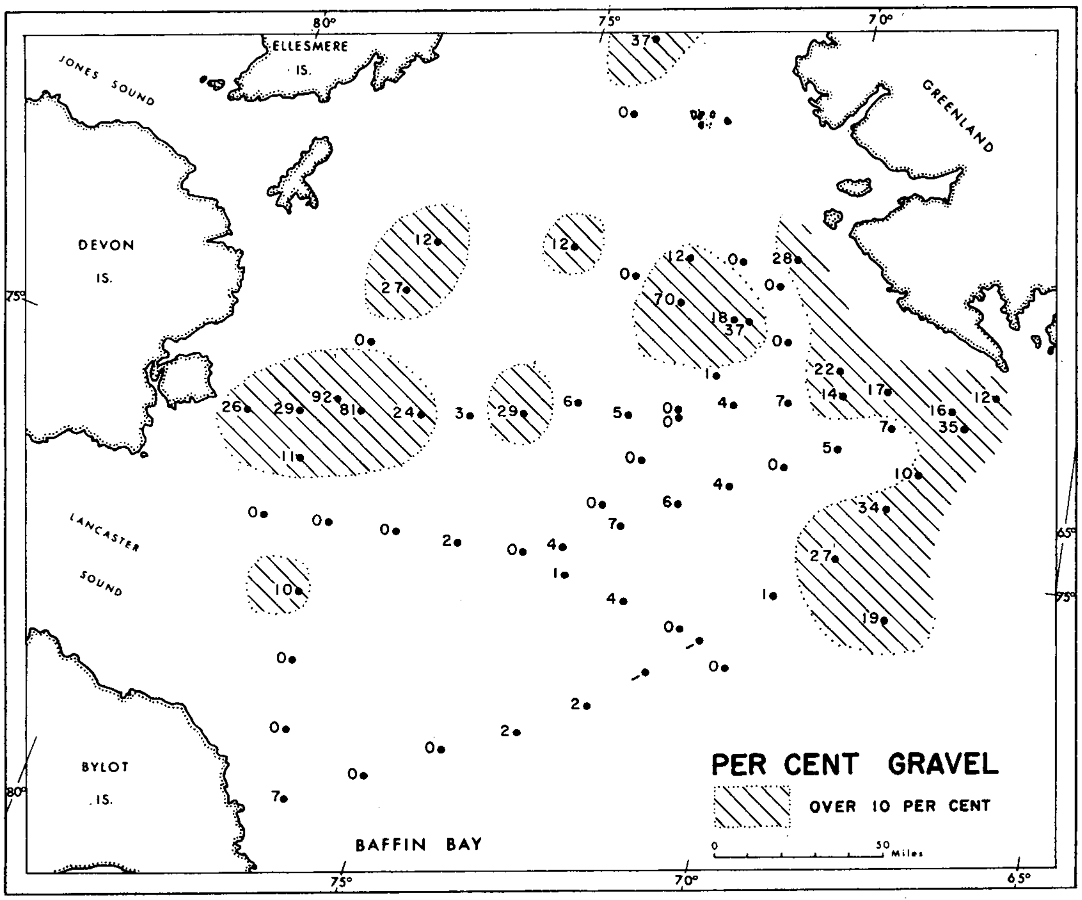
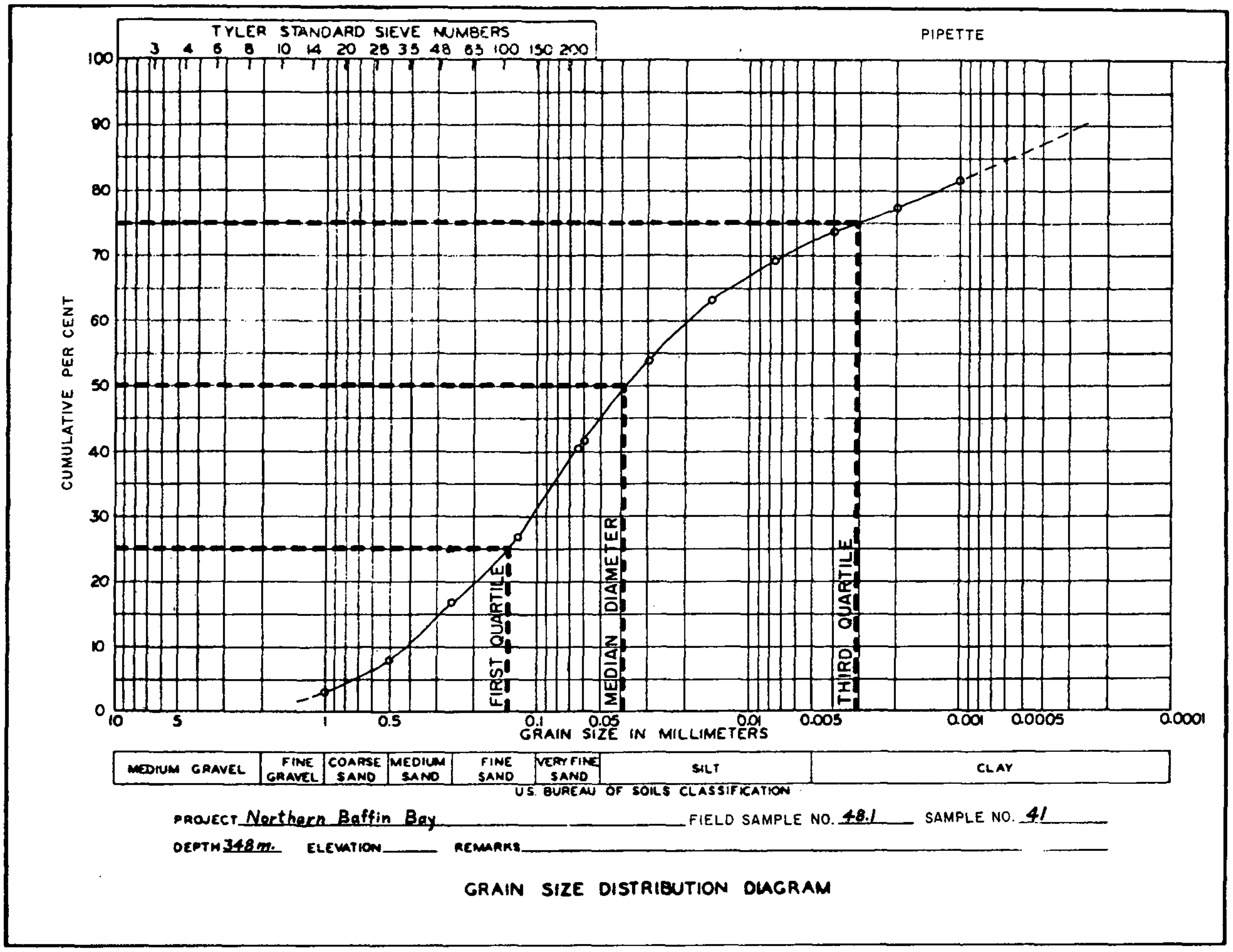


Figure 6 - Percent gravel in the bottom sediment.

Percentages of material coarser than 2 mm have been plotted on Figure 6. Samples exhibiting more than 10 percent content of this fraction have been included in areas of shading. In general, highest gravel concentrations occur in the samples nearest shore, and low to zero concentrations are within the central, deeper portion of the study area.

High gravel content (above 10 percent) in the bottom sediment coincides approximately with the paths of surface currents (Figure 3). To the extent that the measurement of gravel content was representative, therefore, this parameter indicates the marginal zone of movement of detritus-laden ice inferred in the sedimentary model.

Sand, Silt and Clay - Depending upon estimated sand content, 40 to 60 grams of the original sample were processed for mechanical size analysis in the sand-silt-clay range (less than 2 mm in diameter). This material was thoroughly stirred in 250 ml of distilled water, and allowed to stand for at least 24 hours. By that time the sediment had usually settled, and the clear water was decanted to remove some of the dissolved salts. The settled material was treated with 20 ml of "Calgon" solution (containing 1.098 grams "Calgon"), plus distilled water, to effect dispersion of the finer particles. Following several minutes agitation in an electric blender the sample was wet-sieved through a .063 mm screen.



PROJECT Northern Baffin Bay FIELD SAMPLE NO. 48.1 SAMPLE NO. 41
DEPTH 348 m. ELEVATION REMARKS

Figure 7 - Cumulative curve of a representative sample.

That portion of the sample which passed through the .063 mm screen was diluted to one litre, with distilled water, for pipette analysis. The material remaining on the screen was thoroughly dried, and its size distribution was determined by dry-sieving.

Several pipette samples required additional "Calgon" to effect dispersal, and in two instances it was necessary to reduce sediment concentration as well. At two sample stations (33 and 34) only a few pebbles were recovered, finer sediment presumably having been lost in transit to surface. In consequence, pipette analyses are lacking at these locations.

Pipette analyses were carried to the point where all particles in the liter graduate greater than .001 mm in diameter had settled below a test level of 8 cm, at a time of 26 hours, 9 minutes. The cumulative weight percentage of grains in each of Wentworth's (1922) size grades, as determined by pipette and dry-sieving, was plotted against log diameter to obtain a cumulative frequency curve (Fig. 7).

The .001 mm size range is at the lower accuracy limit of the pipette method of mechanical size analysis, and all finer particles were of necessity assigned to a single class ("colloid"). In consequence, size distribution within this class may be inferred only by extrapolation of the cumulative curve. Of the 67 samples suitable for pipette analysis, 38 required some degree of extrapolation to produce the cumulative curve to the 75 percent level. Figure 7 shows a cumulative curve with conjectural size distribution for particles smaller than 86 percent of the sample.

About two-thirds of the samples analyzed showed bimodal size distribution, several of these exhibiting some development of a third maximum. In view of the extrapolations referred to above, and the prominence of non-normal size distributions, effective statistical analysis of the cumulative curves was limited to calculation of average grain diameter and sorting based on quartile measures.

Figure 7 illustrates the first, second, and third quartiles as corresponding to the diameters defined by the intersections of the cumulative curve with the 25, 50, and 75 percent lines respectively. The second quartile is the average grain diameter of the sediment, or the "median diameter", defined by Krumbein (1936) as the middle-most member of the distribution. The sorting measure reported is Trask's (1932) "sorting coefficient", So, which is defined as the square root of the ratio of the first and third quartile grain diameters (So = $\sqrt{Q_1/Q_3}$).

Multi-modal size distribution of many of the samples has been mentioned above as a limiting factor in the application of statistical measures. Analysis of this characteristic, however, enables resolution of textural distribution further to the general zonation defined on the basis of gravel content.

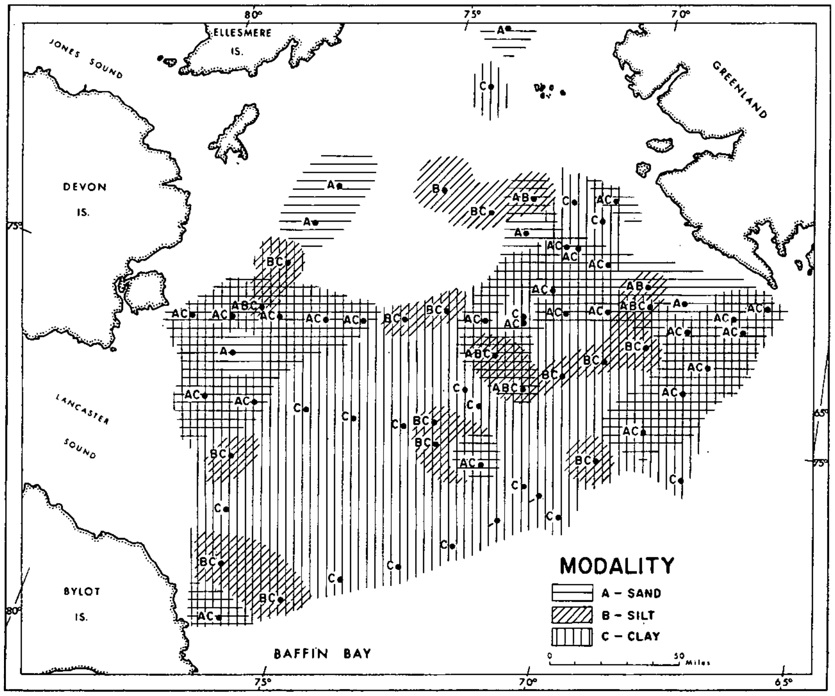


Figure 8 - Position of the modes in size distribution of the bottom sediments.

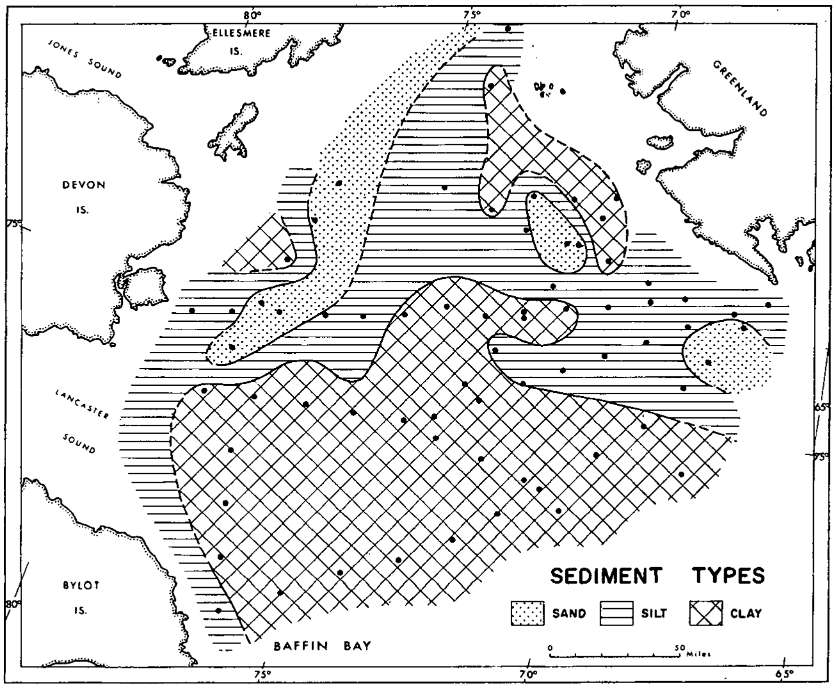


Figure 9 - Sediment-type distribution on the basis of median grain diameters.

With one exception, unimodal maxima occur in either the sand range or the clay range. The 6 samples unimodal in sand are located relatively near shore (Fig. 8) at depths ranging from 269 to 403 metres (average 327 metres). The 16 samples unimodal in the clay range are mainly from the south-central, deep-water portion of the study area, or from local deep-water areas near shore. The depth range for these samples is from 553 to 1,940 metres, with an average depth of 880 metres.

Bimodal samples generally exhibit maxima in either sand and clay, or silt and clay. Approximately one-third of the bimodal distributions fall in the latter category, and tend to occur within a zone peripheral to the main area of unimodal clay samples. Distributions of this type have not been sampled immediately peripheral to the clay accumulations in nearshore depressions, although this may be a function of sample spacing. Sand-clay bimodal distributions concentrate in areas shoreward of the general silt-clay zone.

Although the boundaries of the above "modal provinces" are somewhat irregular, shoreward progression from clays to predominance of coarser fractions, as prescribed by the sedimentary model, is obvious.

Figure 9 shows the distribution of types of bottom sediments defined on the basis of median grain diameter. The averaging effect attending application of this measure results in a more generalized picture than above (Fig. 8), though regional trends are more readily discernible.

Excluding the southwestern quarter of the study area, Figure 9 depicts a zone of sand accumulation located some distance from shore, with progression to finer sediment both toward the basin centre and shoreward. Reference to the bathymetric diagram (Fig. 5) shows that nearshore clay accumulations are coincident with nearshore deep water conditions, and that the areas of sand are generally confined to topographically high parts of the basin floor.

Gravel distribution (Fig. 6) indicates movement of surface water over both the inshore deeps and the offshore shoaler zones. If water movement affects the bottom in the latter case, non-deposition and/or winnowing of finer material would increase the average grain size of the remaining sediment, and weight the percentage composition in favor of coarser particles. Nearshore deposition of the winnowed finer fraction would affect the size distribution of that sediment in the opposite sense.

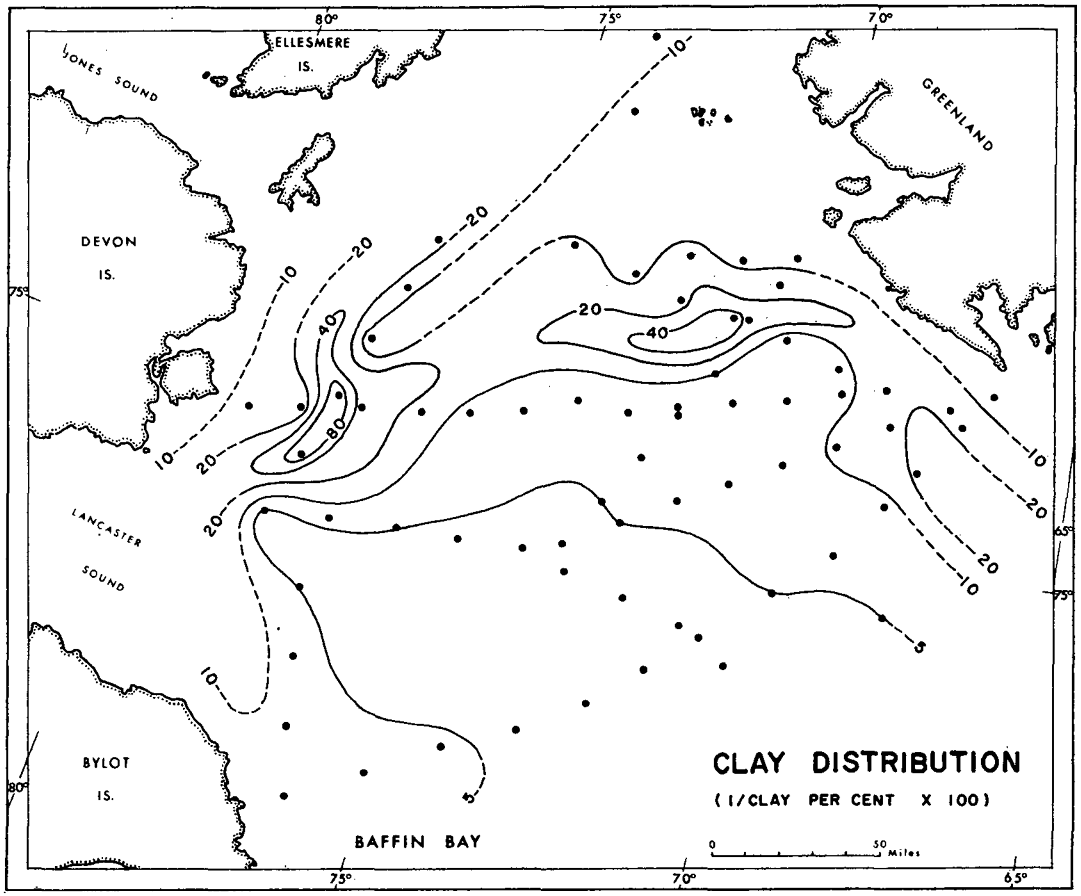


Figure 10 - Clay distribution. The contour values are the inverse of the clay percent, times 100. (See explanation in text).

Figure 10 displays the general pattern of clay distribution. Plotted values are the inverse of the clay percentage, times 100, so that highest values indicate lowest clay content. It is assumed that clay-size particles are the fraction of the sediment most sensitive to water movement, and that non-deposition of this fraction reflects the influence of bottom currents. Plotted values, therefore, vary in sense such that highest values indicate highest bottom current velocity.

The roughly arcuate zone of strong bottom current action (Fig. 10), as inferred in the manner described above, is generally coincident with sand areas (Fig. 9), high gravel content (Fig. 6), unimodal sand occurrences (Fig. 8), and positive topographic relief (Fig. 5). These correlations are further illustration of size-topographic relationships, and they support bottom current-bottom topography interaction as the controlling factor in these relationships.

Sorting - Plotted in Figure 11 are the values of Trask's "sorting coefficient", So. Trask (1932) has described So values of less than 2.5 as indicative of good sorting, and So values greater than 4.5 as reflecting poor sorting. Intermediate values represent medium sorted sediment. Shading on this diagram covers those areas where samples exhibit good to medium sorting. Comparison of this diagram with Figure 9 shows that sorting values in the good to medium range are mainly confined to sand and clay zones.

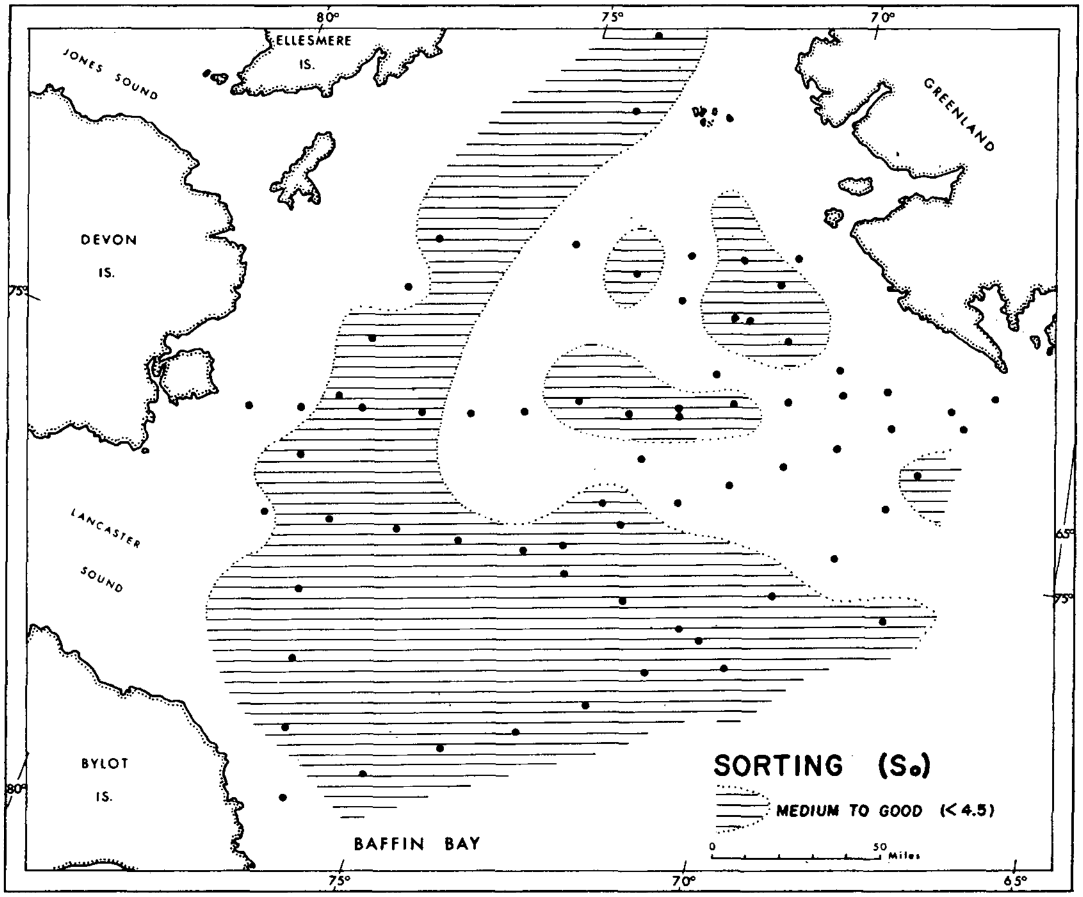


Figure 11- Sorting of the bottom sediment, based on Trask's (1932) "sorting coefficient, So". Shading indicates medium to good sorting.

Viewing sorting as a physical process requiring energy, the improved sorting of sand zones may be attributed to non-deposition of finer material, as discussed earlier. The finer material winnowed from these sand zones impresses its sorted character on the sediment at its site of deposition. Clays depositing in the southern deep water portion of the study area are well sorted, because only particles in this size range can remain in suspension sufficiently long to undergo circulation into this zone. In the isolated clay areas in shallower water (Fig. 9), improved sorting is probably more by virtue of increased clay deposition masking the coarser ice-borne detritus.

Better sorting associated with clay-size sediment indicates undisturbed bottom conditions (Fig. 9). Areas of coarser sediment with medium to good sorting, however, are further evidence of current-bottom interaction affecting the textural properties of the sediment.

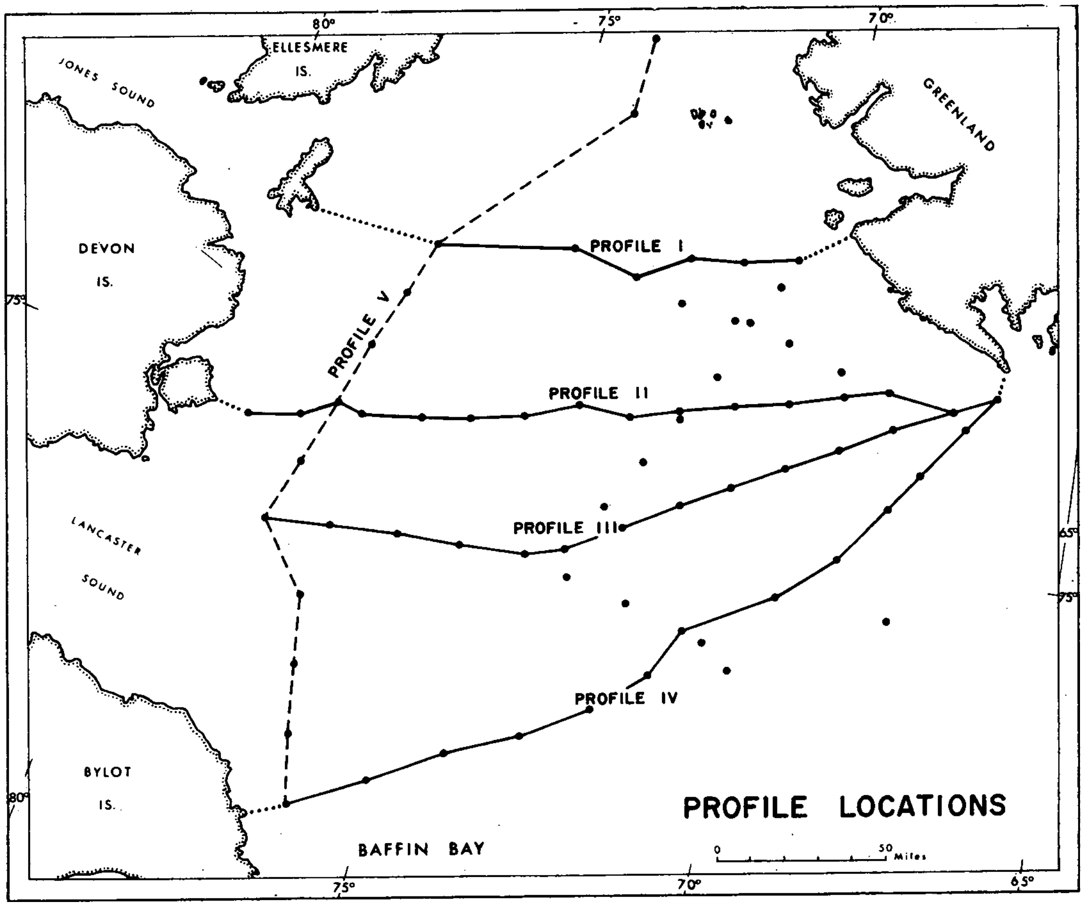
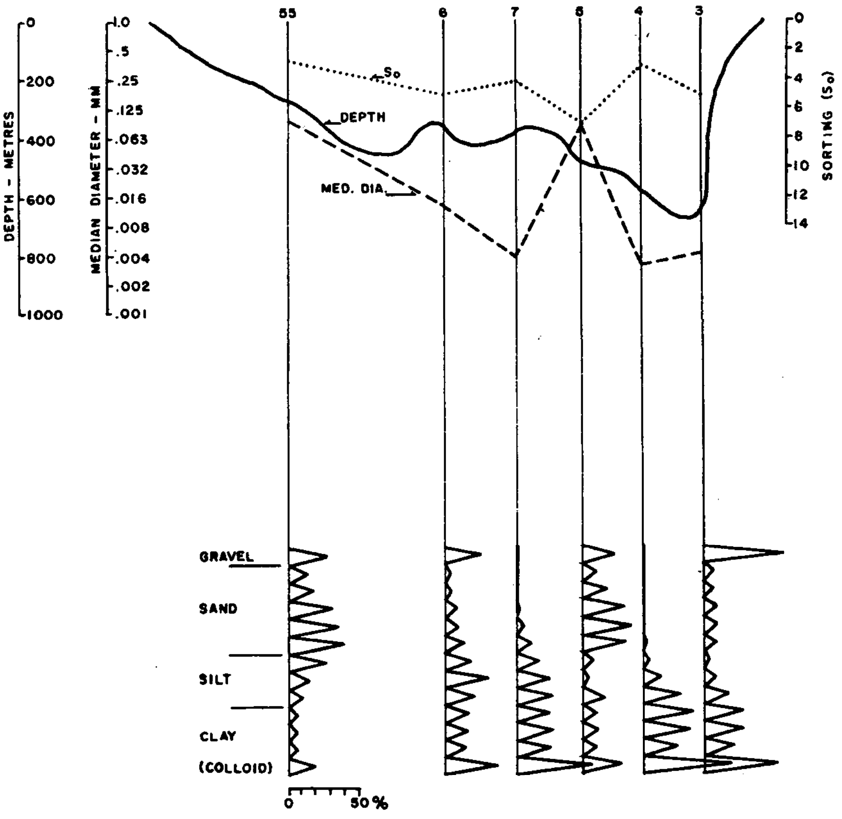
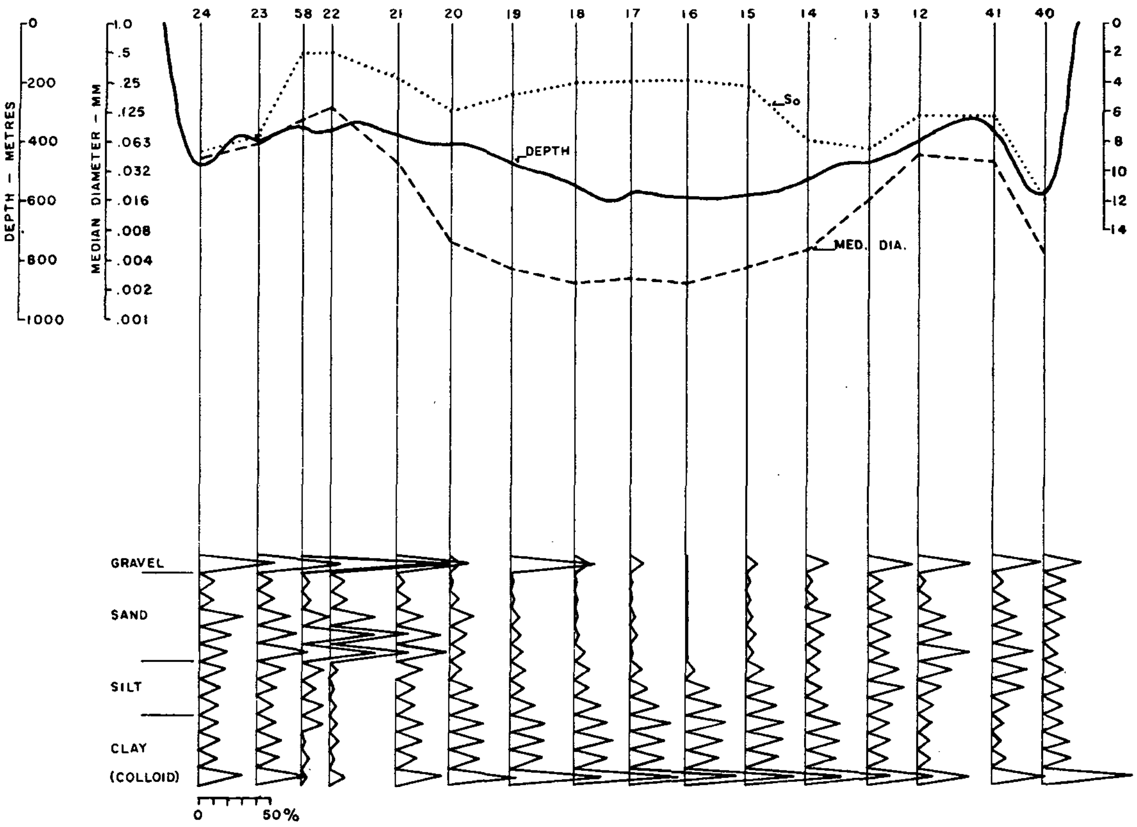


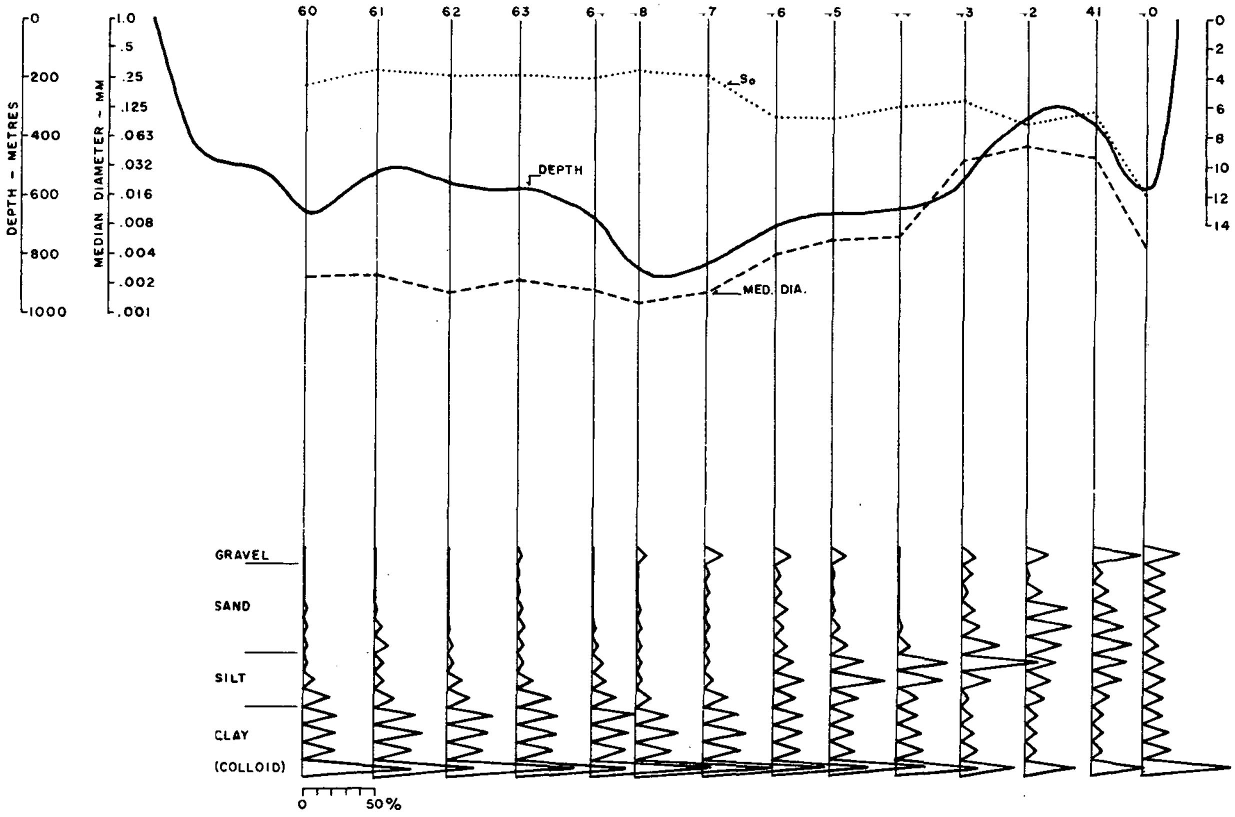
Figure 12 - Profiles of the study area.



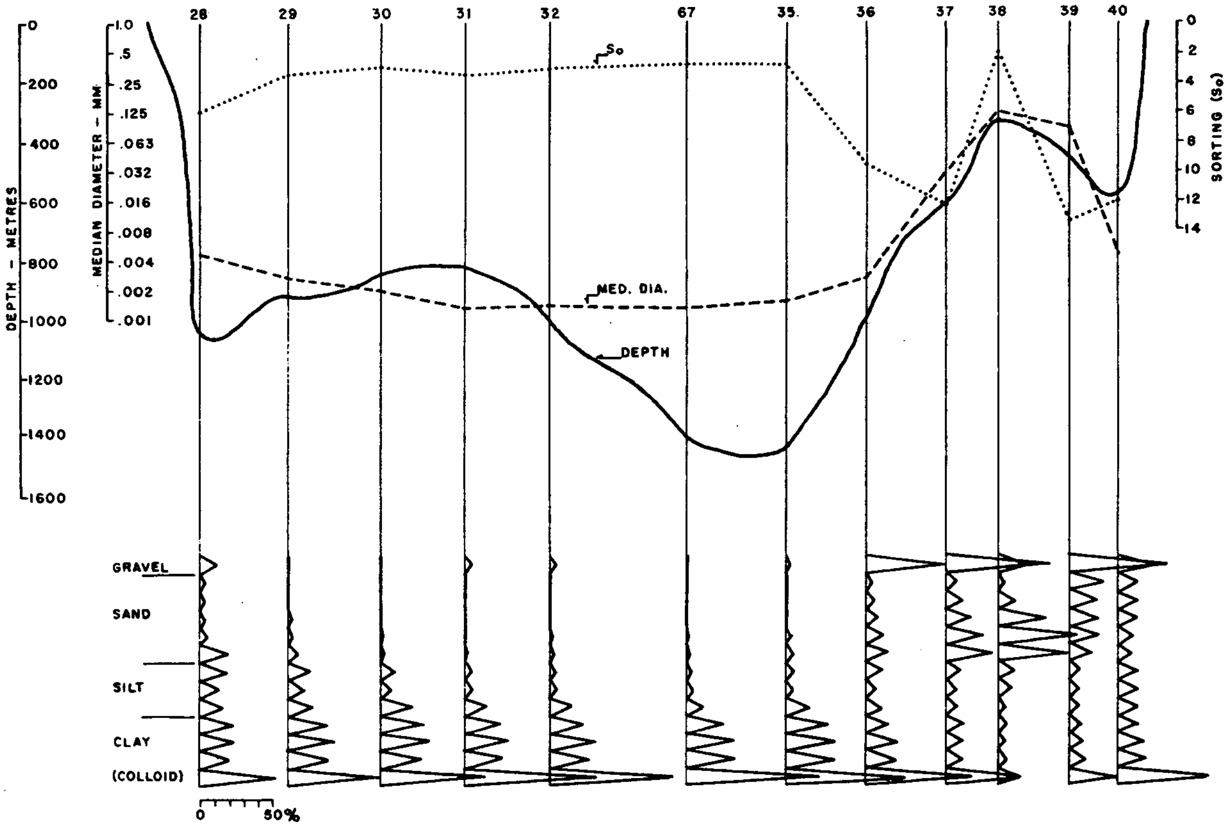
**PROFILE I**



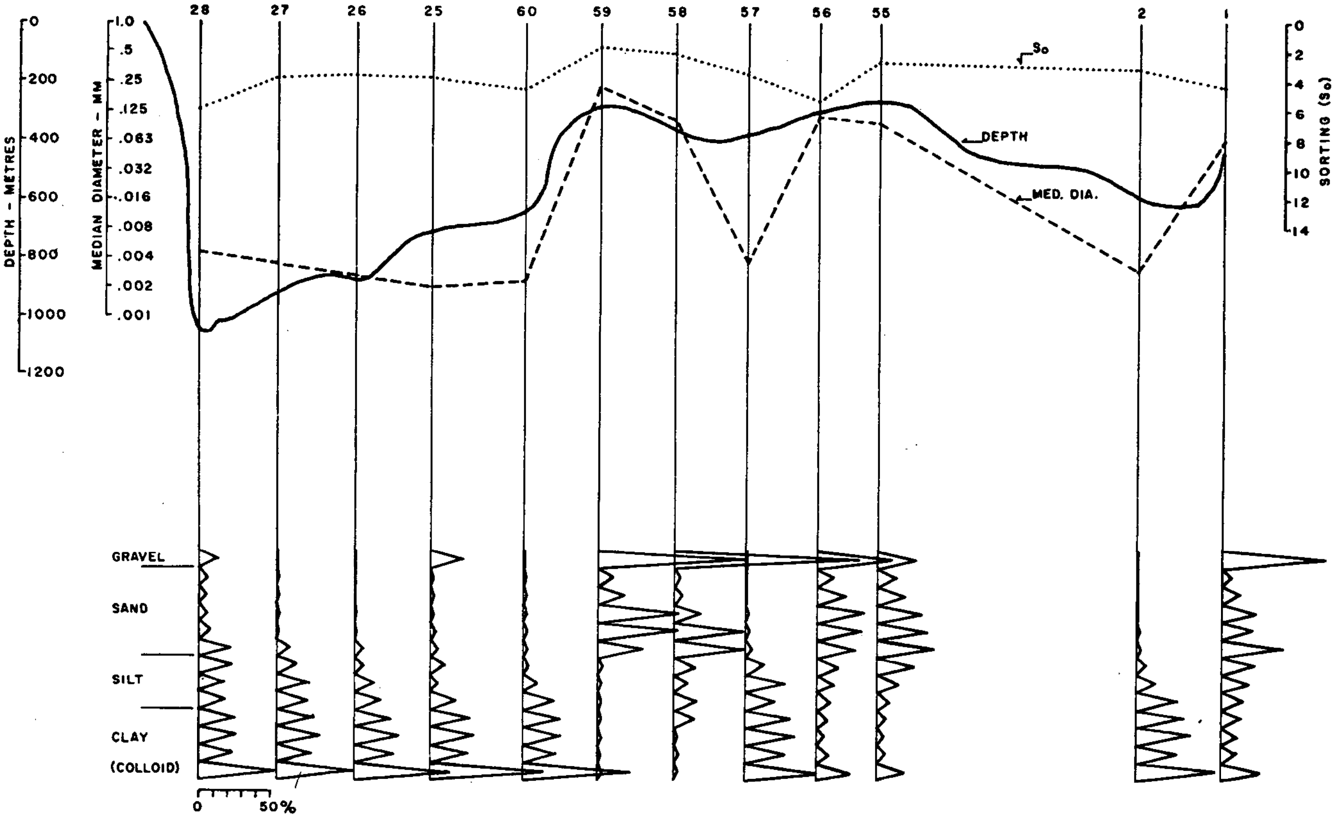
PROFILE II



PROFILE III



# PROFILE IV



# PROFILE V

Profiles - The relationships proposed on the basis of the areal diagrams discussed above are perhaps more effectively illustrated by profile presentation (Fig. 12, Profiles I to V). Median grain diameter and Trask's Sorting Coefficient, So, are plotted to show their lateral variation relative to bottom configuration. Also plotted for each sample is a histogram-type representation of sediment-size distribution. The vertical axis of the latter graphs represents grain diameter, and the weight percent of material in each of Wentworth's size grades is indicated by the amplitude of the peaks to the right of the vertical axis. Weight percent relative to peak amplitude is shown by a scale on each profile. All material coarser than 2 mm has been included in the gravel category, with reservations about the accuracy of this value as discussed earlier. The restrictions applying with respect to the "colloid" size class must also be borne in mind.

The "histogram" plots of gravel content present the same data as the areal diagram discussed earlier (Fig. 6). This mode of illustration, however, may be more effective in attempting analysis of certain trends in gravel distribution.

Bottom samples collected in the southwestern portion of the study area contain little gravel (Profiles III, IV, and V). Since the sedimentary model requires gravel concentration congruent with surface current distribution (Fig. 3), it is desirable to consider a possible explanation for this anomaly.

Surface current velocities in this locale are in the order of 50 cm per second (Fig. 3). Profiles III to V show the water in this area as being deep, ranging from 500 to 1,000 metres. The bottom sediment is clay, with So values in the medium range.

Samples 26 to 30 (Profiles IV and V) are from a somewhat isolated topographic depression (Fig. 5), and the predominance of clay at these stations indicates relatively little movement of bottom water. If the accumulation of clay in this zone is fairly rapid, the gravel content of the sediment may be obscured by this material. Influx of fine sediment from the west, via Lancaster Sound, may be of significant influence in this regard.

The soft consistency of samples collected in this area suggests that larger particles falling from the ice at surface might imbed to some depth in this type of bottom. Possibly the gravel content of the snapper samples is reduced on this account as well.

Higher surface-current velocities in this zone (Fig. 3) may effect more rapid ice clearance, and a correspondingly shorter period of detrital release. Confluence of surface currents in this area, however, may negate this inference.

Station 28, located approximately 10 miles off the east coast of Bylot Island, shows some appreciable content of coarser particles in comparison to stations to the east and north (Profiles IV and V). Possibly this greater amount of coarse material indicates that the peripheral gravel zone is confined to nearshore waters in this region. Further sampling of the bottom sediment, however, would be required to evaluate this consideration.

All profiles exhibit obvious relationship of median grain diameter to water depth, smaller grain size being associated with deeper water. Size control by current-bottom interaction is well illustrated in the northern portion of the study area. Where water is regionally shallow, median grain diameter shows pronounced lateral variation with apparently minor topographic irregularity (Profiles I and V). In deeper water to the south, however, median grain diameter is considerably less responsive to changes of depth (Profiles IV and V).

Considering the "colloid" size class as the sediment fraction most sensitive to water transport, low or high content in this size range may be interpreted as positive or negative evidence, respectively, for bottom-current influence. On this basis, the histogram-type plots at stations 58 and 22 on Profile II, and station 38 on Profile IV, are examples of strong positive indication of bottom water motion. Stations 38 and 39 on the latter profile, and stations 57 and 58 on Profile V, bracket the 400 metre level as the depth to which "colloid" deletion is most pronounced, indicating this level as the approximate lower limit of appreciable water movement.

The association of lowest So values with either coarsest or finest sediment is evident on all profiles. In addition, variations in this parameter also show relation to the 400-metre depth range. Sharp transition from poor to good sorting at this level is well illustrated on Profile IV, stations 37, 38 and 39, and also on Profile II, stations 20 to 22. A further general characteristic of sorting relationships illustrated at these locations is the poor sorting of sediments on the flanks of topographic highs, in the zone of transition from finest to coarsest sediment.

In summary, Profile II may be regarded as constituting a representative transect of the study area. The central, deep water portion of this profile exhibits smallest median grain diameter, with a shoreward progression to coarser material similar to that predicted by the sedimentary model. Medium to good sorting associates with sand and clay, and silt-size sediment shows poor sorting. Gravel content is high marginally, and "colloid" content is high centrally.

Reduced "colloid" indicates bottom current effects to a depth of approximately 400 metres. The latter relationship is not pronounced at the eastern end of the profile, but this may be due to the topographic "flank" situation of these stations (see Fig. 5).

Sediment Color:

Sediment color was described for the samples in their original wet condition, according to the "Rock Color Chart" distributed by the Geological Society of America (1963). Several samples were only described as "dark reddish brown", since numerical designation according to the color chart was not feasible.

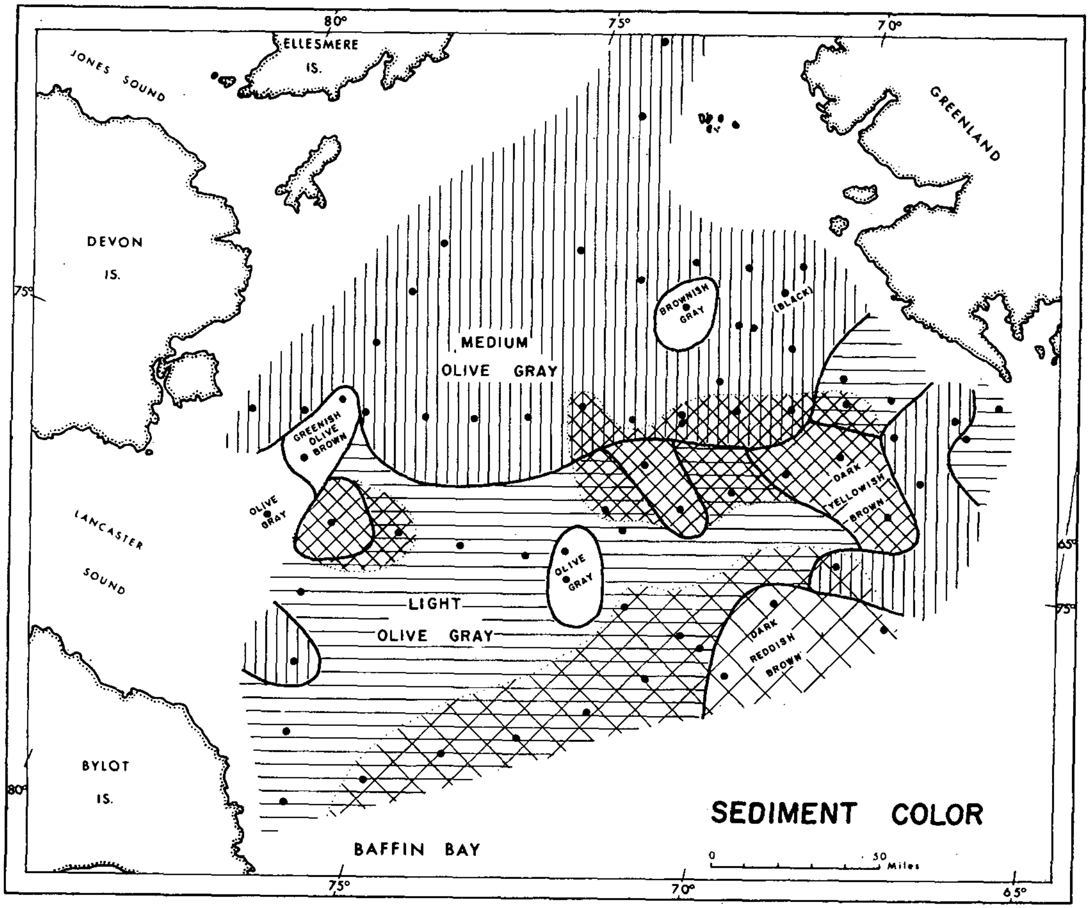


Figure 13 - Sediment color.

The sediment in the northern portion of the study area, where water depth is generally less than 500 metres (Fig. 5), is medium olive-gray in color (Fig. 13). To the south, in approximate coincidence with the main area of clay accumulation (Fig. 9), sediment color is predominantly light olive-gray. Dark reddish brown material was recovered at the 3 sample sites in the deepest water of the latter zone. Cores taken at 2 of these stations reveal this material as constituting a surface layer only, probably not greatly exceeding 10 cm in thickness. A thin surface "skim" of this reddish brown sediment was apparent at a number of sampling stations to the west, as indicated by shading overlap in Figure 13. North of this locality several samples were dark yellowish brown in color, and are probably also from a surface layer, as material of this color was noted as a surface "skim" at several stations to the north and west.

For several samples (stations 14, 15, 18, 35, 40, 45, and 67) mechanical size analysis was carried out on both the darker colored surface layer and the underlying olive-gray material, to determine whether color change reflected a change in texture. The results of these analyses were virtually identical for each sample, indicating the difference as one of color only.

The reddish brown color of some of the sediments suggests oxidation of its iron content. Reddish material at the sediment-water interface in the marine environment is discussed by Emery (1960) as evidence of oxidizing conditions. To the depth that overlying water containing dissolved oxygen can penetrate the sediment, part of the iron in the sediment may be present as a hydrated ferric oxide. At greater depth in the sediment, where a reducing environment is encountered, the oxidized iron changes to a ferrous form.

Within the study area, oxidation of deep-water sediment would appear to be due either to slow deposition or to the long time required for fine material to settle to these depths. Emery (1949) referred to the brownish oxidized color of sediments in the Arctic Basin as evidence of slow deposition. The settling rate of particles, .002 mm in diameter for example, is in the order of 0.3 metre per day (Sverdrup, Johnson and Fleming, 1946).

One sample (number 54) from the northern portion of the study area, in a zone of clay accumulation (Fig. 9), contained black, reduced patches of sediment. No other samples showed any sign of reduction at the time of sampling. Nearly all samples turned partly black while in storage, as contained organic matter underwent decay.

In general, sediment color appears to relate most closely to water depth, although "greenish olive brown", "brownish gray", and "dark yellowish brown" sediments (Fig. 13) show a degree of coincidence with areas of textural anomaly (Fig. 9). Color control by water properties other than depth (temperature, salinity, dissolved oxygen, etc.) is indeterminate. Possibly the rather complex pattern of color distribution on the eastern side of the study area (Fig. 13) reflects water conditions defining the West Greenland Current. Insofar as sediment-size properties relate to water depth, however, sediment coloration confirms the zonation postulated in the model.

## Organic Matter:

The organic carbon content of 17 selected samples was measured with a "Leco" Carbon Analyzer at the Bedford Institute. Carbonate carbon was removed from the sediment by digestion in dilute HCl. After washing and drying, the sample was ground to pass through a .125 mm screen. The "Leco" Carbon Analyzer utilizes the difference in thermal conductivity between oxygen and carbon dioxide. A known weight (1.000 gram) of sample is burned in an enclosed combustion tube through which oxygen is passed. The carbon in the sample is oxidized to carbon dioxide, which is collected in a cylinder with the excess oxygen. The thermal conductivity of this gas mixture is measured by a thermistor type thermal conductivity cell. If the latter is balanced for zero output when the cylinder contains pure oxygen, output of the thermal conductivity cell is essentially proportional to the amount of carbon dioxide in the cylinder.

Organic carbon percent may be expressed as percent organic matter by multiplication using the factor 1.7 (Emery, 1960). Percentage of organic matter in the samples analyzed is recorded in Table I.

Table I - Organic Matter and Carbonate

| Sample Number | Percent Organic Matter | Percent Carbonate |
|---|---|---|
| 1 | 2.2 | 5.3 |
| 2 | 4.6 | 7.8 |
| 3 | 3.9 | 8.8 |
| 7 | 4.4 | 7.7 |
| 16 | 2.3 | 7.6 |
| 23 | 3.0 | 15.2 |
| 24 | 2.9 | 8.7 |
| 28 | 2.7 | 18.3 |
| 31 | 2.2 | 8.2 |
| 40 | 0.9 | 2.2 |
| 42 | 1.5 | 3.8 |
| 53 | 2.8 | 11.2 |
| 55 | 2.4 | 7.0 |
| 57 | 2.7 | 8.3 |
| 60 | 1.6 | 8.6 |
| 64 | 1.9 | 8.0 |
| 68 | 1.3 | 3.1 |

Organic matter content ranged from 0.9 percent to 4.6 percent (Fig. 14). Regionally, higher percentages occur in the northern shallow water portion of the study area, while lower values tend to associate with deeper water conditions.

Generally, lower organic matter content in deep water samples probably reflects either lower organic production in near surface levels of the water column, or a greater degree of oxidation attending the more prolonged period of settling. A slower rate of sediment accumulation would have a similar effect in this regard. Sediment color has already been discussed as evidence of oxidation at these depths.

The highest organic matter values were recorded in the northern portion of the study area in samplings of local accumulations of clay-size material. This is in keeping with the tendency for better preservation of organic detritus in less permeable sediment. As opposed to the deep-

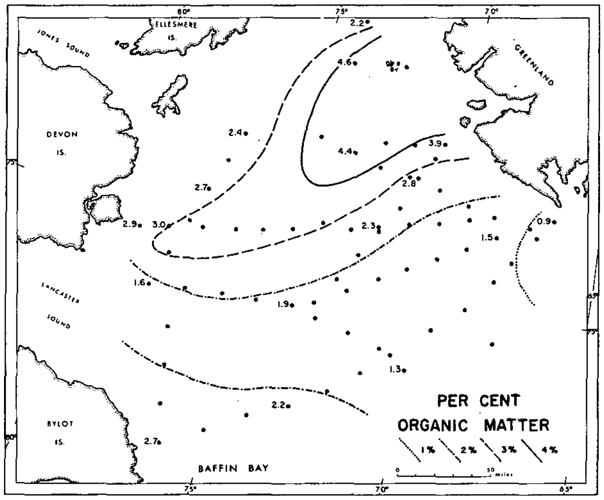


**Figure 14** - **Percent organic matter in the sand-silt-clay fraction of the bottom sediment.**

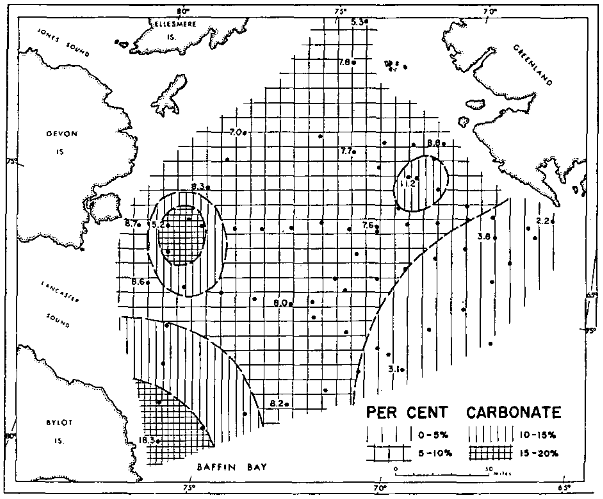


**Figure 15** - **Percent carbonate in the sand-silt-clay fraction of the bottom sediment.**

water clay zone, the regionally high level of organic matter may reflect oxidation as less important in organic matter deletion at these shallow water locations. Also, organic production and sediment accumulation may proceed at higher rates due to more intense water disturbance by surface currents.

The lowest organic matter content was recorded at the easternmost sample site within the study area (Fig. 14). The depth of water at this station was 580 metres. A color "anomaly" has been noted in this general area, and it is speculated that this might relate to some property of the water. Similarly, water characteristics of the West Greenland Current may in some manner affect organic production in this area, or preservation of organic matter in the bottom sediment.

Carbonate:

The 17 samples tested for organic carbon were also analyzed for carbonate. In preparation for analysis sample material less than 2 mm in diameter was thoroughly dried, crushed in a mortar, and sieved to remove all particles larger than .074 mm in diameter. Weighed amounts (1.700 grams) of this material were then treated with 20 percent hydrochloric acid in a Chittick Apparatus (Dreimanis, 1962), and the volume of carbon dioxide evolved was converted to percent carbonate. The percentages reported were calculated on the assumption that the carbonate was present as dolomite, inasmuch as significant reaction with the acid usually continued for at least 45 minutes.

Carbonate values determined for the samples analyzed ranged from 2.2 percent to 18.3 percent (Fig. 15). As opposed to sediment color and organic matter content, which exhibit their most pronounced regional gradation in north-south transition from shallow to deep water (Figs. 5, 13, and 14), carbonate values show greatest regional contrast east-west across the study area. The generally higher carbonate values in western samples might be anticipated, since carbonate rock-types are abundant along the waterways affluent to northern Baffin Bay, and southward movement of Arctic water is along the western side of the study area (Fig. 3).

In Figure 15, the 5, 10, and 15 percent levels have been selected as shading boundaries to accent trends in carbonate content. The influx of carbonate-rich sediment from the Lancaster Sound region might account for the carbonate maximum (18.3 percent) in the southwestern corner of the study area. Low carbonate content in the southeastern portion of the study area may relate to the absence of carbonate rocks along the west coast of Greenland, and the northward movement of surface water in this region by the West Greenland Current.

The two northern maxima in carbonate (15.2 percent and 11.2 percent) are adjacent and within, respectively, areas of coarsest sediment accumulation (Figs. 6 and 9). Otherwise, it does not appear that the carbonate content of the bottom sediment is controlled by textural properties.

The occurrence of carbonate rock fragments as a constituent of the sand-size material varies roughly in accord with the carbonate content of the total sample (sand-silt-clay). This suggests that the carbonate material in the sediment is probably detrital, rather than organic or chemical in origin.

Foraminiferal tests were virtually absent from all samples, except in sediment collected at the easternmost sampling station. While carbonate content at the latter location was the lowest recorded (2.2 percent), foraminiferal tests were a conspicuous part of its sand fraction. Although these observations are not precisely quantitative, they are further indication that carbonate in the bottom sediment is not primarily organic in origin. Also, it again appears that some characteristic water condition is associated with the West Greenland Current.

Carbonate distribution, in summary, relates primarily to regional geology and water circulation. Compositional characteristics of the bottom sediment, therefore, as well as the textural properties, find some expression in terms of the sedimentary model.

Table II - Gravel Lithology and Miscellany

| Sample No. | |
|---|---|
| 1 | Sandstone, gneiss, quartzite, limestone. (Shell fragments) |
| 2 | Limestone. |
| 3 | Gneiss, quartzite, sandstone, limestone. (Shell fragments, faecal pellets) |
| 4 | Gneiss. (Worms) |
| 5 | Gneiss, quartzite, limestone, basalt. |
| 6 | Gneiss, quartzite, sandstone, limestone. |
| 7 | Gneiss, quartzite. |
| 8 | Quartzite, gneiss, limestone, basalt. |
| 9 | Quartzite, gneiss, limestone, basalt. (Shell fragments, worms) |
| 10 | Gneiss. (Shell fragments) |
| 11 | Quartzite, gneiss, limestone. (Stain) |
| 12 | Gneiss, limestone. (Stain) |
| 13 | Gneiss, quartzite, limestone. (Stain) |
| 14 | Quartzite, gneiss, basalt. (Stain) |
| 15 | Gneiss, sandstone, limestone. (Diatoms, spicules) |
| 16 | Gneiss. (Diatoms, spicules) |
| 17 | Gneiss, limestone. |
| 18 | Gneiss, shale, limestone. (Diatoms, spicules) |
| 19 | Gneiss, quartzite, limestone. (Stain, diatoms) |
| 20 | Quartzite, gneiss, limestone. (Worms) |
| 21 | Limestone, gneiss, quartzite, sandstone. |
| 22 | Limestone, gneiss, quartzite, sandstone. (Worms) |
| 23 | Gneiss, limestone, gabbro. (Shell fragments, worms) |
| 24 | Gneiss, limestone, quartzite. (Worms) |
| 25 | Limestone, gneiss, quartzite. |
| 26 | Limestone, gneiss, quartzite. (Worms) |
| 27 | Gneiss, quartzite, limestone. (Worms) |
| 28 | Limestone, quartzite, gneiss. (Stain) |
| 29 | Gneiss, limestone, basalt. (Worms) |
| 30 | No gravel in sample. (Worms) |
| 31 | Gneiss, limestone. |
| 32 | Gneiss. (Stain, diatoms, worms) |
| 33 | Gneiss. (Stain) |
| 34 | Sandstone, gneiss. (Stain) |
| 35 | Gneiss, quartzite, limestone. (Stain, worms) |
| 36 | Gneiss. (Stain) |
| 37 | Gneiss, quartzite, limestone, basalt, sandstone, gabbro. (Stain) |
| 38 | Gneiss, quartzite. (Worms) |
| 39 | Gneiss, quartzite. (Stain, shell fragments) |
| 40 | Gneiss. (Stain) |
| 41 | Gneiss, gabbro, quartzite, limestone. |
| 42 | Gneiss, quartzite, limestone, basalt. (Stain) |
| 43 | Quartzite, gneiss, limestone, basalt. (Worms) |
| 44 | Quartzite. |
| 45 | Gneiss. |
| 46 | Gneiss, quartzite, sandstone. (Stain) |
| 47 | Gneiss, quartzite, limestone, basalt. (Stain, worms) |
| 48 | Gneiss, quartzite, limestone. (Stain) |
| 49 | Limestone, gneiss, quartzite, basalt. |
| 50 | Gneiss, limestone. |
| 51 | Gneiss, limestone, quartzite, sandstone. |
| 52 | Gneiss, quartzite, limestone. (Worms) |
| 53 | Gneiss, quartzite, limestone, basalt, gabbro, sandstone. (Sculpin) |
| 54 | Gneiss. (Black mud) |
| 55 | Gneiss, quartzite, limestone, sandstone. (Coal, shell fragments) |
| 56 | Gneiss, limestone, basalt, quartzite. (Stain, shell fragments) |
| 57 | Gneiss. |
| 58 | Gneiss, limestone, sandstone. |
| 59 | Limestone, gneiss, quartzite. (Shell fragments) |
| 60 | Gneiss, limestone. (Spicules) |
| 61 | Gneiss, quartzite, limestone. |
| 62 | Gneiss, limestone. (Diatoms) |
| 63 | Sandstone, gneiss. (Diatoms) |
| 64 | Gneiss, quartzite. (Diatoms) |
| 65 | Gneiss, limestone. (Stain, diatoms) |
| 66 | Gneiss, limestone. (Stain, diatoms) |
| 67 | Gneiss, limestone, quartzite. (Stain, diatoms, spicules) |
| 68 | Gneiss, limestone. (Stain, diatoms) |
| 69 | Gneiss, sandstone, shale. (Stain, diatoms) |

## Gravel Lithology:

The general lithology of rock fragments greater than 2 mm in diameter is given in Table II. Rock types are listed in order of their decreasing dominance in the sample, on the basis of frequency of occurrence rather than by weight.

Of the more than 1,500 rock fragments examined, 56 percent were classified as "gneiss", 21 percent as "limestone", 17 percent as "quartzite", and 3, 2 and 1 percent as "basalt", "sandstone", and "gabbro" respectively. Several shale particles were noted, and a number of the samples contained molluscan valves and fragments. One sample contained a coal fragment (Fig. 16D).

Over 80 percent of the rock fragments were sharply angular, and of the remaining number which exhibited some degree of rounding, only several could be classified as well rounded. About 50 percent of the quartzite particles were somewhat abraded, as opposed to figures of roughly 23 percent for limestone and 13 percent for gneiss.

At 50 of the 68 sampling stations where rock fragments were recovered, gneissic material predominated. Limestone was the dominant rock type at 8 sampling stations, quartzite at 7, and sandstone at 3. Dominance and complete absence of limestone in the samples is plotted on Figure 16A. Also plotted are dominance of quartzite and the occurrence of sandstone (Fig. 16B), the occurrence of basalt and gabbro (Fig. 16C), and those stations where rock fragments were coated with a brown to black stain (Fig. 16D).

Samples in which limestone constituted the dominant rock-type of the gravel fraction concentrate along the western side of the study area (Fig. 16A). Complete absence of limestone fragments in the samples was recorded mainly on the eastern side. Concentration of this constituent reflects limestone terrains to the west and/or north as the source area for this material, and the "tributaries" to the Baffin Current (Fig. 3) as the transporting media. The lack of limestone to the east agrees with the absence of this rock-type along the west coast of Greenland, and with the

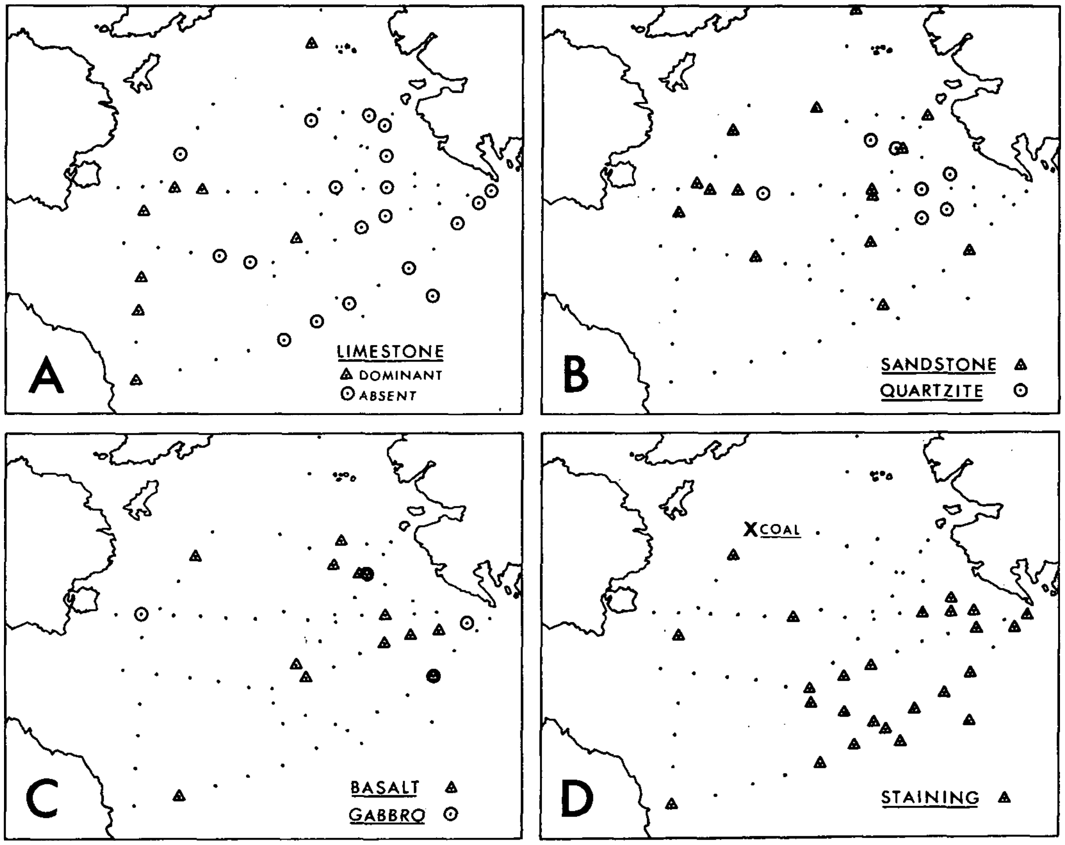


Figure 16 - Gravel lithology.

fact that the surface water in that region is moved northward by the West Greenland Current, as mentioned previously.

Quartzite is dominant mainly on the eastern side of the study area (Fig. 16B). Although reference to quartzite occurrence on the Greenland coast has not yet been found, it would appear that the source of this material lies in that direction, rather than to the north or west.

Sandstone occurrences are scattered over the entire study area (Fig. 16B), but trend to sparse distributions in the easternmost quarter. Relative to movement of surface water this pattern may be considered as reflective of a northward provenance, and "Eo-Cambrian" sandstones are well represented in that direction on the Greenland coast (Troelsen, 1950).

Basalt has been noted mainly at eastern locations (Fig. 16C). The situation of these occurrences is strong evidence for transport of this material from the Disko Island region, by the West Greenland Current.

Gabbro occurrence is limited (Fig. 16C), but relative to the factors discussed above its distribution points to a southeast source, where gabbros are plentiful along the Greenland coast.

The coal fragment found in sample 55 (Fig. 16D) is diagnostic of transport from the north or west. Possibly it is Devonian coal from the Blaa Fiord area, southwest Ellesmere Island (personal communication, H.R. Grenier, University of New Brunswick).

Staining of pebbles (Fig. 16D) was mainly confined to the general region of deep water. It appeared that the stain had been acquired in situ, as pebbles which had not been completely buried in the bottom sediment were free of staining on their upper surfaces. The considerable staining of shallower water sediments on the east side of the study area may relate to some water condition peculiar to the sphere of influence of the West Greenland Current.

## Summary of Results

The gravel content of the samples analyzed, while not an accurate quantitative measure, is highest in a zone approximately coincident with the paths of surface currents.

In the sand-silt-clay range, size distributions unimodal in clay characterize samples from the south-central, deep-water portion of the study area, or samples from local deep-water areas near shore. Shoreward from the central clay zone the general succession is to silt-clay bimodality, to sand-clay bimodality, to samples unimodal in sand.

Distribution on the basis of median grain diameters likewise illustrates shoreward progression from fine to coarse sediment, and clay deposition in nearshore bottom depressions. Offshore sand accumulations occur on topographically high parts of the basin floor.

The intensity of bottom currents was inferred on the basis of the clay content of the sediment. The zone of most intense bottom current action is essentially coincident with the zone of highest gravel content, sand accumulation, and positive topographic relief.

Medium to good sorting values are generally confined to areas of sand or areas of clay.

Profile presentation of data afforded further illustration of the areal relationships summarized above. Explanation for anomalously low gravel content in the southwestern portion of the study area was sought in masking effects, the pattern of surface currents, or sample spacing. "Colloid" deletion and sorting characteristics together indicate the 400 metre level as the approximate lower limit of appreciable water movement.

Sediment color and organic matter content display regional relationship to water depth, and may depend to some extent upon sediment texture. Both these parameters, and also foraminiferal occurrence and gravel staining, suggest that the West Greenland Current is characterized by some unique water condition (temperature, salinity, dissolved oxygen, etc.).

Carbonate distribution relates primarily to regional geology and to water circulation, and gravel lithology reflects similar control.

## Conclusion

In original presentation, the results summarized above were separately interpreted relative to a postulated sedimentary model. It is concluded that the total of these several correlations is sufficient to verify this sedimentary model as iterated below:

Ice-rafting is the dominant agent of sediment transport in the Baffin Bay region. Ice-movement is confined mainly to the lateral zone of surface currents, and gravel distribution in the bottom sediment is determined accordingly. The distribution of finer sediments depends upon hydraulic conditions. Clay accumulates in the central, deep-water area, but may also be deposited within the gravel zone where the bottom water is undisturbed by current action. Where water movement affects the bottom, sorting of the sediment occurs by virtue of non-deposition of fine particles. The latter material constitutes a sorted sediment at its site of deposition. It is improbable that rock-types characterizing terrains to the north and west of Baffin Bay will occur in the sediments accumulating beneath the West Greenland Current.

To the extent that the study area is representative, the results of this investigation may be applied to define general textural and compositional trends in the bottom sediments over the remainder of Baffin Bay.

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