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Reports

Distributional Trends in the Recent Marine Sediments of Tasiujaq Cove of Ekalugad Fiord, Baffin Island, N.W.T.*

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Introduction

The purpose of this investigation was to determine the nature of the Recent alluvial sediments in Tasiujaq Cove, the bay at the head of Sarvalik Fiord. Tasiujaq Cove is the shallowest of three basins in Sarvalik Arm of Ekalugad Fiord (68°50'N, 69°20'W; Figs. 1 and 2). The fiord is located on the mountainous Home Bay coast of eastern Baffin Island. A fairly extensive active sandur (outwash plain) of the valley train type (M. Church - personal communication) is found at the north arm of the fiord across which runs the rivers of three fiord-head valleys. The active portion of this alluvial plain is being built up in a proglacial situation and so the material is directly glacial outwash. The main outwash area extends for about ten kilometres upvalley from Tasiujaq Cove.

The primal basis of this investigation was the bathymetry or submarine morphology of the Cove and the mechanical analysis of fifty-two bottom grab samples collected within the study area. Auxillary lines of research included the determination of tidal characteristics, water quality analysis, water temperature analysis, and heavy mineral separations and identifications.

The samples for this study were collected during August of 1968, as one phase of the study of clastic sedimentation at the head of Sarvalik Fiord with the Division of Quaternary Research and Geomorphology, Department of Energy, Mines and Resources.

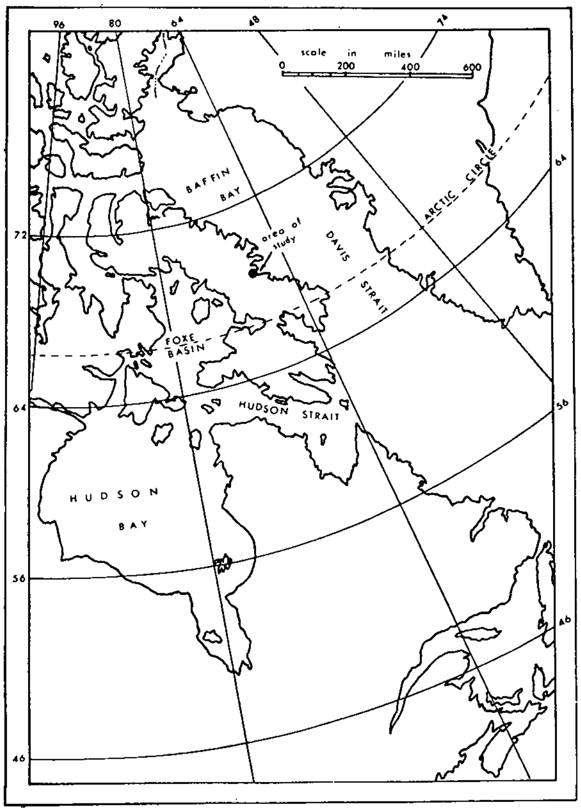

Figure 1: Index map showing the location of the study area.

Figure 2: Tasiujaq Cove and vicinity at the head of Sarvalik Arm, Baffin Island.

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Previous Work

The majority of early papers which deal with Recent sediments from the Arctic contain only brief sediment descriptions, and in some instances no sample was retained for further study.

One of the first investigations of any significance in the Baffin Bay region was that of Boeggild (1900) from reports of the Danish "Ingolf" expedition of 1895 and 1896. On the basis of ninety-one samples collected from the waters around Iceland, Southern Greenland and Davis Strait, four sediment zones paralleling the coastline were differentiated. In order of increasing distance from the shore, they are: shallow water deposits (greater than 0.5 mm); grey deep sea deposits (0.5 to 0.05 mm); transition clay (0.05 to 0.02 mm) and Globigerina clay (less than 0.02 mm). Boeggild went as far as to suggest that grey "deep sea" clay probably covered the entire bottom of Baffin Bay.

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

In 1928, the Godthaab expedition (Riis-Cartensen, 1931) recorded the nature of bottom deposits at each sounding station in Baffin Bay, but no samples were retained for further 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 a and b) studied sediment samples collected by members of the "Marion" expedition of 1928 to Davis Strait. The deposits described contained 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 configuration of the sea bottom and with surface currents and tides. Trask appears to be first to apply quantitative techniques in his grain size work in an attempt to quantify results of Recent sediment analyses from northern waters.

Vibe (1939) reported gravel, sand, sandy clay and clay from shallow waters (ten to sixty-four metres) in the Upernavik and Thule districts of northwest Greenland. Coarse sediments near shore graded outward into finer material, a characteristic previously noted by Boeggild (1900).

Marine sediment from the Canadian Eastern Archipelago was investigated by Perry (1961), and he described it as poorly 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, and silts were predominant in the deeper water offshore.

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 were 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.

Grant (1965) investigated the Recent marine sediments of northern Baffin Bay relative to a sedimentary model with sediment transport mainly by ice-rafting, and ice-movement controlled by surface currents. Of the samples analyzed, zones of highest gravel content were approximately coincident with paths of surface currents. In the sand-silt-clay-range, size distributions showed a shoreward progression from fine to coarse sediment, and clay deposition in nearshore bottom depressions. Offshore sand accumulations occurred on topographical highs of the basin floor.

Marlowe (1968) discovered that the sediments of Baffin Bay were predominantly mud, with minor amounts of sand and gravel. Variations in median grain sizes of mud deposits in the central basin coincided with the boundary of the Labrador Current. Ice-rafting of scattered pebbles and grains of coarse sand were also noted to be of continuous influence.

Dunbar (1951) has compared fiord development on the Greenland coast with that on the Baffin Island Coast. The role of ice as an agent of sediment transport, and the processes which may operate are relatively well documented. Sediment pickup and the abrading action of sea-ice and grounded glacial ice in shallow water, and reference to loading of shore ice by debouching streams and windblown material is discussed by Tarr (1897). 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) discusses mechanisms of ice-rafting 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.

A number of workers have examined the influence of regional bathymetric relationships on oceanographic processes. These latter studies, and several other contributions in the field of physical oceanography in Arctic Canada, have been reviewed by Collin and Dunbar (1964). In fact, little oceanographic work has been done in Baffin Island fiords.

Occurrences of isostatic rebound cutting off part of the sea to form a lake, apart from cutting off of coastal lagoons, has been reported elsewhere in the Arctic and Subarctic regions (Strom, 1957, 1961; Govorukha, 1963; Hansen, 1967; McLaren, 1967; Coakley and Rust, 1968). In Strom's Norwegian lakes (one of which has apparently been isolated from the sea for 6000 years), some of Hansen's examples in Greenland, and perhaps Lake Bonny in Antarctica (Angino, Armitage, and Tash, 1964) contain salt water and may be lakes of this type. Hattersley-Smith (1964) cite an example of a lake on Ellesmere Island that has been isolated from the sea by glacial advance and retains salt water at depth. Hansen and Coakley, et al, have reported entirely fresh water lakes despite having apparently been occupied by the sea in the past.

The results presented in this report are not directly comparable to other authors especially with regard to the discussion of the textural properties of sediments. Prior to the present investigation, authors who includes discussions of granulometric properties of Recent sediments employed the grain size parameters introduced by Trask (1930, 1932). These measures have been shown to be inadequate and those defined by Folk and Ward (1957) have been adopted in this report.

Physical Setting

Ekalugad Fiord lies within a zone of crystalline Precambrian metasediments consisting largely of fissile biotite-schists and massive granite gneisses. A series of exhumed isoclinal folds trend WNN to ESE obliquely across the present topography of the fiordhead with the apparent anticlinal core being composed of massive granite-gneisses and showing up on the landscape as a prominent cliff-former. The overlying series of rocks exhibit rectangular jointing and high fissility that presently contribute a great deal of material to talus slopes along the valley sides and to alluvial deposits. Further sediment was observed to be derived from erosion of former depositional surfaces, now extant as terraces, by processes of mass wasting and river erosion.

The present features of the fiord head owe their origin to the most recent deglaciation. Some fragments of moraine occur along the valley sides, but the most prominent features are the series of glacio-gluvial terraces and outwash surfaces in the valley bottom. The highest is an ice-lateral terrace which runs along the north side of the valley at fifty to sixty metres above sea level, the seaward end of which appears as a sea beach at fifty-seven metres. The next major surface is the prominent fossil outwash plain which received drainage from all the fiordhead valleys. Below this, a series of disjointed terraces fall down to the presently active outwash surface. The three principal surfaces are all reflected in the two major alluvial fans on the north side, which are tri-levelled and successively grade to each major level.

Andrews (1969) has applied radiocarbon techniques to the glacial sequence at the head of Ekalugad Fiord. The Tasiujaq Cove moraine was deposited underwater about 6100 years ago by the last Pleistocene ice tongue to occupy the fiord. By 5700 years B.P., the ice had retreated to the inland moraine system at the head of Ekalugad Fiord (6.8 kilometres upvalley) and alluvial deposition began into the fiord from this position. Between 5700 years B.P. at which time the initial alluvial deposition began and about 4350 years B.P., sea level fell by about twenty metres. The Tasiujaq Cove moraine probably emerged about 4500 years B.P. so that the circulation between the Cove and Sarvalik Fiord has been restricted throughout most of its history.

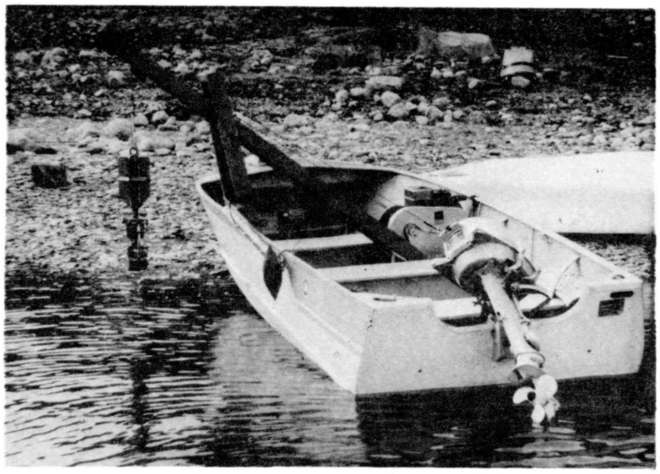


Figure 3: Boat and equipment used in the collection of the field data.

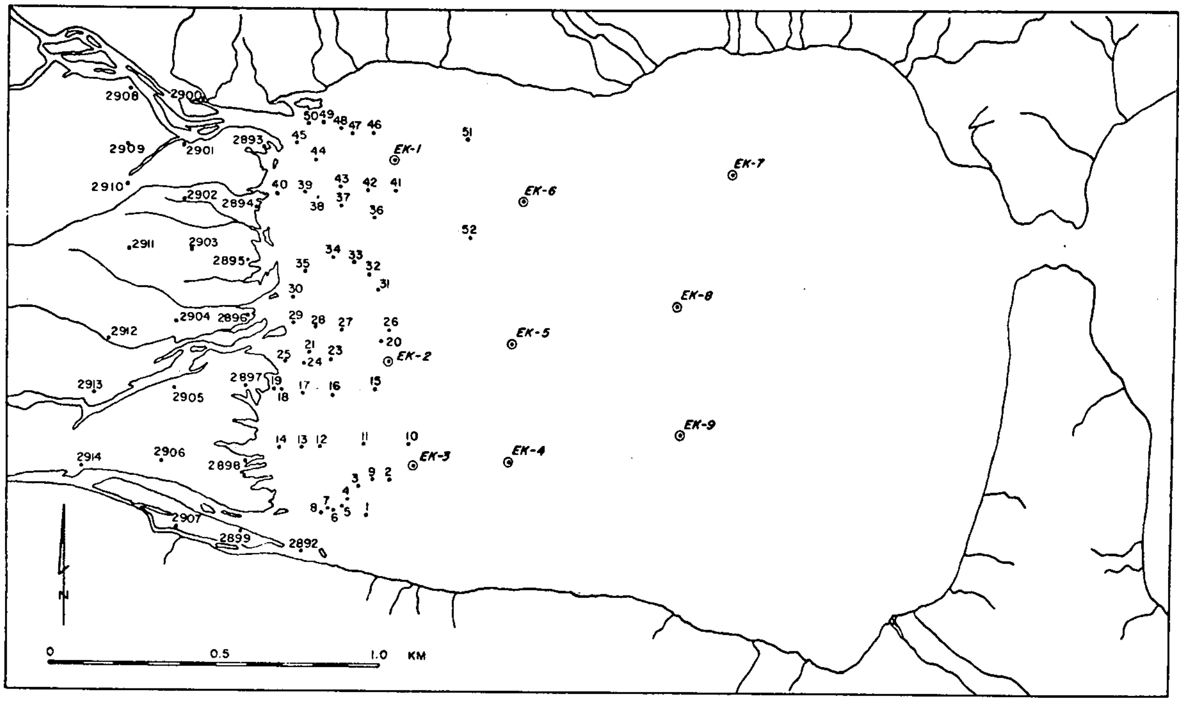


Figure 4: Sampling stations

Methods of Study

Field Methods:

Bathymetry was determined by use of fifty lead-line soundings in the summer of 1967 and by the use of a Ferrograph "Inshore" echo-sounder (Fig. 3). Positions were fixed using a telescoping sextant sighted onto a series of shore range markers.

The offshore samples comprising the major material for this study were recovered with a Dietz-Lafond bottom sampler (Lafond and Dietz, 1948). Fifty-two samples were taken from the foreslope of the sandur and inshore portion of the bottom before the two available samplers were lost. The persistence of ice in the cove until late season and the loss of two samplers forced a reduction of the planned marine sediment sampling program. A number of sandur, river channel and beach samples have been appended for comparative purposes in the study.

Tidal records were taken during the 1967 field season using a Foxboro model 40 tide gauge. The tide appeared to be mixed, mainly diurnal; the highest water usually occurred in early morning. For the period of the record, the average daily tidal range was 0.84 metres; the maximum was 1.03 metres and the minimum 0.58 metres.

Temperature profiles were obtained using a Wallace-Tiernan Thermarine bathythermograph (140 metre type) at nine stations. Water samples and reversing thermometer readings were taken along each temperature profile, from two to five samples being taken in each, using a Knudson bottle with two reversing thermometers (Fig. 4 stations noted on EK-1 to EK-9).

Laboratory Methods:

Mechanical analysis of the sediment samples was carried out in the Sedimentology Laboratory of the Division of Quaternary Research and Geomorphology, Geological Survey of Canada. Oven-dried samples were dry sieved to 44 microns after which pipette analysis were carried out as necessary. [For details see MacDonald and Kelly (1968, p. 7-9) and Krumbein and Pettijohn (1938, p. 95-102)].

Bimodality is apparent in most of the cumulative frequency curves but is not as indicative as expected since the fraction of sediment coarser than two millimetres has been removed as being that portion due to ice-rafting. Such coarse material was separated since this fraction would greatly bias the other statistical parameters calculated, thus masking the distribution pattern of directly water deposited sediment.

Heavy mineral separation used in the procedure described by Krumbein and Pettijohn (1938, p. 343) and then dry weights of the light and heavy fractions were recorded (see MacDonald and Kelly, 1968 for more details). Water sample analysis were undertaken at the Industrial Water's Laboratory, Water Quality Division of the Inland Waters Branch. Complete analysis was carried out on 13 of the samples, and specific conductance determined on the remainder with a multiple range conductivity metre (for details of procedures, see Chawla and Traversy, 1968).

Oceanography

Bathymetry:

Tasiujaq Cove is the shallowest of three basins in the Sarvalik Arm of Ekalugad Fiord (Fig. 5 and 6). From the profile data (courtesy of D. Hodgson, through the Canadian Hydrographic Service), the outer sill of the fiord appears to be solid bedrock. The next sill-like structure may be morainic like that separating Tasiujaq Cove from Sarvalik Arm (M. Church - personal communication).

A delta is being deposited at the distal end of the alluvial outwash plain and is slowly encroaching into Tasiujaq Cove. The cove is now approximately 2.25 kilometres long and 1.85 kilometres at its widest point (surface area is 3.61 square km.). The deepest point determined

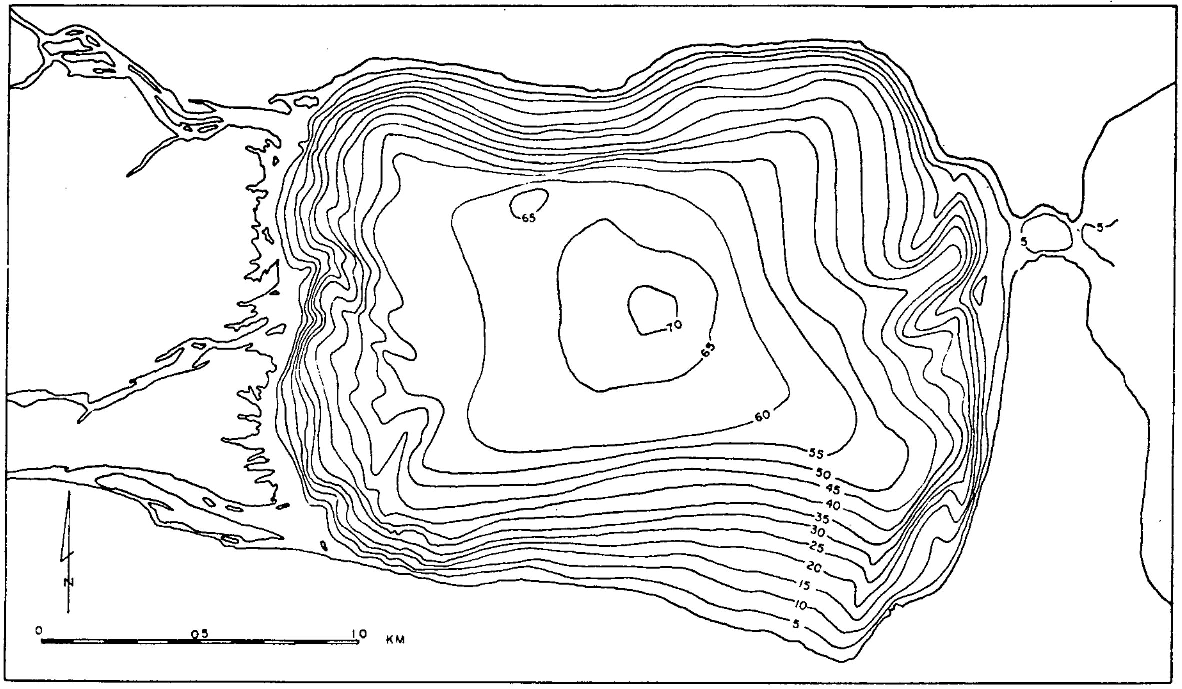
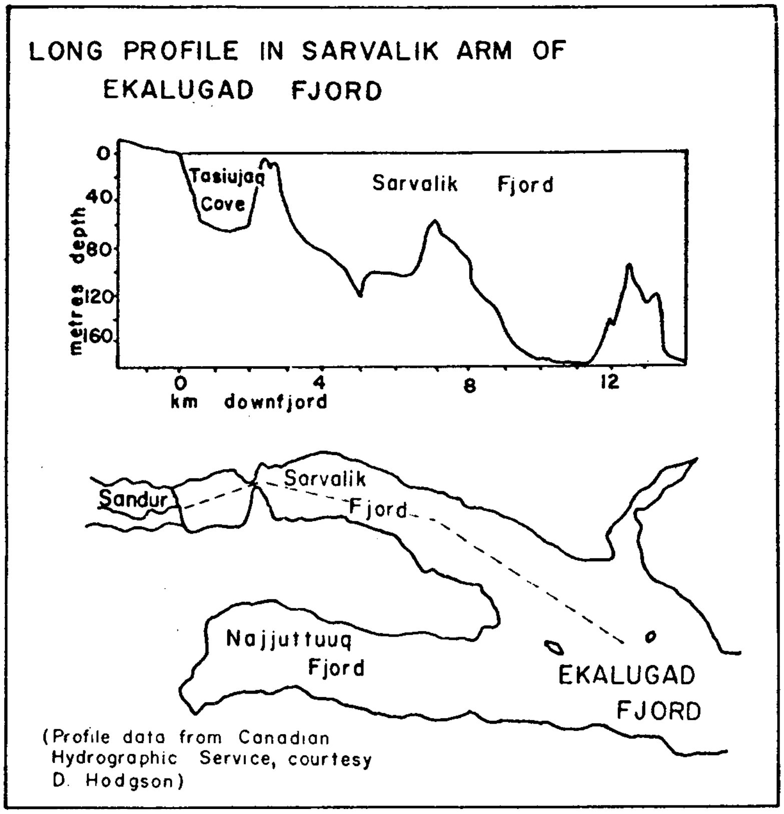


Figure 5: Bathymetry of Tasiujaq Cove.



(Profile data from Canadian Hydrographic Service, courtesy D. Hodgson)

Figure 6: Long profile of Sarvalik Arm of Ekalugad Foird.

from soundings is seventy metres. The channel through the moraine connecting the cove to the fiord has a minimum depth of three metres and is floored by large boulders that are lag deposits from eroded morainic materials (M. Church - personal communication). The narrowness of this tidal gap makes the cove virtually a complete sediment trap for sediment discharged from the fiordhead rivers.

The cove is bounded to the north and south by talus and debris covered slopes rising over five hundred metres respectively. Both sides become quite active debris contributors to the cove during periods of snowmelt. The submarine slopes are relatively steep on both sides as evident from the bathymetric map. The delta foreslopes reflect the active sedimentation occurring by their bathymetric configuration. The mean gradient of the delta is approximately 12 per cent which is a function of the dynamic nature of the hydrologic regime and the coarseness of the sediments being deposited.

Ice Conditions:

The cove is free of ice cover only during the period from late July to the end of September. Due to tidal mixing the channel at the moraine is open for a somewhat longer period; it was free of ice cover on arrival May 29, 1967.

In 1967 the cove ice remained fairly solid until June 30th, but after the rivers began to flow in early July (Fig. 7) and a tidal lead developed the bay ice began to break up rapidly around the river mouths. The cove was completely clear of ice by July 17th while the fiord was still about 85 per cent covered outside the moraine at this date. The fiord ice shifted in and out with the wind for about a week after this. In September, the cove began to freeze on calm nights after September 6th.

In 1968 the cove ice remained solid until after July 20th, except for small areas at the river mouths and the tidal lead at the shore. This is in marked contrast with the 1967 season when all the ice had left the cove by July 17th. On July 26, 1968, the first ice began to break off near shore but cover was still greater than 90 per cent at this date. Ice persisted in the cove until late in the season. The fiord proper remained substantially ice-covered until after August 1st when breakup occurred very rapidly. The fiord was free of ice by August 18th. Much of the ice in Sarvalik Arm blew into Tasiujaq Cove through the tidal channel and was eventually broken up by winds in the cove.

Figure 7: Areas of ice breakup at the mouth of North River and the development of a tidal shore lead in early July, 1967.

Analysis of Water Samples:

The measured variation of bottom temperatures recorded on August 20, 1968 was less than 0.08°C over the entire cove (Table I); the average bottom temperature was -1.41°C, which in some of the profiles was slightly warmer than the coldest temperature recorded at approximately ten metres off the bottom.

A pronounced thermocline exists below surface waters at three to five metres depth (Fig. 8). The thermocline extends ten metres in depth and becomes more pronounced in the stations further away from the effects of river discharge where the temperature gradient is slightly steeper. A noticeable double "bump" is evident in several of the profiles which may represent a double layered stratification of near surface waters. This effect may be related to the time lag in tidal influences in the cove as a result of the restricted circulation through the narrow moraine gap.

There is a considerable contrast between surface and bottom salinities (Fig. 9, Table I). The salinity value used is the sum of the major constituents times 10^{-3}, from Table 2. The average surface value is 0.45 parts per thousand which is in direct contrast to the average bottom salinity of 29.74 parts per thousand, which is somewhat less than that of normal seawater. The average bottom salinities show a remarkable consistency up to depths of twelve to fifteen metres.

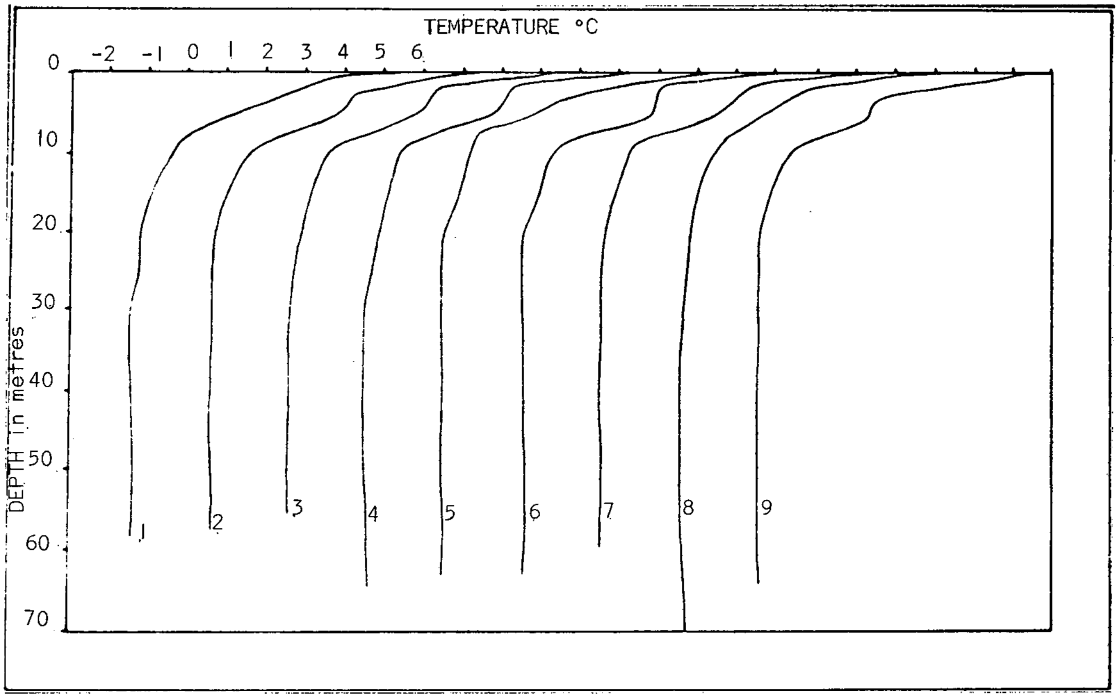


Figure 8: Temperature profiles. Note that each successive curve is displaced 2°C to the right for comparative purposes.

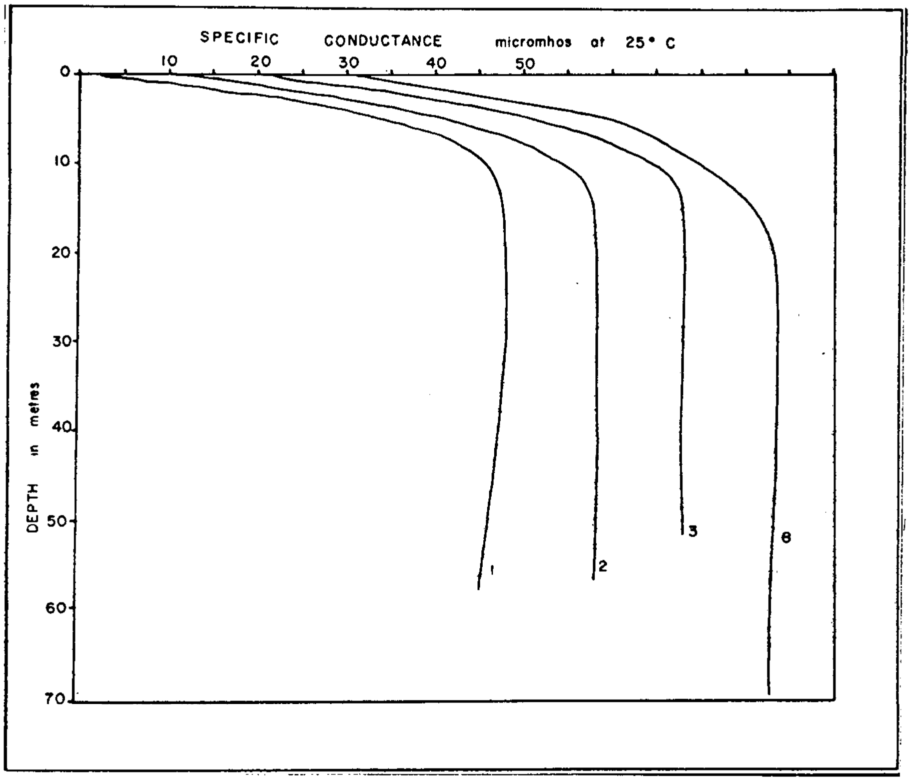


Figure 9: Specific conductance plotted against depth.

Overland runoff usually has quite different salts from those in seawater. This is self-evident in the results of Table I. The only major constituent in the cove waters that is not apparently attributable to seawater is the silica content which appears to be derived from the river waters at the fiordhead. It is significant to note that this constituent is present only in the surface water samples and totally absent in measurable amounts below these depths. There is a marked stratification evident in observations of the major constituents between surface and subsurface waters which can be related to the influence of fresh water input into the environment.

Table I

St. No.	Depth (m)	Temp.	Specific Conductance	Total Hardness	Ca	Mg	Na	K	Cl	NO_3	SiO_2	Sum of Major Constituents
1	sfc.	5.2	1,280	111.0	8.0	22.0	182	10.0	332	0.06	0.70	554.76
	13.7	-0.63	45,600	5,830	340	1,210	9,400	480	16,600			28,021
	27.7	-1.37		no data								
	41.5	-1.40	48,200									
	54.8	-1.40	47,700									
2	sfc.	5.2	982	90.3	6.5	18.0	145	7.8	265	0.05	0.60	442.95
	13.7	-0.84	48,400	6,060	350	1,260	10,000	510	18,000			30,120
	27.7	-1.33	48.700	6,061	350	1,260	10,000	510	18,150			30,271
	41.5	-1.46	48,700	6,060	350	1,260	10,000	510	18,150			30,270
	56.9	-1.39	48,200	6,020	350	1,250	10,000	510	18,000			30,110
3	sfc.	5.2	790	57.8	5.0	11.0	92	5.2	170	0.00	1.20	284.40
	13.7	-0.77	48,600	6,090	360	1,260	10,000	510	18,000			30,130
	27.7	-1.37	48,200									
	41.5	-1.46	48,200									
	53.9	-1.44	48,200									
4	sfc.	5.2	1,000									
	58.4	-1.42	48,200	6,090	360	1,260	10,000	510	18,150			30,280
5	sfc.	5.2	690	51.9	5.0	12.0	97.5	5.4	186	0.05	1.10	307.05
	61.6	-1.44	48,700									
6	sfc.	5.2	1,110									
	64.7	-1.41	48,200									
7	sfc.	5.5	1,120									
	53.8	-1.43	50,000									
8	sfc.	5.3	1,505	65.8	8.2	11.0	222.0	10.5	418	0.05	2.30	672.05
	18.2	-1.11	48,200	6,060	350	1,260	10,000	510	18,050			30,170
	36.8	-1.38	48,300									
	55.4	-1.45	49,000									
	69.4	-1.36	48,200									
9	sfc.	5.2	1,440									
	63.1	-1.41	48,200									
North River			12.4	2.5	0.60	0.24	0.5	0.3	0.5	0.07	1.50	7.2
Middle River			15.3	3.3	0.90	0.20	0.3	0.3	0.1	0.05	1.50	8.6
South River			24.4	6.9	2.30	0.30	0.5	0.5	0.9	0.05	1.80	14.6

Water Circulation:

No direct field observations were made with respect to water circulation, but several significant characteristics of general water movement were observed from patterns of ice breakup (Figs. 7 and 10) and observed sediment discharge (Fig. 11) opposite the river estuaries, and general patterns of ice movement during breakup. The general pattern of water circulation observed appeared to be generally in a counter-clockwise direction. This may be the effect of expected Coriolis force deflections with the physical dimensions of the cove and tidal inlet flow (i.e. the fact that the tidal gap is located to the northerly side of the moraine) through the gap.

Fresh water enters the fiordhead between late June through to early September from three rivers with maximum runoff occurring immediately after periods of maximum snowmelt in early July and/or during summer rainstorms. The average daily influx of water during the 1967 season was 4.24 x 10^6 cubic metres with a daily maximum influx of 16.79 x 10^6 cubic metres on July 14th. In the low runoff season of 1968, only about one-quarter as much runoff was observed.

Figure 10: Drifting ice pans during late season break-up in the cove.

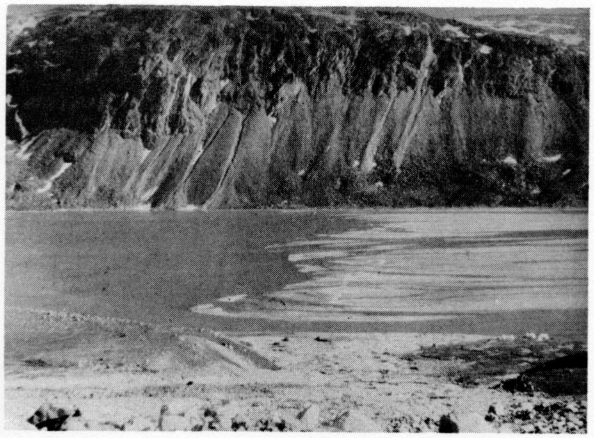


Figure 11: Sediment discharge plumes observed during a period of high discharge from the rivers in late July, 1967.

The discharge of fresh water from the rivers flows directly out over the saline cove waters which produces a stratification of cove waters during runoff periods. This characteristic is evident in the analysis of the water samples. The fact that surface salinities remain very low throughout the entire cove suggests that tidal exchanges through the moraine gap may involve only fresh water or that salt water entering from the fiord sinks upon entering the cove.

In winter, circulation is much more restricted due to ice cover, and cove water conditions are much more uniform since there is no fresh water source during this season. Circulation of sea water most likely occurs into the cove during the winter, but exchange is probably very weak.

Sedimentary Analysis:

This study attempts to outline the pattern of sedimentary characteristics resulting from transport processes under Arctic conditions. Grain size analysis was carried out primarily on the marine bottom samples. Further analysis of some beach, channel and outwash samples were added for comparative purposes. Folk and Ward's (1957) statistical parameters were used in this study with the use of computing services at Queen's University, Kingston, Ontario.

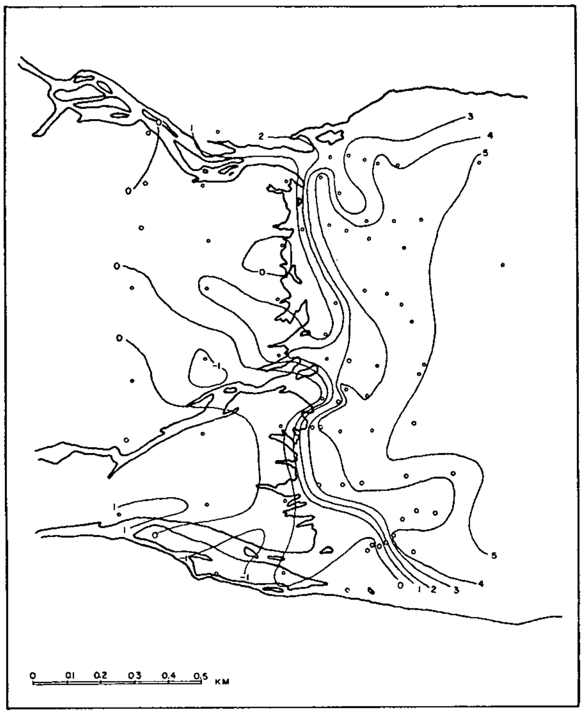


Figure 12: Mean grain size in phi units.

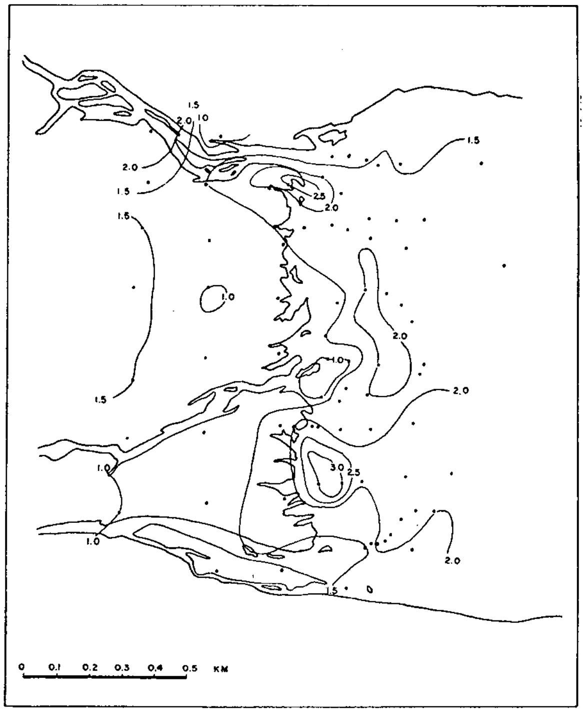


Figure 13: Standard deviation (degree of sorting) in phi units.

Figure 12 shows the distribution of bottom sediments defined on the basis of mean grain size diameter. The general trend implied is a decrease in mean grain size from 0.0 ϕ to 5.0 ϕ in moving across the sandur to the cove into deeper water. A comparison of the bathymetric map (Fig. 5) to mean grain size diagrams (Fig. 12) shows a fairly close correlation between the submarine topography of the sediment deposits and the mean grain size distributions especially in the areas immediately opposite the river outlets. This feature is notable by the extension of the isolines of each map towards deeper water and lower energy conditions. This apparent correlation suggests to some extent the magnitude of fluvial influences in the offshore areas on bottom sediments. Some anomalous patterns occur in particular over the sandur surface which emphasizes the variability of this feature in terms of morphology and grain size due to seasonal migrations and branching of the river channels.

Very poor to extremely poorly sorted values (Fig. 13) are characteristic of all samples irregardless of the environment. Only a few isolated samples indicate improved sorting characteristics. The low degree of sorting overall is explained by consideration of the deposition of widely separated modal classes within an environment of relatively low energy. Intermittent stream flow during short summer runoff periods gives little opportunity to sort the wide range of grain sizes that occur within the drainage basin. Sea ice reduces sorting effectiveness by interfering with normal hydraulic sorting of the rivers both in the rivers and in the cove. The sediments are texturally immature as a whole resulting from the overall reduction of sorting effectiveness due to the environment of deposition.

The offshore sediments are generally better sorted. This is a function of quieter water and a lessened effect of ice grounding experienced along shoreline areas. The greater range of sediments found offshore is an indication of additions due to ice-rafting.

The majority of the marine samples are positively skewed (fine to strongly fine skewed, with some nearly symmetrical). The continental samples appear negatively skewed (coarse skewed). Skewness appears to be sensitive to environment which makes it a useful differentiating tool. The marine samples of this study appeared to range from mesokurtic to very leptokurtic with most samples occurring in the leptokurtic range. The two beach samples, although rather unrepresentative, show similar kurtosis characteristics as the marine samples. Channel samples present a widely varied kurtosis ranging from platykurtic to leptokurtic. The sandur samples are also highly variable, lying predominantly in the mesokurtic area, but ranging overall from very platykurtic to very leptokurtic.

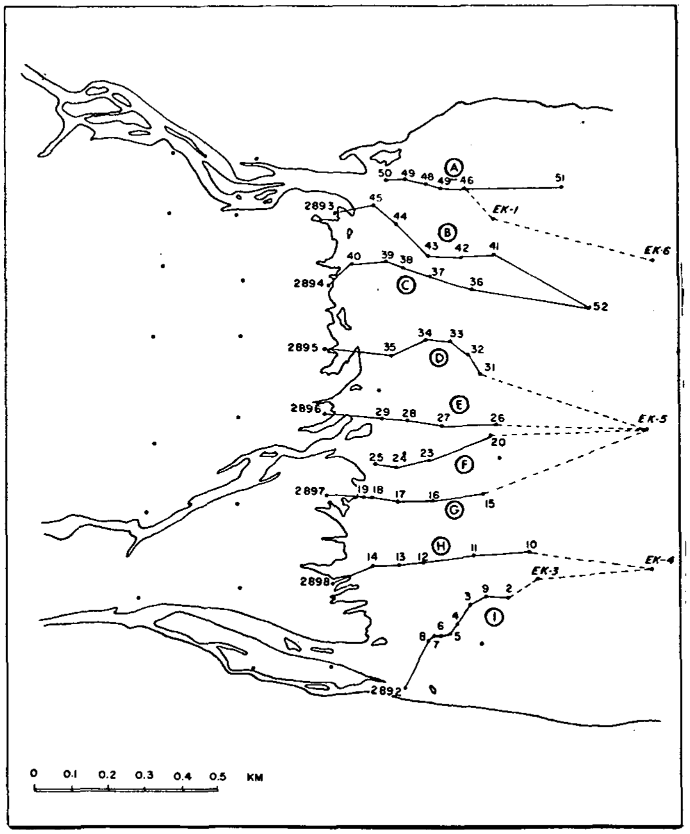


Figure 14: Location of profiles of the study area.

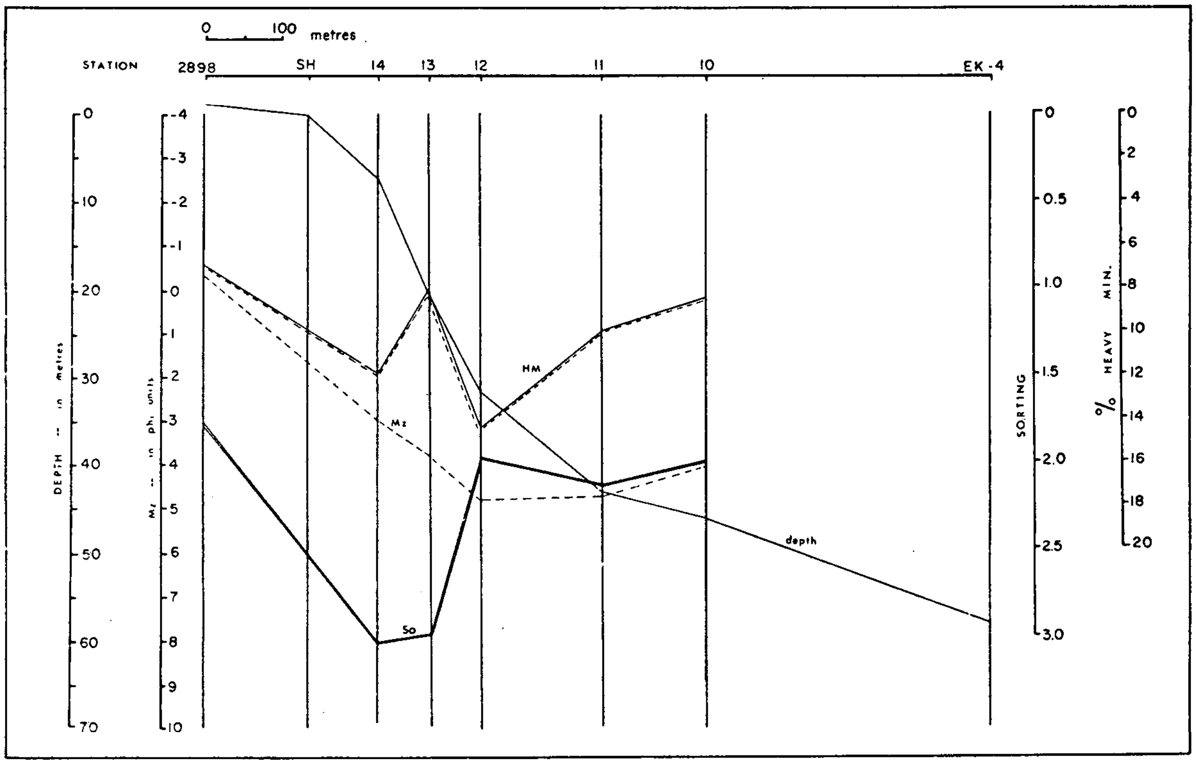


Figure 15: Representative profile showing lateral variations of mean grain size (Mz), standard deviation (So), and percentage heavy minerals to distance from shore, depth and bottom configuration.

Profile Analysis:

The relationships discussed from the 'plan' diagrams can be further illustrated by profile representations. Figure 15 is an example of one of the plotted profiles relating mean grain size, sorting, heavy mineral percentages, water depth, bottom configuration and distance from shore.

Mean grain size decreases, sorting improves and heavy mineral percentages increase as the distance from shore and the depth increase. The relative uniformity of mean grain size in the

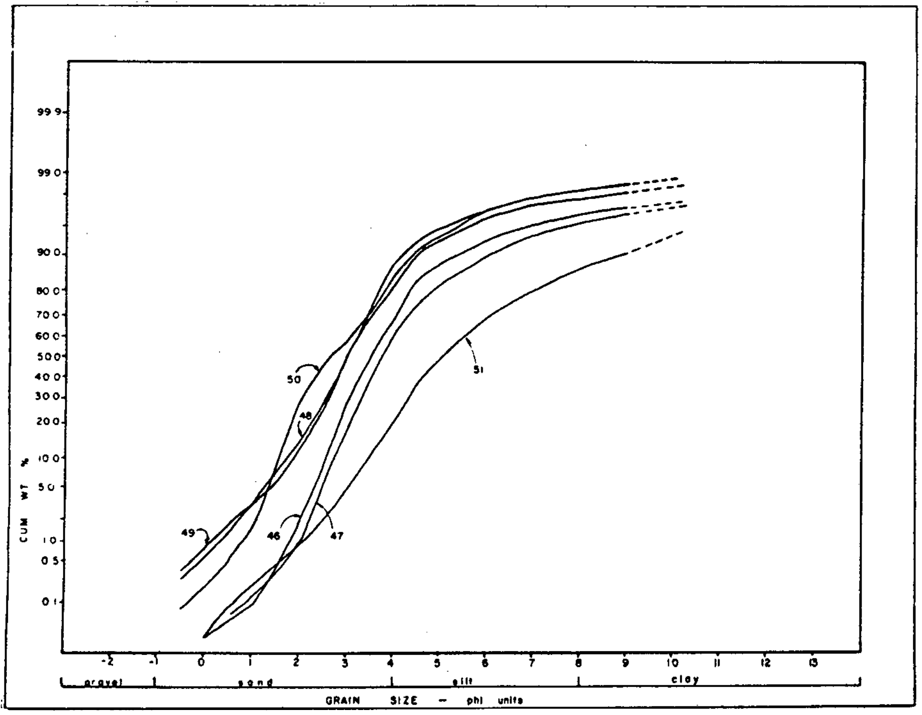


Figure 16: Cumulative frequency curves for a representative profile.

offshore sediments is an indicator that ice-rafting or associated processes arenot quantitatively important sources of detritus in the environment (volumetrically small enough overall to be hidden in the whole).

The very high sorting values and coarse sediments shown in Figures 13, 15 and 21 within the marine area between South and Middle Rivers may be evidence of an earlier river estuary now covered.

Cumulative Frequency Distributions:

Figure 16 displays six representative cumulative frequency curves taken in a line from the shore out into the cove. The juxta-position of the curves to one another indicates a slight overlapping of sediment sample characteristics which is most likely a function of the multiple transporting agents operative in the area. There is a progressive decrease in the slope and a flattening of the curves as one moves from shallow to deeper waters which denotes reduced energy conditions of the fluvial transporting medium and an increase in the proportion of finer sized materials being deposited in this direction (a relative decrease in the proportion of coarser sized grains). Bimodality is apparent in most of the curves but is not perhaps as indicative as expected since the fraction of the sediment sample coarser than two millimetres has been removed. Such coarse material was separated since this size fraction would greatly bias the other statistical parameters calculated.

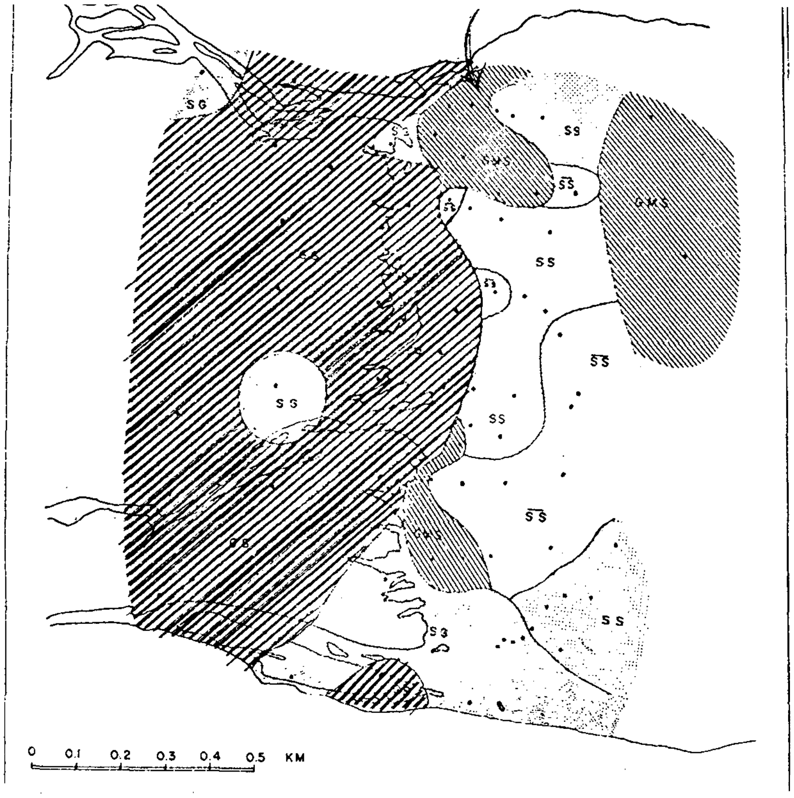


Figure 17: Sedimentary textures: SS - silty sand; $\overline{SS}$ - sandy silt; SG - sandy gravel; GS - gravelly sand; and GMS - gravelly muddy sand.

Textural Characteristics:

Textural trends suggest a possible model of sediment transport. The textural classification and verbal limits of grain size parameters used are those defined by Folk (1954) and Folk and Ward (1957). The two primary agents of transport observed are water currents and ice-rafting.

The samples studied (Fig. 17) have bimodal distributions exhibiting a maxima in either sand and gravel, or sand and silt. Some exceptions display a trimodal distribution of gravel, sand and mud. The sandur, channel and beach deposits generally exhibit sandy gravel or gravelly sand textures. The offshore samples lie in the textural range of silty sands or sandy silts. The areas of gravelly muddy sand and gravelly sandy mud appear to lie in zones of transition between the marine and continental deposits.

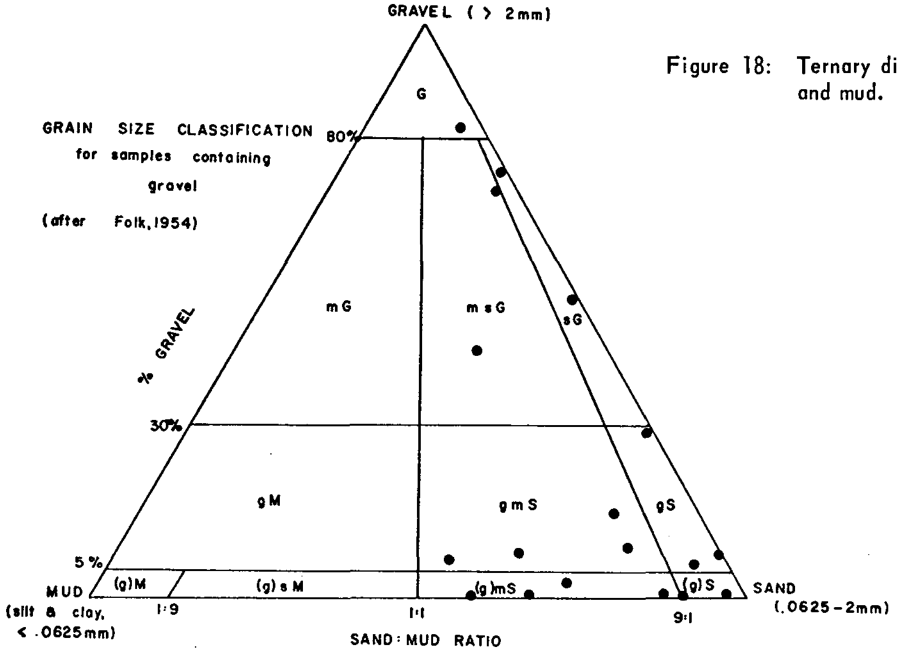


Figure 18: Ternary diagram -- gravel, sand and mud.

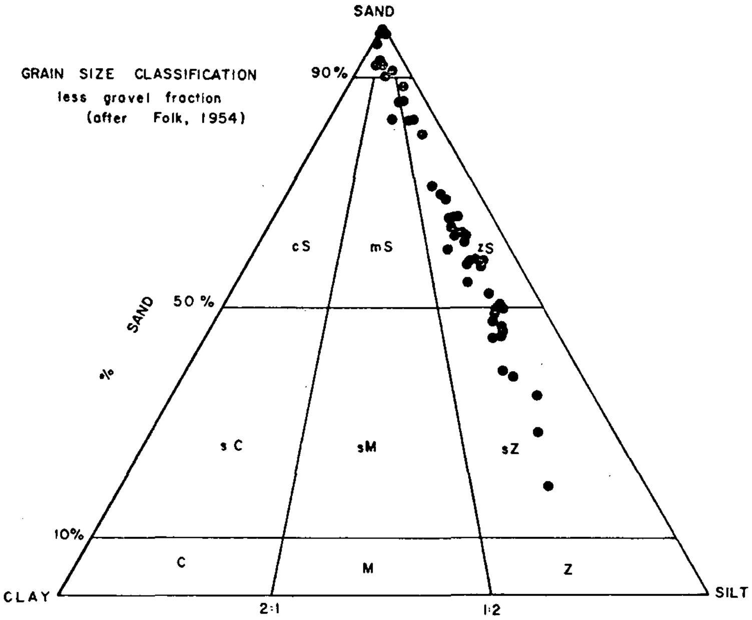


Figure 19: Ternary diagram -- sand, silt and clay.

Lithologic ratios of available samples from textural analyses are presented in two ternary diagrams. These include the plots of only the marine samples. In Figure 18 the plot of gravel (greater than two millimetres), sand (.0625 - 2 mm) and mud (less than 0.0625 mm) lithologic ratios are presented. The fairly widespread distribution of the textural plot of sediments over the right side of the diagram indicate that the normal progression of sediment textures from coarse to fine is not totally prevalent. If progressive sorting by waves and currents acted solely on sediments during sediment transport, the ideal plot would indicate clearly a distribution of sediments along the gravel/sand/mud boundary in the counter-clockwise direction. The scatter presented in this diagram suggests that some coarse sediments are deposited from suspension, such as ice-rafting, and that this mechanism may explain anomalous marine deposits over that portion of the cove samples.

In Figure 19 the ternary diagram of the sand/silt/clay ratios are plotted excluding the material coarser than two millimetres as ice-rafted materials. This plot shows a distribution of sediments clustered closer to the sand/silt/clay sides. This indicates a more ideal dispersion suggesting progressive sorting from high energy to low energy areas was taking place (fewer occurrences of ice-rafted sediments).

It is difficult to estimate from each fraction the amount of sediment that was ice-rafted and deposited from suspension and the amount dispersed by marine and fluvial agencies. In the ideal case where no ice-rafting occurs, sediment dispersal patterns occur only through the agency of water currents and the sand/silt/clay ternary diagram would show a distinct absence of sediments along the sand-clay side based on the assumption that progressive sorting occurred from regions of high energy to regions of low energy. In the gravel/sand/mud diagram, the gravel apex suggests deposition from a high energy zone, with the sand and mud apices indicating progressively decreasing energy zones. The gravel-mud side of the diagram indicates deposition from suspension. Ice-rafting is active over all energy fields, in spite of the fact that marine energy over all fields decreases progressively towards deeper environments. Since ice-rafting occurs primarily in shallower zones, this explains why the coarser gravel/sand/mud materials suggest a greater frequency of this agent of transport than noted in the sand/silt/clay sizes.

Textural Environments:

There is an overall decrease in grain size with increasing distance from shore and the bottom configuration does not appear to play an important role in governing sediment distributions in the nearshore environment. Sediment distribution can be directly attributed to relative volumes of terrigenous materials being carried by individual streams.

Figure 20: Group pan ice which is responsible for some of the derranged textural characteristics observed.

Figure 21: Results of flooding sediment laden river waters over cove ice in late June, 1968, adjacent to the North River estuary.

A low degree of sorting is expected to be characteristic of all the samples collected in the marine environment and is considered to be the result of ineffective sorting combined with the influence of multiple transporting agents operating within the depositional area. Poor sorting is also due to a combination of low tides, negligible currents, restricted wave development due to solid cover ice (Figs. 7 and 10) or large amounts of ice and a churning up of recently deposited sediments in shallow waters by grounded ice (Fig. 20).

After the summer breakup occurs, the wind blows ice in and out from the shore. The ice grooves and ploughs sediments accumulating in shallow waters. Consequently, sediments are not subjected to normal sorting processes operative along coasts in temperate climates.

There are three possible agents of sediment transport moving terrigenous materials to the site of deposition: (i) ice-rafting of material during the summer breakup period; (ii) wind blown sediments from the outwash deposits carried onto the ice; and (iii) normal sedimentary contribution by streams during runoff. In the latter part of the summer, runoff is greatly reduced, exposing recently deposited unconsolidated sediments in braided channel areas of the sandur which can readily be transported by the wind.

The bulk of the sediment is probably provided by the latter agent (Fig. 21). As much as one to five per cent or more material transported is of a coarser texture than that generally carried by streams and does not follow the normal pattern of sediment accumulation. These larger grains are thought to have been dropped from melting ice in the summer season.

Another unique feature of the area occurs during initial spring runoff before shoreline leads have had time to develop. The result is that stream waters loaded with sediment flood out across the ice at high tides and/or high river discharges depositing terrigenous materials on the ice surface (Fig. 21). This inevitably lowers the surface albedo of the cove ice causing higher melting rates in the areas of deposition. The sediment deposited in this manner is either dropped in place during summer melting, or is transported after breakup to other areas and deposited away from their normal site of deposition. Another process commonly coincident with the foregoing is a slushout phenomena which results from the undercutting of sediment-laden snowbanks in the river channels as the river stage rises producing large quantities of water saturated snow and ice in the river discharge at various periods of high runoff.

It is important to note that textural properties of fluvial deposits also do not follow established trends for similar sediment accumulation in more temperate areas (Friedman, 1961). The physical processes normally associated with these environments operate at much reduced levels and are seasonally very variable and therefore are quite incapable of producing textural properties commonly attributed to fluvial processes. The daily and seasonal variations in snowmelt, precipitation and river discharge are the most significant variables. Consequently, the grain size parameters of fluvial deposits have a wide range of values even within the course of a single stream. Three major trends characteristically occur however: (i) downstream decrease in grain size; (ii) improved sorting downstream decrease in grain size; (iii) slight decrease downstream in total quantity and number of heavy mineral species. The stream beds are generally covered by boulders and cobbles which interrupt the normal trend of fluvial sediment transport. The streams exhibit a rapid decrease in gradient towards the stream mouths which results in a large decrease in stream velocity and competence. Due to further breaks of gradient upstream, marked by development of braided channels, this results in delivery of only finer sediment fractions to the stream mouth by fluvial processes.

Heavy/Light Minerals:

Thirteen rock thin sections were studied to identify the possible mineral content to be expected in the sediment samples from an analysis of the parent rock materials in the area. The major mineral constituents of the bedrock identified were quartz, plagioclase, microcline, muscovite, biotite, hornblende, pyrite and zircon.

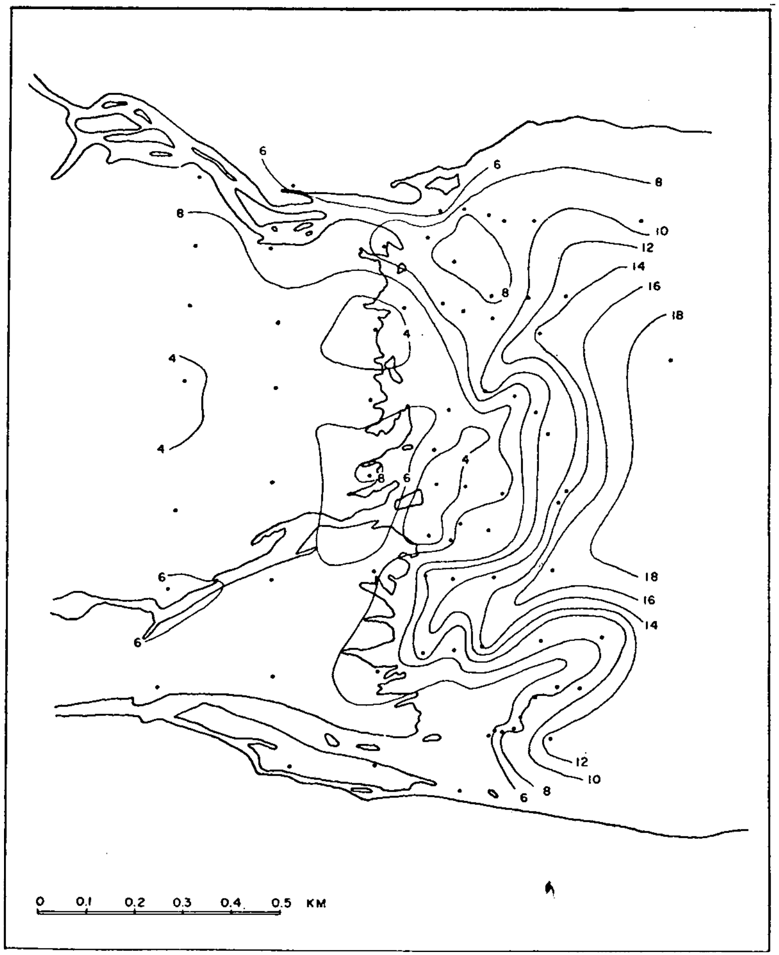


Figure 22: Heavy mineral distributions in percent.

From seven surface samples collected on the sandur in South valley, a variable but slight decrease occurred in the heavy mineral percentages in the downstream direction. A complete reversal of this trend occurred within the marine samples (Fig. 22). This may be explained as a result of the frequent slush-out characteristics common in the river channels during periods of high runoff as already discussed. As a result the normal sorting processes involving the heavy mineral fractions of the bedload are deposited by non-normal means and actually appear to accumulate beyond areas of expected fluvial deposition.

Microscopic analysis of the light mineral fractions mounted on slides revealed that the grains were characteristically very angular to angular (Powers, 1953) in both nearshore and offshore locations. The sphericity of grains and size decreased in the offshore direction. Samples from the nearshore zones exhibited relatively high sphericities with the most dominent mineral as quartz and minor amounts of microcline and muscovite. Offshore samples indicated very low sphericity characteristics and were generally of a platy nature evidenced further in their mineralogic composition of predominantly micaceous grains with very minor amounts of quartz and microcline.

Similar observations on the heavy mineral slides showed that low sphericities were characteristic of both the shallow and deeper samples. Grain outlines ranged from very angular to subangular. In the nearshore shallower samples, the predominant minerals were biotite and muscovite (approximately 70%) with minor amounts of dark quartz (approximately 30%). The offshore samples showed little or no quartz.

Conclusions

The sediments of Tasiujaq Cove owe their origin primarily to fluvial agencies with subsequent dispersal brought about by means of marine currents and ice-rafting/river slush-out mechanisms. This latter process disrupts the normal marine sedimentary sequence and produces several anomalous occurrences of coarse sediments forming an admixture with finer sediments in hydrodynamically quiet areas of sedimentation.

This study has demonstrated the following conclusions: (i) A relationship between mean grain size and decreasing current competency is shown. Mean sizes decrease in the direction of transport as the river inflow loses momentum. Within the study area, sandy gravels and gravelly sands are associated with the sandur, channel and beach deposits; marine samples are predominantly silty sands or sandy silts with some gravel. Anomalous sediment distributions are superimposed on hydraulically deposited sediments through ice-rafting and river slush-out processes. (ii) Standard deviation of the sediments decreases in the direction of sediment transport indicating improved sorting. All samples exhibit poor sorting which reflects the ineffectiveness of sorting processes within this environment. Intermittent streams, low energy beaches, and a combination of ice/water transport agencies in a generally ice-covered marine environment are responsible for the poor sorting characteristics of the sediment. (iii) Skewness appears to be a sensitive indicator of transport direction and current strength. The sandur, channel, and beach samples display negative skewness which is associated with the removal of fine grain sizes in the direction of decreasing current velocity and decreasing grain size. Conversely, the marine samples exhibit a change from negative to positive skewness related to decreasing particle sizes and diminishing current strength. (iv) Heavy mineral distributions tend to decrease rather irregularly in the down-channel and down-sandur directions, but a slight increase is noted in the offshore direction of the marine samples. This distribution in the marine samples may be related to the ice/water combinations of sediment transport. (v) The profile plots effectively show the lateral variations of grain size parameters within the environment. Mean grain size versus water depth indicates that ice transport of detritus is not the most important quantitative source of material in the cove. (vi) Statistical analysis of grain size parameters appears to be a useful tool in differentiating and defining depositional environments, and serves as a useful exercise to show the overlapping of depositional environments. (viii) Strong stratification of the cove waters occurs during the summer runoff period due to the freshwater input into the saline cove waters. This structure is evident from temperature and water quality data reported from the water samples. This stratification will have a significant effect upon the sedimentation of suspended particles within the cove waters. The presence of silica in the surface waters of the cove is evidence of this fact.

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