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PAPER 66-8

SEDIMENTS OF EXETER BAY, BAFFIN ISLAND
DISTRICT OF FRANKLIN

(Report and 13 figures)

Kate Kranck

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1966

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SEDIMENTS OF EXETER BAY, BAFFIN ISLAND DISTRICT OF FRANKLIN

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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

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ABSTRACT

This report presents the results of the first marine geological work to be carried out along the eastern coast of Baffin Island. Samples were collected from an area extending from about 2 miles offshore to a few miles beyond the Continental Shelf. More than 100 bottom samples were collected using a sample pattern with an average distance between stations of one mile.

One of the marked features of sediment distribution in the area is the widespread deposit of coarse gravel present on both the Continental Shelf and slope. Rock types present include those of both local and foreign derivation. The study indicates that in the development of the sedimentary characteristics of the area current transportation is the most active process in inshore regions whereas ice rafting predominates on the offshore shelf and slope.

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INTRODUCTION

This report is an account of a sedimentological study of bottom sediment samples from Exeter Bay, Baffin Island (Figure 1) and the adjacent continental shelf and slope. The purpose of the present study was to obtain petrological information on the sediments in the area and the processes controlling their distribution. Trask (1932) and Boeggild (1900) studied bottom samples from central and western Davis Strait but no previous marine geological work has been done along the eastern coast of Baffin Island. The area sampled extends from about two miles off the mouth of Exeter Bay, across the continental shelf, to a few miles beyond the edge of the continental slope (Figure 2). Bottom samples were obtained using a grab sampler and a sampling pattern with an average distance between stations of about one mile was established. Sieve analyses were done on the samples and mineralogical studies performed of the gravel fraction and the heavy mineral fraction of the sand. Illustrations have been drawn to show the physical environment and the distribution and composition of the sediments. Conclusions were reached regarding the sediments and the sedimentological agents active in the area.

Samples for this study were collected by the Canadian Hydrographic Service in 1959. The writer wishes to thank B. R. Pelletier for assistance and advice and D. H. Loring of the Fisheries Research Board for X-ray diffraction analysis. Assistance in laboratory separation and analysis was given by E. Field and G. Duncan.

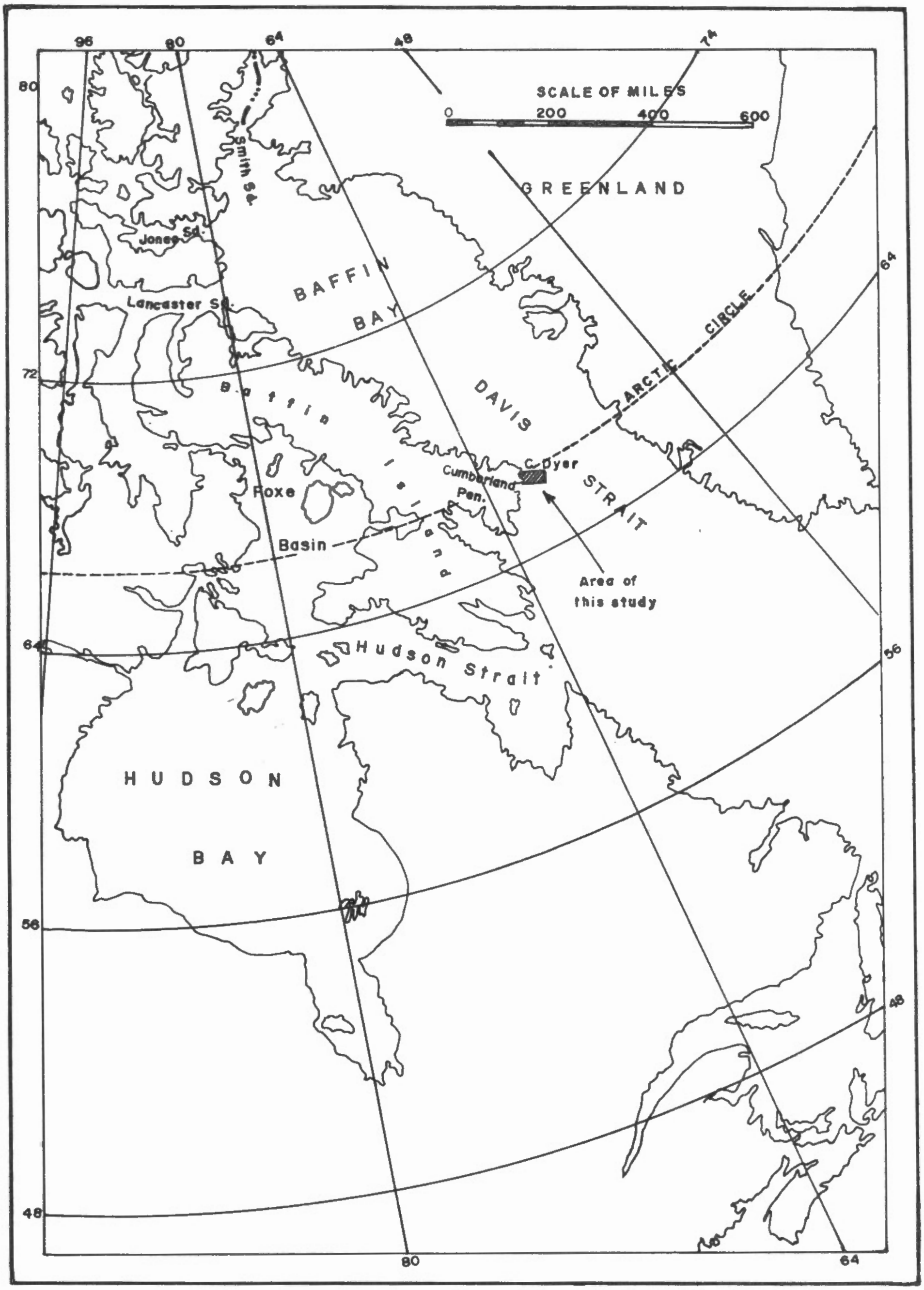

Figure 1. Index map, showing location of study area.

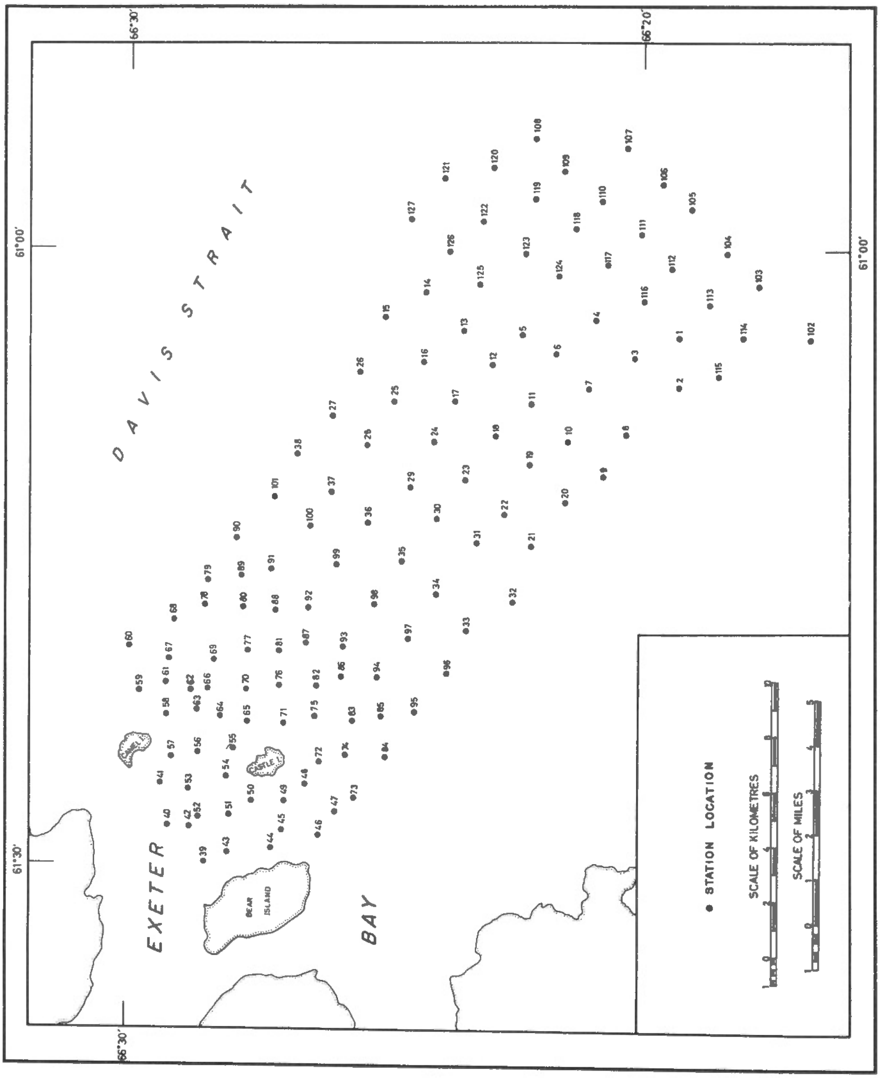

Figure 2. Locations of sample stations.

PHYSICAL ENVIRONMENT

Geography

Exeter Bay is located on the western side of Davis Strait, five miles south of Cape Dyer. The inner part of the bay is divided into two fiord-like branches, a south arm and a north arm, extending ten and seventeen miles inland, respectively. The surrounding country is part of the East Coast Mountain Belt extending the length of Baffin Island and in this area, reaches an elevation of 7,000 feet. Three islands with elevations up to 1,200 feet are situated in the entrance to the northern branch of Exeter Bay.

Regional Geology

Cumberland Peninsula lies within the Baffin-Ellesmere Belt of Precambrian rocks (Fortier, 1957). The geology of the region around Exeter Bay is unmapped, however, an impression of the geology can be obtained by inference from the results of workers in other parts of Cumberland Peninsula. Southwest of Exeter Bay, Riley (1960) mapped a series of intrusive rocks (granites, charnockites) and metamorphic rocks of various types (granulites, amphibolites and granitic gneisses) occurring in northeastward-trending bands from near the head of Cumberland Peninsula, southward. Kidd (1954), working in the Padloping area northwest of Exeter Bay found that the Precambrian rocks of the north-central part of Cumberland Peninsula were similar (granites, amphibolites, granitic and paragneisses) to those found by

Riley. It is therefore likely that the land around Exeter Bay is underlain by the same Precambrian rock types as those found to the northeast and southwest. Kidd also found a belt of volcanic rocks (red and grey plateau basalt) inter-bedded with tuff, sandstones and shale of suspected Mesozoic age in the Padloping-Cape Searle region. These rocks extend inland some five miles and are assumed to run parallel to the coast as far south as Cape Dyer. There is therefore a possibility that the bay is bordered on the north by volcanic rocks.

Bottom Topography

The east coast of Baffin Bay is characterized by a fairly narrow continental shelf averaging about 40 miles (25 km.) in width beyond which a sharp break in slope occurs approximately at the 160 metre contour. At Davis Strait the outer edge of the shelf curves sharply around the eastern part of Cumberland Peninsula, and Cape Dyer extends nearly to its edge. Off Exeter Bay the shelf again widens, with the continental slope situated 40 miles (25 km.) from shore. The upper part of the slope, between the 160 metre contour and the 300 metre contour, is steep but becomes more gentle below this.

The near shore part of the sampling area, which lies inside the 100 metre contour, is characterized by an irregular, hummocky topography similar to that produced by glaciation. The largest of the depressions, an irregularly shaped hole 200 metres deep, lies just east of Camel Island (Figure 3). Immediately seaward of this depression is a topographic feature which rises from a depth of 82 metres to 44 metres. The bottom of the bay has a steep seaward gradient rising rapidly from 25 metres to 45 metres in a distance of 1,480 feet (450 metres) to 1,650 feet (500 metres) from the mainland.

Most of the shelf and slope has a smooth, regular gradient. A sharp seaward bend in the trend of the contour lines occurs along the continental slope (Figure 3). The axis of this deflection is diagonal to the dip of the slope and appears to coincide with the boundary of a zone where the bottom is reported as bedrock. This feature is interpreted as a rock ledge on the continental slope.

Tides and Currents

The mean range of tides in the northern branch of Exeter Bay is 1½ metres and maximum spring range 2½ metres. The northern branch forms a restricted body of water with tidal currents, ranging from 54 to 103 cm/sec (2-3 knots), flowing through the mouth (Pilot of Arctic Canada, 1961). A difference of 1 knot exists between the ebb and flood current in the north arm and is probably due to fresh water runoff from the surrounding area. The outer part of the bay is affected by a counter eddy of the strong Canadian

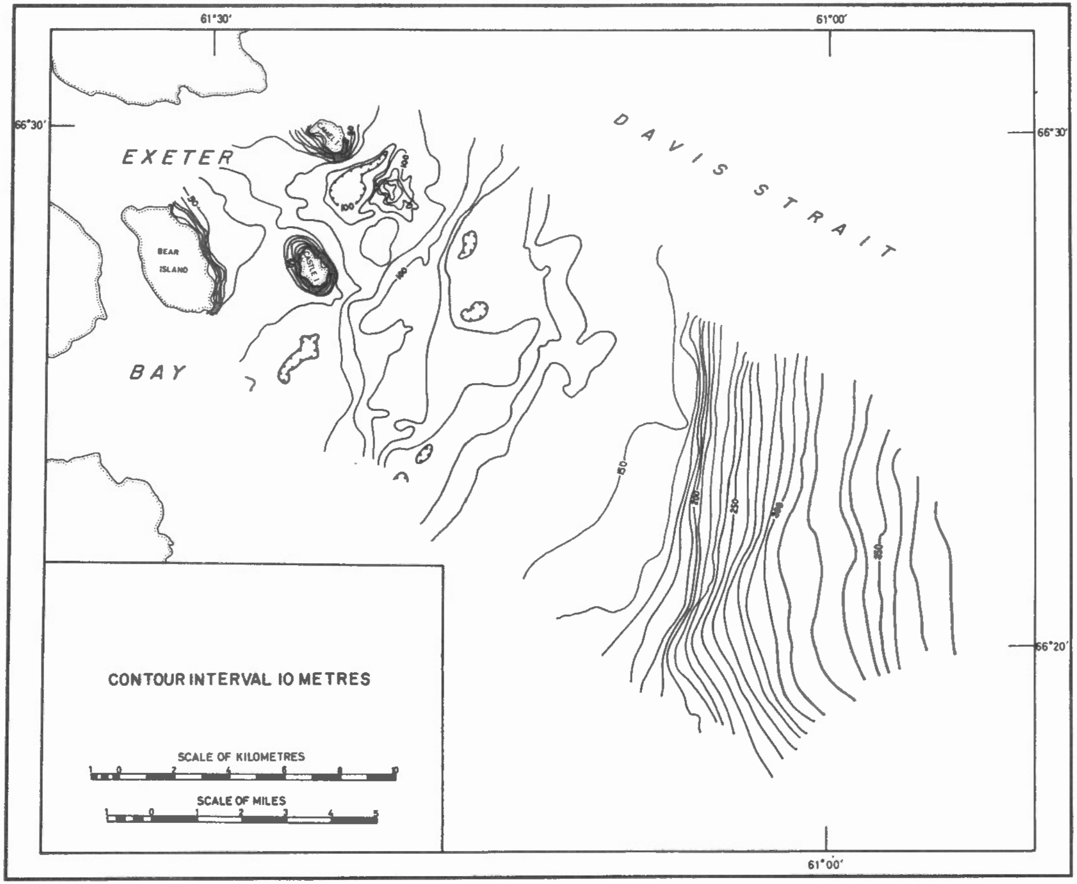

Figure 3. Submarine topography of Exeter Bay area, showing sharp increase of gradient at edge of continental shelf.

Current which flows past the bay. Icebergs that enter this area are deflected from their regular southward course and drift among the islands. However the pattern of a regular clockwise circulating eddy (Figure 4) is probably over-simplified. The strong tidal currents from the inner arms of Exeter Bay would have some effect on the circulation in the outer parts of the bay. Currents up to 100 cm/sec (2 knots) have been measured between the islands in the bay (D. Charles, Canadian Hydrographic Service, personal communication).

The shelf and slope of Exeter Bay is affected by the general pattern of current circulation in Davis Strait and Baffin Bay. Along the eastern shore of these waters, parallel to the coast of Greenland, the West Greenland Current flows northward. At the northern end of Baffin Bay the drift turns westward and then southwest to join the stronger Canadian Current flowing south along the coast of Baffin Island. The Canadian Current is made up of polar waters from Lancaster, Jones and Smith Sounds (Figure 1), and forms the western half of the anti-clockwise, cyclonic circulation of Baffin Bay and Davis Strait. The Canadian Current flows past Cape Dyer and over the continental shelf outside Exeter Bay at 14 - 16 cm/sec (.27 knots) (Pilot of Arctic Canada, 1961).

During the period of sampling, observations were made of icebergs carried by the current past the sampling area

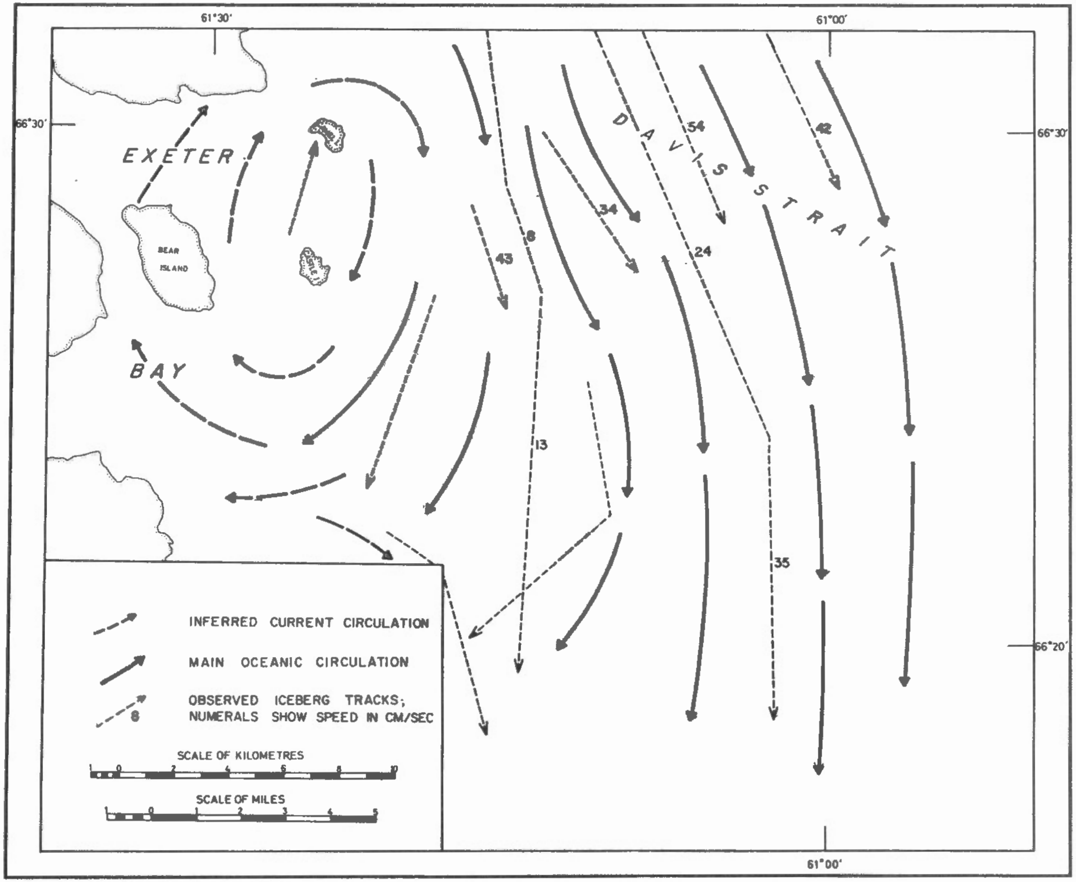

Figure 4. Water circulation patterns at Exeter Bay. (Compilation of data from Hydrographic Survey of Canada).

(Figure 4). An estimate of the drift of the icebergs, and hence of current velocity, was made by taking intermittent fixes on the bergs. Six bergs crossed the sampling area, with velocities ranging between 10 cm/sec (.19 knots) and 66 cm/sec (1.30 knots) and averaging 35 cm/sec (.7 knots). This corresponds with the reported velocity of the Canadian Current.

Ice Conditions

Ice conditions in the study area are largely a result of the nearness of the area to Cape Dyer, the easternmost point on the western side of Davis Strait. Due to the anticyclonic circulation pattern in Baffin Bay, all the icebergs from the bay pass through or close to the sample area. This includes ice brought from Lancaster, Jones, and Smith Sounds, which drain the central parts of the Canadian Archipelago. The sea in the study area is 70 per cent ice-covered during seven to eight months of the year (Pilot of Arctic Canada, 1961). This Arctic ice is kept in constant motion by currents, and consists of medium to giant floes and blocks.

Along with sea ice, abundant icebergs, bergy bits and growlers enter the area. The main stream of icebergs from the glaciers of west Greenland as well as a lesser amount from the smaller glaciers on the Canadian side pass over the study area (Schell, 1952). During the 7-day sampling period, 27 icebergs entered the area from the north and passed through to the south. Only those bergs which drifted inside the 150-metre contour line become stranded in the approaches to Exeter Bay.

SEDIMENT DISTRIBUTION

The bottom samples from Exeter Bay were collected using a grab sampler. A phleger corer was tried whenever the grabber indicated soft bottom but failed to recover any cores. From 127 stations, 110 samples were recovered and stored in plastic core-liner tubes with rubber corks. Grain-size measurements were made by means of conventional dry-sieving methods. Before the size analyses were made the light mineral fraction of the sand in the samples was treated with a .5N hydrochloric acid to remove calcareous shell fragments. Statistical parameters based on quartile measures (Krumbein and Pettijohn, 1938) were calculated for the samples containing sand. As a few pebbles can greatly alter the values of grain size statistics for sandy sediments and obscure the distribution patterns, the gravel content was not included in the calculations.

For the purpose of discussion of bottom sediments, the sample area may be divided into two sections, an inner nearshore area and an outer shelf and slope. The sediments covering each of these sections differ widely in character in that the nearshore area is covered mainly by sand, while the shelf and slope is covered chiefly by coarse gravel. The distribution of sediment in the sample area is illustrated in Figure 5.

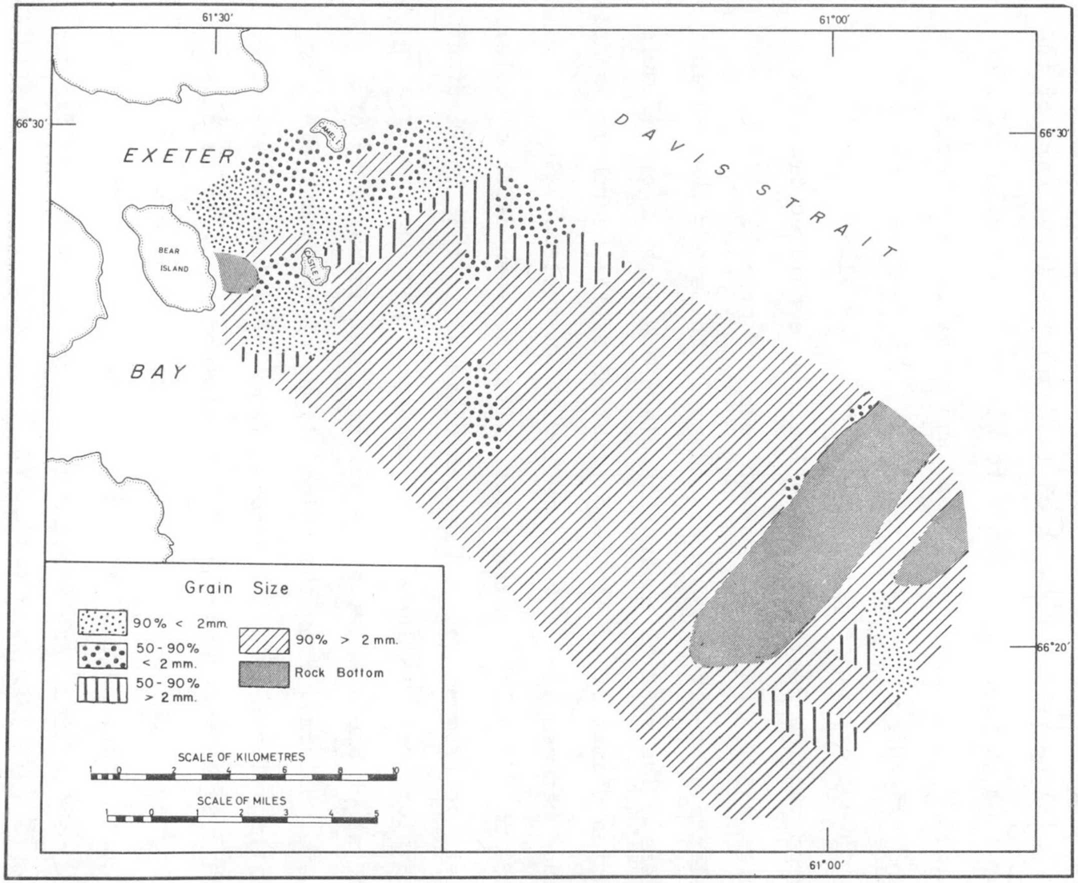

Figure 5. Sediment distribution, showing widespread gravel deposit over continental shelf and sandy deposits near bay mouths.

Nearshore Sediments

The nearshore area which includes the inner part of the bay from between the islands to within 6 to 7 miles of the mainland, contains mostly sand and gravel. Sand occurs in a band extending from near the mouth of Exeter Bay across the northwest corner of the sample area. A smaller sand zone is found outside Bear and Castle Islands, separated from the large sandy area by a ridge of rock and gravel. Off the islands gravelly sand occurs commonly bordering the gravelly areas. The sand is dominantly clean and light brown (Figure 5). Median diameters of the sand fraction of the nearshore samples range between .136 and .69 mm., with an average value of .269 mm. A slight correlation exists between depth of water, distance from shore, and median diameter in that the median diameters are smallest in the innermost part of the area and in the channels between the islands, but increase towards deeper waters. From the calculations of the coefficient of sorting (Trask, 1932) a general range of values between 1.09 and 2.38 with an average of 1.40 was obtained. This showed the sand to be consistently well sorted. No apparent regular distribution pattern is formed by the sorting values and median diameter, showing that a complex range of factors govern the sediment distribution.

In the nearshore region gravel is found east of Camel Island and southeast of Bear Island as well as between Castle and Camel Islands (Figure 5). It is notable that, seaward of all three islands, on the side away from the mouth of the north arm, gravel is found. The gravel occurs both as irregular areas of clean gravel and as a secondary mode in the sandy samples. The gravel found in the sandy samples is mostly fine, with grain sizes up to 8 mm. This type contrasts sharply with the material in the areas of clean gravel, which includes abundant coarse gravel and generally has a median diameter above 8 mm.

Continental Shelf and Slope Sediments

The continental shelf and slope is covered by a widespread deposit of coarse gravel, one of the marked features of the sediment distribution in the area. Areas of gravel extend over 15 miles seaward and covers practically all the shelf and slope in the sample area (Figure 5). The samples recovered were usually small and consisted of a dozen or so pebbles with median diameters larger than 16 mm. This sediment type is somewhat similar to the coarse gravel found in the nearshore area. Minor amounts of sand are contained in the gravel samples and in a few places small areas of sand and gravelly sand occur. Two such areas lie in the centre of the shelf, and north of these a larger, more continuous area occurs which appears to be an extension of the sandier nearshore sediments. Some sand is also found on the continental slope.

The stations from two areas on the continental slope were reported as rock bottom during the sampling and are interpreted as exposed bedrock (Figure 5). The areas, the larger of which measure about two by six miles are linear in shape and trend diagonally across the depth contours. On the shoreward side of the innermost outcrop the contour lines bend parallel to the boundary indicating that the bedrock occurs as a ledge on the slope.

GRAVEL COMPOSITION

A special study was made of the petrological character of the gravel fraction of the samples. The composition of the gravel was determined by means of petrographic analysis of thin section of selected pebbles. Nine rock-type classes were established into which the particles greater than 2 mm. were grouped. These classes were: miscellaneous granite and granite gneiss, sillimanite schist, hornblende schist, miscellaneous basic rock, charnockite, quartzite, basalt, carbonate and sandstone. The gravel composition of each sample is listed in Table 2 of the Appendix. In Figure 6, which illustrates the gravel composition, associated types have been grouped together to form six major types. Each of the distinctive rock-types is discussed below.

Granite and gneiss includes the wide variety of granite and granite gneiss of the type common in the Canadian Shield. These rocks are difficult to distinguish without the aid of a thin section, and have therefore been grouped under one heading. They are not subject to any further interpretation or discussion.

Sillimanite schist occur as fine to medium grained, light grey rocks with a slight greasy lustre. Examination under the petrographic microscope shows the sillimanite pebbles consist of a matted network of subparallel fine needles, altering to biotite and commonly enclosed in a

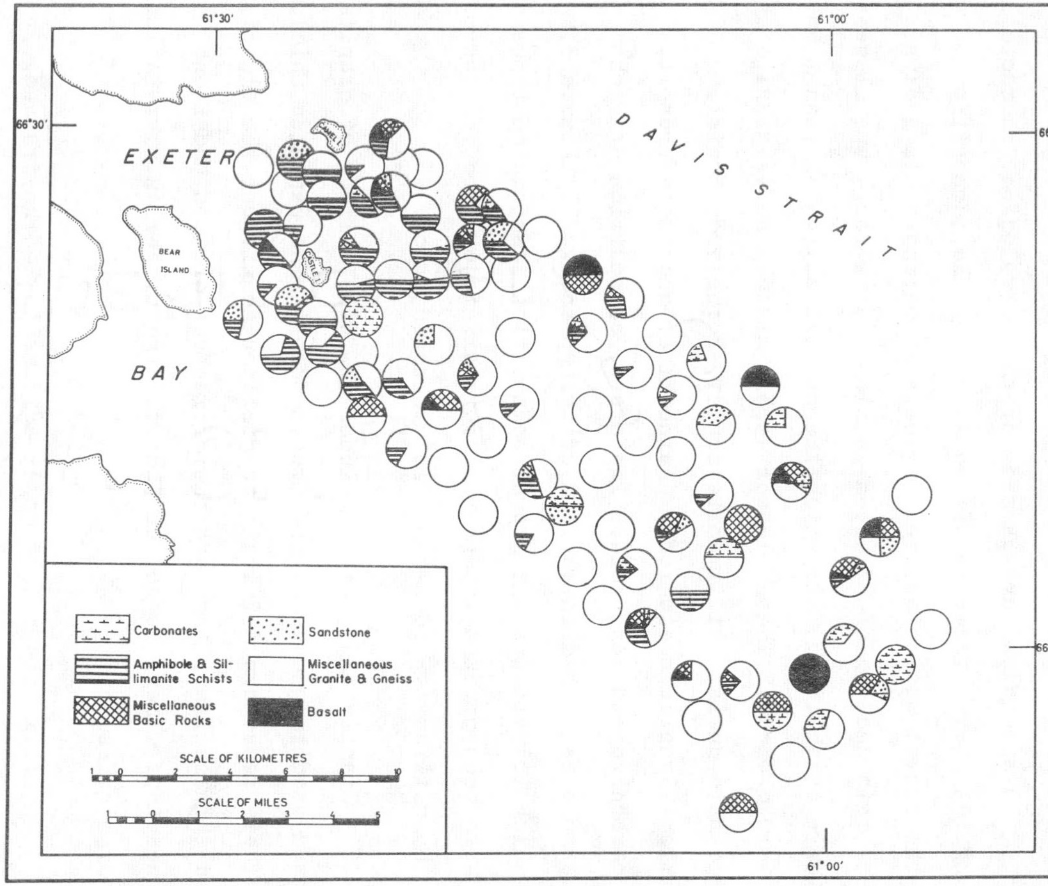

Figure 6. Composition of gravel-size sediment, showing increase in carbonate rock abundance in area of maximum iceberg occurrence.

groundmass of quartz and plagioclase. Accessory minerals are staurolite, zircon, apatite and opaque minerals. Except for the granite and granite gneiss, sillimanite schist is the most common rock-type in the area, making up 17.9 percent of the gravel fraction. It is concentrated in the shallow-water samples and, together with biotite schist, is the dominant rock found in the nearshore region. Seaward across the shelf, relative abundances decrease and on the continental slope practically no sillimanite is found. This distribution is evidence of a local source for the sillimanite-bearing rocks and probably the land around the mouth of Exeter Bay supplies most or all of the sillimanite schist found in the area.

Amphibolite schist occurs most commonly as medium to fine-grained hornblende schist with quartz and plagioclase inter-banded with elongated, subparallel hornblende crystals. Less common is actinolite schist. Chlorite occurs abundantly in some specimens, usually replacing the amphibolite. The amphibolite schist has a distribution pattern similar to that of sillimanite, and in Figure 6 the two types have been combined as one group. These two types are abundant near shore and decrease in abundance seaward. However, small amounts of hornblende schist is found on the outer part of the shelf and slope and its source area is not limited locally.

Miscellaneous basic rock includes, coarse to medium-grained rocks consisting mostly of gabbro. Thin sections show that a great variety of gabbroic rocks occur in the area. The most common of these is olivine gabbro, a rock in which olivine phenocrysts are contained in a groundmass of plagioclase and pyroxene. The miscellaneous basic rocks constitute 1.5 percent of the gravel fraction, and is spread over the whole area with a slight concentration in the central and outer section. A likely source for these rocks is the gabbroic dykes associated with the volcanic rocks of Cape Dyer (Kidd, 1953).

Charnockite consists of a collection of fine-grained, dark greenish grey, hypersthene granites found in the Exeter Bay samples. This unusual rock type makes up as much as 6.3 percent of the gravel in the samples. Both Kidd (1953) and Riley (1960) reported similar rocks from other parts of Cumberland Peninsula, and the charnockites of Exeter Bay may be derived from these or associated outcrops. In Figure 6 charnockites have been grouped with the miscellaneous basic rocks, which have a very similar distribution.

Quartzite is a light-coloured, coarse-grained meta-quartzite and makes up 3.5 percent of the gravel-sized rock fragments. In thin section the quartz exhibits undulose extinction and sutured grain boundaries. Metaquartzites have been reported from many places along the Baffin coast (Riley, 1960, Kidd, 1953), and no particular conclusion on the quartzite pebbles in the study area can be made with respect to its source area. In Figure 6 quartzite has been mapped with the miscellaneous granites and gneisses.

Basalt form 2.7 percent of the pebbles of the area. It is dark-coloured, generally weathered, usually amygdaloidal or porphyritic, and contains either olivine phenocrysts or amygdules filled with chalcedony or calcite, in a groundmass of pyroxenes or plagioclase. As in the case of the miscellaneous basic rocks, they are most common in the deep-water samples on the continental shelf and slope. However, they appear to show a variation in a northeast-southwest direction across the sample area, with a greater concentration on the northeast side of the bay. Basalts and volcanic rocks occurring north of the bay, around Cape Dyer, probably represent the source of the basalt in the bottom samples.

Carbonate makes up 4.1 percent of the total gravel content. X-ray diffraction and thin section studies showed these to consist of both sedimentary limestone and dolomite in a variety of textures. The carbonates are almost exclusively concentrated in the deeper part of the sample area (Figure 6). Only a small amount of carbonate rock is found in the nearshore region, but it is one of the dominant rock-types on the slope. The origin of carbonate pebbles is difficult to explain as no outcrops of sedimentary limestones occur anywhere near the sample area. Trask (1932), in his study of bottom sediments from Davis Strait and the Labrador Sea, also found a seemingly inexplicably high carbonate gravel content. In a search of the literature on the Baffin Bay and Davis Strait coast, he did not find any likely source for the carbonates. To the writer's knowledge no more recent discovery of limestone has been made in this area. This leaves the coast of the sounds leading into northern Baffin Bay, and the region around Foxe Basin as the closest limestone region. The former lies 600 miles up-current (i.e., the Canadian Current) from the sample area and the latter is found 250 miles away, across the height of Baffin Island.

Sandstone makes up 3.1 percent of the pebble fraction and is evenly distributed over the area. The sand grains forming the sandstone vary greatly in grain size and composition and, therefore, is probably not all derived from the same source. Beds of semi-consolidated sandstone associated with the volcanic rocks mentioned above are reported by Kidd (1953) near Padloping Islands and Durban Harbour. However most of the pebbles in the samples are well cemented hard sandstones. Furthermore, it is doubtful that semi-consolidated rocks would have been able to survive the transport into the area. It appears more likely that the sandstones in Exeter Bay are derived from a foreign source similar to that of the limestones.

From the above description and discussion, certain general observations can be made concerning the gravel material in Exeter Bay. The petrological composition is heterogeneous and includes a large variety of unrelated rock types. Pebbles with genetic origins as varied as that of sedimentary limestones, basalt and granite occur. This variation shows the material to have been derived from a mixed source. Some of the rock types such as limestone and sandstone are not known to occur locally and must have been transported a great distance to the sample area. The provenance of others like amphibole and sillimanite schist is believed to be local, probably the shores of Exeter Bay itself. Within the sample area is found a definite distribution or zoning of local and foreign derived material. Local rock types are found most abundantly in the nearshore area and are scarce on the continental shelf and slope, while the offshore area is characterized by rocks believed to have been brought to the area from some distant source.

HEAVY MINERALS

The heavy minerals of the sand fraction were studied to obtain evidence on the petrological origin and geographical source of the sandy material. For each sample containing sufficient sand to give a representative sample, two separations were made by means of bromoform (S.G.-2.89); one on the grains less than 2 mm. in diameter, and one on the .125 mm. to .250 mm. fraction. Detailed results of the heavy mineral separations are listed in Table 3 of the Appendix. The average heavy mineral content of the sand fraction is 15.25 percent by weight and that of the .125 fraction is 15.57 percent.

Heavy minerals in the .125 - .250 mm. fraction were identified optically and verified by means of X-ray spectrography. In Table 3 of the Appendix, the heavy mineral composition of each sample is listed and the geographical distribution of the principal heavy minerals is shown (Figures 7 to 11). The dominant heavy minerals found in the samples are hornblende, sillimanite, garnet, chlorite, pyroxenes and olivine. Minor minerals were sphene, apatite, kyanite, andalusite, staurolite and iddingsite. These minor species made up less than 25 percent of the heavy minerals and have been grouped together as miscellaneous minerals. The occurrence and probably source of each of the major minerals is discussed below.

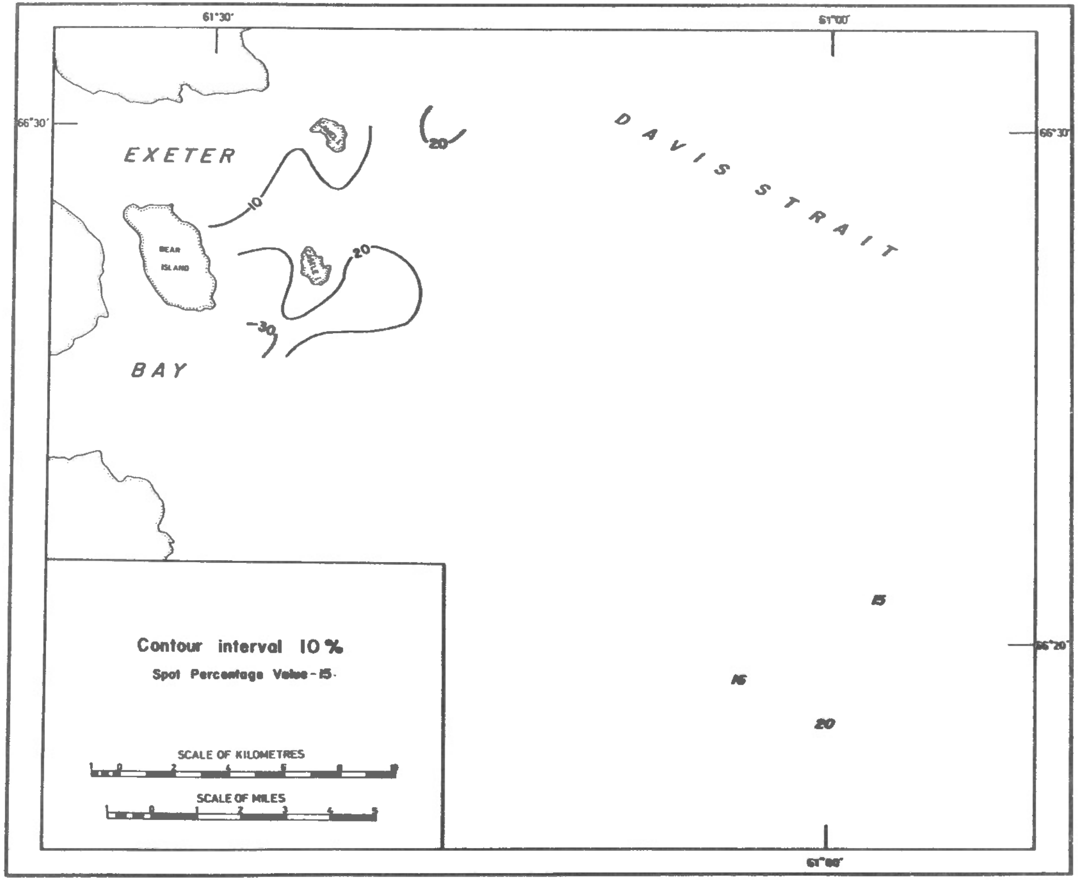

Figure 7. Distribution of sillimanite, showing maximum concentration in mouth of south arm.

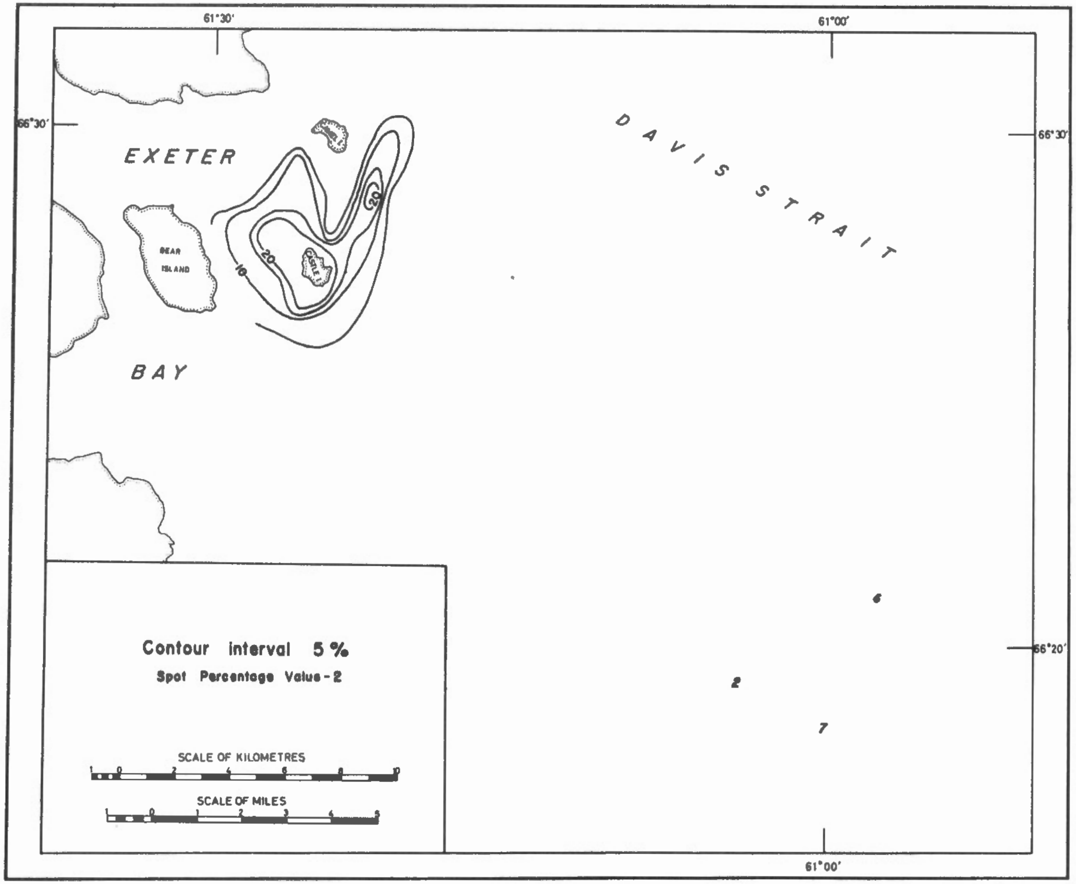

Figure 8. Distribution of garnet, showing concentration around Castle Island.

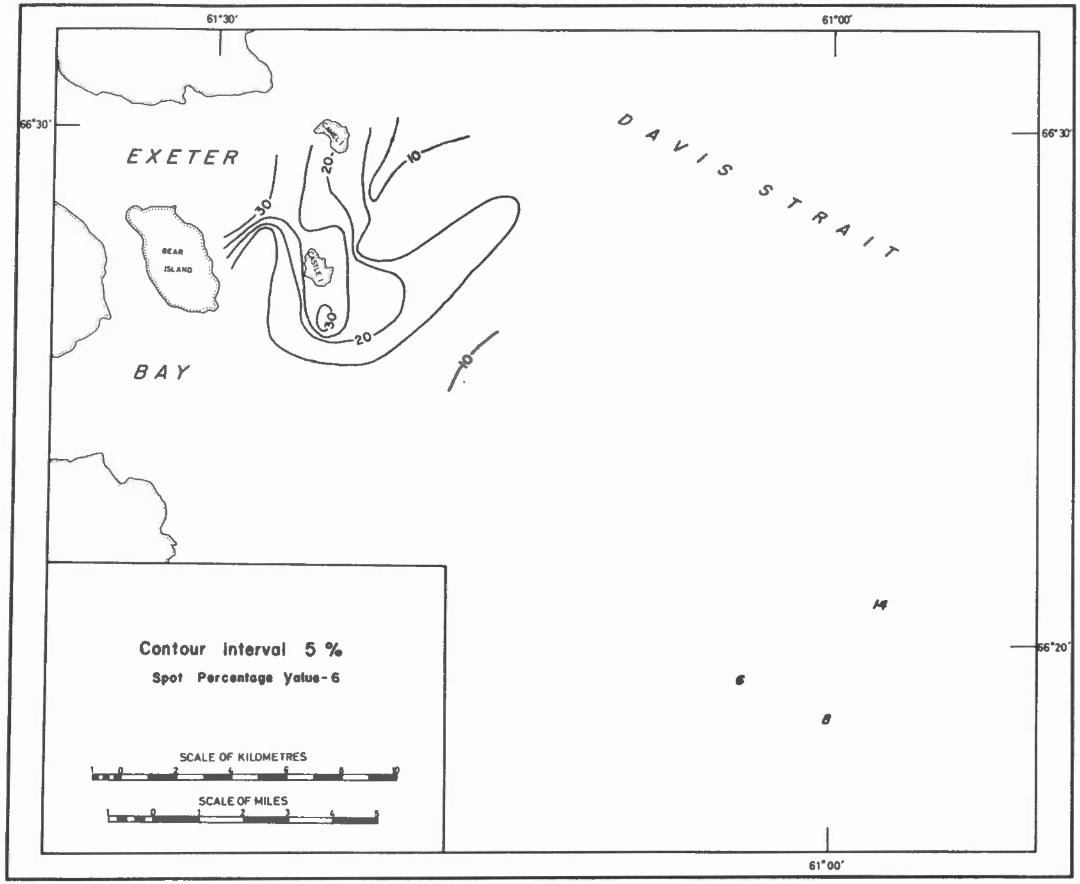

Figure 9. Distribution of amphibole, showing increase in direction of north arm.

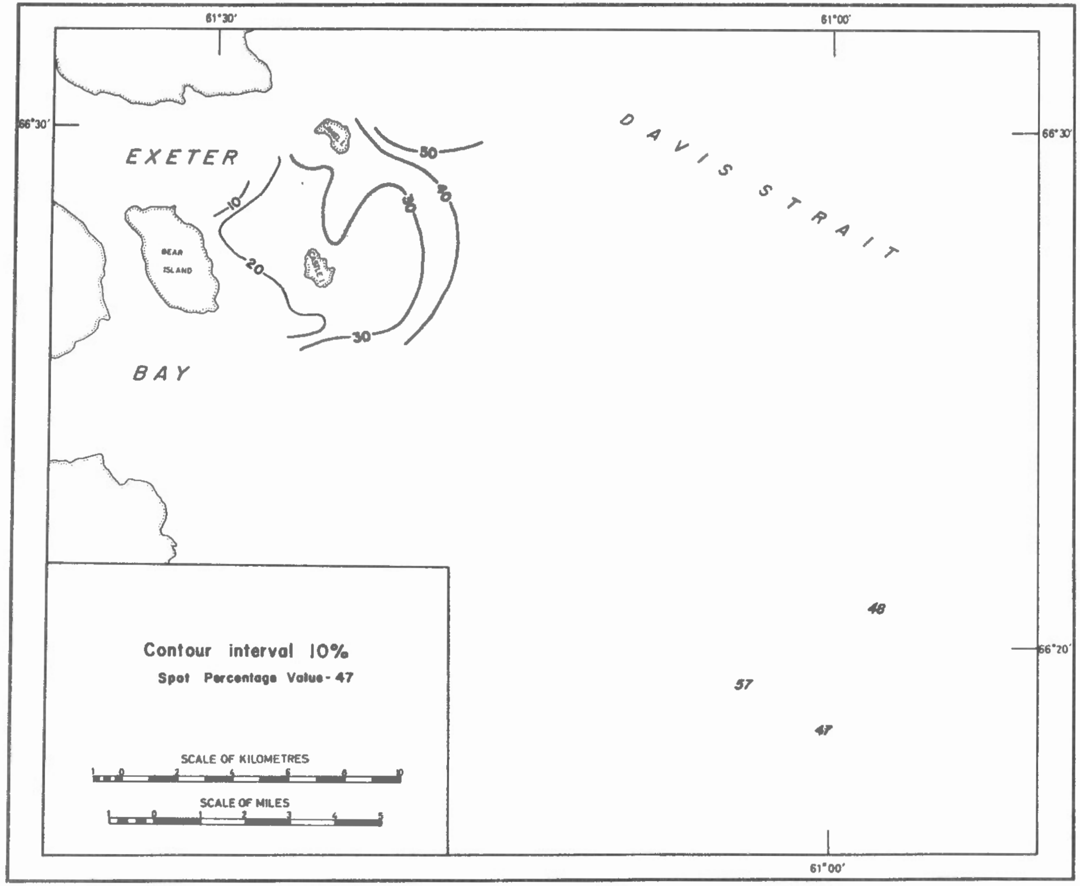

Figure 10. Pyroxene-olivine distribution, showing increase away from study area.

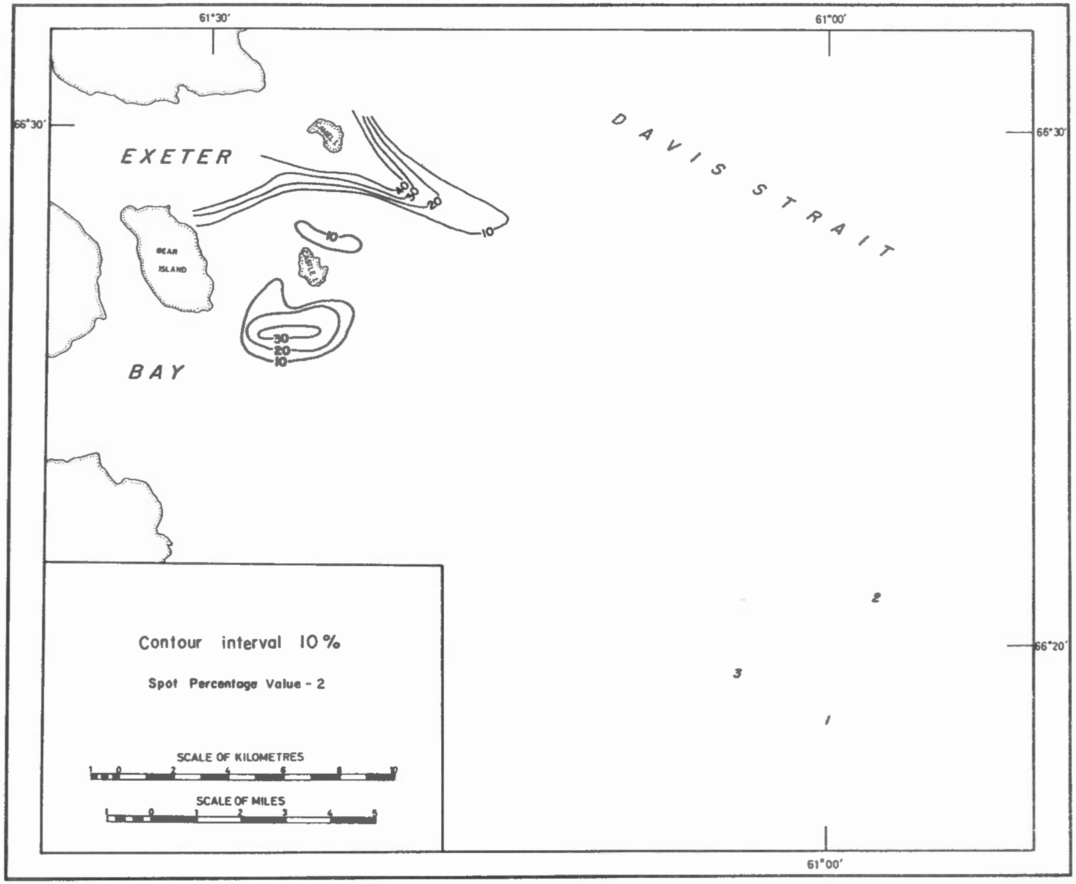

Figure 11. Distribution of mica, showing concentrations in areas of rapid decrease in tidal current.

The most abundant heavy mineral group in the sample area is the pyroxene-olivine group making up between 8.3 and 57.1 percent of the heavy fraction. Several distinct mineral types were included in this group. Because these minerals are related, except for epidote which is a minor constituent and indicative of the same general geological environment, no attempt was made to separate them, also the optical characteristics of these minerals are similar and difficult to distinguish by optical means. The minerals are all colourless, light green or light yellow, stubby grains with high relief and high birefringence. Included in this group are olivine, diopside, augite and minor epidote. A reddish brown, pleochroic hornblende, is also included in this group because of its genetic relation to the other minerals.

The percentage distribution of pyroxene-olivine is illustrated in Figure 10. The significant feature of this distribution is the concentration of high pyroxene-olivine values in the northeastern part of the sample area and on the shelf and slope, with a systematic decrease towards the western and inner part of the area. Samples northeast of Camel Island contain over 50 percent of pyroxene-olivine contrasting sharply with values of 10 to 30 percent found in the southern and central part of the area. This distribution pattern together with the fresh unweathered angular appearance of the grains point to a nearby source of basic or ultrabasic rock north and northeast of the sample area. The material could be derived from basic dykes common in rocks of the Canadian Shield and reported by Kidd (1953) and Riley (1953) in Cumberland Peninsula. However, a likelier source is the basic volcanic rock exposed between Cape Dyer and Cape Searle. Although it is not known if these volcanic rocks extend as far inland as the shore adjacent to the sample area, it can be assumed that streams entering Exeter Bay from the northwest drain land underlain by basic volcanic rocks and carry volcanic material into the bay. Glacial deposits along the north shore are also likely to contain significant amounts of volcanic material and to supply pyroxene-olivine bearing detritus to the adjacent water. The high values (47 to 57 percent) of pyroxene-olivine on the continental shelf and slope are probably a mixture of material carried seaward from the inshore area by the currents and material brought directly from the volcanic rocks around Cape Dyer by ice rafting and currents.

Sillimanite forms the next most abundant heavy mineral in the sample area, constituting between 6.0 and 37.9 percent of the heavy mineral fraction. The sillimanite grains are easily identified, occurring as semi-rounded grains with an internal structure consisting of matted masses of tiny hair-like crystals with subparallel orientation. Similar material was observed in thin sections of rock-fragments from the gravel fraction of the samples. The highest sillimanite values (37.9 percent) are found at the southern edge of the sample area while the rest of the area shows an increase of sillimanite from the shore seaward. The high values in the south point to an abundant source of sillimanite in this direction, probably from the south arm of Exeter Bay. The general decrease of sillimanite from the shore outward in the rest of the area is probably the result of dilution by other heavy mineral species coming from the north arm. The slightly higher rounding of the sillimanite grains compared to the other heavy mineral species in the area is probably the result of greater softness of the compound sillimanite grains, rather than greater exposure to abrasion as a result of longer transport. Judging from the abundance of this fairly rare mineral, much of the region of the sample area is underlain by sillimanite-bearing rocks.

The third most abundant heavy mineral species in Exeter Bay is amphibole forming 5.6 to 34.4 percent of the heavy minerals. Amphibole occurs as dark green to light green pleochroic hornblende, brown to dark brown pleochroic hornblende, and light green to colourless actinolite. Most of the grains are poorly rounded, prismatic, or irregular and cannot have been transported far. Hornblende schists and other pebbles containing amphibole occur abundantly in the gravel fraction as further evidence for a near source of hornblende. The highest content of amphibole is 30 - 34 percent and occurs in the inner part of the bay. From here a zone of high amphibole values extends seaward with lower values on either side. From this distribution it can be concluded that the amphibole either originates on the north shore of Exeter Bay or is being transported by currents out of the north arm itself. The high values around Castle Island can be due either to hornblende rich material being carried here by currents from the north arm or to a source of hornblende on the island itself.

Garnet comprises 0 to 25.1 percent of the heavy minerals in the samples. Most of the garnet occurs as clear pink grains which have been identified by means of X-ray diffraction as almandite. A few grains of a colourless garnet-like mineral, possibly spinel, were also observed. The garnet grains are clear and angular and do not appear to have been subjected to much abrasion. From this may be concluded that the garnet has not been transported far but originates from a fairly local source. Rocks from which the garnet may have been derived are plentiful within the area. Among the gravel fraction of the Exeter Bay samples, garnet bearing schists and gneisses occur abundantly and Kidd (1953) reported garnet-bearing rocks from the inner parts of Cumberland Peninsula. The highest garnet values (25.1 percent) are found concentrated around Castle Island (Figure 7) and it is likely this island is the major source of garnet-rich material. Around the borders of the sample area, low percentages of garnet (less than 5 percent) are probably partly due to dilution by other heavy minerals transported from the mainland.

Green and brown biotite and colourless muscovite were grouped together as mica, and make up between 1.6 and 48.3 percent of the heavy minerals. Mica has not been included in the totals used for the calculations of the other heavy minerals because its tabular shape causes it to behave differently in an aqueous media from the other more equi-dimensional grains. Very high mica concentrations (over 40 percent) occur near the innermost part of the bay with an abrupt decrease to less than 10 percent in the more open waters. The exact cause of this distribution is not known but it appears that a sudden decrease in velocity of the tidal currents from the north arm on entering more open waters causes the mica flakes to be dropped.

The heavy mineral distribution in Exeter Bay is summarized in Figure 12. Four zones, each dominated by a particular mineral, are outlined. Where it appeared that distribution of one mineral masks the distribution of another, ratios based on their percentages were used to adjust the boundaries between the two minerals. For example, low percentages of sillimanite occurring around Castle Island (Sample 48) are believed due to the dilution effect by garnet derived from the island. From the distribution of the zones, it appears that the major heavy mineral species are derived from different sources. Because of the

Figure 12. Distribution of major heavy minerals.

lack of information on the local geology, only general source directions for the heavy minerals can be suggested. High pyroxene values, believed due to the volcanic rock found north of the area, dominate the northeastern edge of the area and continue out towards the slope. The south arm seems to be the source of sillimanite concentrated in the southwestern part of the sample area, and a strong hornblende source lies inside or around the mouth of the north arm of Exeter Bay. Garnet, the only mineral of which the highest concentrations occur in the centre of the sample area, appears to be mainly locally derived from Castle Island.

The heavy mineral grains in Exeter Bay are characterized by sharp angular corners and jagged edges, thus testifying to a lack of long distance transport. Also characteristic for the sediments in Exeter Bay is the lack of maturity of the heavy mineral suite. The heavy mineral fraction contains high percentages of unstable minerals such as pyroxene, hornblende and sillimanite, and very small amounts of the more resistant species such as zircon, tourmaline, and apatite. The heavy mineral percentages of the samples (average 15.25 for total sand fraction) are considerably higher than normal for sandy material. This textural and compositional immaturity is due to the lack of long distance transport as well as the provenance and type of weathering that produce the material. This may be explained as follows; because of the low temperature and precipitation, chemical weathering is almost nonexistent in the Arctic, and mechanical weathering supplies material equivalent in composition to the parent rock. The only factor which might modify the mineralogical composition of the sediment is selective abrasion causing a decrease in the less resistant minerals. In Exeter Bay this factor would be negligible due to the short transport to which the minerals have been subjected. Also abrasion would tend to decrease rather than increase the heavy minerals present in the sediment. Therefore, the mineralogical composition of the source rock has been most significant in controlling the percentage of heavy minerals in the samples. The schists, gneisses, and basic volcanic rocks surrounding Exeter Bay contain abundant minerals such as pyroxene, amphiboles, garnet, and sillimanite and can therefore be expected to supply high heavy mineral concentrations.

SEDIMENTARY PROVINCES AND AGENTS OF DEPOSITION

Two principal sedimentological provinces occur within the sample area; one is a nearshore, dominantly sandy area and the other is an offshore region consisting chiefly of gravel (Figure 5). The texture and mineralogical composition of these areas are dissimilar enough to require different sedimentological processes to account for their distribution. To assess the sedimentary agents active within the sample area, the sediments and physical framework of each province is considered below.

The nearshore shallow area consists principally of fine- to medium-grained sand and lesser amounts of gravelly material. The sand has the homogeneous well-sorted character of normal water-transported marine sediments and has probably been deposited by currents flowing through the narrow channels between the mainland and the islands. Currents constantly rework this material and keep any fine particles in suspension as shown by the low sorting coefficient and lack of silt and clay. Mineralogical evidence shows this sand to be mainly locally derived, and probably includes reworked glacier material and recent sediments eroded from land. Some gravel-size material is found in the nearshore area both as clean coarse gravel and as a secondary mode in poorly sorted gravelly sand. The petrological composition of the gravel is fairly homogeneous and consists mostly of rock types of local derivation (Figure 6). The coarse gravel has the unsorted angular appearance of glacial material, probably representing glacial till from which the fine particles have been winnowed out and deposited as part of the pure sand. This gravel as well as the outcrop east of Bear Island forms areas of non-deposition where currents prevent sediments accumulating. The gravelly sand may also be reworked glacial material, occurring in areas of lower current velocities and water turbulence. An example of this is Sample 49 which is an unsorted sandy gravel protected from reworking by virtue of its location in a depression. Some of the gravel however occurs as isolated pebbles in the sand and is better explained in terms of ice rafting from shore.

The offshore area of Exeter Bay is covered by a coarse gravel deposit which extends across the continental shelf and part of the slope (Figure 5). The gravel is dominantly coarse, chiefly with a grain size range of 4 - 32 mm. The individual pebbles are angular with fresh surfaces and sharp edges. Characteristic of this gravel is the large variety of rock types found among the material, thereby differing from the nearshore region which is dominated by locally derived sillimanite and amphibole schist.

The lack of finer material in the offshore area is probably due to the winnowing effect of the Canadian Current flowing across the shelf and slope of Exeter Bay.

Hjulström (1955) showed that a current with the velocity of the Canadian Current (15 cm/sec), can transport material up to 2 mm. in diameter. In the Exeter Bay region sand transported from shore settles in the nearshore area. On the other hand, because of the strong currents, the clay and silt bypass the shelf and slope and are deposited beyond this region. The lack of material on the shelf and slope in the range of coarse sand to fine material may be the result of a combination of factors including scouring by currents. Also, in a mixture of fine and coarse material, the fines may settle between the pebbles resulting in a veneer of coarse gravel over mixed material. This process would be aided by any currents strong enough to rearrange the particles without transporting them. Sampling by a light clamshell-type sampler would not be likely to pierce the top layer of such gravelly sediments. Consequently, the coarse gravel composition of the shelf may only be apparent and need not exclude the existence of finer material underneath.

The sediments of the offshore area of Exeter Bay may, as in the case of the sediments of the nearshore area, be a reworked glacial deposit. Pleistocene glaciers may have completely covered the continental shelf off Baffin Island and deposited a covering of glacial till similar to that found on the continental shelf of Nova Scotia and other glaciated coasts. However, the texture and composition of the gravel in the offshore region are not consistent with a glacial origin of the material. None of the pebbles show striations or faceting, or approach the flat-iron shape characteristic of glacial material (Van Engel, 1930, Wentworth, 1936). Also, a glacial origin of the gravel is difficult to accept in view of the heterogeneous composition and great variation in source area of the gravel. A glacial till can be expected to have a more uniform composition of largely locally derived material, and at least one of the rock types found in the samples is totally foreign to the area. Carbonate is one of the most common rock types found on the outer shelf and slope (Figure 5) but does not outcrop anywhere within 250 miles. It seems unlikely that this carbonate material was transported by glaciers across Baffin Island from the limestone region around Foxe Basin and deposited on the continental shelf, however, the possibility should be considered. Several Scandinavian geologists (for review see Veltheim, 1962) have investigated the composition of glacial drift in relation to source rock, and have found that glacial material is dominantly locally derived with insignificant amounts transported for distances exceeding 5 km. This would apply especially to carbonate rocks known to have a high "obliteration speed" (Lundquist, 1955). Therefore, it does not appear that the gravel on the shelf is of glacial origin.

A second possible origin of the offshore gravel is ice rafting, the process by which sediments are frozen into shore ice, transported by ice-drift, and deposited in the sea by melting and overturning of the ice. Ice rafting has long been recognized as an important sedimentary agent in high latitudes and is reported and discussed by most workers in Arctic marine geology (Kindle, 1924, Trask 1932, Perry 1961, Pelletier, 1962, Leslie, 1963). Because of its geographical location, Exeter Bay is an area in which ice rafting should be significant. During the summer and fall great quantities of sea and berg ice from the north flow over the sample area and much of this ice can be expected to transport sediments. Both the texture and composition of the gravel on the shelf can be thought of as a product of ice rafting.

Little is known about the grain-size composition of the material carried by ice, but from photographs and descriptions (Campbell and Collin, 1958 and Collin, Marine Sciences Branch, personal communication) it appears that the grain-size range varies greatly and that the material is generally coarse and poorly-sorted. This is to be expected, since the sediment originates in the shore area where coarse material is the chief constituent in beach and scree deposits. Furthermore, the greater absorption of solar heat by larger rock fragments causes these particles to melt through the ice faster than the sand-size particles, which results in selective deposition of gravel.

The great variation in the rock-type composition found on the shelf off Exeter Bay can be explained by ice rafting, because ice-rafted material would be derived from a much larger source area than gravel deposited in any other manner. Limestone, sandstone, and basalt are foreign to the immediate vicinity of Exeter Bay but occur north of the area. These rock types are most abundant on the outer part of the shelf and slope, as should be the case if they had been dropped from ice flowing with the Canadian Current. This accounts for the occurrence of the limestone pebbles in the gravel which have hitherto been difficult to account for by other sedimentological agents. In a study of a series of bottom sediments from Lancaster Sound, Buckley (Geological Survey of Canada, personal communication) found that more than 50 percent of the ice-rafted material (particles larger than 2 mm.) consisted of carbonate rocks. Since ice from Lancaster Sound and the other straits off northern Baffin Bay make up much of the ice pack flowing past the western side of Davis Strait, high carbonate percentages can also be expected in ice-rafted material of Exeter Bay. As well as ice flowing with the Canadian Current, some sea ice from the immediate vicinity of the sample area transports material out to the continental shelf and slope, as shown by the small amounts of local material found scattered here. Thus, it appears that the gravel deposit on the shelf and slope has been rafted here by ice carried into the area from the north by the Canadian Current. A lesser amount of local ice transports material from the immediate sample area. This shows that ice rafting is the principal sedimentological agent active in the offshore area of Exeter Bay and illustrates its importance as a geological agent in high latitude areas.

To illustrate the relationship between foreign ice-rafted material and locally derived material, sillimanite schists and limestone has been plotted in Figure 13 as fractions of their combined totals. Sillimanite schist was chosen to represent locally derived material and limestone the foreign ice-rafted material. The resulting diagram shows that two definite zones exist within the area; an inshore zone where sediments are dominantly of local origin and an offshore area of mainly foreign derived ice-rafted sediments.

Isolated areas of sandy sediments also occur on the shelf and slope (Figure 5). A narrow band of sandy gravel between the nearshore sand and the shelf gravel probably is a boundary zone where the two types of sediments mix. Similarly, the sandy material on the inner part of the shelf is probably an extension of the nearshore sand region. It is not known whether the areas of sand on the slope are isolated occurrences or the shoreward boundary of the sand and mud found farther out in Davis Strait (Trask, 1932). The sand was probably deposited on the slope because of the diminished influence of the Canadian Current in deeper water.

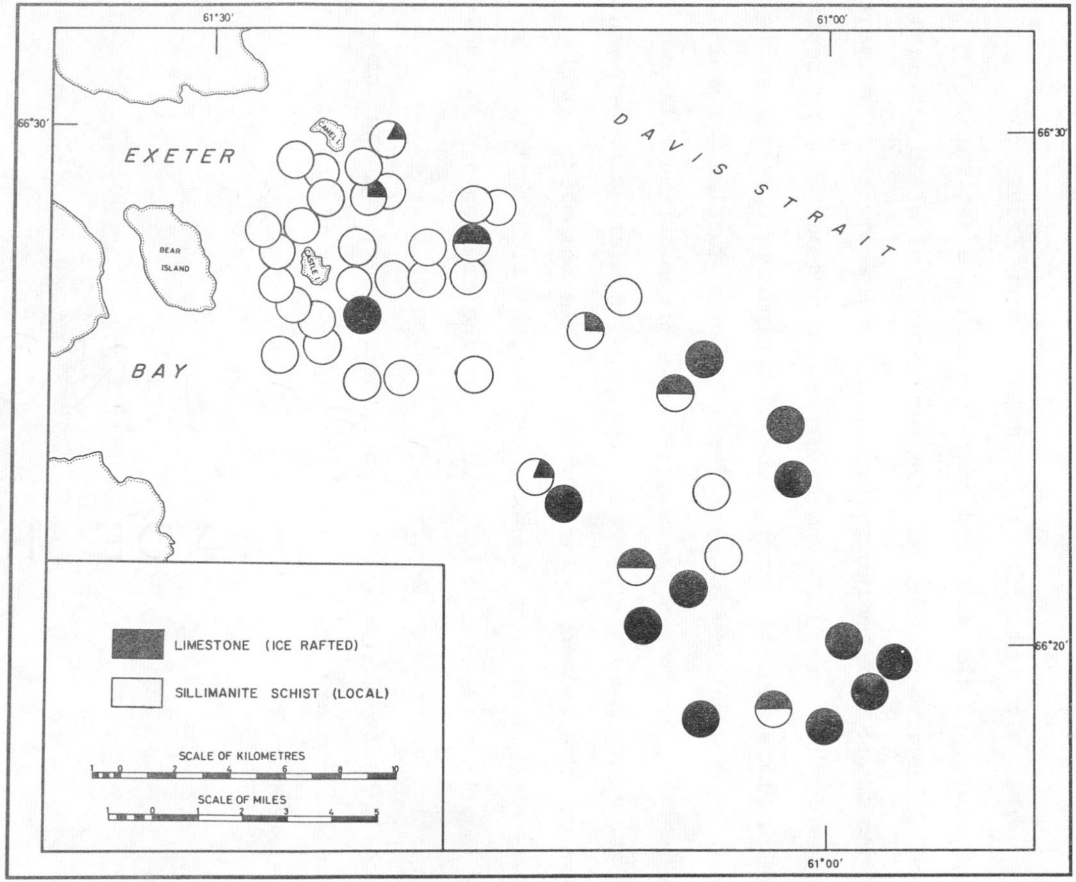

Figure 13. Ratio of locally-derived to ice-rafted detritus, showing concentration of limestone in area of maximum iceberg occurrence.

SUMMARY AND CONCLUSIONS

Grain-size analysis of 104 samples from Exeter Bay indicates that the main sediment types in the region are sand and coarse gravel, with lesser amounts of mixed material. It was found that medium to fine sand is the dominant sediment in the inshore region. Coarse gravel occurs on the continental shelf. Petrological examination of the pebble fraction indicates that a variety of rock types, of both local and foreign derivation, occurs in the region. The distribution patterns of the heavy minerals reflects the varying sources of sediment supply. The sediment distribution, pebble composition and heavy mineral pattern suggest that current transportation is the most active agent responsible for the sedimentary characteristics of inshore region. Ice rafting of foreign and locally derived material accounts for the textural and compositional characteristics of the sediment on the offshore shelf and slope.

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A P P E N D I X

TABLE 1

SAMPLE DEPTHS AND SAND CONTENTS

Station Number	Depth Metres	Weight percent of grains greater than 2 mm. diam.	Sand fraction Md* (mm)	So**
1	271	91	.225	1.55
2	225			
3	265			
4	296			
5	250			
6	247			
7	190			
8	183			
9	155			
10	155			
11	165			
12	212			
13	256			
14	293			
15	298			
16	210			
17	155			
18	152			
19	155			
20	155			
21	148			
22				
23	146			
24	150			
25	148			
26	164			
27	144			
28	146			
29	146			
30	146			
31	146			
32	144			
33	113			
34	132			
35	133			
36	141			
37	141			
38	144			
39	58	.8	.143	1.24
40	73			
41	77	12.3	.167	1.32
42	69	0	.136	1.19
43	58	.8	.341	1.29

TABLE 1 (cont'd)

Station Number	Depth Metres	Weight percent of grains greater than 2 mm. diam.	Sand fraction Md* (mm)	So**
44	57			
45	64			
46	68			
47	71.3	1.1	.151	1.21
48	68	.6	.295	1.27
49	62	37.9	.69	2.38
50	64			
51	58	.3	.48	1.19
52	68			
53		26.3	.340	1.41
54	64	8.3	.150	1.73
55	79	0	.147	1.09
56	91	6.6	.235	1.23
57	86	1.5	.160	1.34
58	93			
59	80	24.3	.154	1.21
60	91	.1	.236	1.15
61				
62		35.9	.170	1.64
63	95	43.3	.273	1.29
64	90	.9	.261	1.24
65	86	65.7	.461	1.19
66	80			
67	88			
68	95			
69	84			
70	93			
71	77			
72	71.3	2.5	.283	1.47
73				
74	71	3.3	.380	1.63
75	97			
76	95			
77	95.1			
78	99			
79		29.2	2.63	1.36
80	130	84.8	.210	1.24
81	108			
82	102	79.5	.179	1.36
83	90			
84	75			
85	86			
86	97			
87				
88	122			
89	127			
90	143			

TABLE 1 (cont'd)

Station Number	Depth Metres	Weight percent of grains greater than 2 mm. diam.	Sand fraction Md* (mm)	So**
91	126			
92	121			
93	110	5.5	.360	1.94
94	104			
95	95			
96	117			
97	112			
98	119	88.0	.57	1.74
99	119			
100	135			
101	141			
102	238			
103	267			
104	302	78.0	.27	1.32
105	330			
106	357			
107	377			
108	382			
109	371			
110	346	1.4	.255	1.39
111	327			
112	314			
113	282			
114	241			
115	212			
116	298			
117	318			
118	329			
119	347			
120	364			
121	357			
122	338			
123	325			
124	313			
125	302			
126	324			
127	335			

* Md (mm) - Median diameter, than which 50% of the grains in a sample are larger and 50% smaller.

**So - Trask's sorting coefficient.
( ), which expresses the spread of the 25 percentile grain size in mm (Q1) and the 75 percentile size (Q3) around a central median.

TABLE 2

PEBBLE COMPOSITIONS

Frequencies in Number Percentages

Sample No.	Basalt	Limestone	Quartzite	Sandstone	Amphibole schist	Sillimanite schist	Miscellaneous basics	Charnockites	Miscellaneous Granite and Gneiss	Total Number of Pebbles
1			5	3	17		3	5	67	36
2	14						14		72	7
5								100		1
6		50							50	2
7						50			50	2
8	7			13	20	7	7	13	33	15
10		14	14			14			58	7
11				7	7			36	50	14
12						14			86	7
14		25						75		4
15	50							50		2
16				34					66	3
17									100	2
19									100	1
20									100	1
21					20				80	5
22		50		50						2
23									100	1

TABLE 2 (cont'd)

Sample No.	Basalt	Limestone	Quartzite	Sandstone	Amphibole schist	Sillimanite schist	Miscellaneous basics	Charnockites	Miscellaneous Granite and Gneiss	Total Number of Pebbles.
24									100	1
25		5				5			90	22
26		18							82	11
27									100	3
28			14		14				72	7
29									100	4
31		7		10	3	26	3		51	31
32									100	3
33									100	2
34									100	4
35			11		11				78	9
37	6	6				17			71	18
38			4		4	22	4	4	61	23
40									100	1
41					33	33			33	3
46					22				78	9
48					33	33			33	3
49			10		5	10			75	20
50	8				8	67			50	12
51						100				1
53									100	2

TABLE 2 (cont'd)

Sample No.	Basalt	Limestone	Quartzite	Sandstone	Amphibole schist	Sillimanite schist	Miscellaneous basics	Charnockites	Miscellaneous Granite and Gneiss	Total Number of Pebbles
54					7	13			80	15
56						50			50	4
57						50			50	4
58						13			87	8
59	11	6				29		11	41	18
61									100	1
62	5			5		33	5	5	47	21
63		11				33			56	9
65			4		8	40		4	44	98
67			100							1
69					50				50	2
71						56			44	9
72						50			50	4
73					25	50			25	4
74						67			33	3
75		100								4
76						50			50	2
77					18	29			53	17
78					8	33	8	17	33	12
79		15	5		15	15			50	22

TABLE 2 (cont'd)

Sample No.	Basalt	Limestone	Quartzite	Sandstone	Amphibole schist	Sillimanite schist	Miscellaneous basics	Charmockites	Miscellaneous Granite and Gneiss	Total Number of Pebbles
80	7	7	3		3	7		10	63	40
81			10	4	10	38			38	29
83									100	1
84			50						50	2
85				15		24			61	13
88						29			71	7
89					33				66	3
90									100	1
91									100	1
93					25				75	4
94			11			33			56	9
95								50	50	2
96					20				80	5
97	17						33		50	6
98			7	7	11	7	4	7	57	28
99									100	1
101	50							50		2
102							50		50	2
103									100	1
104		33							67	3

TABLE 2 (cont'd)

Sample No.	Basalt	Limestone	Quartzite	Sandstone	Amphibole schist	Sillimanite schist	Miscellaneous basics	Charnockites	Miscellaneous Granite and Gneiss	Total Number of Pebbles
105		8	8	17				33	34	12
106		100								1
107									100	1
111		33							67	6
112	100									1
113		50					50			2
115		20							80	5
118	6		11		6			38	39	18
119	25			25				25	25	4
120									100	2
125	13	8	5	15	3			23	25	39

TABLE 3

HEAVY MINERAL CONTENT

Mineral Frequencies in Number Percent of Heavy Fraction

Station Number	Weight percentage of total sand fraction	Weight percentage of fine sand fraction	Garnet	Sillimanite	Opaque	Amphibole	Pyroxene Olivine	Miscellaneous	Mica
1		13.4	2.0	16.2	18.2	5.6	57.1	1.0	3.4
39	15.5	11.6	3.8	6.8	6.8	30.3	8.3	43.9	34.7
41	14.0	14.3	11.1	16.2	2.6	27.4	32.5	10.3	15.3
42	16.6	9.9	.8	8.3	12.1	31.1	14.4	32.6	35.6
43	16.3	25.7	9.7	9.7	9.2	34.4	23.6	13.3	2.5
47	12.7	8.5	1.4	37.9	14.3	15.0	17.1	14.3	31.0
48	10.0	20.9	19.5	14.8	20.0	19.1	23.8	2.9	4.1
49	18.0	17.8	13.4	24.7	4.1	19.1	19.6	19.1	11.4
51	7.8	18.9	25.1	16.6		14.3	29.1	14.8	4.9
53		13.1	11.1	16.3	7.4	26.3	25.8	13.2	14.4
54	22.9	32.4	19.2	16.4	6.8	24.9	21.5	11.3	12.4
55	15.2	8.8	4.4	17.4	14.1	22.3	33.2	9.8	8.0
56	10.7	3.4	5.3	12.1	13.7	23.2	33.2	12.6	6.4
57	10.4	6.2	2.8	8.5	7.6	19.8	28.0	23.0	48.3
59	23.5	15.8	11.5	9.9	10.5	9.9	57.1	11.9	5.0

TABLE 3 (cont'd)

Station Number	Weight percentage of total sand fraction	Weight percentage of fine sand fraction	Garnet	Sillimanite	Opaque	Amphibole	Pyroxene Olivine	Miscellaneous	Mica
60	14.1	15.3	4.1	24.5	10.2	6.6	53.6	1.0	6.2
62	15.8	12.6	4.8	11.2	16.8	12.8	28.8	24.2	41.3
63		26.2	21.1	18.8	12.4	9.6	25.2	12.9	4.4
64	16.7	24.6	19.1	15.0	9.8	18.6	28.9	8.8	3.0
65	31.7	21.3	14.0	19.0	6.7	14.0	29.1	17.3	12.6
72	3.8	12.1	7.3	28.5	4.0	31.5	11.9	16.6	28.4
74	14.1	13.1	5.4	7.8	15.6	16.8	34.1	10.4	23.4
79	23.3	21.9	10.9	16.7	4.7	16.7	44.3	6.8	9.9
80		13.9	5.6	14.2	3.6	17.8	42.1	16.8	8.4
82	10.2	7.4	0	21.7	10.1	19.6	25.5	23.3	6.4
93	22.5	13.5	9.8	16.5	10.6	12.7	43.2	7.2	5.6
98		17.9	9.6	19.3	10.2	10.2	43.2	7.6	3.0
104		12.9	7.0	19.6	11.6	8.0	47.3	6.5	2.0
110	5.4	8.1	6.0	15.4	14.3	13.7	48.4	2.1	1.6