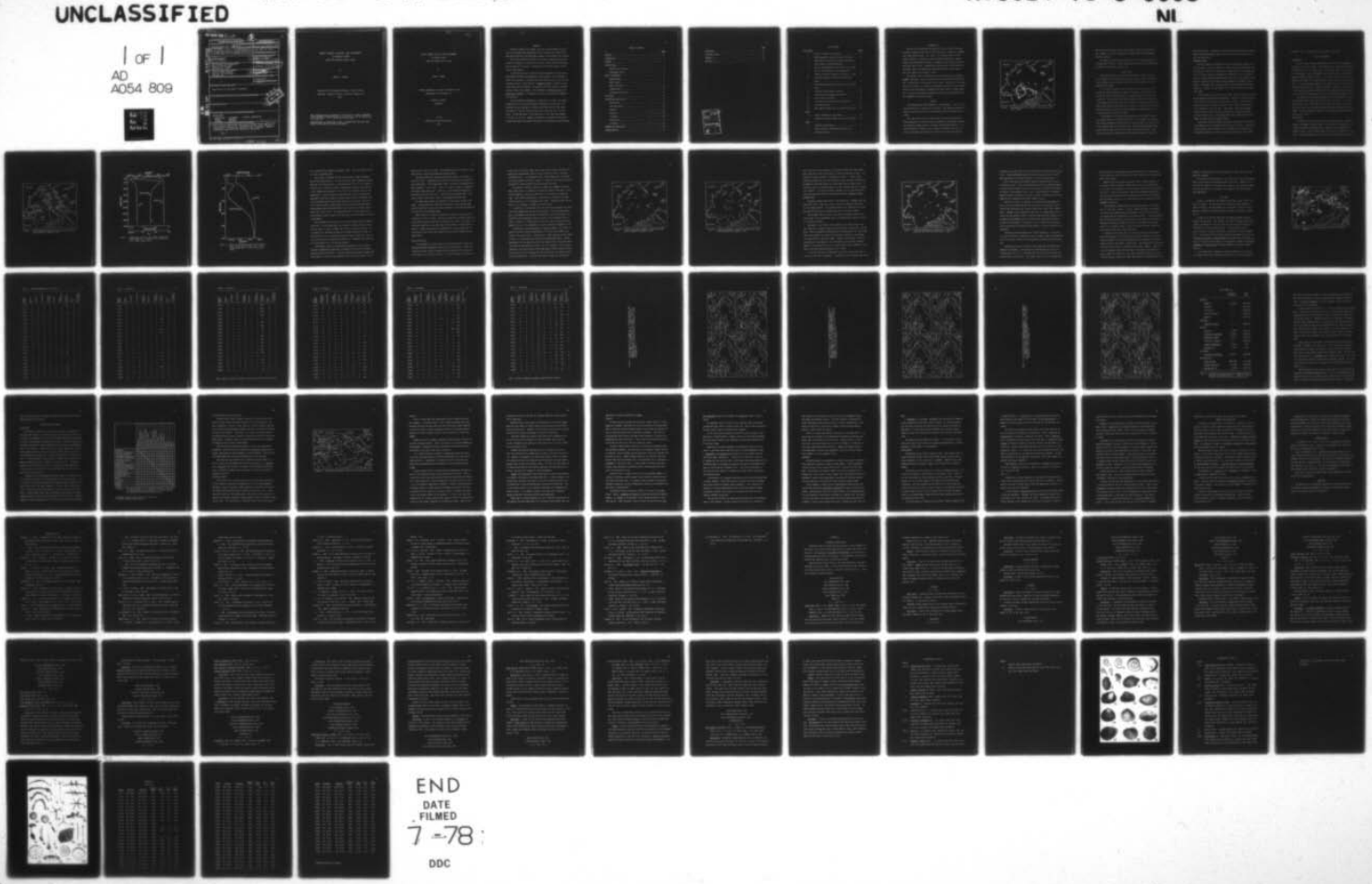
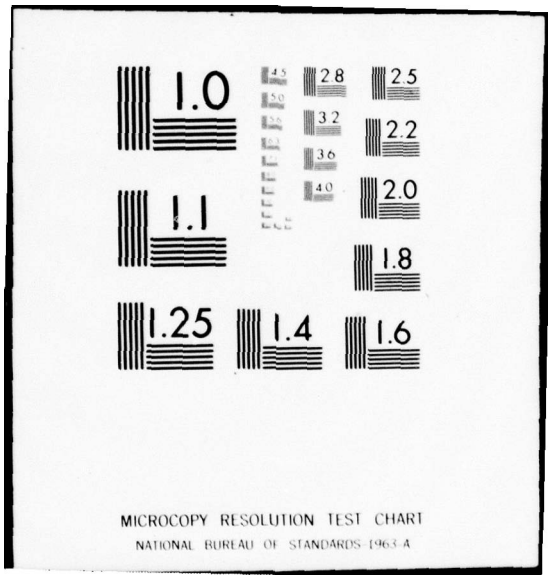
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Some 16 taxa of invertebrates have been recovered from the tops (three centimeters) of cores in the central Arctic Ocean. Holothurians are most widely distributed. Relationship of sediment type and mollusc taxa is apparent. Carbonate compensation layer may not be important in the Arctic.

(Alpha Cordillera-Canada Basin).

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RECENT SPONGES, MOLLUSCS, AND ECHINODERMS IN SEDIMENT CORES FROM THE CENTRAL ARCTIC OCEAN

by

James H. Gamber

University of Wisconsin-Madison, Arctic Ocean
Sediment Studies Program, Technical Report 23
1976

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RECENT SPONGES, MOLLUSCS, AND ECHINODERMS IN SEDIMENT CORES FROM THE CENTRAL ARCTIC OCEAN

by

James H. Gamber

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

(GEOLOGY)

at the

University of Wisconsin-Madison

1976

ABSTRACT

Skeletal elements from sponges, molluscs, and echinoderms are present in the upper three centimeters of 64 of the 68 cores studied from the Alpha Cordillera and Canada Basin regions in the central Arctic Ocean.

The 16 taxa identified include five types of sponge spicules, one species of pteropod, six species of bivalves, three holothurian species, and one species of echinoid. Holothurians are the most widely distributed of these groups.

A correlation analysis comparing faunal abundances of the more common groups with depth, percentage of coarse sediment, and percentage of water in the sediment, indicates depth and related factors to be the most important control on distribution. Bathyarca frielei is generally associated with coarser sediment. The pectinids are more common in sediment having a lesser water content. The abundance of Elpidia glacialis and Pourtalesia jeffreysi is influenced at least to some extent by geographical location.

Such environmental parameters as temperature, salinity, and oxygen concentration are relatively constant throughout the study area, and therefore are not important in defining the distribution of the fauna. The supply of food and nutrients may be more important, but is poorly known. The maximum depth in the study area is well above the compensation level for calcite. However, dissolution of aragonite which occurs at shallower depths may explain the paucity of pteropods at greater depths.

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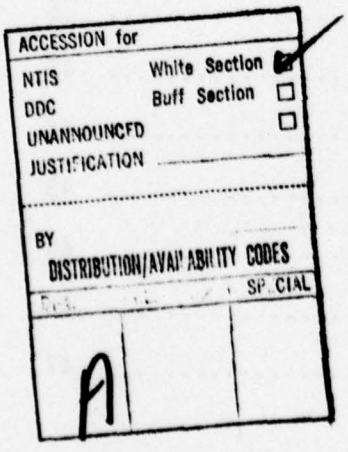
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INTRODUCTION

Study of the paleoecology and geologic history of the Arctic Ocean has been in progress since 1967 at the University of Wisconsin. Sediment cores taken from Fletcher's Ice Island, T-3, provide a basis for the studies (Figure 1). Research to date includes paleontologic, sedimentologic, and paleoecologic studies, a summary of which recently has been published (Clark, 1975). Paleontologic work has dealt with Foraminifera, ostracodes, and silicoflagellates (Steurwald and Clark, 1972; Larson, 1975; Joy, 1974; and Ling et al., 1973).

The present study is concerned with the distribution and ecology of sponges, pteropods, bivalves, holothurians, and echinoids recovered from the T-3 cores taken in the central Arctic Ocean. Specifically, the objective of this study is to identify and describe the remains of the sponges, molluscs, and echinoderms, to determine the distribution of these groups, and to relate the distribution patterns with the various measured ecologic parameters of the Arctic Ocean.

METHODS

The sediment cores have diameters of 3½ centimeters. This is a limiting size factor for organisms of the study. The complete procedure for opening and processing the cores has been previously described by Clark (1969).

Only the coarse fraction (greater than 62 microns) from the top three centimeters of each core half was examined for pteropods, holothurian sclerites, sponge spicules, bivalves, and echinoderm material. The coarse fraction of another 43 core samples was examined, but only the first 25 pteropods and holothurian sclerites (from the Genus Elpidia)

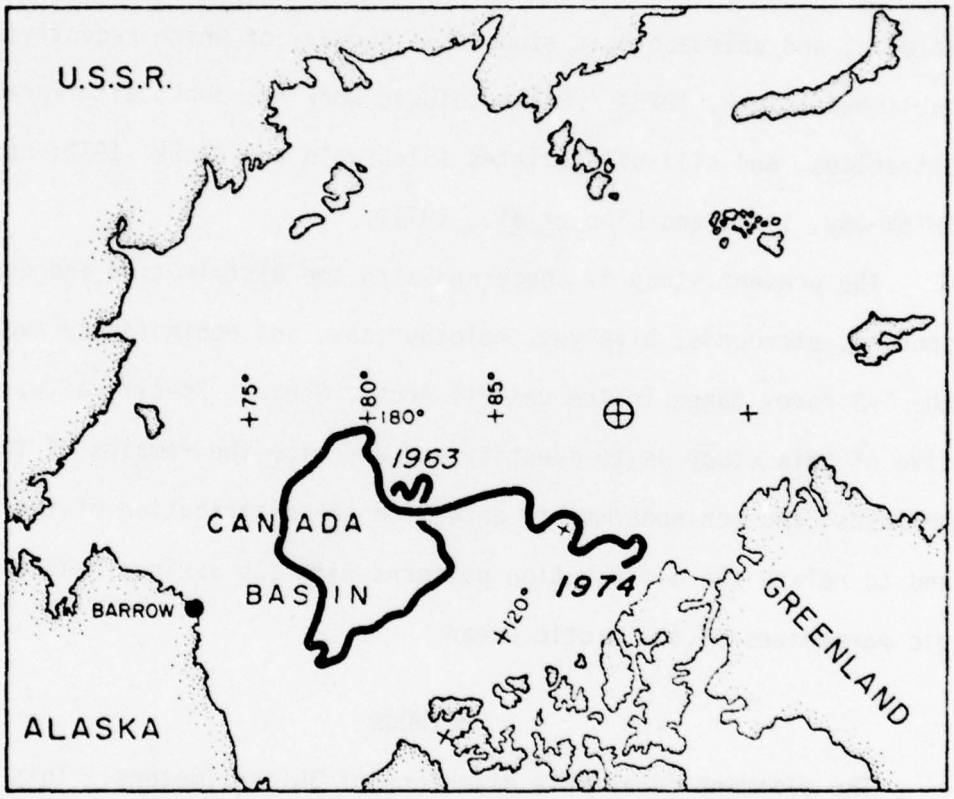


Figure 1. Map showing track of Fletcher's Ice Island in the Arctic Ocean.

were picked and saved due to the large numbers involved; the balance was only counted. All other microfauna of interest were picked throughout the entire sample.

The skeletal elements were studied with a JEOL Scanning Electron Microscope, model JSM-504. Typical specimens were mounted and photographed on the SEM using Polaroid type 52 film.

PREVIOUS WORK

There has been very little research concerning sponges, molluscs, and echinoderms in the central Arctic Ocean. Almost all of the work has been confined to more southerly areas away from the permanent ice pack.

CENTRAL ARCTIC REGION

In an extensive report on the ecology of the central Arctic, Paul and Menzies (1973) reported four genera of sponges, four species of bivalves, and two holothurian species in 90 bottom samples from the Alpha Cordillera. Ericson and Wollin (1959) examined several cores from west of the Lomonosov Ridge and noted the occurrence of sponge spicules, pteropods, small bivalves, and holothurian sclerites. Nine species of bivalves and one holothurian species in samples dredged from the Chukchi Rise are listed by Brodskii and Nikitin (1955).

Fifteen genera of bivalves were reported by Clark (1960) from bottom samples taken over the Alpha Cordillera. Clark (1962) also described the bivalves dredged from the drifting ice Station Charlie in the vacinity of the western flank of the Chukchi Rise. Herman (1969) examined several cores from the Alpha Cordillera and noted two pteropod species. Leung (1971) reported two pteropod species from plankton samples collected in

the central Arctic. Two species of holothurians were described by Agatep (1967a) from bottom samples taken from the drifting ice Station Arlis II over the Canada Basin.

PERIPHERAL AREAS

The most important taxonomic work from the peripheral areas to the south includes a report by MacGinitie (1955) on marine invertebrates from Point Barrow, Alaska, describing several sponge species, two pteropod species, 30 bivalve species, two species of holothurians, and one echinoid species. Hansen (1885) examined sponges collected on the Norwegian North Atlantic Expedition, which covered the Norwegian Sea northward to Spitzbergen. Brondsted (1933) studied sponges from the Norwegian and Greenland Seas. Sponges from the Alaskan Arctic were described by de Laubenfels (1953).

Friele (1886) and Friele and Grieg (1901) studied bivalves collected by the Norwegian North Atlantic Expedition. MacGinitie (1959) described the bivalves in the vicinity of Point Barrow, Alaska. Grieg (1911) reported 23 species of bivalves collected in Baffin Bay by the Norwegian Arctic Expedition with the "Fram". Both Jensen (1912) and Ockelmann (1958) studied bivalves from east of Greenland. Bivalves collected in the East Siberian Sea by the Norwegian North Polar Expedition with the "Maud" are described by Soot-Ryen (1936).

Danielssen and Koren (1882) described in great detail the holothurians dredged during the Norwegian North Atlantic Expedition. Mortensen (1932) studied some echinoderms from the Norwegian and Greenland Seas. Echinoderms dredged in the Siberian Sea were examined by Grieg (1936).

Mortensen (1907) studied echinoids from eastern Greenland.

ARCTIC ENVIRONMENT

GEOMORPHOLOGY

The core samples studied were obtained from parts of two geomorphic provinces in the Arctic Ocean: the Canada Basin and the Alpha Cordillera. The abyssal plain of the Canada Basin is strikingly smooth and flat with a uniform depth of about 3790 meters, and covers an area of about 254000 square kilometers (Hunkins, 1968). It is bounded rather abruptly to the north by the scarps of the Alpha Cordillera and to the west by the Chukchi Rise. A very gradational boundary to the south and east is formed by the Canadian Continental Rise. Sediment thickness is greatest near the continent and thins toward the Alpha Cordillera, suggesting that the source area is mainly the continental shelf via submarine canyons (Herman, 1974).

The Alpha Cordillera ranges between 250 and 800 kilometers in width and stretches almost across the length of the Arctic Basin. It is composed of many small, relatively discontinuous ridges with as much as 100 meters of relief and crest depths between 1500 and 2000 meters (Hunkins, 1968). The major geomorphic features of the Arctic Ocean are shown schematically in Figure 2.

WATER MASSES

The vertical structure of the Arctic Ocean water mass is relatively constant throughout the entire ocean. The variation in temperature, salinity, and oxygen concentration for a station in the Canada Basin is shown in Figure 3 and in greater detail for the first 500 meters in Figure 4. Based on temperature, there are three distinct water masses pres-

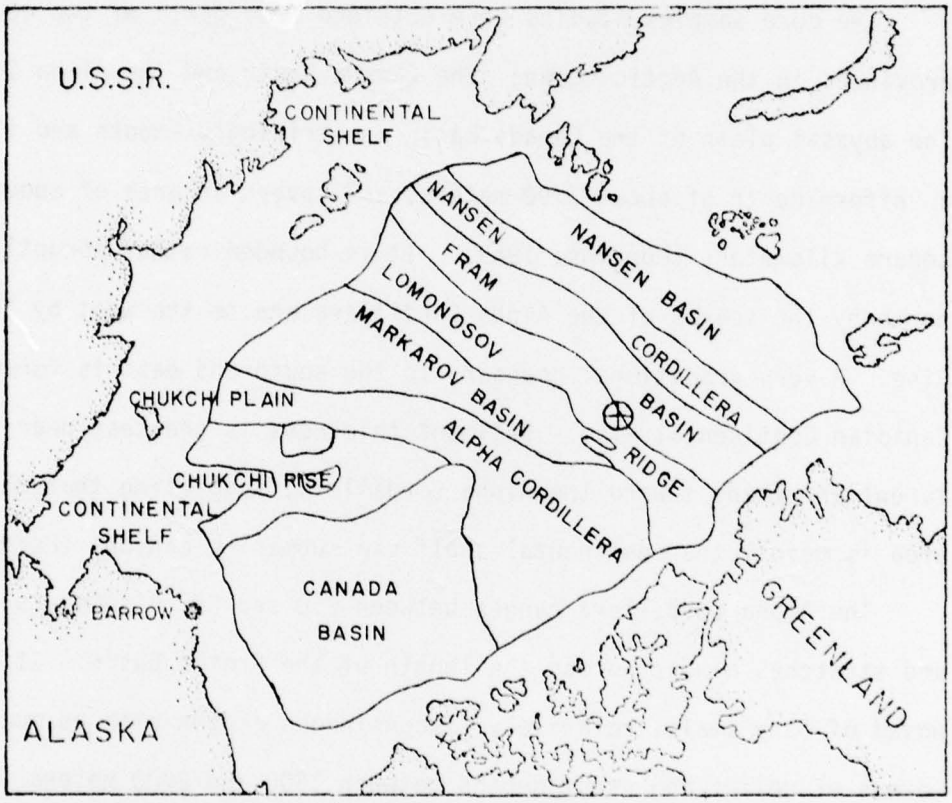


Figure 2. Major geomorphic regions of the Arctic Ocean (after Demenitskaya and Hunkins, 1970).

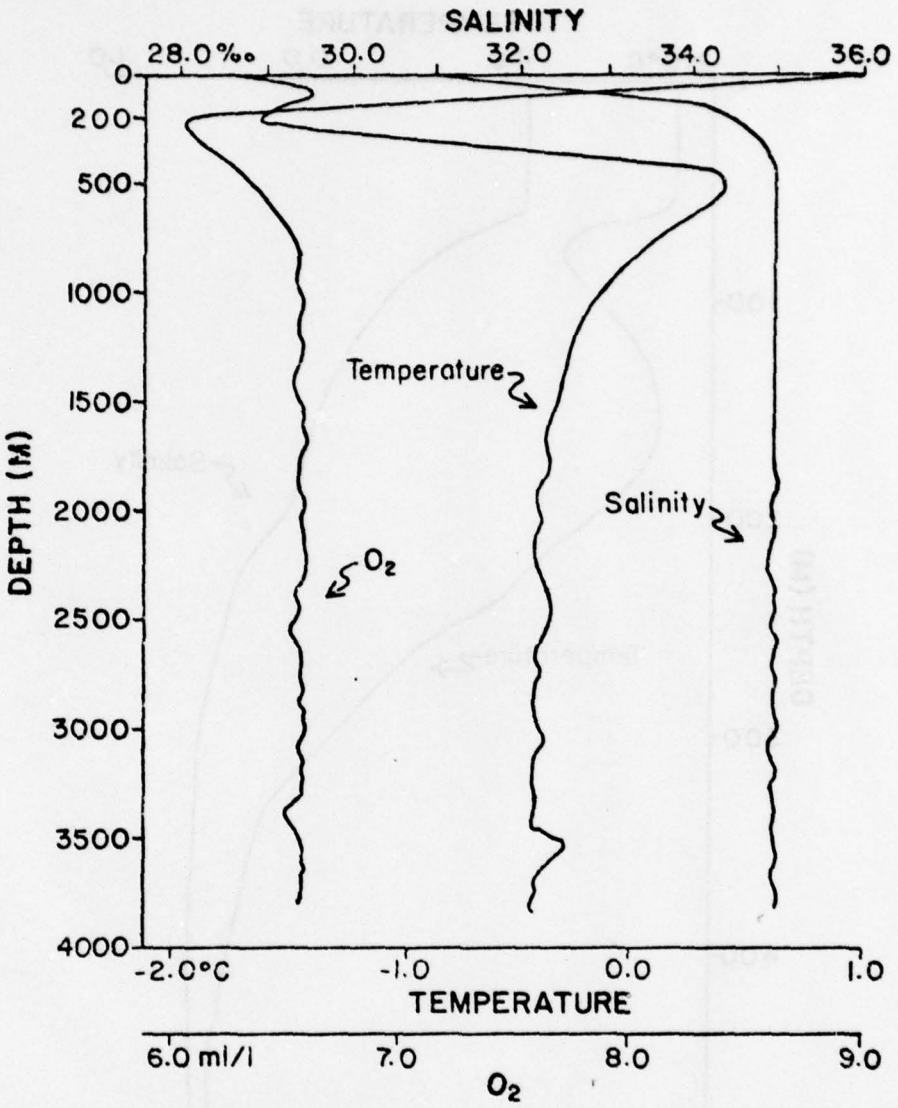


Figure 3. Temperature, salinity, and oxygen concentration versus depth for a station in the Canada Basin. After Kinney et al. (1970).

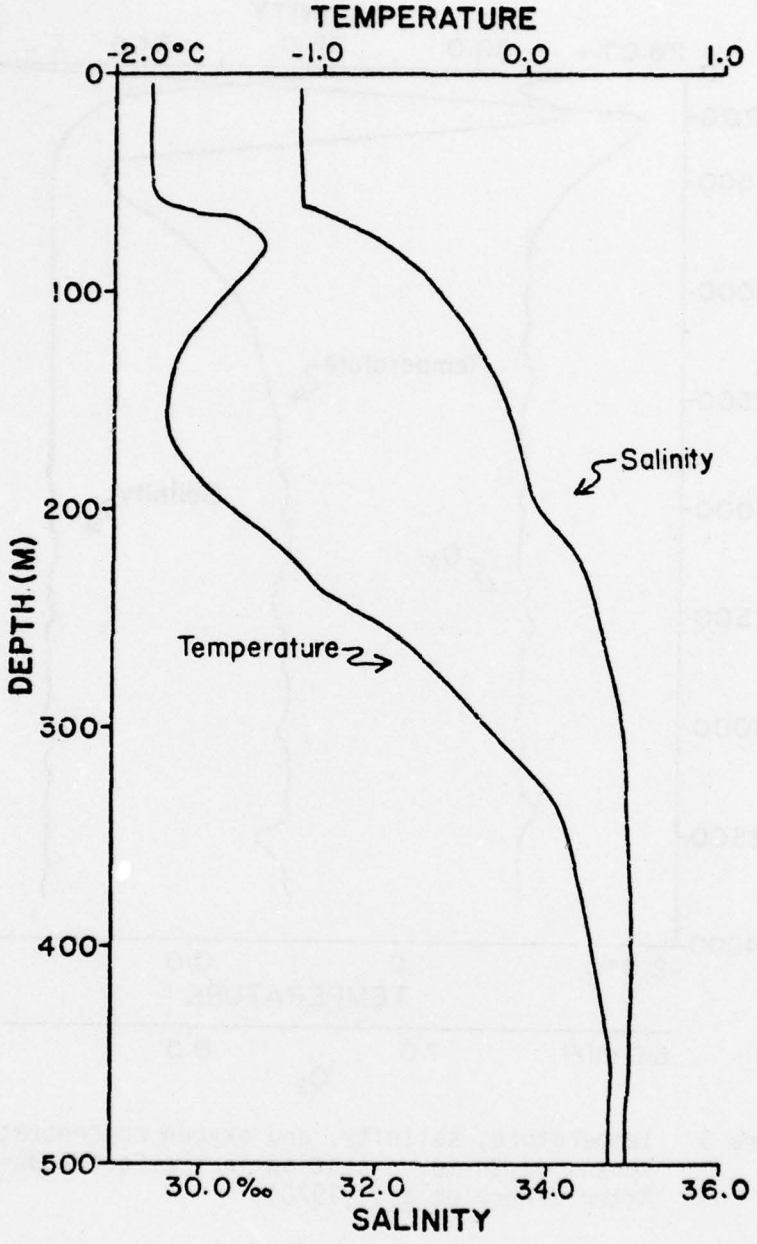


Figure 4. Details of temperature and salinity versus depth for the top 500 meters for a station in the Canada Basin. After Kinney et al. (1970).

ent as described by Coachman and Aagaard (1974): the Arctic water, Atlantic layer, and bottom water.

Arctic water, extending from the surface down to about 200 meters, has varying characteristics. At the surface the water temperature ranges from near the freezing point in ice-covered areas to 1° or 2°C or more in ice-free areas. Below the surface, temperatures typically are cold with a small temperature maximum of -1°C in the 75 to 100 meter layer in the Canada Basin. Salinity tends to range spatially as well as vertically. Geographic variations primarily are due to the influx of freshwater from river discharge causing low salinity values (27 to 30 o/oo), and the inflow of North Atlantic surface water into the Arctic through the Norwegian-Greenland Seas and eastern Baffin Bay, resulting in higher salinity values (33 to 34.5 o/oo). At any given location, salinity tends to be uniform down to about 50 meters and then increases to an average of 35 o/oo at 200 meters.

Both temperature and salinity of the surface waters exhibit seasonal variations. In the Canada Basin, for example, surface salinities range from 31 o/oo to 33 o/oo in summer and 32 o/oo to 34 o/oo in winter. Arctic water also is modified by heat gain through absorption of solar radiation and heat loss through open water and leads in pack ice. The surface salinity may be altered by the addition of freshwater due to melting of ice and exclusion of salt during freezing.

The Atlantic layer lies between 200 and 900 meters and is characterized by temperatures above 0°C, but generally less than 1.5°C with a maximum at 300 to 500 meters. Salinity increases with depth to about 400 meters where it levels off and becomes nearly uniform with values in the

range of 34.9 o/oo to 35.0 o/oo. The ultimate source of the water is the North Atlantic through the Norwegian-Greenland Seas.

The bottom water mass constitutes about 60 percent of the water in the Arctic Basin. Temperatures are below 0°C and decrease with depth to about 2000 meters in the Canada Basin where a minimum is encountered with values between -.4 and -.5°C. There is a slight increase in temperature with depth below 2000 meters. Salinity is quite uniform averaging between 34.92 o/oo and 34.97 o/oo. The source of the bottom water is the same as that of the Atlantic layer, the Norwegian-Greenland Seas.

All three water masses are important for the various fauna in the study. The pteropods are restricted to the Arctic water and the upper part of the Atlantic layer, while the remainder of the fauna are benthonic and occur only in the bottom water.

Water density is primarily controlled by salinity, so vertical distribution is similar in both. The Arctic Ocean waters exhibit essentially a two layered system on the basis of density with a thin, less dense, surface layer underlain by the main body of water which is quite uniform in density. The two water masses are separated by a strong pycnocline, restricting vertical motion and transfer of heat and salt between the two water bodies.

WATER CIRCULATION

The knowledge of current patterns in the Arctic Ocean is much less developed than the temperature and salinity distributions. Surface circulation has been primarily deduced from the observed drift of various ice islands, flow stations, and ships. The surface waters from the Eur-

asian side of the Arctic Ocean tend to move slowly toward the North Pole, become more concentrated, and exit from the basin as part of the East Greenland Current. In the Beaufort Sea, surface waters have a clockwise circulation pattern as shown in Figure 5. Surface circulation gives every indication of being primarily driven by prevailing winds.

The swiftest currents in the Arctic Ocean occur between 50 and 250 meters where there is a significant increase in density with depth. These currents appear as pulses with durations of a few days to perhaps two weeks. Galt (1967) measured such a pulse from T-3 and found a maximum relative velocity of 57 centimeters per second. These high speed currents appear to be responses to change in the wind field.

Circulation of the Atlantic layer was inferred by Coachman and Barnes (1963) from temperature and salinity variations. Atlantic water enters west of Spitzbergen and descends to subsurface levels with the main flow paralleling the continental slope of Eurasia into the Canadian Basin as shown in Figure 6. Current velocities are very low with measured speeds between zero and five centimeters per second (Coachman and Aagaard, 1974).

Circulation of the bottom water is largely unknown. Galt (1967) reported two direct velocity measurements of 1.5 and 2.6 centimeters per second in the Canada Basin. Hunkins et al. (1969) measured current speeds of four to six centimeters per second on the Mendeleyev Ridge. Another measurement from the abyssal plain of the Canadian Basin indicated motion less than one centimeter per second. This also suggests a basic counter-clockwise circulation pattern with bottom water entering the more eastern Arctic Basin from the Norwegian Sea and flowing over the Lomonosov Ridge into the Canada Basin. The water then moves southward on the western

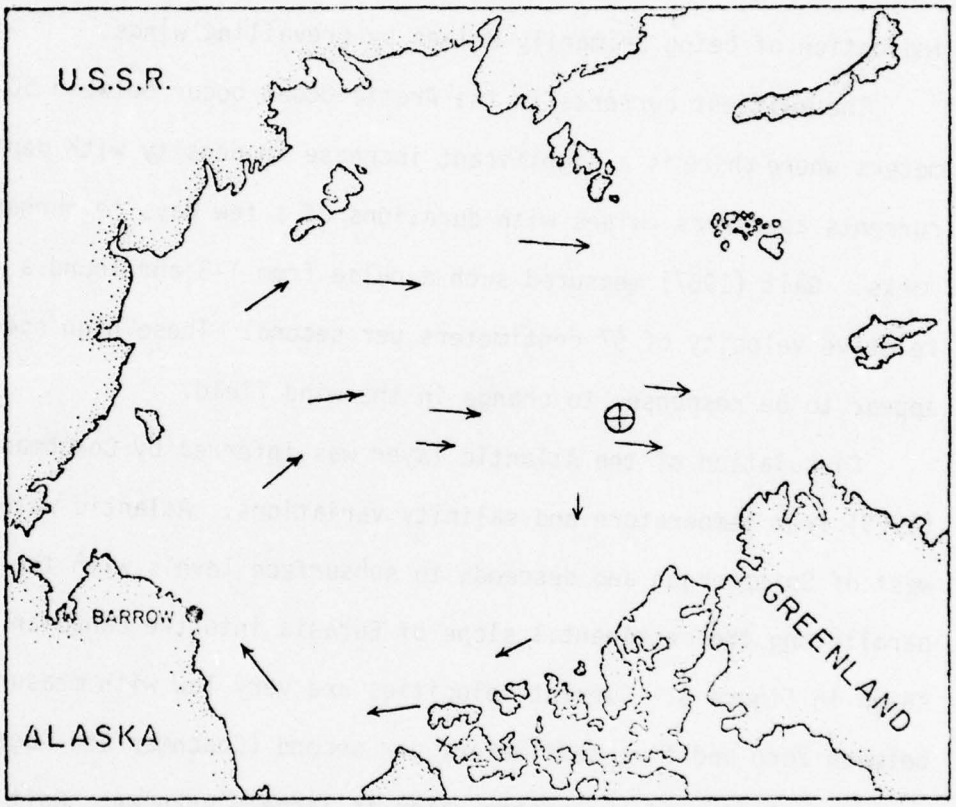


Figure 5. Surface circulation pattern in the Arctic Ocean (after Coachman and Aagaard, 1974).

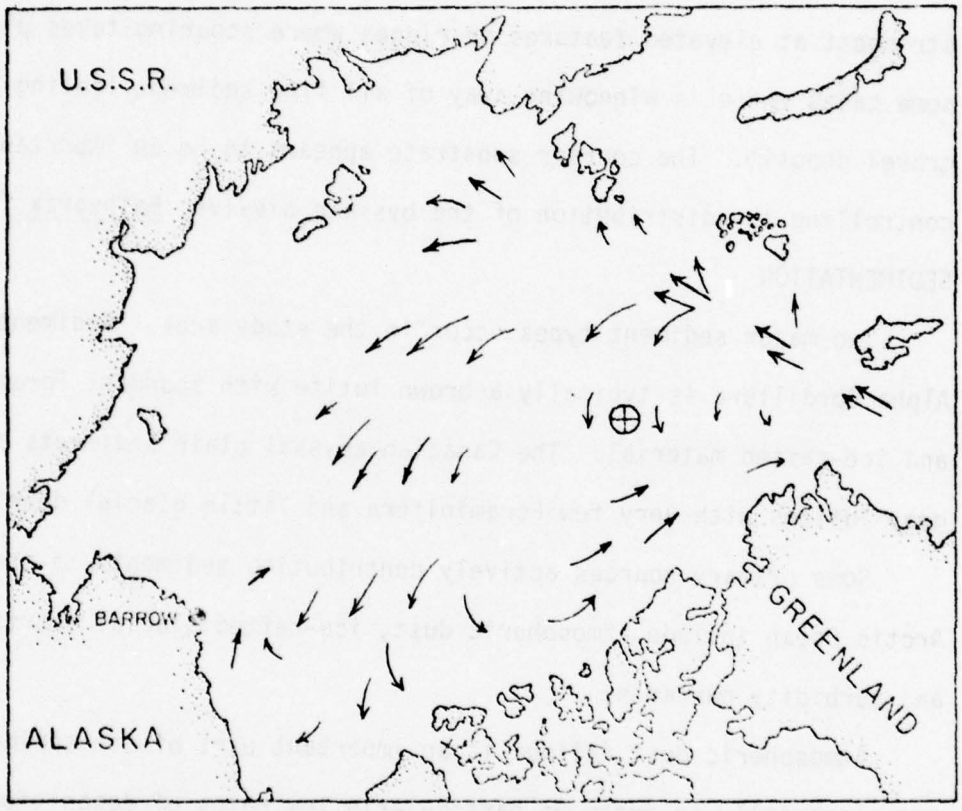


Figure 6. Inferred mid-depth circulation in the Arctic Ocean (after Coachman and Aagaard, 1974).

side of the basin and ultimately mixes upward through the surface water which flows out of the Arctic Ocean via the East Greenland Current. This proposed circulation pattern is depicted in Figure 7. Hunkins et al. (1970) have noted from sea floor photographs that the bottom currents are strongest at elevated features on ridges where scouring takes place. In some cases there is winnowing away of all fine sediment leaving a residual gravel deposit. The coarser substrate appears to be an important factor controlling the distribution of the byssate bivalve, Bathyarca frielei.

SEDIMENTATION

Two major sediment types occur in the study area. Sediment from the Alpha Cordillera is typically a brown lutite with abundant Foraminifera and ice-rafted material. The Canadian abyssal plain sediments are olive-gray lutites with very few Foraminifera and little glacial debris.

Some primary sources actively contributing sediments to the central Arctic Ocean include atmospheric dust, ice-rafted glacial debris, biotics, and turbidity currents.

Atmospheric dust fallout is an important part of the sediment budget, especially in areas of particularly low rates of deposition. Mullen et al. (1972) estimated the average rate of accumulation to be .09 mm/1000 years which amounts to as much as ten percent by weight of the sediment in certain parts of the Arctic Ocean. However, Darby, et al. (1975) determined that the atmospheric dust contribution to the total sediments amounts to one percent or less at a location about 1400 kilometers to the west of the area reported by Mullen et al. (1972).

Ice-rafted detritus is widespread in the Arctic Ocean floor and accounts for the coarser sediments. In addition erratics greater than eight

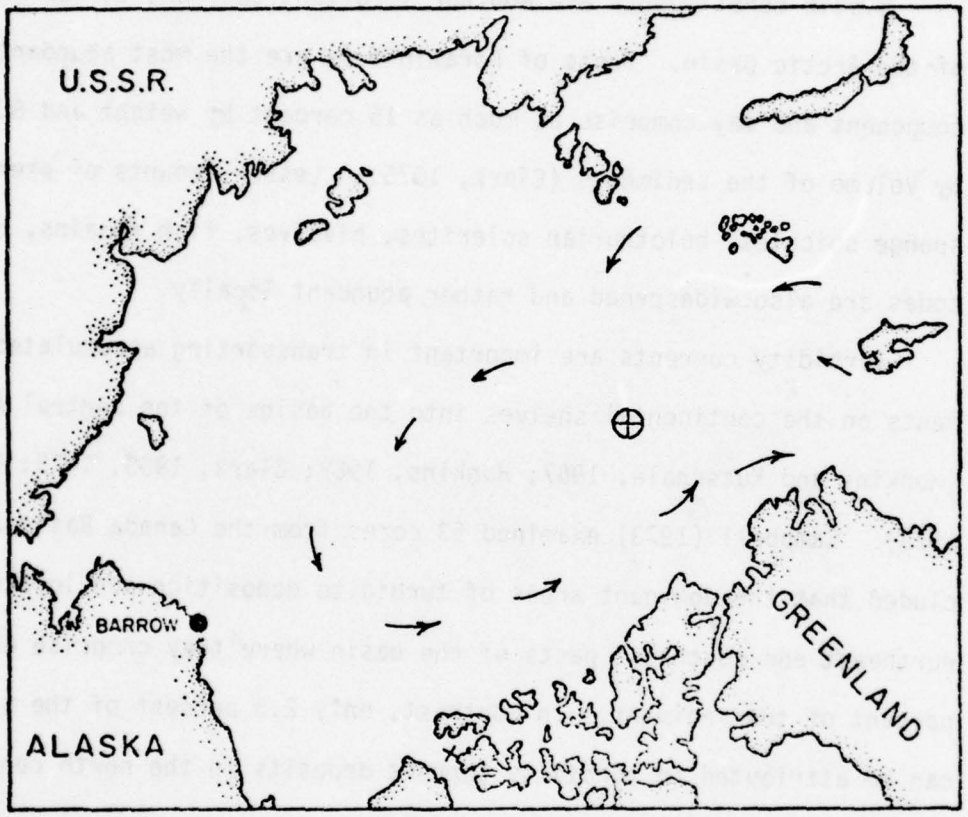


Figure 7. Postulated bottom water circulation in the Arctic Ocean (as described by Hunkins et al., 1969)

millimeters have been found in 44 of the 100 cores studied by Mullen et al. (1972). Bottom photographs examined by Hunkins et al. (1970) indicate that deposition of ice-rafted erratics is a fairly random process.

Biotic constituents are another important sediment source in parts of the Arctic Basin. Tests of Foraminifera are the most abundant organic component and may comprise as much as 15 percent by weight and 80 percent by volume of the sediments (Clark, 1975). Lesser amounts of pteropods, sponge spicules, holothurian sclerites, bivalves, fish remains, and ostracodes are also widespread and rather abundant locally.

Turbidity currents are important in transporting accumulated sediments on the continental shelves into the basins of the central Arctic (Hunkins and Kutschale, 1967; Hunkins, 1968; Clark, 1969, 1975; Campbell, 1973). Campbell (1973) examined 53 cores from the Canada Basin and concluded that the dominant areas of turbidite deposition are located in the northeast and southeast parts of the basin where they comprise about 27 percent of the sediment. In contrast, only 2.5 percent of the sediment can be attributed to turbidity current deposits in the north central Canada Basin.

Turbidity currents probably occur rather frequently. On the basis of carbon 14 dating of foraminiferal tests, Campbell (1973) estimated that the last turbidity current in the Canada Basin occurred around 700 years ago.

Sedimentation rates in the Arctic Ocean have been calculated using magnetic stratigraphy. Clark (1970) has reported rates of 0.8 to 1.6 mm/1000 years and 2.2 to 2.6 mm/1000 years for the Alpha Cordillera and Chukchi Plain, respectively. The highest rates occur in the Canada Basin

where turbidity current deposits have been accumulating. Average rates in this region are about 80 mm/1000 years and range from 4 to 462 mm/1000 years (Clark, 1975).

Based on both radiocarbon and uranium series isotope analyses, Ku and Broecker (1967) estimated a depositional rate of 2.1 mm/1000 years for the upper 29 centimeters of a core obtained from the foot of the Alpha Cordillera. Hunkins and Kutschale (1967) also estimated sedimentation rates by dating Foraminifera in the sediment using the carbon 14 method. They indicated a rate of 1.5 to 3 mm/1000 years for the Alpha Cordillera.

CARBONATE DISSOLUTION

The carbonate compensation depth ranges considerably in different parts of the world's oceans. Li et al. (1969) determined the compensation depth to be between 500 and 3000 meters for calcite in the Pacific and between 4000 and 5000 meters in the North Atlantic. These differences may be attributed primarily to variations in the amount of dissolved CO_2. Although the carbonate compensation level is not known for the Arctic Ocean, it is probably similar to that of the North Atlantic, where the Arctic bottom water most likely originates.

Carbonate dissolution rates for calcite, Mg-calcite and aragonite were also measured by Milliman (1974) in the North Atlantic and the compensation depths for calcite and aragonite were estimated at over 5000 meters and about 3500 meters, respectively. Some dissolution of aragonite did take place at depths as shallow as 2500 meters, however. These figures are somewhat higher than the 1000 to 2500 meters calculated by Li et al. (1969) for aragonite. Chen (1964) studied pteropod ooze in cores from the Bermuda Pedistal and found concentrations of pteropod shells are

greatest at 2200 meters and diminish gradually to 4200 meters, and subsequently disappear.

The maximum depth encountered in the study area is around 3800 meters which is well above the compensation depth of calcite. However, the distribution of aragonite is of importance, because it may provide an explanation for the paucity of pteropods in core samples from depths greater than 2600 meters.

THE FAUNA

Molluscs, echinoderms, and sponge spicules were found in 64 of the 68 cores studied. The location of cores containing these organisms is shown in Figure 8, and the abundance by core sample is given in Table 1. Specific information on sample location and depth is contained in Appendix II.

A total of 16 taxa was identified from among the 65000 specimens found in the 64 cores. This includes five types of sponge spicules, one species of pteropod, at least six species of bivalves, three species of holothurians, and one echinoid species. The distribution of the fauna is shown in Figures 9-11, and the description is given in Appendix I. The holothurians are the most widely distributed of these groups. Pourtalesia jeffreysi and Myriotrochus have not been previously known to occur in the central Arctic Ocean. The bathymetric ranges for Portlandia intermedia and Kolga hyalina have been extended over previous reports (Table 2).

It is impossible to compare the relative abunances of all the various groups collectively, because the skeleton of a particular organism

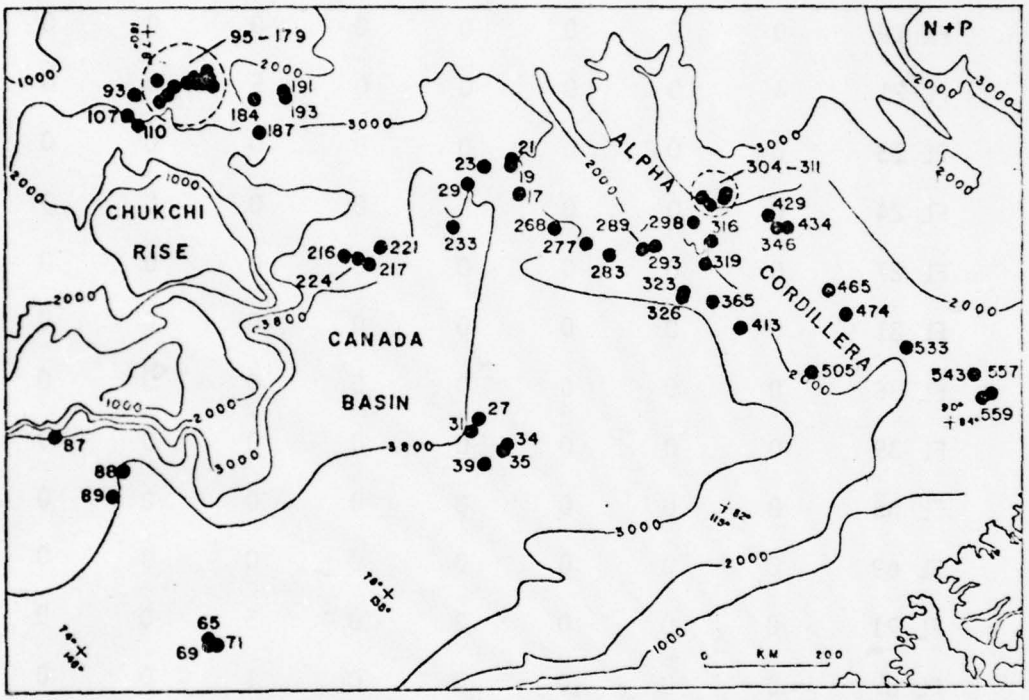


Figure 8. Map of the Arctic Ocean showing location of samples studied.

Table 1. Faunal abundances by core sample.

Sample Number	Thenea sp.	Tetraxons	Triradiates	Klostose monaxons	Monaxons	Sponges (combined)	Limacina helicina	Nucula sp.	Portlandia intermedia
FL 17	0	0	0	0	0	0	243	0	0
FL 19	0	0	0	0	0	0	0	0	0
FL 21	4	0	0	0	0	5	0	0	0
FL 23	0	0	0	0	0	0	0	0	0
FL 24	0	0	0	0	0	0	0	0	0
FL 27	0	0	0	0	0	0	0	0	0
FL 31	0	0	0	0	0	0	0	0	0
FL 36	0	0	0	0	0	0	0	0	0
FL 39	0	0	0	0	0	0	0	0	0
FL 65	0	0	0	0	0	0	0	0	0
FL 69	0	0	0	0	0	0	0	0	0
FL 71	0	0	0	3	0	5	0	0	0
FL 87	0	0	0	0	0	1	0	0	0
FL 93	1	1	0	0	0	15	0	0	0
FL 95	8	0	0	0	0	19	367	0	3
FL107	0	0	0	0	0	0	0	0	0
FL110	1	0	0	0	0	1	3	0	0
FL116	1	0	0	0	0	2	9	0	0
FL125	0	0	0	0	0	0	110	0	1
FL126	0	0	0	0	0	0	194	0	0
FL138	0	0	0	0	0	0	43	0	0
FL142	4	2	1	0	0	17	625	0	1

Table 1. Continued.

Sample Number	Thenea sp.	Tetraxons	Triradiates	Klostose monaxons	Monaxons	Sponges (combined)	Limacina helicina	Nucula sp.	Portlandia intermedia
FL149	0	0	0	0	0	0	273	0	0
FL166	0	0	0	0	0	1	23	0	0
FL173	0	0	0	0	0	0	1	0	0
FL179	1	0	0	0	0	1	54	0	0
FL182	1	0	1	0	0	1	661	0	11
FL184	1	0	0	0	0	1	84	0	0
FL187	0	0	0	0	0	1	69	0	2
FL191	3	0	0	0	0	3	2613	2	18
FL193	0	0	0	0	0	0	1120	0	0
FL216	0	0	0	0	0	0	0	0	0
FL217	0	0	0	0	0	0	0	0	0
FL221	0	0	0	0	0	0	0	0	0
FL224	0	0	0	0	0	0	0	0	0
FL233	0	0	0	1	0	1	1	0	0
FL268	0	0	0	0	0	0	48	0	0
FL277	0	0	0	0	0	0	115	0	2
FL283	5	0	0	0	0	6	725	0	0
FL289	0	0	0	0	0	0	0	0	0
FL293	0	0	0	0	0	1	2155	0	0
FL298	0	0	0	0	0	0	15	0	0
FL304	0	0	0	0	0	0	26	0	0
FL306	0	0	0	0	0	0	132	0	0

Table 1. Continued.

Sample Number	Thenea sp.	Tetraxons	Triradiates	Klostose monaxons	Monaxons	Sponges (combined)	Limacina helicina	Nucula sp.	Portlandia intermedia
FL310	0	0	0	0	0	2	4405	0	6
FL311	0	0	0	0	0	2	4618	0	1
FL316	0	0	0	0	0	0	1329	0	0
FL319	0	0	0	0	1	1	1104	0	0
FL323	0	0	0	0	0	0	11	0	0
FL326	2	0	0	0	0	1	248	0	0
FL343	0	0	0	0	0	0	1419	0	0
FL346	0	0	0	0	0	0	396	0	3
FL365	0	0	0	0	1	1	45	0	3
FL413	1	0	0	0	0	1	566	0	4
FL423	0	0	0	0	1	3	4559	0	0
FL429	1	0	0	0	0	1	736	0	2
FL434	0	0	0	0	0	0	2257	0	0
FL465	3	0	1	0	0	4	1487	0	2
FL474	3	3	0	0	0	40	7474	3	0
FL505	0	0	0	0	0	0	77	0	1
FL533	0	0	0	0	0	0	884	0	0
FL542	0	0	0	0	0	1	30	0	1
FL557	0	0	0	0	0	0	0	0	0
FL559	0	0	0	0	0	2	52	0	0

Note: Sponges (combined) includes spicules that could not be classified.

Table 1. Continued.

Sample Number	Bathyarca frielei	Pectinidae	Limatula hyperborea	Cuspidaria sp.	Bivalves (combined)	Pourtalesia jeffreysi	Kolga hyalina	Elpidia glacialis	Myriotrochus sp.
FL 17	0	0	0	0	1	0	0	42	3
FL 19	0	0	0	0	0	0	0	3	0
FL 21	0	0	0	0	0	0	0	119	0
FL 23	0	0	0	0	0	0	0	3	0
FL 24	0	0	0	0	0	0	0	1	0
FL 27	0	0	0	0	0	0	0	3	0
FL 31	0	0	0	0	0	0	0	1	0
FL 36	0	0	0	0	0	0	0	9	0
FL 39	0	0	0	0	0	0	0	1	0
FL 65	0	0	0	0	0	0	0	30	0
FL 69	0	0	0	0	0	0	0	1	0
FL 71	0	0	0	0	0	0	0	494	0
FL 87	0	0	0	0	0	0	0	29	0
FL 93	0	0	0	0	0	1	0	16	0
FL 95	0	0	0	0	13	20	12	574	1
FL107	0	0	0	0	0	0	13	252	0
FL110	0	1	0	0	2	0	0	415	0
FL116	0	0	0	0	0	0	0	12	0
FL125	0	0	0	0	2	10	7	289	0
FL126	0	0	0	0	2	27	1	632	1
FL138	0	0	0	0	0	0	0	15	0
FL142	0	0	0	0	0	2	0	361	3

Table 1. Continued.

Sample Number	Bathyarca frielei	Pectinidae	Limatula hyperborea	Cuspidaria sp.	Bivalves (combined)	Pourtalesia jeffreysi	Kolga hyalina	Elpidia glacialis	Myriotrochus sp.
FL149	0	0	0	0	0	2	0	100	0
FL166	0	1	0	0	1	2	0	196	0
FL178	0	0	0	0	0	0	2	11	0
FL179	0	1	0	0	2	7	7	179	0
FL182	4	0	2	1	18	9	4	1707	15
FL184	0	3	0	0	7	1	57	596	3
FL187	0	1	0	0	4	0	4	555	0
FL191	0	3	0	0	32	1	106	1069	27
FL193	0	2	0	0	8	0	4	494	2
FL216	0	0	0	0	0	0	0	192	0
FL217	0	0	0	0	0	0	0	1	0
FL221	0	0	0	0	0	0	0	173	0
FL224	0	0	0	0	0	0	5	639	0
FL233	0	0	0	0	0	0	0	40	0
FL268	0	0	0	0	2	0	0	171	0
FL277	0	0	0	0	5	0	1	245	0
FL283	0	1	0	0	3	0	5	358	0
FL289	0	0	0	0	0	0	0	23	0
FL293	0	2	0	0	38	5	18	464	2
FL298	1	0	0	0	1	0	27	227	0
FL304	0	0	0	0	0	0	4	228	0
FL306	0	0	0	0	0	0	0	124	0

Table 1. Continued.

Sample Number	Bathyarca frielei	Pectinidae	Limatula hyperborea	Cuspidaria sp.	Bivalves (combined)	Pourtalesia jeffreysi	Kolga hyalina	Elpidia glacialis	Myriotrochus sp.
FL310	0	1	0	0	30	0	149	523	0
FL311	0	0	0	0	5	0	135	871	0
FL316	3	1	0	0	5	0	20	372	0
FL319	0	0	0	0	2	0	0	353	35
FL323	0	2	0	0	2	0	1	112	0
FL326	0	1	0	0	3	0	18	572	0
FL343	0	0	0	0	1	2	56	196	0
FL346	0	0	0	0	9	0	16	504	0
FL365	0	2	0	0	9	0	1	147	0
FL413	0	0	0	0	48	0	128	2426	0
FL423	5	11	0	0	33	14	49	984	67
FL429	1	2	0	0	13	0	41	431	30
FL434	2	1	0	0	10	0	187	1205	1
FL465	5	1	0	0	12	0	10	1085	8
FL474	9	3	0	0	34	8	62	934	23
FL505	0	3	0	0	4	0	58	424	10
FL533	3	1	0	0	8	0	34	291	4
FL542	0	1	0	0	6	1	80	169	1
FL557	0	9	0	0	9	9	5	27	0
FL559	2	0	0	0	2	0	50	187	1

Note: Bivalves (combined) includes unidentifiable juveniles.

Figure 9. The distribution of A: Thenea sp.; B: Klostose monaxons (●), monaxons (■), and tetraxons (▲); C: Triradiates; and D: Limacina helicina in the central Arctic Ocean. (Core locations are shown in Figure 6; specific information is given in Appendix II.)

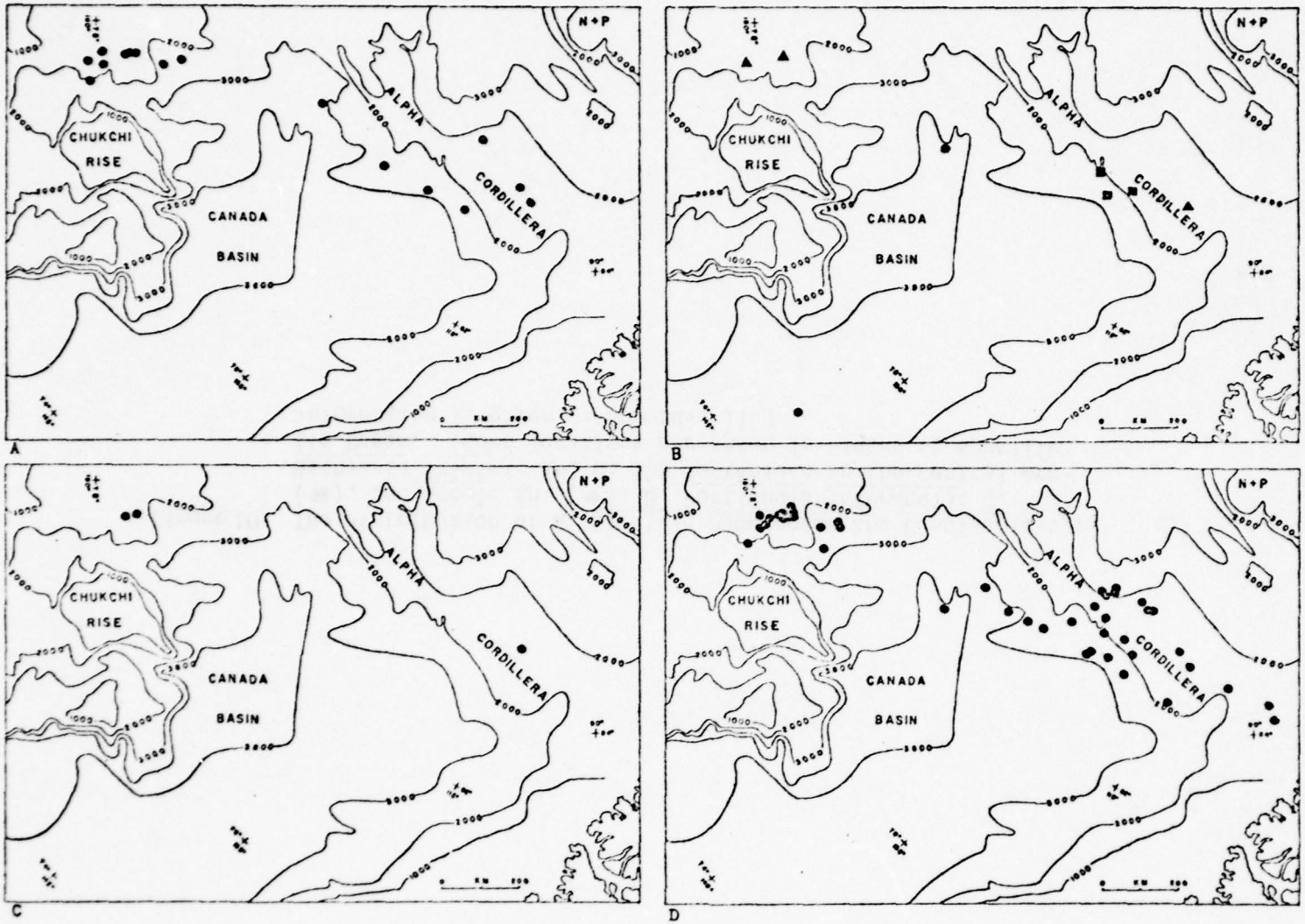

A
CHUKCHI
RISE
CANADA
BASIN
ALPHA
CORDILLERA
N+P
B
CHUKCHI
RISE
CANADA
BASIN
ALPHA
CORDILLERA
N+P
C
CHUKCHI
RISE
CANADA
BASIN
ALPHA
CORDILLERA
N+P
D
CHUKCHI
RISE
CANADA
BASIN
ALPHA
CORDILLERA
N+P

Figure 10. The distribution of A: Limatula hyperborea and Cuspidaria sp. (■), and Nucula sp. (●); B: Portlandia intermedia; C: Bathyarca frielei; and D: the Pectinidae in the central Arctic Ocean. (Core locations are shown in Figure 6; specific information is given in Appendix II.)

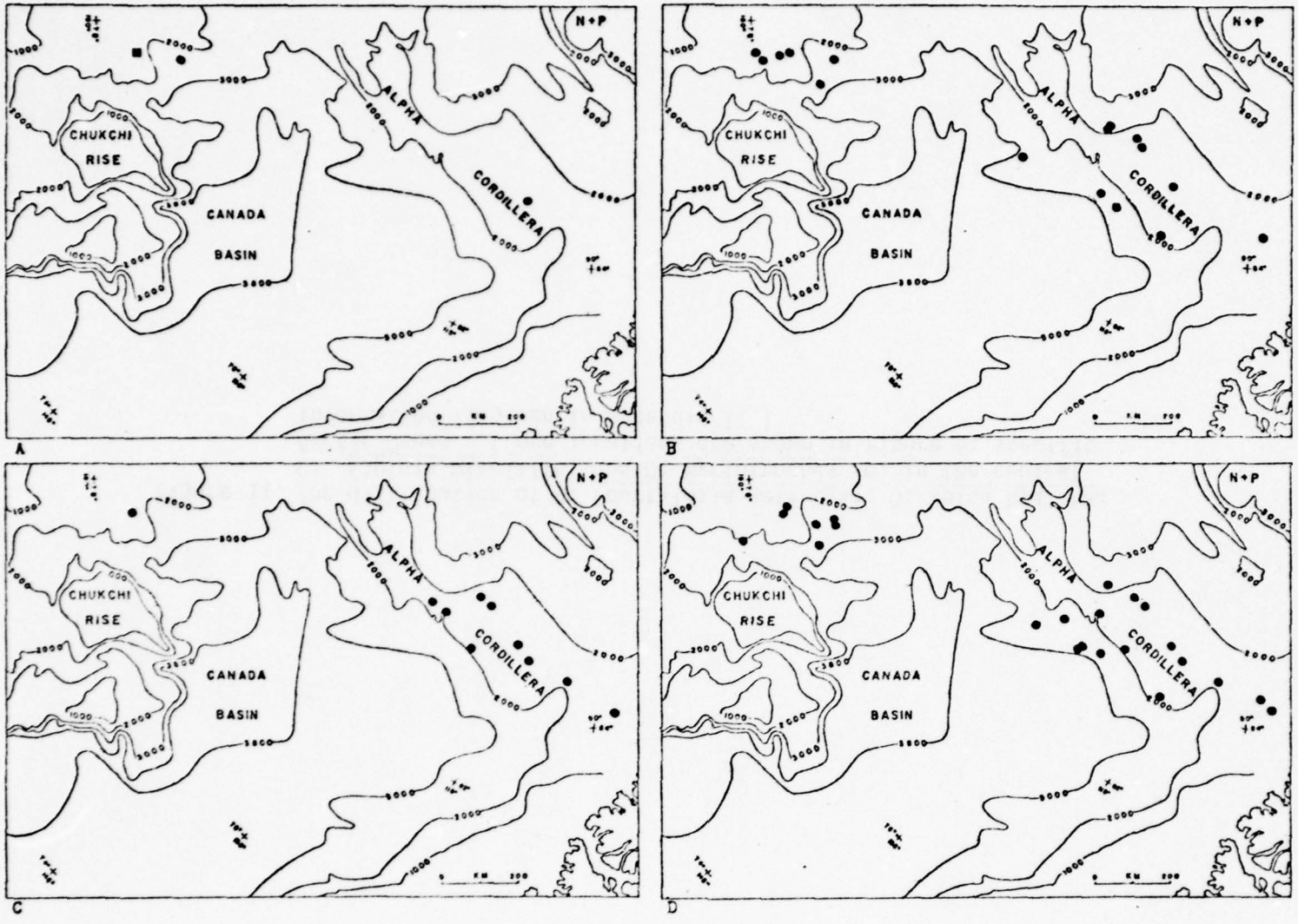
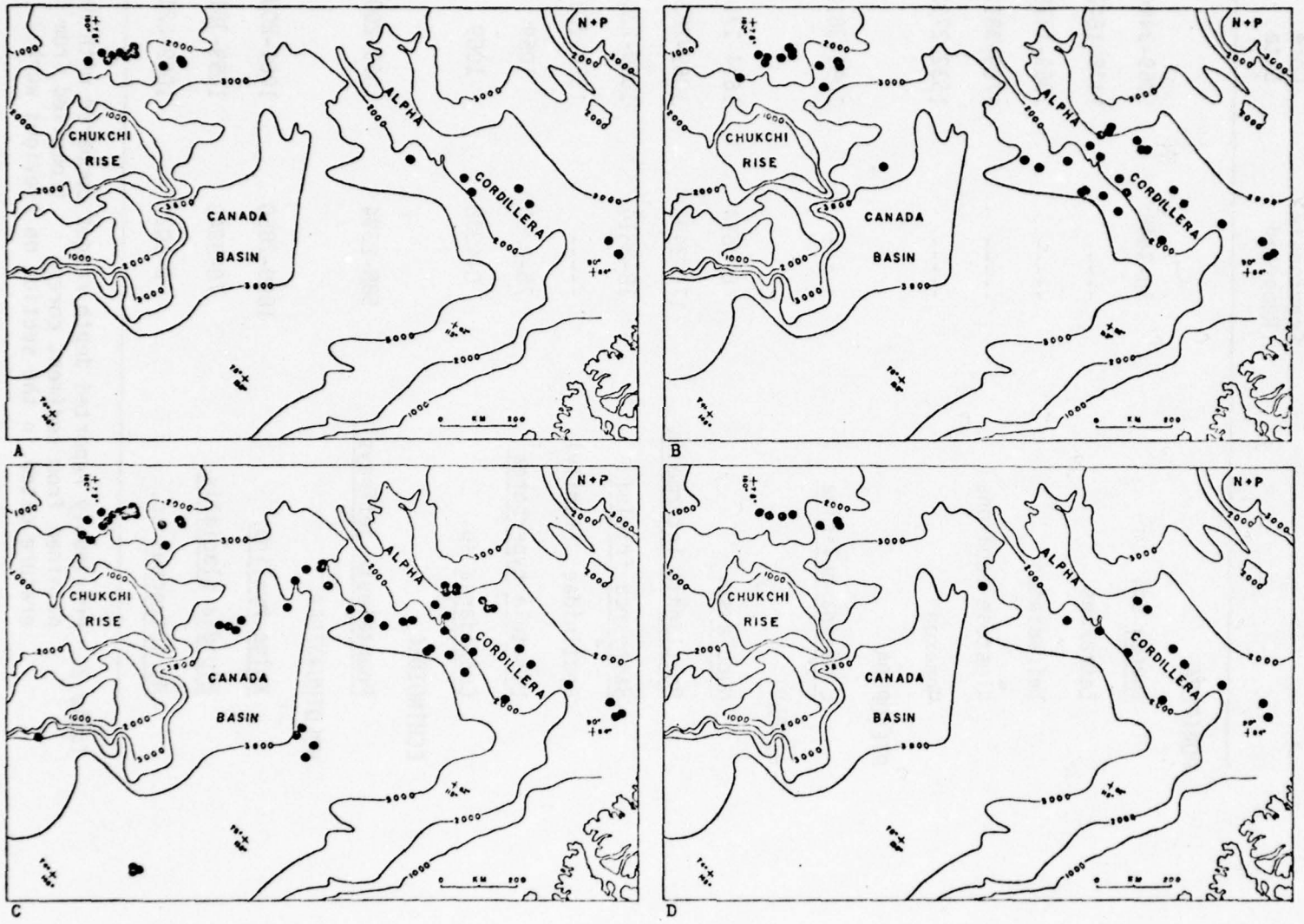

A
B
C
D
CHUKCHI
RISE
CANADA
BASIN
ALPHA
CORDILLERA
N+P

Figure 11. The distribution of A: Pourtalesia jeffreysi; B: Kolga hyalina; C: Elpidia glacialis; and D: Myriotrochus sp. in the central Arctic Ocean. (Core locations are shown in Figure 6; specific information is given in Appendix II.)


N+P
CHUKCHI
RISE
ALPHA
CORDILLERA
CANADA
BASIN
A
B
C
D

	DEPTH RANGE (m)	
	Previously Reported	Core Data
PORIFERA		
Thenea sp.	30-3548	1069-3494
Tetraxons	-----	1478-1647
Triradiates	-----	1069-1478
Klostose monaxons	-----	3709-3812
Monaxons	-----	1532-2732
PTEROPODA		
Limacina helicina	-----	1069-3812
BIVALVIA		
Nucula sp.	6-3694	1644-1717
Portlandia intermedia	174-2493	1069-2871
Bathyarca frielei	18-2814	1069-2215
Pectinidae (family)	-----	1356-2732
Limatula hyperborea	75-2250	1069
Cuspidaria sp.	0-4336	1069
ECHINOIDEA		
Pourtalesia jeffreysi	588-2394	1069-2095
HOLOTHUROIDEA		
Kolga hyalina	1800-2850	1069-2095
Elpidia glacialis	70-8940	1069-3812
Myriotrochus sp.	0-10210	1069-2213

Table 2. Previously reported depth ranges compared with data obtained from sediment cores. (Compiled from literature cited in the section on previous work.)

may consist of multiple elements. Shells of pteropods and bivalves are more easily understood, and can be quantitatively compared with one another. Portlandia intermedia is the most abundant bivalve, while the pectinids are most widespread.

An obvious dearth of fauna exists in the core samples from the Canada Basin. One possible explanation for this is that the water depth and associated factors are not tolerable for most of the organisms dealt with in the study (Table 2). Another possibility for the paucity of fauna is the much higher sedimentation rate, which may be 50 to 100 times greater than in the shallower waters on the Alpha Cordillera. Hence, the available time for skeletal debris to accumulate in a given thickness of sediment is drastically reduced. Most likely, several controlling factors unique to each type of organism limit the distribution in the Canada Basin.

A major concern in any study of the distribution of the remains of organisms is whether or not they are in situ, or have been transported. The most obvious evidence of transport is the occurrence of shallower water forms in water depths greater than previously noted. All the fauna with the exception of P. intermedia and K. hyalina were found in core samples from water depths well within those previously reported. This does not preclude the possibility of transport, but certainly does not lend support to it.

The fauna appears quite similar to that found in the North Atlantic, especially the Norwegian-Greenland Seas. This is in accordance with the supposition that the two water masses are quite similar with the primary source of the Arctic Ocean water being the North Atlantic. The shallow

waters of the Bering Strait probably prohibit any major mixing of Pacific fauna with that of the Arctic.

DISTRIBUTION AND ECOLOGY

CORRELATION

A correlation analysis was performed in an effort to determine any distributional patterns not evident by simple qualitative observation of the data. The abundances of 11 of the more common groups were correlated with the few environmental parameters available for the core samples which are depth, percentage of coarse sediment over 62 microns, and percentage water in the sediment. Other factors such as water temperature, salinity, and oxygen concentration were not included, because they are nearly constant throughout the study area. The correlation matrix is shown in Figure 12. Faunal abundances were expressed in numbers per gram of dry sediment to reduce the effect of sample size on the results. The DSTAT2 program of the STATJOB series, which is available at the Academic Computing Center at the University of Wisconsin-Madison, was used to compute the correlation matrix.

In general depth and dependent parameters appear to be the most significant limiting factors in the distribution of the various fauna. This is evident in that depth correlated with abundances more strongly and frequently than any of the other parameters. Seven of the 11 groups exhibited a negative correlation with depth at the 95 percent level of confidence. Further depth control may be indicated by the absence of certain organisms above or below a given water depth in the study area. Limacina helicina and Elpidia glacialis are the only species that extend throughout

	Thenea sp.	Porifera (combined)	Limacina helicina	*Portlandia intermedia*	Bathyarca frielei	Pectinidae	Bivalvia (combined)	Pourtalesia jeffreysi	Kolga hyalina	Elpidia glacialis	Myriotrochus sp.	Depth	%Coarse	%Water	Region
Thenea sp.			+												
*Porifera (combined)**			+						+	+					
Limacina helicina					+	+	+		+	+	+	-			
Portlandia intermedia							+		+	+	+				
Bathyarca frielei						+	+			+	+	-	+		
Pectinidae							+				+	-		-	
Bivalvia (combined)**									+	+	+	-	+		
Pourtalesia jeffreysi										+		-			-
Kolga hyalina										+	+				
Elpidia glacialis											+	-			-
Myriotrochus sp.												-			
Depth													-	+	+
% Coarse															
%Water															
Region															

Figure 12. Correlation matrix. (+) indicates positive correlation, (-) indicates negative correlation, and blanks indicate no correlation at the 95% confidence level.

*Includes spicules that could not be classified.
**Includes unidentifiable juveniles.

the entire depth range of the area.

The most direct effect of depth, hydrostatic pressure, exerts relatively little control over the distribution of marine organisms. However, temperature, salinity, light intensity, dissolved oxygen, food supply, and other depth-dependent parameters may have an important influence on species distribution. Food supply, for example, decreases markedly with depth below 200 meters, because of reduced food production below the photic zone. In general there is a corresponding decrease in abundance of organisms with increase in water depth.

Only the bivalves displayed correlation with the two sedimentary parameters. Both the bivalves (combined) and Bathyarca frielei were positively correlated with the percentage of coarse sediment. The pectinids correlated negatively with the percentage water in the sediment.

The study area was divided into six geographic regions shown in Figure 13 , which were correlated with the faunal abundances. P. jeffreysi and E. glacialis did correlate with region at the 95 percent confidence level, indicating abundances were influenced at least to some extent by geographic location.

LIMITING FACTORS

Some of the major limiting factors which influence the distribution of most benthonic organisms are temperature, salinity, depth-dependent parameters, type of substrate, energy conditions, turbidity, and biological factors including food supply, predation, competition, etc. Temperature and salinity of the bottom water in the central Arctic are not important environmental parameters, because both are nearly constant throughout the area. The significance of the other factors varies with type of

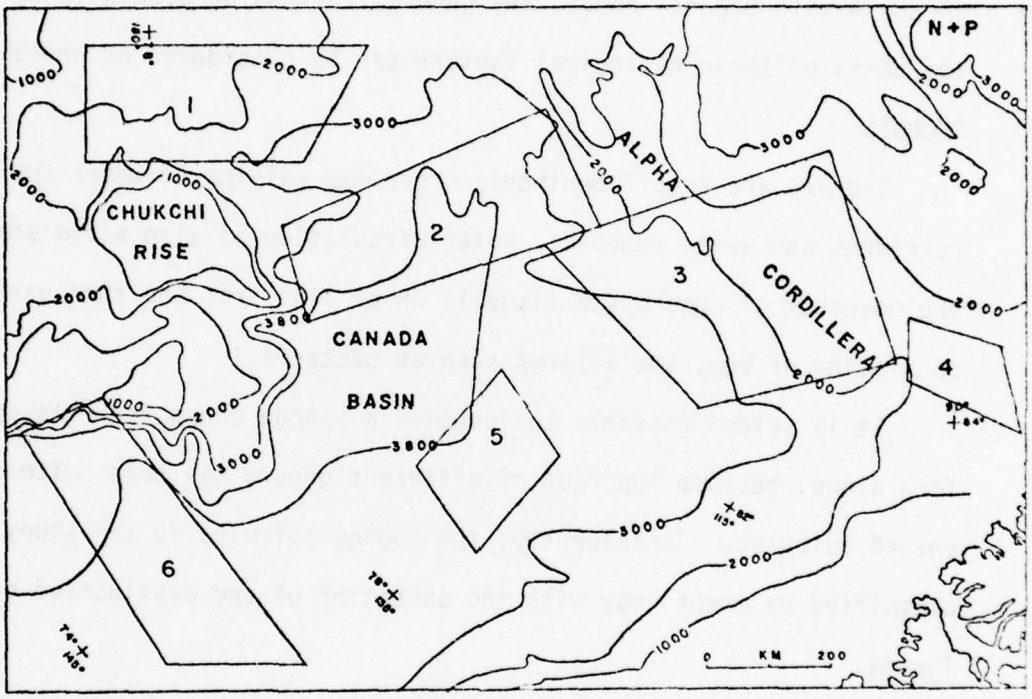


Figure 13. Map showing the regions used in the correlation analysis.

organism.

Little is known about the requirements of most suspension and deposit-feeders. In addition there is only limited knowledge concerning available food and nutrient supply and the relationships among organisms in the Arctic Ocean. Hence, any generalizations or conclusions made on the basis of these biological factors can be considered as preliminary.

SPONGES

Sponges are sessil benthonic organisms relying on water currents for nutrients and waste removal. Water circulation is also aided somewhat by the movement of choanocyte flagella which also trap the food particles consisting of very small forms such as bacteria.

It is seldom possible to identify a sponge genus from its spicule form alone, because hundreds of different genera may have quite similar shaped spicules. Consequently, the sponge spicules in the study are classified by morphology with the exception of one distinctive genus, Thenea.

A major problem exists in quantifying the sponge data, because only parts of the organism are dealt with rather than a whole one. There is a possibility that some cores may have fortuitously contained the remains of a single sponge still closely assembled at the place of burial, resulting in an erroneous appearance of abundance. However, the distribution of sponge spicules is rather general and numbers per sample quite low, indicating that the quantity of spicules present is probably representative of the average content in the sediment. If this is the case, the concentration of spicules should reflect general trends in the population density of the sponges themselves on the deep-sea bottom. Many of the

specimens were broken with only the rhabdome remaining, making classification impossible.

Sponges occupy a wide range of water depths with siliceous sponges generally more common at greater depths and calcareous ones restricted to more shallow water. However, a few calcareous spicules were recovered from three core samples from depths in excess of 1000 meters.

Individual sponges are usually quite sensitive to temperature and can only survive the fluctuations of the environment where they are living, although a given species as a whole may occur in Arctic, temperate, and tropical water.

Probably the two most important physical parameters which could limit the distribution of sponges would be water circulation and turbidity. Because the strength of currents would directly affect the amount of nutrients available and determine the effectiveness of waste removal, sponges tend to favor more turbulent water. Mud and silt from highly turbid waters would tend to clog inhalent openings, thus preventing any extensive colonization of sponges in such environments.

Thenea, more widespread in occurrence than all other forms combined, is primarily restricted to the Alpha Cordillera. Current strength in the Canada Basin, evidently less than 1/6 that of the Alpha Cordillera, may be insufficient to provide the necessary nutrients and sanitation. Turbidity currents result in an intolerably high amount of suspended sediment at times. It is doubtful, however, that they occur frequently enough to prohibit colonization of the area permanently.

Depth and its related parameters are also important, because most of the samples from the Canada Basin are from water depths greater than the

3548 meters previously reported for Thenea.

BIVALVES

Bivalves occupy a considerable variety of aquatic niches. A large number are infaunal, burrowing into the soft substrate at varying depths. Many of the more shallow burrowers emerge to the surface and migrate laterally, while the deeper ones are generally sedentary. Epifaunal bivalves may be free-living or attached either by means of a byssus or by cementation of one of the valves. Some of the free-living pectinids and limids have the ability to swim by clapping of valves.

Two major feeding habits developed in bivalves are suspension-feeding and deposit-feeding. The food supply for suspension feeders consists of protists, chiefly diatoms and dinoflagellates, which are strained from the water by gills. Deposit-feeders generally use inhalent siphons to collect food from the sediment, but in the Nuculacea this is achieved by appendages of the labial palps. A small group of bivalves, the septibranchs, have developed a carnivorous habit, drawing worms and crustaceans into the mantle cavity.

The shell form is highly reflective of environmental demands, resulting in strikingly similar shapes in even distantly related bivalves that occupy the same niche. For example, rapid burrowers are generally elongate, streamline, and lack ornamentation, whereas slow burrowers have more ovate, inflated shells.

The bivalves found in the Arctic Ocean fill several of the above niches. Both P. intermedia and Nucula are shallow burrowers and deposit-feeders. B. frielei is an epifaunal, filter-feeder possessing a very small byssus. Other epifaunal bivalves include the pectinids and Lima-

tula hyperborea, both filter-feeders; and Cuspidaria, which is carnivorous.

No specimens found in the Arctic core sediments were articulated, so numerical data refers to single valves only. Most of the cores having bivalves contain numerous unidentifiable fragments.

All of the bivalve specimens are juveniles, which presents a major difficulty in identification. However, there are a few larger specimens which are mature enough to have developed at least some characteristics of the adult forms.

Depth and its related parameters are important factors to all bivalves in the study area, each form having a limited bathymetric range. L. hyperborea and Cuspidaria were present only in the sample from the shallowest depth, 1069 meters. The bivalves collectively, as well as B. frielei and the pectinids show a trend toward decreasing abundance with increasing depth as evidenced by negative correlation of abundances with depth at the 95 percent confidence level. Diminishing food supply in both the water and sediment in progressively deeper water might explain the observed trends.

The abundance of B. frielei correlates positively with the percentage of coarse sediment, indicating a general preference for coarser sediment which would provide for better byssal attachment. This selectivity of substrate is further demonstrated by the distribution pattern showing occurrences confined to the region of the Alpha Cordillera with the coarsest sediment (Figure 8C).

The pectinid bivalves are negatively correlated with the percentage water in the sediment. If water content can be used as an indicator of

the firmness of the substrate, then the lower the percentage of water, the harder the sediment surface. This might suggest a preference for harder substrates by the pectinids, which is logical because many in this group are free-living, requiring a sediment surface at least compact enough to support their own weight.

There is a conspicuous absence of bivalves in the Canada Basin. This may be due to the depths in the Canada Basin exceeding the various parameters that are tolerable for the bivalves. Perhaps there is a lack of sufficient circulation essential to the filter-feeders, or turbidity currents may create unfavorable conditions. Because the deepest parts of the Canada Basin lie above the compensation level for calcite, dissolution probably is not an important factor.

ECHINOIDS

Echinoids generally are adapted to a rather wide range of conditions from intertidal to depths in excess of 7000 meters. They are benthonic and may be free-living, occupy rock crevices, or burrow into soft sediment. The burrowers are deposit feeders which carry fine particles of sediment by ciliary tracts, mucous threads, and highly modified tube feet. Bathymetric ranges differ among genera, but generally the shallow water forms are much more restricted than those occupying greater depths.

Plate fragments, single valves of ophicephalous pedicellariae, and spines from the species Pourtalesia jeffreysi were found in the core sediments. Pedicellariae, which are rasping, defense, and scavenging organs, are each composed of three valves attached to a muscular stem. The spines on the living animal are articulated to the plate tubercles and moved by ligaments or muscles which decay after death, freeing the spines from the

body.

P. jeffreysi is a burrower, presumably dwelling partially submerged in the substrate with the upper surface exposed. The shallower waters over the Alpha Cordillera are preferred with the deepest occurrence at 2095 meters. A trend toward lesser abundance with increasing depth is shown by a negative correlation with depth at the 95 percent confidence level.

The species also correlated with region. It is difficult to speculate what factors would control the abundances geographically. Perhaps uneveness of food supply is an explanation.

HOLOTHURIANS

Holothurians occupy several ecologic niches. They inhabit rocky to muddy substrates and may crawl on the sediment surface, burrow, swim, or attach themselves to hard substrates or seaweeds. Members of the Order Dendrochirotida are planktonic feeders, but the majority are deposit-feeders.

Holothurian sclerites seldom are distinctive enough to use as a sole criteria for taxomonic identification to even generic level. There is not only the problem of similar-shaped sclerites occurring in different species, but also various types of sclerites within the same animal. Fortunately, the three holothurian taxa dealt with in this study each possess only one major type of sclerite, which is sufficiently distinctive to enable identification at least to genus level with some confidence. There is also the problem of quantifying the data, because only parts of an organism are dealt with.

The three species of holothurians are deposit feeders commonly found

in muddy sediments. E. glacialis and K. hyalina possess tube feet enabling them to crawl about on the sediment, whereas Myriotrochus is a member of the Order Apoda, which lack tube feet and are generally burrowers.

The factors associated with depth appear to be most important for the distribution and abundance of holothurians. Both E. glacialis and Myriotrochus are negatively correlated with depth. While E. glacialis occurs throughout the depth range of the study area, K. hyalina and Myriotrochus are limited to depths no greater than 3467 and 2213 meters, respectively. Because holothurians generally are quite tolerant of large bathymetric ranges, it is likely that some other parameter associated with depth is responsible for the observed distributional patterns. Perhaps the availability of food decreases with depth, limiting the number of organisms that can be supported.

Some geographic control on the abundance is suggested by the correlation of E. glacialis and region. Again, this could be a function of the abundance of food.

PTEROPODS

Pteropods are pelagic organisms, so that many of the ecologic parameters such as water depth and substrate type have no relevance. However, many of the other limiting factors including temperature, salinity, turbidity, etc. are still important.

A single species, Limacina helicina plus one variety have been found in the core sediments. Pteropods are rather abundant in several cores with 4000 to over 7000 specimens per sample. The abundance and distribution observed in the sediment may not reflect that which is above, be-

cause the shells are very light and could be transported great distances after death.

Generally, most pteropods are confined to the top 700 meters in the water column. Limacina usually ranges between about 50 and 250 meters from the surface (Morton, 1954). There is also a tendency to migrate vertically, descending during the day and ascending at night in response to light.

Pteropods are not particularly sensitive to temperature, often encountering changes in excess of 10°C during vertical movement. The temperature profile for the top 500 meters in Figure 5 shows a vertical temperature variation in the Canada Basin of 2°C which is well within the tolerable levels of most pteropods. While some variation in the temperature and salinity of the surface water in the study area does exist, it is probably rather minimal, because the region lies entirely within the permanent ice pack. Therefore, it is not likely that temperature or salinity are important factors limiting the distribution of pteropods.

Another possibility is that the distribution reflects regions of more abundant food. The diet of pteropods consists primarily of coccolithophores, radiolarians, and Foraminifera.

Probably the most plausible explanation for the observed distribution is the dissolution of the thin, fragile aragonitic tests. There is some disagreement concerning where the compensation level lies, (as discussed in a previous section), but it is not unreasonable to assume that depth in the Canada Basin is sufficient for some dissolution. This idea is substantiated by a negative correlation of L. helicina abundance with depth. It also seems unlikely that regions with a paucity of pteropods

fortuitously coincide with regions having greater water depths.

SUMMARY AND CONCLUSIONS

Five types of sponge spicules, one species of pteropod, at least six species of bivalves, three species of holothurians, and one echinoid species were found in the top three centimeters of 64 sediment cores from water depths ranging between 1069 and 3812 meters. Holothurians have the most widespread occurrence of the groups. Pourtalesia jeffreysi and Myriotrochus sp. have not been previously known to occur in the central Arctic Ocean. The bathymetric ranges for Portlandia intermedia and Kolga hyalina have been extended over prior reports.

Depth and related factors are the most important influence on distribution. Of the various fauna seven of the 11 more common groups exhibited a negative correlation with depth. The absence of certain organisms above or below a given water depth in the study area indicates further control by depth-dependent parameters. Limacina helicina and Elpidia glacialis are the only species found throughout the depth range of the study area.

The abundance of E. glacialis and P. jeffreysi is influenced at least to some extent by geographic location.

Only the bivalves exhibit correlation with the two sedimentary parameters. Both the bivalves (combined) and Bathyarca frielei are associated with coarser sediment. The pectinids are more abundant in sediment with a lesser water content.

The Arctic fauna appears quite similar to that found in the North Atlantic, especially the Norwegian-Greenland Seas. Major mixing of Pacific and Arctic faunas is probably prohibited by the shallow waters of the Bering Strait.

Because many of the physical and chemical environmental parameters including temperature, salinity and oxygen concentration are relatively constant throughout the study area, they are not important in the faunal distributions. Biological factors such as food supply, predation, competition, etc. may be more important, but are poorly known. Dissolution of aragonite may explain the paucity of pteropods at greater depths.

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REPOSITORY

The SEM mounts of the specimens figured are in the repository of the Department of Geology and Geophysics, University of Wisconsin, Madison, and are filed under UW 1638-1 to UW 1638-44.

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APPENDIX I

SYSTEMATIC DESCRIPTIONS

Sixteen varieties of sponge spicules, molluscs, and echinoderms are described. The classification scheme basically follows that which is developed in the Treatise on Invertebrate Paleontology, but has been supplemented when more detail was necessary. The morphologic classification used for the sponge spicules is after Butler (1961).

Identification of the bivalves is with some uncertainty, because all specimens are juvenile forms. For this reason along with poor preservation, the bivalve shown in Plate 1, figures 11 and 12 was not identified, but included for future reference.

Phylum PORIFERA

Class DEMOSPONGEA Sollas, 1875

Order CHORISTIDA Sollas, 1880

Suborder ASTROPHORA Sollas, 1887

Family THENEIDAE Sollas, 1883

Genus THENEA Gray, 1867

THENEA SP.

Pl. 2 figs. 6, 11

Thenea GRAY, 1867, p. 541: HANSEN, 1885, p. 18, pl. 5, fig. 6-9; SOLLAS, 1888, p. cxxviii, 59; VON LENDENFELD, 1907, p. 179, pls. 19-23; BRONSTED, 1933, p. 6; PAUL AND MENZIES, 1973, p. 96, fig. 18C

Description. Symmetrical form with one or more distinct oscules, and with specialized pore areas; Skeletal elements in the core samples are tetraxon spicules which are dichotriaenes, each consisting of an

elongated rhabdome and a cladome of three forked cladi.

Rather variable in size. Rhabdomes average greater than 0.80 mm long and 0.048 mm thick; protocladi average 0.125 mm in length and 0.04 mm in thickness; and deuterocladi, 0.30 mm long and 0.035 mm thick.

Remarks. Identification to species on the basis of spicule form along is impossible. The spicule shape is quite distinctive for the genus, however.

Occurrence. A total of 40 recognizable specimens was found in 16 core samples. Thenea has been reported from the West Indies, S. W. Europe, Prince Edward Island, S. E. Australia, the west coast of South America (Sollas, 1888), Scotland, western Africa, eastern Africa (Lendenfeld, 1907), Norwegian Sea, Barents Sea (Hansen, 1885), N. W. Greenland, Jan Mayen, Spitzbergen (Bronsted, 1933), and Alpha Cordillera (Paul and Menzies, 1973).

TETRAXONS

Pl. 2 fig. 5

Description. Tetraxon spicules are anatriaenes consisting of a very elongated rhabdome and a cladome of three short cladi directed back toward the rhabdome. All specimens are broken.

Rhabdomes average greater than 1.4 mm in length and are 0.03 mm thick. Length of cladi averages about 0.098 mm and thickness 0.027 mm.

Occurrence. A total of six specimens of this type sponge spicule was found in samples FL 93, FL 142, and FL 474.

TRIRADIATES

Pl. 2 fig. 12

Description. Calcareous triradiates are irregular Y-shaped triacts, one ray slightly longer than the other; pointed extremities.

Specimens range little in size, longest ray about 0.37 mm long, two shorter rays are 0.32 mm long. Thickness averages about 0.025 mm.

Occurrence. A total of three triradiate type sponge spicules was found in core samples FL 182, FL 142, FL 465.

KLOSTOSE MONAXONS

Pl. 2 fig. 20

Description. Klostose monaxons are Group I Oxeaklosters; slender, slightly curved and pointed at both extremities.

Average length, 0.96 mm and thickness, 0.23 mm.

Occurrence. A total of four Klostose monaxons were found in core samples FL 71 and FL 233.

MONAXONS

Pl. 2 fig. 21

Description. Rather thick monaxial spicules terminated by a rough textured bulb-like process; impossible to ascertain whether extremities are similar or dissimilar because all specimens are broken.

Thickness extremely variable ranging from 0.04 mm to 0.14 mm, largest fragment 2.5 mm long.

Occurrence. A total of three spicules of this type was found samples FL 319, FL 365, and FL 423.

Phylum MOLLUSCA

Class GASTROPODA Cuvier, 1797

Subclass OPISTHOBRANCHIA Edwards, 1848

Order THECOSOMATA de Blainville, 1824

Family SPIRATELLIDAE Thiele, 1926

Genus LIMACINA Cuvier, 1817

LIMACINA HELICINA Phipps, 1774

Pl. 1 figs. 1-7, 10

Clio helicina PHIPPS, 1774, p. 195.

Limacina helicina, PELSENER, 1888, p. 21-22; FRIELE and GRIEG, 1901, p.121; ODHNER, 1907, p. 92-93; BONNEVIE, 1914, p.12; HERMAN, 1969, p. 270, pl. 2, figs 26, 27; LEUNG, 1971, p. 23-28, figs. 2 A, B, 3 C, D.

Description. Small, thin transparent to translucent shell, smooth surface, low spire, very distinct, deep umbilicus, sinistral coiling.

Diameter of largest specimens: 0.50 mm, height: 0.40 mm. Majority of specimens much smaller, only one whorl; average diameter: 0.15 mm and height: 0.10 mm.

Remarks. An aberrant form was found in two core samples. It has a higher spire than the other forms, horizontal to subhorizontal striations, and dextral coiling. The differences may be due simply to mutation, or perhaps they represent a different species.

Occurrence. L. helicina is quite abundant and widely distributed in the study area. More than 40000 specimens were found in a total of 44 core samples. This species has been previously reported from the White Sea, Kara Sea, Spitzbergen, eastern and western Greenland, Baffin Bay, Norway, Laborador (Odhner, 1907), Davis Strait, Point Barrow, Aleutians (Pelsener, 1888), Gulf of Biscay (Friele and Grieg, 1901), Newfoundland (Bonnevie, 1933), and the Alpha Rise (Herman, 1969).

Class BIVALVIA Linne, 1758

Subclass PALAEOTAXODONTA Korobkov, 1954

Order NUCULOIDA Dall, 1889

Superfamily NUCULACEA Gray, 1824

Family NUCULIDAE Gray, 1824

Genus NUCULA Lamarck, 1799

NUCULA SP.

Pl. 1 figs. 14, 15

Nucula SMITH, 1885, p. 225-230, pl. 63, figs. 8-13; FRIELE and GRIEG, 1901, p. 18-19; THIELE and JAECKEL, 1932, p. 193-200, pl. 2 figs. 35-49; CLARK, 1960, p. 5, pl. 1, figs. 15-18; CLARK, 1962, p. 99; PAUL and MENZIES, 1973, p. 127.

Description. Shell subriangular, inequilateral, hinge-line rather thick with well developed taxodont dentition; two series of somewhat compressed, columnar teeth separated by a prominent chondrophore; juvenile specimens have only two teeth in anterior series and one in posterior series; outer shell surface sculptured with fine radial lines and rather fine, closely spaced, concentric growth-lines; umbo smooth.

Average length of single valves: 1.0 mm; height: 0.89 mm; width; 0.4mm.

Occurrence. Only five specimens of Nucula were found in samples FL 191 and FL 494. This genus has been reported from South Africa, northwestern South America (Smith, 1885), eastern Africa, southeast Asia (Thiele and Jaeckel, 1932), Alpha Cordillera (Clark, 1960), and west flank of the Chukchi Rise (Clark, 1962).

Superfamily NUCULANACEA Adams and Adams, 1858

Family NUCULANIDAE Adams and Adams, 1858

Genus PORTLANDIA Morch, 1857

PORTLANDIA INTERMEDIA Sars, 1865

Pl. 1 figs. 13, 16

Yoldea intermedia SARS, 1865, p. 38, figs. 92-96.

Portlandia intermedia SARS, 1878, pl. 4, figs. 9a-b; FRIELE and GRIEG, 1901, p. 16; OCKELMANN, 1958, p. 27-29, pl. 1, fig. 12; CLARK, 1960, p. 8, pl. 1, figs. 6-8.

Description. Shell ovate-elliptical, thickness rather variable, transparent to opaque, posterior end somewhat long and narrowed; umbo rather prominent with relatively small sub-central beak; taxodont dentition with two series of teeth nearly equal in length, both series contain the same number of teeth, 5 to 8 teeth in each series; margin beneath beak interrupted by small oval-shaped resiliifer, outer surface marked by closely spaced, very fine growth-lines.

Average length of some of the larger specimens: 1.62 mm; height: 1.10 mm; width: 0.47 mm.

Remarks. Valves in samples from deeper water tend to be thin and relatively transparent, while those from shallower depths are thicker and generally opaque.

Occurrence. Portlandia intermedia is the most abundant bivalve in the study area. A total of 61 specimens was found in 16 core samples. This species has also been reported from Spitzbergen, Shetland Islands, Kara Sea, Bering Sea (Friele and Grieg, 1901), eastern and western Greenland, north of Iceland, Barents Sea, Siberian Sea (Ockelmann, 1958), Alpha

Cordillera (Clark, 1960), and west flank of the Chukchi Rise (Clark, 1962).

Subclass PTERIOMORPHIA Beurlen, 1944

Order ARCOIDA Stoliczka, 1871

Superfamily ARCACEA Lamarck, 1809

Family ARCIDAE Lamarck, 1809

Subfamily ANADARINAE Reinhart, 1935

Genus BATHYARCA Kobelt, 1891

BATHYARCA FRIELEI Friele, 1877

Pl. 1 figs. 17, 18

Arca frielei FRIELE, 1877, p. 2

Arca imitata SMITH, 1885, p. 321

Arca frielei FRIELE and GRIEG, 1901, p. 20

Arca (Bathyarca) frielei OCKELMANN, 1958, p. 42, pl. 1, fig. 17.

Bathyarca frielei CLARK, 1960, p. 9, pl. 1, figs. 10-14; CLARK, 1962, p. 101, pl. 2, figs. 12, 14.

Description. Shell extremely variable in shape, generally subovate, inequilateral, reduced anteriorly, inflated; umbo large and situated anteriorly; beak prominent and curved toward anterior; relatively long, straight hinge-line bearing two series of teeth separated by an elongate edentulous gap, anterior teeth oriented obliquely to hinge-line, posterior series sub-parallel to hinge-line, largest specimen has two teeth in the anterior and three teeth in the posterior series; outer shell surface ornamented with radial costellae and prominent, concentric growth-lines, both costellae and growth-lines are most pronounced at the margin and least pronounced on umbo.

Average length of larger specimens: 1.44 mm; height: 1.30 mm, width: 0.42 mm.

Occurrence. A total of 35 specimens was found in 10 core samples. Bathyarca frielei has previously been reported from the Azores, Faroe Channel (Friele and Grieg, 1901), eastern Greenland, Jan Mayen (Ockelmann, 1958), Alpha Cordillera (Clark, 1960), west flank of the Chukchi Rise (Clark, 1962).

Order PTERIOIDA Newell, 1965

Suborder PTERIINA Newell, 1965

Superfamily PECTINACEA, Rafinesque, 1915

Family PECTINIDAE Rafinesque, 1815

Pl. 1 fig. 19

Description. Shell rounded, very thin, nearly smooth with very fine, microscopic growth-lines, hinge-line rather long and straight, edentulous; auricles are nearly equal; byssal notch rather well marked; umbo small with beak not projecting beyond hinge-line.

Average length of larger specimens: 0.7 mm; height: 0.6mm; width; 0.06 mm.

Occurrence. This Family has a widespread occurrence in the study area. A total of 54 specimens was found in 23 core samples.

Superfamily LIMACEA Rafinesque, 1815

Family LIMIDAE Rafinesque, 1815

Genus LIMATULA Wood, 1839

LIMATULA HYPERBOREA Jensen, 1909

Pl. 1 fig. 8

Limatula hyperborea JENSEN, 1909, p. 329, figs. 1a-d.

Lima hyperborea JENSEN 1912, pl 2, figs. 5a-e.

Lima (Limatula) hyperborea OCKELMANN, 1958, p. 72, pl. 2, fig. 3.

Limatula hyperborea CLARK, 1962, p. 102, pl. 2 fig. 13.

Description. Shell thin, vertically ovate, extremely convex, ventral margin nearly evenly rounded; straight hinge-line, auricles small, subequal; beak small, incurved; umbo rather prominent and smooth; shell covered with numerous, fine, but sharp radial ridges which are most pronounced in the middle of the valve, diminish toward the margins, and are absent from the auricles; two middlemost ridges generally stronger and spaced further apart, forming a marked median furrow.

Occurrence. *Only two specimens were found in core sample FL 182.* L. hyperborea has been reported previously from eastern Greenland (Jensen, 1912), northwestern Greenland, Jan Mayen, Spitzbergen, the Kara Sea, Barents Sea (Ockelmann, 1958), Siberian Sea, west flank of the Chukchi Rise (Clark, 1962)

Subclass ANOMALODESMATA Dall, 1889

Order PHOLADOMYOIDA Newell, 1965

Superfamily PANDORACEA Rafinesque, 1815

Family CUSPIDARIIDAE Dall, 1886

Genus CUSPIDARIA Nardo, 1840

CUSPIDARIA SP.

Pl. 1 fig. 9

Cuspidaria THIELE and JAECKEL, 1932, p. 252-257; OCKELMANN, 1958, p. 160-166, pl. 3 figs. 6-10; CLARK, 1960, p. 13.

Description. Shell ovate, rather inflated, posterior end strongly rostrate, ventral margin regularly curved; umbo large with very prominent, incurved beak; hinge-line thin with a posterior lateral tooth on right valve; also has a resilium; outer surface covered by numerous, closely spaced, very fine growth-lines.

The length of measured specimen: 1.6 mm; height: 1.2 mm; and width: 0.3 mm.

Occurrence. Only one specimen was found in core sample FL 182. This genus has also been reported from the east coast of Africa (Thiele and Jaeckel, 1932), eastern and western Greenland, Jan Mayen, Baffinland, Barents Sea, Kara Sea, Nova Scotia (Ockelmann, 1958), and the Alpha Cordillera (Clark, 1960)

PHYLUM ECHINODERMATA

Class ECHINOIDEA Leske, 1778

Subclass EUECHINOIDEA Bronn, 1860

Superorder ASTELOSTOMATA Zittel, 1879

Order HOLASTEROIDA Durham and Melville, 1957

Family POURTALESIIDAE Agassiz, 1881

Genus POURTALESIA Agassiz, 1869

POURTALESIA JEFFREYSI Thomson, 1874

Pl. 2 figs. 13-19

Pourtalesia jeffreysi THOMSON, 1874, p. 747-748, pl. 70, figs. 1-10; LOVEN, 1883, p. 1-95, pls. 1-5; MORTENSEN, 1907, p. 58, pls. 5, 7, 8, 11; DODERLEIN, 1906, p. 269; MORTENSEN, 1932, p. 40.

Description. Test is bottle shaped, posterior rostrate, rather small,

averaging between 30 and 35 mm; detailed description given by Loven (1883); skeletal elements found in core samples include fragments of plates, valves of ophicephalous pedicellariae, and spines; plates contain numerous primary tubercles, mamelon perforate with circular pit, straight neck, parapet crenulate, extra-scrobicular surface covered by numerous miliary tubercles; pedicellariae valves "ladle" shaped with margin of "bowl" serrate; primary spines nearly straight, cylindrical shafts having mesh structure with prominent longitudinal ribs, milled ring very pronounced, distal ends are generally broken off, also some forms are quite robust, club-shaped with distal end flattened; secondary spines very small with bent, flared distal ends, some have several crenated ribs, base crenulate, around margin of socket.

Length of primary spines ranges from over 4 mm to less than 1.3 mm, average diameter about 0.7 mm; length of measured secondary spine: 0.56, diameter: 0.02 mm; pedicellariae average 0.26 mm in length, greatest width averages 0.16 mm.

Remarks. The pedicellariae valves are very diagnostic of the species.

Occurrence. A total of 121 skeletal elements of P. jeffreysi occurred in 17 core samples. This species has also been reported from the Norwegian Sea (Mortensen, 1907 and Thomson, 1874), eastern Greenland (Mortensen, 1907), and southeast of Faeroe Islands (Doderlein, 1906)

Class HOLOTHUROIDEA de Blainville, 1834

Order ELASIPODA Theel, 1882

Family ELPIDIIDAE Theel, 1882

Genus KOLGA Danielssen and Koren, 1882

KOLGA HYALINA Danielssen and Koren, 1882

Pl. 2 figs. 1-4

Kolga hyalina DANIELSSEN and KOREN, 1882, p. 3-20, p. 1-3; THEEL, 1882, p.39; MORTENSEN, 1932, p. 43., AGATEP, 1967a, p. 140.

Description. Body varies in size not exceeding 50 mm in length and about 15 mm in width, 10 tentacles; described in detail by Danielssen and Koren (1882); skeletal elements found in Arctic samples consist of sclerites which are quite variable in shape, ranging from rectilinear to strongly curved; a few to numerous denticles on some; frequently branched at ends with the ramifications serrate; mostly transparent, a few white, opaque.

Length rather variable averaging about 0.43; thickness averages about 0.03 mm.

Remarks. Identification of this species is somewhat uncertain, because it is based exclusively on sclerites which are only partially distinctive. Some sclerites are slightly larger than those described by Danielssen and Koren (1882), but are quite similar in all other respects.

Occurrence. A total of 1377 sclerites was obtained from 36 core samples. Kolga hyalina has been previously reported from Greenland Sea (Theel, 1882), Norwegian Sea (Danielssen and Koren, 1882, and Mortensen, 1932), Canada Basin (Agatep, 1967a), and Alpha Cordillera (Paul and Menzies, 1973).

Genus ELPIDIA Theel, 1876

ELPIDIA GLACIALIS Theel, 1876

Pl. 2 figs. 7-10

Elpidia glacialis THEEL, 1876, p. 1-30; THEEL, 1882, p. 18-19; DANIELSSEN and KOREN, 1882, p. 16-19, MORTENSEN, 1932, p. 41-43, pl. 1, figs. 4-5; HEDING, 1940, p. 370-371; HANSEN, 1956, p. 34-38, fig. 1-6; AGATEP, 1967a, p. 135-139, figs. 1-2; Agatep, 1967b, p. 61, pl. 2, figs. 1-4; PAUL and MENZIES, p. 119-121.

Description. Body is ovate ranging in length from 8 to 25 mm, slightly more than twice as long as broad. (Described in detail by C. P. Agatep, 1967a). Skeletal elements in core samples are sclerites which are extremely variable in shape; consist of main rods, four shorter arms near the center, and in some, two vertical apophyses projecting perpendicular from junction of the arms and main rod; main rods are long and generally straight, but curved in some; arms are both straight and curved; vertical apophysis straight and pointed; in some arms are distinctly set off from the main rod, while in others arms pass smoothly into rod by rounded curves.

Rods vary in length from 0.26 mm to 1.1 mm, averaging about 0.65 mm; arms range from 0.015 mm to 0.40 mm, averaging 0.25 mm; vertical apophyses vary from 0.50 mm to complete absence; rods and arms both avarage about 0.035 mm in thickness, varying between 0.02 mm and 0.10 mm.

Remarks. Hansen (1956) recognized several geographical subspecies from various deep-sea locations, primarily on the basis of the arrangement and number of paired dorsal papillae. The sclerites found in the core samples apparently are from the Arctic subspecies E. glacialis glacialis. Hansen also noted variations in the sclerites among the subspecies. How-

ever, just as much variation was noted in the nearly 23000 sclerites examined, and it was quite difficult to select what could be called a "typical" specimen. A similar range in shape of sclerites was exhibited by specimens collected from a continuous population northeast of Iceland (Hansen, 1956). Therefore, subspecies delineation on the basis of sclerite form alone does not seem to be valid.

Occurrence. E. glacialis is the most widespread of the holothurians found in the study area. Nearly 23000 sclerites were found in 64 core samples. This species has also been reported from the Japan Sea (Theel, 1882), Norwegian Sea, (Danielssen and Koren, 1882), northwest Greenland, Baffin Bay, Spitzbergen, Kara Sea (Mortensen, 1932), northwest coast of Africa (Heding, 1940), Sunda, New Britain, and Kermadec trenches, Tasman Sea (Hansen, 1956), Canada Basin (Agatep, 1967a), Alpha Cordillera (Paul and Menzies, 1973), and Antarctic waters (Agatep, 1967b)

Order APODA Brandt, 1835

Family MYRIOTROCHIDAE Ostergreen, 1907

Genus MYRIOTROCHUS Steenstrup, 1851

MYRIOTROCHUS SP.

Pl. 2 figs. 22-25

Myriotrochus STEENSTRUP, 1851, p. 55-60, pl. 3; DANIELSSEN and KOREN, 1882, p. 28, pl. 5, figs. 1-5; THEEL, 1885, p. 37; CLARK, 1907 , p. 30, 127, pl. 8; HEDING, 1935, p. 19; HANSEN, 1956, p. 419.

Description. Cylindrical shaped body with 10 or 12 tentacles, variable in size ranging from about 6 mm to 65 mm in length, various species described by Clark (1907) and Heding (1935); skeletal elements developed

as wheels with spokes having wing-like lateral distensions; numerous large, flat pointed teeth, projecting horizontally inward from the rim; vary considerably in size, smaller wheels generally have more spokes; 9to 16 spokes, averaging about 12; 22 to 30 teeth with average about 25.

Diameter of wheels ranges from 0.14 mm to 0.30 mm, average 0.22 mm.

Remarks. The sclerites do not conform exactly to any one particular species with regard to number of spokes, teeth and average diameter. However, the wheels do resemble rather closely Myriotrochus theeli which has from 12 to 15 spokes, 24 to 30 teeth, and a diameter between 0.130 mm and 0.225 mm. Clark (1907) reported this species from northwest of Jan Mayen at a depth of about 2000 meters. He also noted some minor differences in the characteristics of the wheels of Myriotrochus rinkii when comparing specimens from the Bering Sea, Newfoundland, Norway, and eastern Siberia, suggesting that there might be some geographical variation. The wheels examined from the central Arctic Ocean might be from M. theeli, with the minor differences from those in the Jan Mayen area purely due to regional variation.

Occurrence. A total of 237 wheels was obtained from 19 core samples. Myriotrochus has also been reported from eastern and western Greenland, the Norwegian Sea, northern Norway (Theel, 1885; and Danielssen and Koren, 1882), northeastern coast of North America (Theel, 1885; Mortensen, 1932, and Heding, 1935), Philippine and New Britain trenches (Hansen, 1956), and the coast of Korea (Clark, 1907).

EXPLANATION OF PLATE 1

Figures

1-6, 10 Limacina helicina Phipps. 1, apical view, juvenile, 60X, sample FL283, UW 1638-1; 2, apical view, juvenile, 60X, sample FL193, UW 1638-2; 3, apical view, 60X, sample FL125, UW 1638-3; 4, umbilical view, 55X, sample FL464, UW 1638-4; 5, apical view, juvenile, 60X, sample FL283, UW 1638-5; 6, umbilical view, juvenile, 60X, sample FL283, UW 1638-6; 10, apertural view, 60X, sample FL193, UW 1638-10.

7 Limacina helicina (?) Phipps. apical view, dextral coiling, 60X, sample FL182, UW 1638-7.

8 Limatula hyperborea Jensen. exterior view, left valve, juvenile, 30X, sample FL182, UW 1638-8.

9 Cuspidaria sp. interior view, left valve, juvenile, 25X. sample, FL182, UW1638-9.

11,12 Juvenile bivalves. 11, interior view, right valve, 70X, sample FL182, UW1638-11; 12, exterior view, right valve, 60X, sample FL182, UW 1638-12.

13,16 Portlandia intermedia Sars. 13, interior view, left valve, juvenile, 25X, sample FL182, UW 1638-13; 16, exterior view, left valve, juvenile, 30X, sample FL182, UW 1638-16.

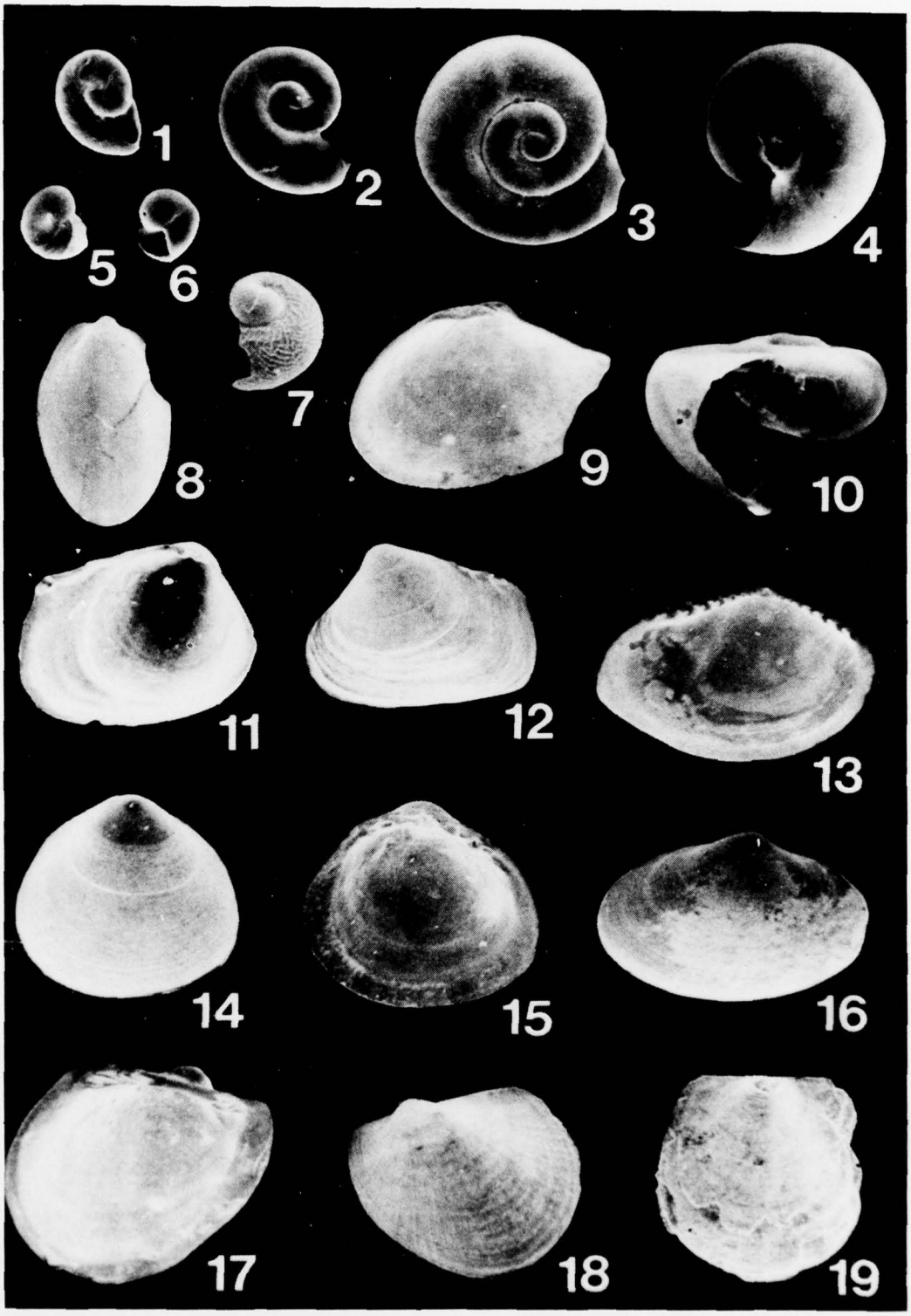
14,15 Nucula sp. 14, exterior view, right valve, juvenile, 40X, sample FL474, UW 1638-14; 15, interior view, left valve, juvenile, 35X, sample FL474, UW 1638-15.

17,18 Bathyarca frielei Friele. 17, interior view, left valve, juvenile, 20X, sample FL474, UW 1638; 18, exterior view, left valve,

Figures

juvenile, 20X, sample FL182, UW 1638-18.

19 Bivalve, Family Pectinidae, exterior view, right valve, juvenile, 35X, sample FL166, UW 1638-19.


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EXPLANATION OF PLATE 2

Figures

1-4 Kolga hyalina Danielssen and Koren. Sclerites as follow: 1, 160X, FL179, UW 1638-20; 2, 140X, sample FL413, UW 1638-21; 3, 80X, sample FL310, UW 1638-22; 4, 90X, sample FL179, UW 1638-23.

5 Sponge spicule. tetraxon, 40X, sample FL474, UW 1638-24.

6,11 Thenea sp. 6, spicule, 30X, sample FL21, UW1638-25; 11, spicule, 40X, sample FL191 , UW 1638-30.

7-10 Elpidia glacialis Theel. Sclerites as follow: 7, 90X, sample FL184, UW 1638-26; 8, 80X, sample FL166, UW 1638-27; 9, 40X, sample, FL95, UW 1638-28; 10, 75X, sample FL434, UW 1638-29.

12 Sponge spicule. calcareous triradiate, 50X, sample FL182, UW 1638-31.

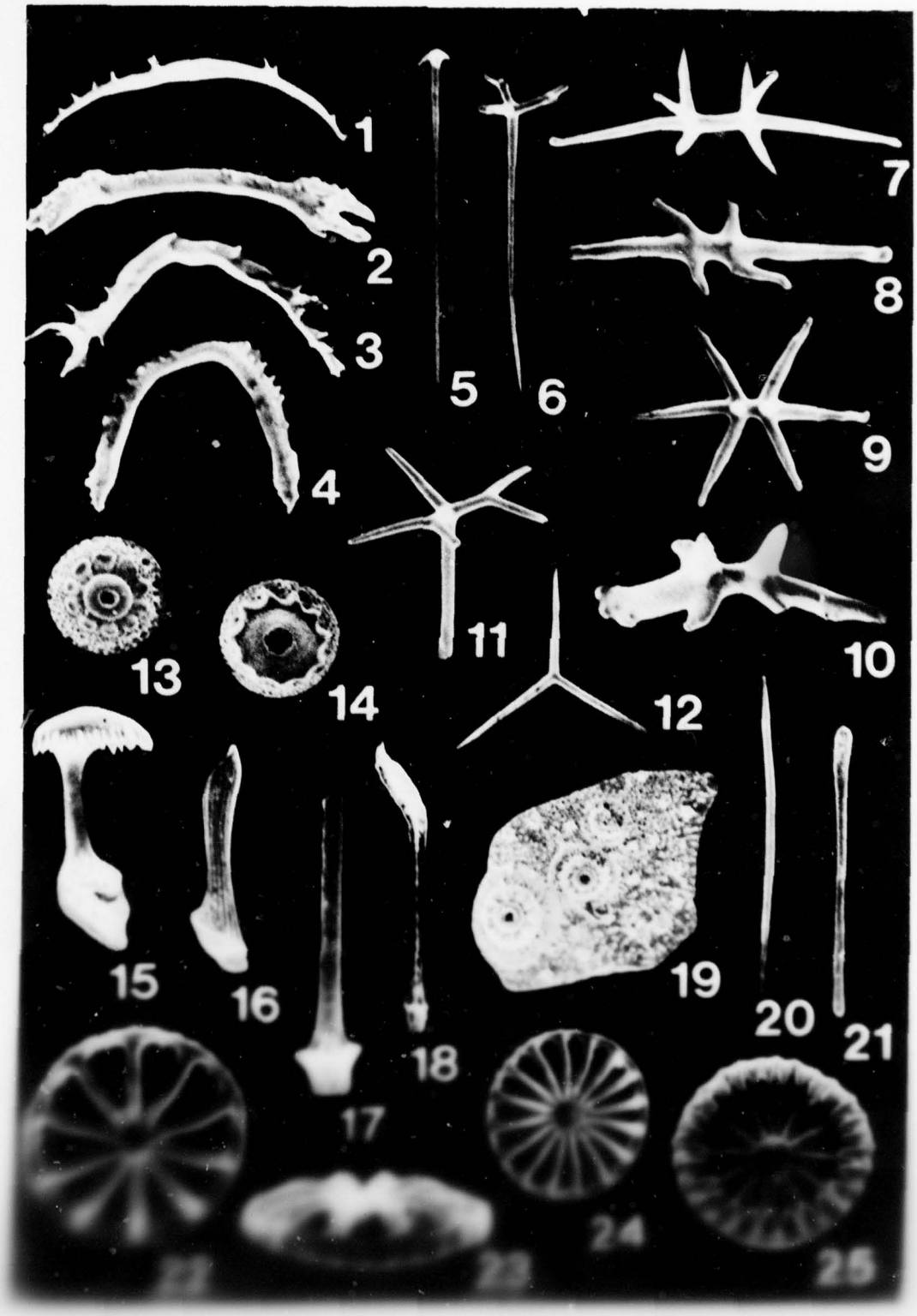
13-19 Pourtalesia jeffreysi Thomson. 13, primary tubercle, 50X, sample FL149, UW 1638-32; 14, articulating end of a primary spine base, 180X, sample FL95, UW 1638-33; 15, valve of ophicephalous pedicellariae, inside view, 100X, sample FL95, UW 1638-34; 16, primary spine, 30X, sample FL126, UW 1638-35; 17, primary spine, 30X, sample FL126, UW 1638-36; 18, small secondary spine, 90X, sample FL182, UW 1638-37; 19, plate fragment, 30X, sample FL95, UW 1638-38.

20 Sponge spicule. klostose monaxon, 50X, sample FL71, UW 1638-39.

21 Sponge spicule. monaxon, 50X, sample FL365, UW 1638-40.

22-25 Myriotrochus sp. Sclerites as follow: 22, view showing spokes, 120X, sample FL193, UW 1638-41; 23, oblique view, 150X, sample FL505, UW 1638-42; 24, view showing spokes, 150X, sample FL191,

UW 1638-43; 25, view showing teeth, 150X, sample FL505, UW 1638-14.


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APPENDIX II

CORE DATA

Sample	Latitude	Longitude	(meters) Depth	Dry Weight	Wt.% Crse.	Wt.% Water
FL 17	82° 58.99'	159° 4.22'	2215	5.94g	19.7	34.1
FL 19	83 3.46	162 49.52	3417	2.89	21.4	44.7
FL 21	83 1.34	163 29.31	3494	2.11	16.1	49.8
FL 23	83 2.09	163 0.39	3748	3.46	1.4	48.5
FL 24	82 23.02	162 6.52	3743	2.76	2.9	56.0
FL 27	80 46.82	140 25.71	3709	8.67	0.3	60.2
FL 31	80 32.44	139 55.87	3712	6.97	0.1	59.7
*FL 34	80 47.41	136 54.82	3675	1.09	5.5	61.4
*FL 35	80 46.10	136 49.02	3683	4.01	0.3	41.0
FL 36	80 38.71	137 29.80	3683			
FL 39	80 21.88	136 46.51	3680	2.18	1.8	51.8
FL 65	75 33.23	141 44.21	3709	5.90	1.4	56.4
FL 69	75 35.23	140 29.34	3690			
FL 71	75 43.48	140 37.00	3709	12.75	11.9	38.0
FL 87	75 18.49	156 7.18	2903	14.50	6.2	34.1
*FL 88	75 54.10	152 23.38	3783	10.70	0.3	50.1
*FL 89	75 38.49	151 8.51	3802	4.20	0.2	54.8
FL 93	77 48.63	175 21.28	1597	4.94	8.5	47.2
FL 95	78 2.27	176 17.44	1351	13.22	6.9	39.9
FL107	77 37.87	173 42.67	1873	4.31	16.0	43.5
FL110	77 48.06	173 11.57	2003	14.53	7.1	34.7
FL116	76 5.30	174 46.49	1570	10.91	4.0	37.8
FL125	76 16.23	175 25.60	1390	5.64	5.7	38.4

Sample	Latitude	Longitude	(meters) Depth	Dry Weight	Wt.% Crse.	Wt.% Water
FL126	78° 21.88'	175° 51.31'	1181	7.41g	6.2	32.2
FL138	78 36.55	176 23.78	1360	13.65	3.9	39.1
FL142	78 40.56	175 53.26	1478	12.61	8.9	39.3
FL149	78 34.29	176 8.63	1422	5.55	7.2	35.2
FL166	78 47.07	176 11.54	1578	2.66	4.3	40.0
FL178	78 53.76	176 29.64	1592	9.50	1.5	35.0
FL179	78 52.56	176 38.67	1645	23.51	11.7	31.7
FL182	78 56.61	175 22.40	1069	11.12	10.2	35.0
FL184	79 31.81	174 7.74	2095	10.29	10.0	42.8
FL187	79 33.31	171 39.64	2408	16.52	11.3	40.1
FL191	79 55.72	174 27.15	1717	10.63	13.4	40.7
FL193	80 1.34	174 2.55	1753	10.80	11.1	38.6
FL216	80 23.69	157 41.54	3576	17.70	21.8	28.2
FL217	80 36.27	157 58.87	3713	22.53	15.5	38.9
FL221	80 32.78	159 29.64	3638	16.34	8.9	45.7
FL224	80 27.81	158 48.30	3467	6.22	17.0	34.3
FL233	81 55.34	158 5.45	3812	11.35	0.5	53.4
FL268	83 16.32	152 58.32	3062	12.60	22.2	33.9
FL277	83 34.55	149 26.46	2871	12.08	20.4	40.0
FL283	83 47.92	146 12.86	2639	14.91	18.8	35.1
FL289	84 14.69	144 16.97	2357	12.74	32.7	30.1
F1293	84 25.00	143 4.57	2058	13.12	24.7	34.2
FL298	85 7.83	142 51.23	1971	12.81	19.8	34.7
FL304	85 28.28	143 8.52	2277	7.58	19.1	38.9
FL306	85 24.93	144 33.92	2263	14.38	21.1	35.7

Sample	Latitude	Longitude	(meters) Depth	Dry Weight	Wt.% Crse.	Wt.% Water
FL310	85° 43.80'	142° 39.16'	2424	13.21g	13.5	40.4
FL311	85 41.93	142 21.15	2332	7.84	20.4	43.6
FL316	85 8.72	138 13.91	1785	13.37	23.6	31.8
FL319	84 52.64	136 2.41	2016	7.78	21.6	40.0
FL323	84 17.80	135 6.17	2674	15.54	13.4	31.9
FL326	84 12.89	135 41.40	2653	16.47	20.8	35.0
FL343	85 4.50	130 38.04	1753	5.33	27.4	42.7
FL346	84 51.22	130 42.69	2372	10.02	21.4	37.3
FL365	84 28.48	131 22.31	2732	13.06	22.7	36.7
FL413	84 25.56	125 15.22	2390	13.69	19.4	43.7
FL423	84 55.72	126 43.37	1532	13.99	24.8	34.7
FL429	86 3.08	133 55.29	2215	9.86	21.8	16.9
FL434	86 1.05	129 26.45	2058	11.09	23.1	41.8
FL465	85 34.94	114 59.36	1356	15.06	17.6	33.0
FL474	85 20.88	110 0.23	1647	12.66	23.1	37.1
FL505	84 16.53	112 24.67	1753	12.80	19.5	31.9
FL533	85 5.90	98 17.80	1855	13.77	27.3	29.8
FL542	84 42.00	86 34.20	2033	18.30	14.4	24.1
FL557	84 20.80	85 15.20	1818	11.91	3.0	32.8
FL559	84 23.06	84 34.04	1786	11.25	18.2	36.2

*Indicates barren core samples.