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Recent foraminifera in the Canadian Arctic

ABSTRACT

The Recent foraminifera in the ice-covered seas of the Canadian Arctic were found to be distributed in two bathymetric zones with their common boundary at about the 200-metre isobath. The information was used to support a theory of a regional lowering of sea level during the Holocene. The rate of sedimentation during the past 8000 years is indicated to be 4.4 cm. per 1000 years.

INTRODUCTION

Recent foraminifera found in bottom sediments of Hecla and Griper Bay and Hazen Strait were investigated. The area lies between longitudes 109°W and 116°W and between latitudes 75°30′N and 77°30′N. It belongs to the channel system of the Queen Elizabeth Islands in the Canadian Arctic Archipelago (text-figure 1) and is situated between Melville, Prince Patrick and Mackenzie King Islands. This reconnaissance study is designed primarily to give information on the type of foraminifera living in the Arctic environment at the present time. Moreover, it offers some insight on Arctic ecology and oceanography. The long range purpose of the investigation is to contribute to the reconstruction of the post-Tertiary history of the Northern Hemisphere. Typical high-latitude assemblages are established for the existing environmental conditions. and the information is extrapolated to that from comparable studies in the North Atlantic.

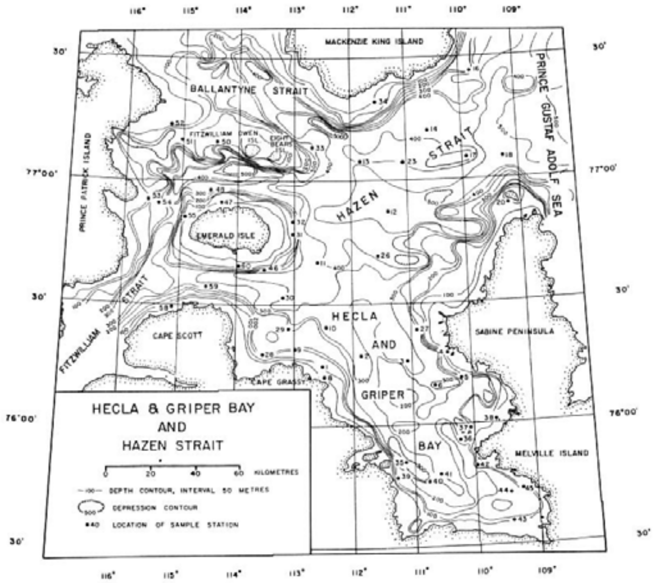
PREVIOUS WORK

This is a continuation of marine geology studies of the interisland seas and channels of the Queen Elizabeth Islands and the adjacent Arctic continental shelf. Systematic work in the area was initiated in 1960 in conjunction with the Polar Continental Shelf Project. General trends in sedimentation in the Arctic environment were described by Pelletier (1962). Using the available soundings, he pointed out the role that glacial scour must have played in the final carving of the channels. Additional data in subsequent studies (Marlowe and Vilks, 1963; Horn, 1963; Marlowe, MS.; Pelletier, 1966) supported these observations. Wagner (1962, MS.) gave an account of the foraminifera of the continental shelf region off Ellef Ringnes and Borden Islands, and Marlowe and Vilks (1963) and Vilks (1964) described foraminifera from the inshore waters of Prince Gustaf Adolf Sea.

FIELD AND LABORATORY WORK

Forty-eight bottom grab samples and two cores were taken during the field season of 1966. The logistical support was provided by the Polar Continental Shelf Project. De Haviland Otter and Beaver aircraft were used to transport field equipment and personnel from the P. C. S. P. base at Mould Bay, Prince Patrick Island, to a fly camp on Cape Grassy, Melville Island. A Bell 204B helicopter, equipped with a Decca Lambda navigating device, was used to transport equipment to the sampling sites. Sediment samples were taken through seal holes and leads in the ice with a Dietz-LaFond bottom grabber and with a piston corer. A gasoline-powered winch was used to lower and raise the sampling gear. Near the centre of Hazen Strait, at Station 13 (long. 111°52′, lat. 77°05′),

TEXT-FIGURE 1
Index map showing the area studied in the Arctic Archipelago of northern Canada.



TEXT-FIGURE 2
Bottom topography of Hecla and Griper Bay, Hazen Strait and Ballantyne Strait, and the locations of sample stations.

salinity and temperature determinations were carried out with the use of a Knudsen reversing water bottle fitted with double thermometer racks. All grab samples were preserved in alcohol at the time of sampling and and were stained with rose Bengal.

The field work was comparatively difficult, mainly because of the relative inaccessibility to the area and the extreme sampling conditions. Although refined ecological studies were not anticipated, more information on the physical environment might be useful. For meaningful quantitative comparisons of both living and dead specimens the Dietz-LaFond is not a dependable sampler. G. A. Bartlett, Atlantic Oceanographic Laboratory, Bedford Institute (personal communication), observed that a cloud of fine sediment is thrown into suspension before the Dietz-LaFond sampler encounters the bottom. Thus a fraction of the living community of the surface layer may be excluded from the sample. The penetration of the sampler in soft sediment is not controlled, and, as a result, it is difficult to estimate how much of the sample taken represents the surface layer. Because of these uncertainties only broad trends in foraminiferal distribution were utilized in the present study.

Conventional laboratory methods were followed. The sediment was dried, weighed, then washed through a 230-mesh sieve and dried and weighed again. Tests were separated from the coarse fraction with tetrachlorethylene. Concentrates were inspected for the determination of relative percentages of species in the sample.

ECOLOGY

Bottom topography

The area represents a typical high-latitude, partly landlocked, marine environment with low temperatures, extensive ice cover, and deeply glaciated submarine topography. Bottom features are characterized by steep shore faces, isolated depressions and raised central plateaux (text-figure 2). The relatively flat central region of Hazen Strait is bordered by the 400-metre isobath, which also defines the Lougheed Island Basin to the west (Marlowe, MS.) To the north, the flat bottom is broken sharply by a steep rise towards Mackenzie King Island. At the entrance of Ballantyne Strait the bottom rises from a depression of 500 metres to the 50-metre isobath within ten kilometres. Although Ballantyne Strait is only 50 to 100 metres deep where it joins the Arctic Ocean, it reaches 500 metres in depth where it connects with Hazen Strait. Similarly, the narrow channel between Emerald Isle to the south and Fitzwilliam Owen and Eight Bears Islands to the north opens into Hazen Strait at depths of slightly less than 400 metres. The steep U-shaped cross section of these submarine valleys and the steep headland regions resembling cirques were probably formed by glaciers moving in a southeasterly direction. These glaciers may have been tributaries to the flow that occupied the present site of Hazen Strait.

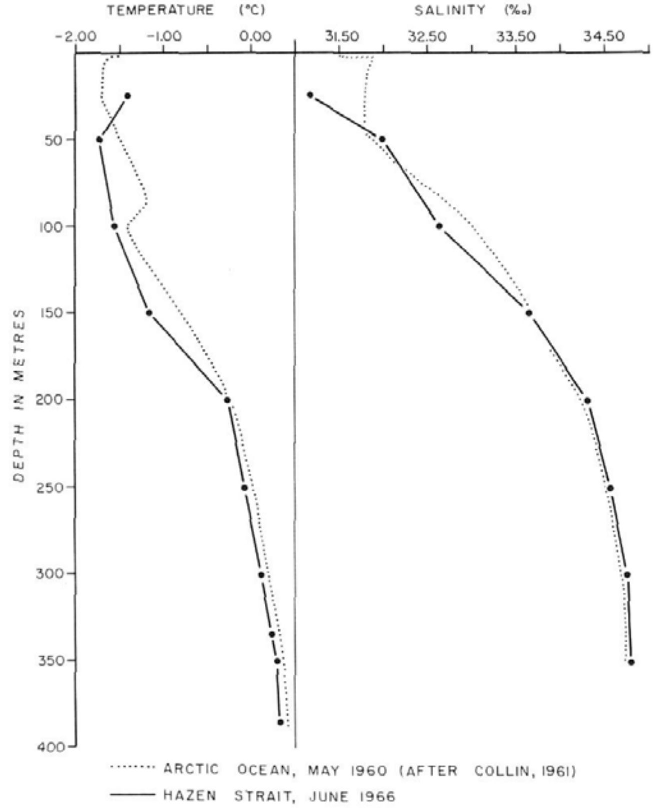
The bottom topography of Hecla and Griper Bay also shows evidence of glacial scour. The initially flat, shelf section along the shores is terminated by a sharp increase in slope at a depth of 50 metres, the slope flattening again at around 200 metres. There are a number of isolated depressions along the sides of the bay and a raised central section grading slightly towards Hazen Strait. These features suggest the movement of glacial ice in a northerly direction. The bay was probably carved from two initially separated fluvial valleys, connected by the Hazen Strait valley to a drainage system that occupied the present site of Prince Gustaf Adolf Sea (Fortier and Morley, 1956).

Bottom sediments

The bottom surface sediment consists mainly of very fine light-brown mud. Sediment in which 90 per cent of the particles are smaller than 0.063 millimetre in diameter occupies Hazen Strait, including the relatively shallow localities off Mackenzie King Island and Cape Grassy. Slightly coarser sediment is found in the eastern part of Hecla and Griper Bay. The fine fraction here varies between 70 and 80 per cent except for Station 5 off Sabine Peninsula, where it is 64 per cent. Sediments taken at the shallow stations off Emerald Isle and Cape Scott contain a fine fraction of over 98 per cent of the total sample by weight, but sediments off Prince Patrick Island are much coarser, the fine fraction decreasing to 9 per cent at Station 52. There is no apparent evidence of a correlation between sediment texture and bottom topography or distance from shore. A more detailed study of sedimentology in the area is being carried out by R. M. McMullen, Bedford Institute of Oceanography. The samples used in this study and those used by McMullen are not statistical duplicates, so there may be some variation in the results from the respective mechanical analyses.

Oceanography

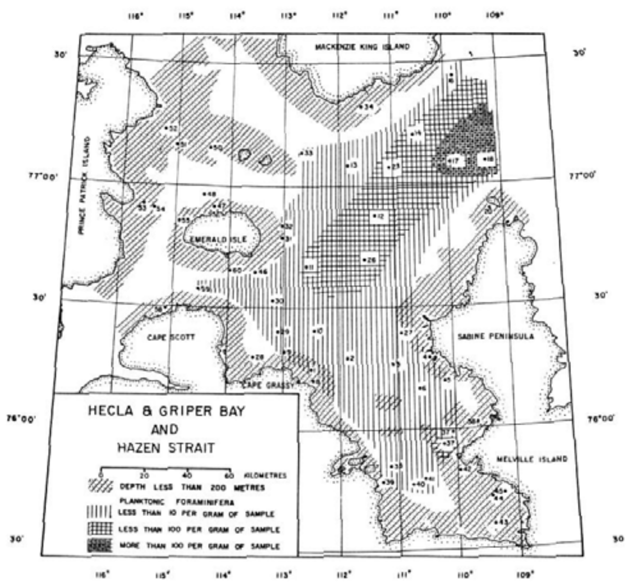
The relative inaccessibility of the area limited oceanographic measurements, other than those carried out at Station 13. However, water masses have been studied in the Arctic Ocean across the entrances to Prince Gustaf Adolf Sea and Peary Channel (Collin and Dunbar, 1964) and Prince of Wales Strait (Bailey, 1957). Measurements taken at these localities indicate a net flow of water from the Arctic Ocean to Baffin Bay. Currents in Hazen Strait are invariably influenced by the general movement of water masses toward the south, and, in view of the lack of direct measurements, only speculations can be made concerning the possible rates of water exchange in the study area. The two channels that connect Hazen Strait to the Arctic Ocean are Ballantyne Strait and Prince Gustaf Adolf Sea. Of the two, Prince Gustaf Adolf Sea is the deeper and the main contributor of water from the Arctic Ocean. Although



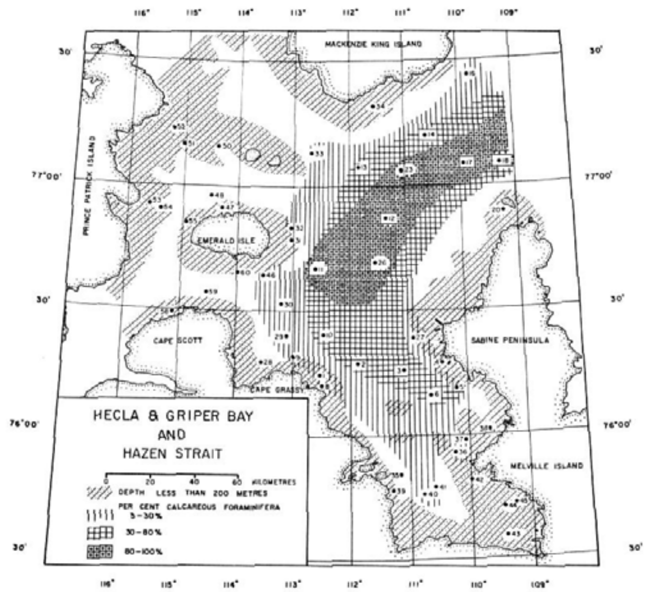
TEXT-FIGURE 3
Temperature and salinity relationship with depth at Station 13 and in the Arctic Ocean.

Ballantyne Strait is also deep off Mackenzie King Island, the shallow water between Brock and Prince Patrick Islands and the chain of the Polynia Islands may effectively block almost all movement of water towards the south through Ballantyne Strait. Faunal evidence, discussed later in this report, also suggests very little, if any, influx of Arctic Ocean water through Ballantyne Strait. The extremely fine sediments in both the deep and shallow waters of Hazen Strait indicate weak currents.

The fine sediment in the shallow coastal waters can only exist in an environment that is constantly covered with ice, preventing the formation of a turbulent beach zone. According to Collin and Dunbar (1964), the area is under a continuous ice cover during the summer months, and only the southern tip of Hecla and Griper Bay is ice-free during the summer of a "light ice" year. The thickness of the ice depends on its age and origin. Young ice grows up to 2 metres in thickness during the winter, but ice thicker than 4 metres was encountered in Hazen Strait. This pack ice may be several seasons old and owes its thickness to rafting and piling of old pressure ridges. In the summer, open leads were



TEXT-FIGURE 4
Distribution of planktonic foraminifera.



TEXT-FIGURE 5
Distribution of calcareous foraminifera.

observed across the bay and in Hazen Strait, but they were seldom wider than a few metres. In the spring, the melt water and runoff from the land form small lakes on top of the ice, and, with the advancing season, this water enters the sea through the leads or through seal holes. Toward the end of summer, extensive shore leads are formed, which are generally widest at river deltas. The settling of the sediment is slow, and water in the shore leads remains turbid until freeze-up.

The temperature and salinity relationships in a column of Arctic water have been described by several authors. Coachman and Barnes (1961) recognized three layers of water in the Arctic Ocean, two of which are identified in Hazen Strait from data obtained at Station 13. The surface layer down to about 200 metres consists of cold dilute water of Arctic origin, while below this layer is found warmer and more saline water of Atlantic origin. At about 900 metres the intermediate layer is replaced by colder water with constant salinities at about 34.90‰.

The relation of salinity and temperature with depth, measured at Station 13, is shown in text-figure 3. The readings were taken on June 29, 1966. The curves are superimposed on curves from the data of Collin (1961), obtained at the entrance of Prince Gustaf Adolf Sea in early May. Below 200 metres the two curves agree very closely, both in temperature and salinity, but a slight discrepancy is shown in the upper 25 metres, where Collin's observations show temperatures lower and salinities higher. This is probably due to the difference in dates of measurements, as, at the end of June, melt water had been entering the sea for at least 2 weeks, thus causing lower salinities and higher temperatures. The similarity of the deeper waters in the two localities indicates an influx of water from the Arctic Ocean into Hazen Strait *via* Prince Gustaf Adolf Sea. The extent of the influx can be determined by distribution studies of the sole planktonic foraminifer, *Globigerina pachyderma* (Ehrenberg). Text-figure 4 shows that, with very few exceptions, *G. pachyderma* is restricted to waters deeper than 200 metres and to areas that are open to the Prince Gustaf Adolf Sea. Similarly, the number of *G. pachyderma* per 10 grams of sample increases considerably towards Prince Gustaf Adolf Sea. It is evident, therefore, that *G. pachyderma* is endemic to the Atlantic layer, and that the presence of this planktonic species in the sediment can be used to determine the lateral limits of Atlantic water. The direction of water movement can be inferred from the relative abundances of the tests, since larger numbers of tests are found closer to the source. The same criterion excludes the possibility of subsurface water entering the study area *via* Fitzwilliam Strait.

DISTRIBUTION OF FORAMINIFERA

General distribution

The area investigated is comparatively large (30,000 sq. km.) within a relatively wide range of depth (17–457 metres). With classical areas of foraminiferal investigation, Hazen Strait and Hecla and Griper Bay differ on two accounts; first, in the extensive cover of

TABLE 1
Relative percentages of foraminiferal species. X indicates percentages less than 0.5

	STATION NUMBER	45	53	52	58	4	38	34	8	47	60	43	42	55	20	50	31
	DEPTH (METRES)	17	31	33	35	43	48	63	65	66	70	76	82	87	94	99	107
1	ADERCOTRYMA GLOMERATA																
2	ASTERELLINA PULCHELLA		X	1		1		1		X							
3	ASTRONONION GALLOWAYI		X	X													
4	ASTRORHIZA ARENARIA			X													
5	BATHYSIPHON RUFUS																
6	BOLIVINA SP CF B INFLATA																
7	BUCCELLA FRIGIDA	X			X	3	X		X	X		X		X		X	
8	BULIMINA MARGINATA																
9	CASSIDELLA COMPLANATA		X				X	X	X					X			
10	CIBICIDES LOBATULUS		X				X		3								
11	CORNUSPIRA INVOLVENS																
12	CRIBROSTOMOIDES CRASSIMARGO	1	6	2	28	8	17	12	10	17	74	9	26	28	3	34	7
13	CRIBROSTOMOIDES JEFFREYSII		X	1	4	10	2	3	16	6	X	1	3	3	1	5	10
14	CRIBROSTOMOIDES SUBGLOBOSUS											1					
15	CRUCILOCULINA ERICSONI																
16	DENTALINA BAGGI																
17	DENTALINA FROBISHERENSIS																
18	DENTALINA PAUPERATA			X													
19	EGGERELLA ADVENA		X												X		
20	ELPHIDIUM BARTLETTI				X			X	1	X							X
21	ELPHIDIUM INCERTUM	1	1			2	X	X									
22	EPONIDES TENER																
23	FISSURINA SP CF F BRADII																
24	FISSURINA MARGINATA																
25	FISSURINA VENTRICOSA																
26	GLOBIGERINA PACHYDERMA					1			X								
27	GLOMOSPIRA GORDIALIS	X	1	1	X		1	X		X		X	X		X	X	1
28	HYPERAMMINA ELONGATA		X	X	1			1	2	1		1	1	1	1	6	2
29	ISLANDIELLA ISLANDICA							X	X			X					
30	ISLANDIELLA NORCROSSI		X			2		X									
31	ISLANDIELLA TERETIS	X		X	X	X	2	X	3	X							
32	LAGENA APIOPLEURA																
33	LAGENA FLATULENTA																
34	LAGENA GRACILIS																
35	LAGENA GRACILLIMA																
36	LAGENA LAEVIS																
37	LAGENA MERIDIONALIS																
38	LAGENA MOLLIS																
39	LAGENA NEBULOSA																
40	LAGENA SP CF L PLUMIGERA																
41	MELONIS ZAANDAMI								1								
42	NONIONELLINA LABRADORICA																
43	NUMMOLOCULINA SP A																
44	OOLINA APICULATA																
45	OOLINA GLOBOSA																
46	OOLINA HEXAGONA																
47	OOLINA MELO																
48	PARAFISSURINA ARCTICA																
49	PARAFISSURINA TECTULOSTOMA								X								
50	PATELLINA CORRUGATA																
51	PLANISPIRINOIDES BUCCULENTUS																
52	PROTELPHIDIUM ORBICULARE	1	X														
53	PYRGO SUBSPHAERICA																
54	QUINQUELOCULINA ARCTICA																
55	QUINQUELOCULINA SADKOVI																
56	QUINQUELOCULINA SEMINULUM																
57	RECURVOIDES TURBINATUS	X	3	X	2	2	1	1	1	5	5	5	4	3	2	2	4
58	REOPHAX FUSIFORMIS	X	1	1	X	1	1	1	2	1	1	1	1	X	X	1	3
59	REOPHAX GRACILIS													X			
60	REOPHAX GUTTIFER						X						X			X	
61	REOPHAX NODULOSUS		X		1		1	X	2	2	2	6	2	1	1	1	2
62	REOPHAX PILULIFER				X			X	1								
63	RHABDAMMINA ABYSSORUM																
64	ROBERTINOIDES CHARLOTTENSIS					1											
65	SACCAMMINA ATLANTICA	3	1	3	4	5	1	1	1	5	4	4	X	1	1	4	2
66	SACCAMMINA SPHAERICA		X		X	1	7	2	1			6	3	X	1	1	2
67	SACCORHIZA RAMOSA				X				X	X		1			X	1	X
68	SILICOSIGMOILINA GROENLANDICA			X						X		X					
69	SPIROPLECTAMMINA BIFORMIS	25	12	28	13	24	3	3	2	8		2	2	5	7	1	6
70	STETSONIA HORVATHI												X				
71	TEXTULARIA EARLANDI	4	3		1	6	1	X	1	1		1	X		1	X	2
72	TEXTULARIA TORQUATA	16	8	42	5	7	X	3	1	7	1		1	9	15	3	1
73	TRILOCULINA TRIHEDRA																
74	TROCHAMMINA NANA	48	52	18	33	7	56	63	37	36	12	50	44	39	57	32	46
75	TROCHAMMINA QUADRILOBA		7	X			X		X	X		1	1		1	X	X
76	TROCHAMMINELLA ATLANTICA	1	3	2	5	13	6	3	10	6	X	9	10	4	7	6	5
77	TROCHAMMINELLA BULLATA	X		X	1	5	1	3	5	4		1	3	6	1	2	6
78	VALVULINERIA ARCTICA																
	TOTAL FORAMINIFERA	2176	3439	8355	3085	194	1271	8842	1556	2851	576	1148	1826	1568	18323	1985	2526
	SAMPLE WEIGHT (GM)	34	45	82	69	109	20	83	20	47	63	24	19	37	96	31	35

	STATION NUMBER	44	51	32	39	54	5	9	36	46	41	27	16	28	37	40	29
	DEPTH (METRES)	137	148	159	168	172	193	200	205	224	231	234	237	243	246	249	265
1	ADERCOTRYMA GLOMERATA																
2	ASTERELLINA PULCHELLA		X														
3	ASTRONONION GALLOWAYI										X						
4	ASTRORHIZA ARENARIA				1								X				
5	BATHYSIPHON RUFUS	X					X					X	X		X		
6	BOLIVINA SP CF B INFLATA																
7	BUCCELLA FRIGIDA		X				4	1	X				1				1
8	BULIMINA MARGINATA														X		X
9	CASSIDELLA COMPLANATA						1	X	1	1	X	1	X			X	X
10	CIBICIDES LOBATULUS		X	2			3		2	4		X	X		X		X
11	CORNUSPIRA INVOLVENS																
12	CRIBROSTOMOIDES CRASSIMARGO	14	9	27	3	26				1	1	1	X	3		1	1
13	CRIBROSTOMOIDES JEFFREYSII	2	11	8	2			1		2	1	1	1	X	1	1	
14	CRIBROSTOMOIDES SUBGLOBOSUS		X				6	1		1		1	X		1	2	2
15	CRUCILOCULINA ERICSONI						X										
16	DENTALINA BAGGI								X					X			
17	DENTALINA FROBISHERENSIS						X	X									
18	DENTALINA PAUPERATA																
19	EGGERELLA ADVENA									1							
20	ELPHIDIUM BARTLETTI			2			X			1			1				1
21	ELPHIDIUM INCERTUM		X	1			2	2					1		X		2
22	EPONIDES TENER						4	X	X			3	X			X	1
23	FISSURINA SP CF F BRADII						X										
24	FISSURINA MARGINATA						X	X									
25	FISSURINA VENTRICOSA						X										
26	GLOBIGERINA PACHYDERMA			1	1		23	6	76	6	1	11	7		2	4	2
27	GLOMOSPIRA GORDIALIS		1		X		X			1	1	1			X		1
28	HYPERAMMINA ELONGATA		1	4	X	3	X	X		1		X	3	4	X		1
29	ISLANDIELLA ISLANDICA			1			8	2	5	1	X	4	2		3	1	3
30	ISLANDIELLA NORCROSSI			1			1			1		1			X	X	1
31	ISLANDIELLA TERETIS			2			26	3	14	1		4	10	X	2	1	2
32	LAGENA APIOPLEURA						X										
33	LAGENA FLATULENTA							X				X					
34	LAGENA GRACILIS																
35	LAGENA GRACILLIMA							X					X				
36	LAGENA LAEVIS																
37	LAGENA MERIDIONALIS																
38	LAGENA MOLLIS						X										X
39	LAGENA NEBULOSA						X										
40	LAGENA SP CF L PLUMIGERA																
41	MELONIS ZAANDAMI						X	X		1		1			X		X
42	NONIONELLINA LABRADORICA											X					X
43	NUMMOLOCULINA SP A																
44	OOLINA APICULATA						X	X									X
45	OOLINA GLOBOSA						X	X		X							
46	OOLINA HEXAGONA																
47	OOLINA MELO						X										
48	PARAFISSURINA ARCTICA																
49	PARAFISSURINA TECTULOSTOMA																
50	PATELLINA CORRUGATA																
51	PLANISPIRINOIDES BUCCULENTUS																
52	PROTELPHIDIUM ORBICULARE																
53	PYRGO SUBSPHAERICA											X					
54	QUINQUELOCULINA ARCTICA															X	
55	QUINQUELOCULINA SADKOVI						X		X								
56	QUINQUELOCULINA SEMINULUM												X				
57	RECURVOIDES TURBINATUS	8	5	3	7	3	1	16	X	16	3	1	9	6	6	7	5
58	REOPHAX FUSIFORMIS	X	2	5	1	1	1	3		1	2	2	1	1	2	3	X
59	REOPHAX GRACILIS																
60	REOPHAX GUTTIFER		1		X	3	5	16		6	2	7	4	9	7	9	16
61	REOPHAX NODULOSUS	1	1	1	1		2	3		6	2	5	7	3	3	3	2
62	REOPHAX PILULIFER					1	X										X
63	RHABDAMMINA ABYSSORUM																
64	ROBERTINOIDES CHARLOTTENSIS																
65	SACCAMMINA ATLANTICA	9	1	2	1	4	1	2		1	2	3	X	2	11	7	2
66	SACCAMMINA SPHAERICA	13	X	11	1	2	1	1	3	7	8	11	7	4	1	4	2
67	SACCORHIZA RAMOSA	X	X		X								X				
68	SILICOSIGMOILINA GROENLANDICA		X														
69	SPIROPLECTAMMINA BIFORMIS	3	3		1	4							1	1	X		X
70	STETSONIA HORVATHI						X	X		1	1			X	1	X	1
71	TEXTULARIA EARLANDI	1	1		2	1		1		1	1	X	2	1		X	1
72	TEXTULARIA TORQUATA		12	1		2				1		X	X	1			X
73	TRILOCULINA TRIHEDRA																
74	TROCHAMMINA NANA	39	35	18	64	36	4	16	1	31	57	16	31	45	45	42	32
75	TROCHAMMINA QUADRILOBA	1	3	6	4	2	X	2		1	3	3	2	2	1	1	2
76	TROCHAMMINELLA ATLANTICA	9	10	5	7	3	X	2		3	8	4	4	7	3	5	2
77	TROCHAMMINELLA BULLATA	1	3	2	4	10	2	17		5	6	10	5	10	9	5	14
78	VALVULINERIA ARCTICA						1									X	
	TOTAL FORAMINIFERA	869	5989	765	732	544	3468	872	922	189	1232	640	1349	2045	665	276	1948
	SAMPLE WEIGHT (GM)	18	68	88	25	39	102	36	13	30	35	40	55	34	24	23	57

	STATION NUMBER	59	17	6	3	48	30	35	33	10	11	13	23	26	14	18	12
	DEPTH (METRES)	294	297	306	312	322	331	335	349	349	381	385	391	405	440	457	458
1	ADERCOTRYMA GLOMERATA														X		
2	ASTERELLINA PULCHELLA													X			
3	ASTRONONION GALLOWAYI																
4	ASTRORHIZA ARENARIA									X		X					
5	BATHYSIPHON RUFUS	X															
6	BOLIVINA SP CF B INFLATA		X								X			X	X	X	X
7	BUCCELLA FRIGIDA		X							X	1	1	X	X	1	X	
8	BULIMINA MARGINATA																
9	CASSIDELLA COMPLANATA	1	1	1	1		1		1	X	1	X	2	1	2	X	X
10	CIBICIDES LOBATULUS	X	4	1	4				1	2	1	1	1	X	1	1	1
11	CORNUSPIRA INVOLVENS											X					
12	CRIBROSTOMOIDES CRASSIMARGO	3				6	6	1	13	1						X	
13	CRIBROSTOMOIDES JEFFREYSII		X		X		1		7								
14	CRIBROSTOMOIDES SUBGLOBOSUS	X	X	9	10	12	1	5	2	8	4	17	2	4	6	X	4
15	CRUCILOCULINA ERICSONI										X						
16	DENTALINA BAGGI																X
17	DENTALINA FROBISHERENSIS				X					X					X		
18	DENTALINA PAUPERATA															X	
19	EGGERELLA ADVENA																
20	ELPHIDIUM BARTLETTI		X						3	1	X				1	X	
21	ELPHIDIUM INCERTUM	X				X					X	1	X		1	X	
22	EPONIDES TENER		2	4	6		1		1		2	2	3	6	3	2	1
23	FISSURINA SP CF F BRADII		X								X						
24	FISSURINA MARGINATA		X							X	X	2	X	X		X	X
25	FISSURINA VENTRICOSA		X														
26	GLOBIGERINA PACHYDERMA	X	42	18	27		7	2	4	33	48	30	39	35	44	69	51
27	GLOMOSPIRA GORDIALIS							1		X				X	X		
28	HYPERAMMINA ELONGATA	1		X		1	2		6	6							
29	ISLANDIELLA ISLANDICA	1	5	11	7		2		1	1	8	3	8	6	4	1	4
30	ISLANDIELLA NORCROSSI		X	X								X	X			X	X
31	ISLANDIELLA TERETIS		33	10	25		5		4	9	27	16	33	26	13	21	26
32	LAGENA APIOPLEURA		X													X	X
33	LAGENA FLATULENTA			X	1											X	X
34	LAGENA GRACILIS		X	X	X								X				
35	LAGENA GRACILLIMA							X		X							
36	LAGENA LAEVIS				X									X			
37	LAGENA MERIDIONALIS															X	
38	LAGENA MOLLIS																
39	LAGENA NEBULOSA															X	
40	LAGENA SP CF L PLUMIGERA												X		X		
41	MELONIS ZAANDAMI		X		1		1				1	X	X	X	X	X	
42	NONIONELLINA LABRADORICA					X											
43	NUMMOLOCULINA SP A		X		1					X		X	X	X		X	
44	OOLINA APICULATA				X							1	X			X	X
45	OOLINA GLOBOSA															X	
46	OOLINA HEXAGONA					X											
47	OOLINA MELO		X	X												X	X
48	PARAFISSURINA ARCTICA			X	X						X						X
49	PARAFISSURINA TECTULOSTOMA										X		X	X		X	
50	PATELLINA CORRUGATA		X														
51	PLANISPIRINOIDES BUCCULENTUS		X													X	
52	PROTELPHIDIUM ORBICULARE																
53	PYRGO SUBSPHAERICA							X									
54	QUINQUELOCULINA ARCTICA																
55	QUINQUELOCULINA SADKOVI			X	X						X	X	X		1	X	X
56	QUINQUELOCULINA SEMINULUM		X									X	X	X		X	
57	RECURVOIDES TURBINATUS	7	X	3	2	8	8	5	1	4	X	X	X	1	1	X	X
58	REOPHAX FUSIFORMIS	2	X	1		3	5	5	5	1		2	X	X			X
59	REOPHAX GRACILIS																
60	REOPHAX GUTTIFER	19	X	9	3	15	1	10	1	10	2	4	2	3	10	X	2
61	REOPHAX NODULOSUS	1		1	2	1	3	2	10	4		1		X	2	X	
62	REOPHAX PILULIFER						1	X		2							
63	RHABDAMMINA ABYSSORUM																X
64	ROBERTINOIDES CHARLOTTENSIS		X				1						X				
65	SACCAMMINA ATLANTICA	1	X	4	1	X	1	14	1	4		2	X	1	1	X	X
66	SACCAMMINA SPHAERICA	3	X	1	X						X		X	X		X	X
67	SACCORHIZA RAMOSA	X				X											
68	SILICOSIGMOILINA GROENLANDICA																
69	SPIROPLECTAMMINA BIFORMIS	X				1											
70	STETSONIA HORVATHI		6	1			2	X					2	5	X	X	4
71	TEXTULARIA EARLANDI	2		X			1	X						X			
72	TEXTULARIA TORQUATA	2													X		
73	TRILOCULINA TRIHEDRA		X							X		X	X			X	
74	TROCHAMMINA NANA	39	1	18	5	26	41	39	4	9	X	1	2	6	4	X	2
75	TROCHAMMINA QUADRILOBA	4	X	X	X	1	1	X							X	X	X
76	TROCHAMMINELLA ATLANTICA	4	X	1		1	3	3	1	X	X	X	X	X			
77	TROCHAMMINELLA BULLATA	8	X	5	2	18	6	10		7	1	1	X	1	3	X	1
78	VALVULINERIA ARCTICA		4	1	1		1			X	3	X	4	1	1	1	2
	TOTAL FORAMINIFERA	1253	31811	787	806	560	394	844	200	1172	2652	713	1540	1884	1153	15610	3654
	SAMPLE WEIGHT (GM)	88	86	77	59	36	71	33	41	82	68	90	35	42	42	38	68

ice and, second, in the occurrence of a low temperature and salinity layer on top of a more saline and warmer layer of bottom water. The combined effect of these factors directly and indirectly prevents the formation of the classical distribution patterns of benthic foraminifera described by Phleger (1964). The turbulent nearshore zone and the various shelf zones found along the continents in lower latitudes are absent in the study area, although the composite faunas are comparable. In Hazen Strait and in Hecla and Griper Bay a major change in fauna occurs at about 200 metres of depth. The shallow-water fauna of the upper 200 metres is dominated by arenaceous species, while the deep-water fauna is dominated by calcareous species. The relative distribution of calcareous and arenaceous species is illustrated in text-figure 5, which shows that the percentage of calcareous forms is higher in deeper waters and in areas closer to Prince Gustaf Adolf Sea.

Species distribution

Seventy-eight foraminiferal species belonging to 48 genera and 28 families were studied. The most widely represented families in terms of species are the Nodosariidae, Glandulinidae, Miliolidae and Hormosinidae. The most widely occurring genus is *Lagena*, represented by 9 species. It is followed by *Reophax* with 5 species, *Oolina* with 4, and *Cribrostomoides, Islandiella, Quinqueloculina, Dentalina* and *Fissurina* with 3 species each. The remainder of the genera are represented by one or two species each. The most widely distributed species throughout the study area are:

Trochammina nana (Brady)
T. quadriloba Höglund
Trochamminella atlantica Parker
T. bullata Höglund
Saccammina atlantica (Cushman)
S. sphaerica Brady
Reophax nodulosus Brady
R. fusiformis (Williamson)
Recurvoides turbinatus (Brady)

Species that dominate in the shallow-water zone are:

Spiroplectammina biformis (Parker and Jones)
Cribrostomoides crassimargo (Norman)
C. jeffreysii (Williamson)
Asterellina pulchella (Parker)
Textularia torquata Parker

The following species are dominant in the deep-water zone:

Globigerina pachyderma (Ehrenberg)
Islandiella teretis (Tappan)
I. islandica (Nørvang)
Cribrostomoides subglobosus (Cushman)
Stetsonia horvathi Green

There are a number of species which are rare and found only in the deep-water zone (see table 1):

Bolivina sp. cf. *B. inflata* Heron-Allen and Earland
Bulimina marginata d'Orbigny
Cruciloculina ericsoni Loeblich and Tappan
Dentalina baggi Galloway and Wissler
D. frobisherensis Loeblich and Tappan
Eponides tener (Brady)
Fissurina sp. cf. *F. bradii* Silvestri
F. marginata (Montagu)
F. ventricosa (Wiesner)
Lagena apiopleura Loeblich and Tappan
L. flatulenta Loeblich and Tappan
L. gracilis Williamson
L. gracillima (Seguenza)
L. laevis (Montagu)
L. mollis Cushman
L. nebulosa Cushman
Melonis zaandami (Van Voorthuysen)
Nonionellina labradorica (Dawson)
Oolina apiculata Reuss
O. globosa (Montagu)
O. melo d'Orbigny
Parafissurina arctica Green
Planispirinoides bucculentus (Brady)
Pyrgo subsphaerica (d'Orbigny)
Quinqueloculina sadkovi (Bogdanowicz)
Q. seminulum (Linné)
Triloculina trihedra Loeblich and Tappan
Valvulineria arctica Green

TABLE 2
Comparison of foraminiferal content in sediment from the deep and shallow zones

	Shallow Zone			Deep Zone		
	No. of species per sample	Tests per gm. of sample	Living over total specimens	No. of species per sample	Tests per gm. of sample	Living over total specimens
Mean ($\bar{x}$)	19	62	.03	27	53	.02
Variance (s)	4.5	42	.04	6.7	99.10	.09
$\frac{100\ s}{\bar{x}}$	23.68%	67.74%	126.78%	24.89%	186.98%	272.73%

The difference in faunal content of the deep and shallow zones is also shown in table 2. The mean number of species per sample is lower in the shallow zone, although the mean number of tests per gram of sample is higher. This agrees with one of the few broad generalizations that can be made about the distribution of foraminifera. Usually, in terms of species, the nearshore fauna is poor in comparison with the faunal population of the nearby continental shelf. The optimum depth for a rich foraminiferal fauna depends on local conditions, but generally it is between 40 and 100 metres on the shelf. In Prince Gustaf Adolf Sea (Marlowe and Vilks, 1963), in Hecla and Griper Bay and in Hazen Strait the optimum depth is somewhere below 200 metres. It is clear that the relationship between depth and distribution is more indirect than direct and, in the present instance, it is highly suggestive that the influx of calcareous genera at depths below 200 metres is associated with the particular water mass that occupies that level.

The change in the foraminiferal fauna at the 200-metre isobath is common in the interisland seas of the Queen Elizabeth Islands so far studied. Marlowe and Vilks (1963) and Vilks (1964) found an extremely rich arenaceous fauna in the sediments of Prince Gustaf Adolf Sea at localities shallower than 200 metres. The deep-water fauna is similar to that of the Arctic Shelf described by Wagner (1962, MS.). Farther to the west in the Chukchi Sea and near Point Barrow the similarities are less pronounced. Many of the lagenids found by Loeblich and Tappan (1953) in shallow water at Point Barrow occur only in deep water in Hazen Strait and in Hecla and Griper Bay. A shallow-water inshore fauna which differs from that of the present study by greater abundances of *Buccella frigida* (Cushman), *Elphidium incertum* (Williamson), *E. bartletti* Cushman, *Protelphidium orbiculare* (Brady) and *Eggerella advena* (Cushman) was described by Cooper (1964) from the Chukchi Sea. The shallow-water fauna along the Siberian coast was described by Todd and Low (1966), and among the few species also found in Hecla and Griper Bay and in Hazen Strait the most important is *Reophax fusiformis* (Williamson) (=*R. curtus* Cushman).

TABLE 3
Percentages of foraminiferal species reported in various studies of the arctic and subarctic regions that are also found in Hecla and Griper Bay and in Hazen Strait

Authors	Locality	Con-specific percentages	Bathy-metric range (metres)
Marlowe and Vilks, 1963	Inshore waters, Ellef Ringnes Island, N.W.T.	75%	5–125
Vilks, 1964	Inshore waters, Mackenzie King Island	79%	2–284
Wagner, MS.	Polar Continental Shelf	61%	149–1249
Wagner, 1962	Polar Continental Shelf	49%	166–1239
Green, 1960	Arctic Ocean	28%	433–2760
Carsola, MS.	Beaufort Sea	53%	18–3541
Carsola, MS.	Chukchi Sea	51%	64–1994
Cooper, 1964	Chukchi Sea	45%	7–61
Loeblich & Tappan, 1953	Point Barrow	47%	3–223
Leslie, MS.	Hudson Bay	49%	26–230
Bartlett, 1964	ScotianShelf	48%	14–120
Bartlett, MS.	Mahone and St. Margaret's Bays, Nova Scotia	45%	0–73

A summary of faunal comparison with other faunas from the arctic and subarctic regions is shown in table 3. About 50 per cent of the species reported from the North Atlantic and Hudson Bay are found in the present study area, whereas the corresponding figure for the forms from the abyssal Arctic Ocean is only 28 per cent.

From this it may be concluded that the circumpolar arctic and subarctic shelf faunas are reasonably similar, regardless of distance and longitude, and that there is a distinctive abyssal fauna in the Arctic Ocean.

TABLE 4
Species distribution in two sediment cores. Numbers indicate specimens counted.

STATION NUMBER	1											2				
DEPTH (METRES)	145											306				
PER CENT MUD	97	98	99	99	99	95	97	96	94	93		98	92	99	98	99
CORE INTERVAL (CM.)	0-2	5-7	10-12	15-17	20-22	25-27	30-32	35-37	40-42	70-72		0-3	5-7	10-12	16-18	23-25
BUCCELLA FRIGIDA	1															
CRIBROSTOMOIDES CRASSIMARGO	3	7				1										
C. JEFFREYSII	1											2				
GLOBIGERINA PACHYDERMA	7									2		34	3	1		
HYPERAMMINA ELONGATA	6	1														
RECURVOIDES TURBINATUS	7	2										2	1	1		
REOPHAX NODULOSUS	7	3										1		1		
ROBERTINOIDES CHARLOTTENSIS	1															
SACCAMMINA SPHAERICA	7	1			2							3				
SACCORHIZA RAMOSA	1															
SPIROPLECTAMMINA BIFORMIS	3	1														
TEXTULARIA EARLANDI	5	1										1				
TROCHAMMINA NANA	38	52	2									2		1		
T. QUADRILOBA	2	2										2				
TROCHAMMINELLA ATLANTICA	8	2											1			
TEXTULARIA TORQUATA		1														
GLOMOSPIRA GORDIALIS		2	1				NO FAUNA								NO FAUNA	
BATHYSIPHON RUFUS		1														
TROCHAMMINELLA BULLATA			1	1								3				
CASSIDELLA COMPLANATA								2	1	3						
CIBICIDES LOBATULUS								3	1	2			1			
ISLANDIELLA ISLANDICA								6	7	10						
ELPHIDIUM BARTLETTI								1								
ISLANDIELLA TERETIS									2			24				
ELPHIDIUM INCERTUM									1							
TRILOCULINA TRIHEDRA									1	1						
VALVULINERIA ARCTICA												16				
STETSONIA HORVATHI												18	1			
REOPHAX FUSIFORMIS												1				
R. GUTTIFER												11	1			1
BOLIVINA SP. CF. B. INFLATA												1				
ISLANDIELLA NORCROSSI												1				
LAGENA APIOPLEURA												1				
EPONIDES TENER												4				

Sediment core studies

Foraminiferal content in the subsurface sediment of Hecla and Griper Bay was studied in two cores, and the results are shown in table 4. The proportion of fine sediment remains high throughout each core, but the richness and type of species change in the lower layers. Core 1 was taken at a depth of 145 metres, and the upper 10 centimetres of sediment in this core contain typical shallow-water forms of the area under study. Below this surficial 10 centimetres of sediment the fauna is sparse, and no fauna at all was found in the 30–32 cm. interval. Below 35 centimetres in the core there is an abrupt appearance of calcareous forms together with a complete absence of the benthonic species that were found in the surface layers. The calcareous assemblage of the lower layers contains species that are abundant in the deep-water zone of surface sediment in Hecla and Griper Bay and in Hazen Strait. In the core, *Triloculina trihedra* Loeblich and Tappan occurs below 40 centimetres, but in the surface sediments at other stations the species occurs only at depths below 297 metres.

Only a very short interval of core 2 was available for study, and, although it was obtained only 18 km. from core 1, it was taken at a greater depth, and consequently the surface layers contain species that are characteristic of deep waters in the study area (see table 4). As in core 1, the richness and abundance of the species decrease below the surface layers, and there is no fauna at all in the 16–18 cm. interval. There may be a correlation between the barren layers of the two cores. In core 2 the barren layer is closer to the surface because the core was sampled about 18 km. farther from the shore and in an area of slower rate of sedimentation.

The meagre data obtained from the two cores seem to indicate a change in environment which took place at some time in the past. The barren subsurface layers are found also in Prince Gustaf Adolf Sea (Marlowe, MS.) but not in the Arctic Ocean (Green, 1960; Ericson and Wollin, 1959) or in Hudson Bay (Leslie, MS.). The sparseness of foraminiferal tests in the sediment below the surface layer indicates the presence of more severe conditions for biologic activity at an earlier time. This earlier time of deposition of the barren layers may correspond to a period of more extensive coverage of ice, which lacked even the limited openings during the short summer season of the present time. This would prevent any exposure of surface waters to solar radiation, thus restricting primary production in the area to a level insufficient to maintain an effective food chain. In the rigid environment of the high latitudes, where the prey-predator relationship is very precarious, a comparatively small change in environment may eliminate the existing biota, whereas a change of similar magnitude in the mid-latitudes or tropical regions may not produce enough effect on the living community to leave a record in the sediment. Owing to the marginal aspect of the study area, with respect to the biosphere in a global sense, a much larger time interval is required to reoccupy the marine environment, once it has become barren, and therefore a comparatively small change in the environment will produce a barren zone in the sediment, as evidenced in the core. Thus the explanation of the barren subsurface layer in Prince Gustaf Adolf Sea and Hecla and Griper Bay does not necessarily call for a large-scale change in the physical environment.

The change of the shallow-water forms in the surface sediment of core 1 to deep-water forms below 35 cm. may indicate either a higher sea level in the past, or the presence of the surface Arctic water–Atlantic water boundary at a shallower depth. The first possibility is supported by the observations made by Craig and Fyles (1960) of a regional uplift that has taken place in the Arctic since the Pleistocene ice age. Of interest to the present study is their report on a radiocarbon date for marine shells collected from the Sabine Peninsula on Melville Island. (Ref. No. for the radiocarbon date is I (GSC)–21, Craig and Fyles (1960).) The shells were taken from surface material 53 metres above the present sea level and were dated at 8,275±320 years B.P. On the assumption that the mollusks lived in shallow water, the present site of collection of core 1 would be in water that was at least 53 metres deeper 8,000 years ago, and this would bring the environment within the range of depth that is occupied by deep-water species at the present. By applying this date, it is also possible to make a crude calculation of sedimentation rates. The deep-water foraminifera are found at 35 cm. below the top of the core, and, if one assumes that they lived at about the same time as the dated shells, 35 cm. of sediment was deposited in 8,000 years or 4.4 cm. per 1,000 years.

When considering the possibility of a thinner layer of the Arctic surface water without a corresponding change in sea level, it is necessaty to speculate on climatic changes that involve the whole arctic and subarctic regions. A major factor in the appearance of the warmer and more saline Atlantic water at shallower depths would be a prolonged warmer climate in the Arctic regions. Because of the relative shortness of the core and the proximity of the core station to the land, only about 5 kilometres away, it could not represent a time interval larger than the Holocene. Since the beginning of the Holocene, there has been, despite minor fluctuations, a constant warming of the climate, and therefore a thicker, rather than a thinner, layer of the Arctic surface water in the past would be expected.

Summary and conclusions

The continental shelf environment of the high Arctic was studied in terms of foraminifera and was divided into two bathymetric zones at the 200-metre isobath. The upper zone consists principally of arenaceous species and the lower zone of calcareous species, including the planktonic *Globigerina pachyderma*. These faunal divisions were correlated with the two water masses in the region, *i.e.,* the Arctic surface water, and the warmer and more saline water of Atlantic origin below. The distribution pattern of the planktonic tests found in the sediment was used to infer the movement of the subsurface water. A high relative percentage of these tests was found at the entrance of Hazen Strait adjacent to Prince Gustaf Adolf Sea, with diminishing percentages towards the west and southwest into Hecla and Griper Bay. These observations indicated an influx of the lower water mass into this area from the Arctic Ocean *via* Prince Gustaf Adolf Sea.

Sediment core studies show that regional changes have taken place in climate and/or sea level during the Holocene. A subsurface layer lacking fauna is thought to indicate that a more severe climate existed between the present and a period not more than 8,000 years ago. Species typical of shallow water are found in the upper layers of the cores examined, but deeper layers contain species which are typical of deeper water. This relationship suggests that there has been a lowering of sea level in the area. The calcareous fauna at 35 centimetres in core no. 1 was correlated with marine shells found in the surface material on the Sabine Peninsula at a locality 100 km. distant. The age of these shells has been determined by radiocarbon dating, and, if the correlation is correct, the rate of sedimentation at Station 1 is 4.4 centimetres per 1,000 years.

SYSTEMATICS

The following foraminiferal species have been compared with type collections, including the Cushman collections, at the U.S. National Museum, Washington, D.C. The species found in Hazen Strait and in Hecla and Griper Bay have been adequately described by Cushman (1948), Loeblich and Tappan (1953), and others; therefore, only peculiarities noted in the present fauna are described here.

Family ASTRORHIZIDAE
Subfamily ASTRORHIZINAE Brady, 1881
Genus ASTRORHIZA Sandahl, 1858

Astrorhiza arenaria Carpenter
Plate 1, figure 1

Astrorhiza arenaria CARPENTER in Norman, 1877, p. 213. – CUSHMAN, 1948, p. 5, pl. 1, fig. 1.

Remarks: Common at a wide range of depths.

Genus RHABDAMMINA M. Sars, 1869

Rhabdammina abyssorum M. Sars
Plate 1, figure 2

Rhabdammina abyssorum M. SARS, in Carpenter, 1869, p. 60. – BRADY, 1884, p. 266, pl. 21, figs. 1–3, 6.

Remarks: only one specimen was found in Hazen Strait at 458 metres in depth.

Subfamily RHIZAMMININAE Rhumbler, 1895
Genus BATHYSIPHON M. Sars, 1872

Bathysiphon rufus de Folin
Plate 1, figure 3a–b

Bathysiphon rufum DE FOLIN, 1886, p. 283, pl. 6, figs. 8a–c. *Bathysiphon rufus* de Folin. – LOEBLICH and TAPPAN, 1953, p. 16, pl. 1, fig. 1.

Description: Test an elongate, tapering hollow tube with irregular constrictions at varying intervals; wall very thin, finely arenaceous, flexible; colour reddish brown.

Remarks: Common at moderate depths.

Subfamily HIPPOCREPININAE Rhumbler, 1895
Genus HYPERAMMINA Brady, 1878

Hyperammina elongata Brady, 1878
Plate 1, figure 4

Hyperammina elongata BRADY, 1878, p. 433, pl. 20, fig. 2a–b. – LOEBLICH and TAPPAN, 1953, p. 19, pl. 1, fig. 6.

Remarks: Very common in the study area, found at all depths.

Genus SACCORHIZA Eimer and Fichert, 1899

Saccorhiza ramosa (Brady)
Plate 1, figure 5

Hyperammina ramosa BRADY, 1879, p. 33, pl. 3, figs. 14–15.
Saccorhiza ramosa (Brady). – BARKER, 1960, pl. 23, figs. 15–19.

Remarks: This species occurs in Hazen Strait and in Hecla and Griper Bay in small numbers at about every other station shallower than 168 metres. It is less common in the deep nearshore stations (down to a depth of 322 metres) and absent in the deep offshore stations.

Family SACCAMMINIDAE
Subfamily SACCAMMININAE Brady, 1884
Genus SACCAMMINA M. Sars, 1869

Saccammina atlantica (Cushman)
Plate 1, figure 13

Proteonina atlantica CUSHMAN, 1944, p. 5, pl. 1, fig. 4.

Remarks: This species is one of the few that in the area of the present study occur consistently at all depths in moderately high numbers.

Saccammina sphaerica Brady
Plate 1, figure 6

Saccammina sphaerica BRADY, 1871, p. 183. – M. SARS in G. O. Sars, 1872, p. 250. – BRADY, 1884, p. 253, pl. 18, figs. 11, 13, 15.

Remarks: The species may attain very large sizes (up to 5 mm. in diameter) in Hecla and Griper Bay and in Hazen Strait. It is ubiquitous with respect to depth in the study area, and at the deeper stations the coarse fraction of the sediment may consist entirely of fragments of *S. sphaerica* tests.

Family AMMODISCIDAE
Subfamily AMMODISCINAE Reuss, 1862
Genus GLOMOSPIRA Rzehak, 1885

Glomospira gordialis (Jones and Parker)
Plate 1, figure 7a–b

Trochammina squamata Jones and Parker var. *gordialis* JONES and PARKER, 1860, p. 304.
Glomospira gordialis (Jones and Parker). – Todd and BRÖNNIMANN, 1957, p. 22, pl. 1, fig. 22.

Remarks: Common in the sediments of Hecla and Griper Bay and of Hazen Strait. Range of depth not limited.

Family HORMOSINIDAE
Subfamily HORMOSININAE Haeckel, 1894
Genus REOPHAX de Montfort, 1808

Reophax fusiformis (Williamson)
Plate 1, figure 8a–b

Proteonina fusiformis WILLIAMSON, 1858, p. 1, pl. 1, fig. 1. – HÖGLUND, 1947, p. 52, pl. 4, fig. 21.
Reophax fusiformis (Williamson). – BRADY, 1884, p. 290, pl. 30, figs. 7–11.
Reophax curtus CUSHMAN, 1920, p. 8, pl. 2, figs. 2–3. – LOEBLICH and TAPPAN, 1953, p. 22, pl. 2, figs. 1–4.
Reophax subfusiformis EARLAND, 1933, p. 74, pl. 2, figs. 16–19. – HÖGLUND, 1947, p. 82, pl. 9, figs. 1–2, 4 (not 3); pl. 26, figs. 1–36; pl. 27, figs. 1–19; text-figs. 43–50.
Reophax regularis HÖGLUND, 1947, p. 86, pl. 9, figs. 11–12; pl. 26, figs. 37–43; pl. 27, figs. 24–27.

Description: Test free, elongate, usually slightly arcuate, tapering at the initial end, consisting of 2 to 4 chambers which are slightly inflated; final chamber pyriform in outline; early sutures obscured, later ones either obscured or somewhat constricted, either horizontal or slanted; wall coarsely arenaceous, mostly of quartz grains; aperture terminal, rounded.

Remarks: The species is very common and ubiquitous in the study area. A continuous gradation of forms from the *R. fusiformis* (Williamson) type to the *R. subfusiformis* Earland type was found, and *R. fusiformis* was retained because it is the senior name.

Reophax gracilis (Kiaer)
Plate 1, figure 9

Nodulina gracilis KIAER, 1900, p. 24, text-figs. 1–2.
Reophax gracilis (Kiaer). – PARKER, 1952, p. 397, pl. 2, fig. 1.

Remarks: Tests found in Hazen Strait have very thin arenaceous walls that are flexible when wet. Rare.

Reophax guttifer (Brady)
Plate 1, figure 10

Lituola (Reophax) guttifera BRADY, 1881, p. 49.
Reophax guttifera (Brady). – BRADY, 1884, p. 295, pl. 31, figs. 10–15.

Remarks: Specimens found in Hazen Strait and in Hecla and Griper Bay are very fragile and commonly the chambers are broken apart. Rare in localities shallower than 160 metres, very common at the deep stations.

Reophax nodulosus Brady
Plate 1, figure 11

Reophax nodulosa BRADY, 1879, p. 52, pl. 4, figs. 7–8. – BRADY, 1884, p. 294, pl. 31, figs. 1–9.

Remarks: Common in Hecla and Griper Bay and in Hazen Strait at all depths except at some of the shallow nearshore stations.

Reophax pilulifer Brady
Plate 1, figure 12

Reophax pilulifera BRADY, 1884, p. 292, pl. 30, figs. 18–20.

Description: Test free, straight or slightly irregular, consisting of up to eight globular chambers; aperture round, at the extremity of a slender neck on the last chamber.

Remarks: The species differs from *R. fusiformis* in having more globular chambers and a slender neck. It occurs in Hecla and Griper Bay and in Hazen Strait at depths between 35 and 349 metres. Rare.

Family RZEHAKINIDAE
Genus SILICOSIGMOILINA Cushman and Church, 1929

Silicosigmoilina groenlandica (Cushman)
Plate 1, figure 14a–b

Quinqueloculina fusca Brady var. *groenlandica* CUSHMAN, 1933, p. 2, pl. 1, fig. 4.
Silicosigmoilina groenlandica (Cushman). – LOEBLICH and TAPPAN, 1953, p. 38, pl. 4, figs. 7–9.

Remarks: This species is rare in Hecla and Griper Bay and in Hazen Strait. Depth range 33–148 metres.

Family LITUOLIDAE
Subfamily HAPLOPHRAGMOIDINAE Maync, 1952
Genus ADERCOTRYMA Loeblich and Tappan, 1952

Adercotryma glomerata (Brady)
Plate 1, figure 15

Lituola glomerata BRADY, 1878, p. 433, pl. 20, fig. 1a–c.
Adercotryma glomeratum (Brady). – LOEBLICH and TAPPAN, 1953, p. 26, pl. 8, figs. 1–4.

Remarks: One small specimen was found at Station 12 at 458 metres in depth.

Genus CRIBROSTOMOIDES Cushman, 1910

Cribrostomoides crassimargo (Norman)
Plate 1, figure 16a–b

Haplophragmium crassimargo NORMAN, 1892, p. 17.

Alveolophragmium crassimargo (Norman). – LOEBLICH and TAPPAN, 1953, p. 29, pl. 3, figs. 1–3.

Remarks: This species is very common at depths down to 350 metres but is rare in deeper waters.

Cribrostomoides jeffreysii (Williamson)
Plate 1, figure 17a–b

Nonionina jeffreysii WILLIAMSON, 1858, p. 34, pl. 3, figs. 72–73.
Alveolophragmium jeffreysi (Williamson). – LOEBLICH and TAPPAN, 1953, p. 31, pl. 3, figs. 4–7.

Remarks: Very common at depths between 60 and 360 metres but does not occur in deeper waters.

Cribrostomoides subglobosus (Cushman)
Plate 1, figure 18a–b

Haplophragmoides subglobosum (G. O. Sars). – CUSHMAN, 1910, p. 105, text-figs. 162–164.
Labrospira subglobosa (G. O. Sars). – CUSHMAN, 1948, p. 28, pl. 3, fig. 3a–b.

Description: Test usually planispiral, but coiling direction may change up to 90°. Test involute; sutures indistinct; periphery slightly lobulate to entire. Wall arenaceous, slightly rough; colour reddish-brown; aperture an elongate slit at base of apertural face.

Remarks: The species occurs only at depths greater than 200 metres and is common in the deep waters.

Genus RECURVOIDES Earland, 1934

Recurvoides turbinatus (Brady).
Plate 1, figure 19a–b

Haplophragmium turbinatum BRADY, 1884, p. 313, pl. 35, fig.9a–c.
Recurvoides turbinatus (Brady). – PARKER, 1952, p. 402, pl. 2, figs. 23–24.

Remarks: This species is very common in Hecla and Griper Bay and in Hazen Strait at all depths.

Family TEXTULARIIDAE
Subfamily SPIROPLECTAMMININAE Cushman, 1927
Genus SPIROPLECTAMMINA Cushman, 1927

Spiroplectammina biformis (Parker and Jones)
Plate 1, figure 20a–b

Textularia agglutinans d'Orbigny var. *biformis* PARKER and JONES, 1865, p. 370, pl. 15, figs. 23–24.
Spiroplectammina biformis (Parker and Jones). – LOEBLICH and TAPPAN, 1953, p. 34, pl. 4, figs. 1–6.

Remarks: This is a very common species in Hazen Strait and in Hecla and Griper Bay at depths down to 66 metres, less common between 66 and 172 metres, and rare down to 322 metres. Not found in deeper waters.

Subfamily TEXTULARIINAE Ehrenberg, 1838
Genus TEXTULARIA Defrance, 1824

Textularia earlandi Parker
Plate 1, figure 21

Textularia tenuissima Earland, 1933, p. 95, pl. 3, figs. 21–30 (not Haeusler, 1881). – HÖGLUND, 1947, p. 176, pl. 13, fig. 1a–b; text-figs. 154–155.
Textularia earlandi PARKER, 1952, p. 458 (footnote), pl. 2, fig. 4.

Remarks: The specimens from Hazen Strait and from Hecla and Griper Bay are very similar to the types of Parker (1952) and the figures of Höglund (1947). The species is common in the study area over a wide range of depth, although the occurrences decrease at the deeper localities.

Textularia torquata Parker
Plate 1, figure 22

Textularia torquata PARKER, 1952, p. 403, pl. 3, figs. 9–11.

Remarks: The species is very common in Hazen Strait and in Hecla and Griper Bay in waters shallower than 172 metres, common between 172 and 349 metres, rare in deeper water.

Family TROCHAMMINIDAE
Subfamily TROCHAMMININAE Schwager, 1877
Genus TROCHAMMINA Parker and Jones, 1859

Trochammina nana (Brady)
Plate 1, figure 23a–b

Haplophragmium nanum BRADY, 1881, p. 50. – BRADY, 1884, p. 311, pl. 35, figs. 6–8.
Trochammina nana (Brady). – LOEBLICH and TAPPAN, 1953, p. 50, pl. 8, fig. 5.

Remarks: This is the most common species in Hecla and Griper Bay and in Hazen Strait. It was present at every station, but higher relative percentages were found at stations shallower than 200 metres.

Trochammina quadriloba Höglund
Plate 1, figure 24a–b

Trochammina pusilla HÖGLUND, 1947, p. 201, pl. 17, fig. 4a–c (not Geinitz, 1848).
Trochammina quadriloba HÖGLUND, 1948, p. 46.

Remarks: The species is common in Hazen Strait and in Hecla and Griper Bay at all depths.

Genus TROCHAMMINELLA Cushman, 1943.

Trochamminella atlantica Parker
Plate 2, figure 1a–b

Trochamminella atlantica PARKER, 1952, p. 409, pl. 4, figs. 17–19.

Remarks: The species is very common in Hazen Strait and in Hecla and Griper Bay at all depths, although the higher relative percentages occur at depths shallower than 200 metres.

Trochamminella bullata Höglund
Plate 2, figures 2a–b

Trochamminella bullata HÖGLUND, 1947, p. 213, pl. 17, fig. 5a–c.

Remarks: The species is common in Hazen Strait and in Hecla and Griper Bay at all depths.

Family ATAXOPHRAGMIIDAE
Subfamily GLOBOTEXTULARIINAE Cushman, 1927
Genus EGGERELLA Cushman, 1933

Eggerella advena (Cushman)
Plate 2, figure 3

Verneuilina advena CUSHMAN, 1922, p. 141.
Eggerella advena (Cushman). – CUSHMAN, 1937, p. 51, pl. 5, figs. 12–15. – CUSHMAN, 1948, p. 32, pl. 3, fig. 12.

Remarks: This species occurs at three localities in small numbers. Present only in the shallow waters of Hazen Strait.

Family NUBECULARIIDAE
Subfamily SPIROLOCULININAE Wiesner, 1920
Genus PLANISPIRINOIDES Parr, 1950

Planispirinoides bucculentus (Brady)
Plate 2, figure 4a–b

Miliolina bucculenta BRADY, 1884, p. 170, pl. 114, fig. 3.
Planispirinoides bucculentus (Brady). – PARR, 1950, pp. 287–288, pl. 6, figs. 1–6; text-figs. 1–5.

Remarks: Found only in Hazen Strait at depths of 297 and 457 metres. Rare.

Family FISCHERINIDAE
Subfamily CORNUSPIRINAE Rhumbler, 1904
Genus CORNUSPIRA Schultze, 1854

Cornuspira involvens (Reuss)
Plate 2, figure 5

Operculina involvens REUSS, 1850, p. 370, pl. 46, fig. 20.
Cornuspira involvens (Reuss). – LOEBLICH and TAPPAN, 1953, p. 49, pl. 7, figs. 4–5.

Description: Test planispiral, robust; spiral suture indistinct; wall calcareous; surface smooth except for a few irregular depressions. Greatest diameter of hypotype 3 mm., thickness 0.5 mm.

Remarks: The single specimen compares closely with those of Loeblich and Tappan from Greenland. It was found at Station 13.

Family MILIOLIDAE
Subfamily QUINQUELOCULININAE Cushman, 1917
Genus CRUCILOCULINA d'Orbigny, 1839

Cruciloculina ericsoni Loeblich and Tappan
Plate 2, figure 6

Cruciloculina ericsoni LOEBLICH and TAPPAN, 1957, p. 234, pl. 74, figs. 3–7.

Remarks: Specimens from Hazen Strait are smaller than the holotype and lack the small ridge around the aperture. The species is found in small numbers in deep waters.

Genus PYRGO Defrance, 1824

Pyrgo subsphaerica (d'Orbigny)
Plate 2, figure 7a–b

Biloculina subsphaerica D'ORBIGNY, 1839, p. 162, pl. 8, figs. 25–27.
Pyrgo subsphaerica (d'Orbigny). – PARKER, 1952, p. 405, pl. 3, fig. 17.

Description: Test oval in outline, inflated; chamber development biloculine, the last chamber extending beyond the previous one all around the margin; aperture ovate, with a small simple tooth.

Remarks: The two specimens found in Hecla and Griper Bay are similar in general outline to *Pyrgo williamsoni* (Silvestri) of Loeblich and Tappan, 1953, but they lack the pronounced bifid tooth of the hypotypes of those authors. It is possible that the two specimens assigned here to *P. subsphaerica* are actually juveniles of *P. williamsoni*.

Genus QUINQUELOCULINA d'Orbigny, 1826

Quinqueloculina arctica Cushman
Plate 2, figure 8a–b

Quinqueloculina arctica CUSHMAN, 1933, p. 2, pl. 1, fig. 3a–c.

Remarks: One small specimen was found in Hecla and Griper Bay at a depth of 249 metres.

Quinqueloculina sadkovi (Bogdanowicz)
Plate 2, figure 9a–b

Miliolina sadkovi BOGDANOWICZ in Stschedrina, 1946, p. 142, pl. 3, fig. 15.

Remarks: This species was separated from *Q. seminulum* (Linné) on the basis of its relatively small apertural opening, bifid tooth, more circular outline, and less distinctive sutures. However, the specimens lack the outside ornamentation described for the holotype of *Q. sadkovi*. Depth range of occurrence in Hazen Strait and in Hecla and Griper Bay is between 193 and 458 metres. Rare.

Quinqueloculina seminulum (Linné)
Plate 2, figure 10a–b

Serpula seminulum LINNÉ, 1758, p. 786.
Quinqueloculina seminula (Linné). – PARKER, 1952, p. 456, pl. 2, fig. 7a–b.

Remarks: This species is found only in Hazen Strait at depths greater than 237 metres. Rare.

Genus TRILOCULINA d'Orbigny, 1826

Triloculina trihedra Loeblich and Tappan
Plate 2, figure 11

Triloculina trihedra LOEBLICH and TAPPAN, 1953, p. 45, pl. 4, fig. 10.

Remarks: The species is rare in Hazen Strait and occurs at depths between 297 and 457 metres.

Family NODOSARIIDAE
Subfamily NODOSARIINAE *Ehrenberg, 1838*
Genus DENTALINA Risso, 1826

Dentalina baggi Galloway and Wissler
Plate 2, figure 12

Dentalina baggi GALLOWAY and WISSLER, 1927, p. 49, pl. 8, figs. 14–15. – LOEBLICH and TAPPAN, 1953, p. 54, pl. 9, figs. 10–15.

Remarks: This species occurs in small numbers at three localities in both Hazen Strait and Hecla and Griper Bay. Depth range 205–458 metres.

Dentalina frobisherensis Loeblich and Tappan
Plate 2, figure 13

Dentalina frobisherensis LOEBLICH and TAPPAN, 1953, p. 55, pl. 10, figs. 1–9.

Remarks: This species occurs at five stations in small numbers. Depth range 193–440 metres.

Dentalina pauperata d'Orbigny
Plate 2, figure 14

Dentalina pauperata D'ORBIGNY, 1846, p. 46, pl. 1, figs. 57–58. – LOEBLICH and TAPPAN, 1953, p. 57, pl. 9, figs. 7–9.

Remarks: This species occurs at two stations. One living juvenile was found at Station 52 at a depth of 33 metres, and one large specimen at Station 18 at a depth of 457 metres.

Genus LAGENA Walker and Jacob, 1798

Lagena apiopleura Loeblich and Tappan
Plate 2, figure 15

Lagena apiopleura LOEBLICH and TAPPAN, 1953, p. 59, pl. 10, figs. 14–15.

Remarks: Rare. Found in the deeper waters of Hazen Strait and of Hecla and Griper Bay.

Lagena flatulenta Loeblich and Tappan
Plate 2, figure 16

Lagena flatulenta LOEBLICH and TAPPAN, 1953, p. 60, pl. 11, figs. 9–10.

Remarks: Rare. Occurs in deep water of Hecla and Griper Bay and Hazen Strait.

Lagena gracilis Williamson
Plate 2, figure 17

Lagena gracilis WILLIAMSON, 1848, p. 13, pl. 1, fig. 5. – BRADY, 1884, pp. 445, 464, pl. 58, fig. 3. – CUSHMAN and TODD, 1947, p. 11, pl. 2, fig. 4.

Remarks: Specimens from Hecla and Griper Bay and from Hazen Strait compare closely with Brady's figure 3. Rare. Occurs at depths greater than 300 metres.

Lagena gracillima (Seguenza)
Plate 2, figure 18

Amphorina gracillima SEGUENZA, 1862, p. 51, pl. 1, fig. 37.
Lagena gracillima (Seguenza). – CUSHMAN, 1923, p. 23, pl. 4, fig. 5.

Remarks: The specimens from Hecla and Griper Bay and from Hazen Strait are symmetrical and compare closely with the figured hypotypes of Cushman (1923). Rare. Distribution in the study area is restricted to waters deeper than 200 metres.

Lagena laevis (Montagu)
Vermiculum laeve MONTAGU, 1803, p. 524.

Lagena laevis (Montagu). – PARKER, 1964, p. 626, pl. 97, fig. 30.

Remarks: The specimens from Hecla and Griper Bay and from Hazen Strait compare closely with Parker's figured hypotype (1964). The general shape is more elongated than the figured hypotypes of Loeblich and Tappan (1953). Rare. Found in two stations at depths of 312 and 405 metres.

Lagena meridionalis Wiesner
Plate 2, figure 19

Lagena gracilis Williamson var. *meridionalis* WIESNER, 1931, p. 117, pl. 18, fig. 211.
Lagena meridionalis Wiesner. – LOEBLICH and TAPPAN, 1953, p. 62, pl. 12, fig. 1.

Remarks: Rare. Occurs at one station in water 457 metres deep.

Lagena mollis Cushman
Plate 2, figure 20

Lagena gracillima (Seguenza) var. *mollis* CUSHMAN, 1944, p. 21, pl. 3, fig. 3.
Lagena mollis Cushman. – LOEBLICH and TAPPAN, 1953, p. 63, pl. 11, fig. 26.

Remarks: The specimens found in Hecla and Griper Bay are slightly more elongated than the holotype and are comparable to one of Loeblich and Tappan's figured specimens (1953, pl. 11, fig. 26). They occur at 193 and 265 metres.

Lagena nebulosa Cushman
Plate 2, figure 21

Lagena laevis (Montagu) var. *nebulosa* CUSHMAN, 1923, p. 29, pl. 5, figs. 4–5.
Lagena nebulosa Cushman. – BARKER, 1960, pl. 56, fig. 12.

Remarks: The species differs from *Lagena laevis* in having a more cylindrical test. Rare in Hazen Strait and in Hecla and Griper Bay. Found at depths of 193 and 457 metres.

Lagena sp. cf. ***L. plumigera*** Brady
Plate 2, figure 22

Cf. *Lagena plumigera* BRADY, 1881, p. 62. – BRADY, 1884, p. 465, pl. 58, figs. 25, 27.

Description: Test unilocular, flask-shaped with a flat base; wall calcareous, finely perforate; surface ornamented with 12 longitudinal costae, every second one extending to the end of the apertural neck.

Remarks: The species differs from Brady's figs. 25 and 27 in having less extensive costae. Rare. Found only in Hazen Strait at 391 and 440 metres in depth.

Family GLANDULINIDAE
Subfamily OOLININAE Loeblich and Tappan, 1961
Genus FISSURINA Reuss, 1850

Fissurina sp. cf. ***F. bradii*** Silvestri
Plate 2, figure 23a–b

Cf. *Fissurina bradii* SILVESTRI, 1902, p. 147.

Description: Test free, unilocular, compressed, rounded in outline; wall calcareous, finely perforate, transparent; test with three extensive marginal keels; surface otherwise smooth; aperture terminal in form of an elongate slit. Maximum diameter 0.2 mm., maximum thickness 0.05 mm.

Remarks: This species was found in small numbers at three locations. Depth range 193–381 metres.

Fissurina marginata (Montagu)
Plate 2, figure 24a–b

Vermiculum marginatum MONTAGU, 1803, p. 524.
Fissurina marginata (Montagu). – LOEBLICH and TAPPAN, 1953, p. 77, pl. 14, figs. 7–9. – PARKER, 1964, p. 625, pl. 98, fig. 11.

Remarks: This species is variable, particularly in the characters of the entosolenian tube and the roundness of the tests. Occurs in moderate numbers at localities deeper than 193 metres.

Fissurina ventricosa (Wiesner)
Plate 2, figure 25

Lagena (*Entosolenia*) *marginata* var. *ventricosa* WIESNER, 1931, p. 120, pl. 19, fig. 222 (not *Lagena ventricosa* Silvestri, 1904).
Fissurina ventricosa (Wiesner). – LOEBLICH and TAPPAN, 1953, p. 79, pl. 14, fig. 15.

Remarks: This species is more globular than *Fissurina marginata* (Montagu) and lacks the marginal keel. Occurs in small numbers at two stations at 193 and 297 metres in depth.

Genus OOLINA d'Orbigny, 1839

Oolina apiculata Reuss
Plate 2, figure 26a–b

Oolina apiculata REUSS, 1851, p. 22, pl .2, fig. 1.

Remarks: The species is rare in Hecla and Griper Bay and in Hazen Strait and occurs between 193 and 458 metres in depth.

Oolina globosa (Montagu)
Plate 2, figure 27a–b

"Serpula (Lagena) laevis globosa" WALKER and BOYS, 1784, p. 3, pl. 1, fig. 8 (non-binominal nomenclature).
Vermiculum globosum MONTAGU, 1803, p. 523.
Oolina globosa (Montagu). – Parr, 1950, p. 302.

Remarks: This species is found in Hecla and Griper Bay and in Hazen Strait between 193 and 457 metres in depth. Rare.

Oolina hexagona (Williamson)
Plate 2, figure 28

Entosolenia squamosa (Montagu) var. *hexagona* WILLIAMSON, 1848, p. 20, pl. 2, fig. 23.
Oolina hexagona (Williamson). – LOEBLICH and TAPPAN, 1953, p. 69, pl. 14, figs. 1–2.

Remarks: This species was found at only one locality in Hecla and Griper Bay at a depth of 312 metres.

Oolina melo d'Orbigny
Plate 2, figure 29

Oolina melo D'ORBIGNY, 1939, p. 20, pl. 5, fig. 9.

Remarks: Found in Hecla and Griper Bay and in Hazen Strait between the depths of 193 and 458 metres. Rare.

Genus PARAFISSURINA Parr, 1947

Parafissurina arctica Green
Plate 2, figure 30

Parafissurina arctica GREEN, 1960, p. 70, pl. 1, fig. 2a–b.

Description: Test rounded, slightly compressed; periphery with a keel of variable extent which may be ornamented with spines; wall finely perforate; aperture hooded with an entosolenian tube extending to the bottom of the test.

Remarks: Found in Hecla and Griper Bay and in Hazen Strait between 297 and 458 metres of depth. Rare.

Parafissurina tectulostoma Loeblich and Tappan
Plate 3, figure 1a–b

Parafissurina tectulostoma LOEBLICH and TAPPAN, 1953, p. 81, pl. 14, fig. 17.

Remarks: The species is rare in the shallow waters of Hecla and Griper Bay, but more common in Hazen Strait at depths between 381 and 457 metres.

Family BOLIVINIDAE
Genus BOLIVINA d'Orbigny, 1839

Bolivina sp. cf. ***B. inflata*** Heron-Allen and Earland
Plate 3, figure 2a–b

Cf. *Bolivina inflata* HERON-ALLEN and EARLAND, 1913, p. 68, pl. 4, figs. 16–19.

Remarks: The morphology of the specimens from Hazen Strait is comparable with the type description except for the lack of a rough surface. Cushman's U.S. National Museum specimens from the Gulf of Paria have thicker walls and rougher surfaces, although one from the collection agreed well with the present specimen.

Occurs at depths greater than 297 metres. Rare.

Family ISLANDIELLIDAE
Genus ISLANDIELLA Nørvang, 1958

Islandiella islandica (Nørvang)
Plate 3, figure 3

Cassidulina islandica NØRVANG, 1945, p. 41, text-figs. 7–8.
Islandiella islandica (Nørvang). – LOEBLICH and TAPPAN, 1964, p. C556, text-fig. 439, *1–3*.

Remarks: This species is absent in waters shallower than 200 metres in Hecla and Griper Bay and in Hazen Strait, but in deeper waters it is very common.

Islandiella norcrossi (Cushman)
Plate 3, figure 4a–b

Cassidulina norcrossi CUSHMAN, 1933, p. 7, pl. 2, fig. 7.

Remarks: One of the few calcareous species that occur in shallow water in Hecla and Griper Bay and in Hazen Strait. Also found in deep water.

Islandiella teretis (Tappan)
Plate 3, figure 5

Cassidulina teretis TAPPAN, 1951, p. 7, pl. 1, fig. 30a–c.

Remarks: Very common species in the deeper waters of the study area.

Family BULIMINIDAE
Subfamily BULIMININAE Jones, 1875
Genus BULIMINA d'Orbigny, 1826

Bulimina marginata d'Orbigny
Plate 3, figure 6

Bulimina marginata D'ORBIGNY, 1826, p. 269, pl. 12, figs. 10–12. – PARKER, 1952, p. 415, pl. 5, fig. 26.

Remarks: Less spinose than specimens from southern waters. The last two chambers have lost their margins. The present specimens are like those collected by Cushman off Baltimore Island and deposited in the U.S. National Museum. They occur in deep water and are rare.

Family DISCORBIDAE
Subfamily DISCORBINAE Ehrenberg, 1838
Genus BUCCELLA Andersen, 1952

Buccella frigida (Cushman)
Plate 3, figure 7a–b

Pulvinulina frigida CUSHMAN, 1922, p. 144.
Buccella frigida (Cushman). – ANDERSEN, 1952, p. 144, text-figs. 4–6.

Remarks: Occurs in both deep and shallow waters. Common.

Genus STETSONIA Parker, 1954

Stetsonia horvathi Green
Plate 3, figure 8a–b

Stetsonia horvathi GREEN, 1960, p. 72, pl. 1, fig. 6a–b.

Remarks: The species is rare in Hazen Strait and in Hecla and Griper Bay at depths shallower than 200 metres but is common in deeper waters. The bathymetric range of occurrence is 82–458 metres.

Subfamily BAGGININAE Cushman, 1927
Genus VALVULINERIA Cushman, 1926

Valvulineria arctica Green
Plate 3, figure 9a–c.

Valvulineria arctica GREEN, 1960, p. 71, pl. 1, fig. 3a–c.

Remarks: The species is absent at depths of less than 200 metres in Hazen Strait and in Hecla and Griper Bay, and is rare at deeper localities.

Family ASTERIGERINIDAE
Genus ASTERELLINA Anderson, 1963

Asterellina pulchella (Parker)
Plate 3, fig. 10a–b

Pninaella (?) pulchella PARKER, 1952, p. 420, pl. 6, figs. 18–20.
Asterellina pulchella (Parker). – ANDERSON, 1963, p. 314, pl. 1, figs. 5–7.

Remarks: Specimens found in the arctic are slightly flatter than the holotype. They commonly occur in shallow water down to 66 metres, but their presence was recorded also at 405 metres in depth.

Family SPIRILLINIDAE
Subfamily PATELLININAE Rhumbler, 1906
Genus PATELLINA Williamson, 1858

Patellina corrugata Williamson
Plate 3, figure 11

Patellina corrugata WILLIAMSON, 1858, p. 46, pl. 3, figs. 86–89.

Remarks: One specimen was found in Hazen Strait at a depth of 297 metres.

Family ELPHIDIIDAE
Subfamily ELPHIDIINAE Galloway, 1933
Genus ELPHIDIUM de Montfort, 1808

Elphidium bartletti Cushman
Plate 3, figure 12

Elphidium bartletti CUSHMAN, 1933, p. 4, pl. 1, fig. 9. – LOEBLICH and TAPPAN, 1953, p. 96, pl. 18, figs. 10–14.

Remarks: This species is common in Hecla and Griper Bay and in Hazen Strait. Its depth range is 43–457 metres.

Elphidium incertum (Williamson)
Plate 3, figure 13

Polystomella umbilicatula (Walker) var. *incerta* WILLIAMSON, 1858, p. 44, pl. 3, fig. 82a.
Elphidium incertum (Williamson). – PHLEGER, 1952, p. 83, pl. 14, fig. 7.
Elphidium clavatum Cushman. – LOEBLICH and TAPPAN, 1953, p. 98, pl. 19, figs. 8–10.

Remarks: This species is common in Hecla and Griper Bay and in Hazen Strait. Depth range 17–457 metres.

Genus PROTELPHIDIUM Haynes, 1956

Protelphidium orbiculare (Brady)
Plate 3, figure 14

Nonionina orbicularis BRADY, 1881, p. 415, pl. 21, fig. 5a–b.
Elphidium orbiculare (Brady). – LOEBLICH and TAPPAN, 1953, p. 102, pl. 19, figs. 1–4.
Protelphidium orbiculare (Brady). – TODD and LOW, 1961, p. 20, pl. 2, fig. 11.

Remarks: Found in Hazen Strait and in Hecla and Griper Bay at depths of 17 and 31 metres. Rare.

Family GLOBIGERINIDAE
Subfamily GLOBIGERININAE Carpenter, Parker and Jones, 1862
Genus GLOBIGERINA d'Orbigny, 1826

Globigerina pachyderma (Ehrenberg)
Plate 3, figure 15a–c

Aristerospira pachyderma EHRENBERG, 1861, p. 303.
Globigerina pachyderma (Ehrenberg). – BÉ, 1960, p. 66, text-fig. 1a–c.

Remarks: The continuous gradation in morphology of this species was found to correspond with the growth series described by Bé (1960). Basically, two types exist: 1) test fragile; spherical chambers distinct; final chamber larger than earlier chambers; relatively large aperture; and 2) test robust; chambers indistinct due to thickening of test; final chamber smaller than or equal to the penultimate chamber, giving a quadrate appearance of the test in ventral view; aperture small. According to Bé (1961), the first type is the juvenile stage of the second. In Hazen Strait and in Hecla and Griper Bay, tests of both the juveniles and the adults were found in the rare occurrences at depths less than 200 metres. The species is very common in the sediment at depths greater than 200 metres with the relative percentage increasing towards Prince Gustaf Adolf Sea.

Family EPONIDIDAE
Genus EPONIDES de Montfort, 1808

Eponides tener (Brady)
Plate 3, figure 16a–b

Truncatulina tenera BRADY, 1884, p. 665, pl. 95, fig. 11.

Remarks: Common in Hecla and Griper Bay and in Hazen Strait. Depth range 193–457 metres.

Family CIBICIDIDAE
Subfamily CIBICIDINAE Cushman, 1927
Genus CIBICIDES de Montfort, 1808

Cibicides lobatulus (Walker and Jacob)
Plate 3, figure 17a–b

Nautilus lobatulus WALKER and JACOB in Kanmacher, 1798, p. 642, pl. 14, fig. 36.
Cibicides lobatula (Walker and Jacob). – CUSHMAN, 1931, p. 118, pl. 21, fig. 3.

Remarks: Abundant at localities with relatively coarse sediments. The distribution is not controlled by depth.

Family CAUCASINIDAE
Subfamily FURSENKOININAE Loeblich and Tappan, 1961
Genus CASSIDELLA Hofker, 1951

Cassidella complanata (Egger)
Plate 3, figure 18a–b

Virgulina schreibersiana Cziczek var. *complanata* EGGER, 1893, p. 292, pl. 8, figs. 91–92.
Virgulina complanata Egger. – PARKER, 1952, p. 417, pl. 6, fig. 2a–b.

Remarks: Occurs at a wide variety of depths but increases in numbers at the deeper stations.

Family NONIONIDAE
Subfamily NONIONINAE Schultze, 1854
Genus ASTRONONION Cushman and Edwards, 1937

Astrononion gallowayi Loeblich and Tappan
Plate 3, figure 19

Astrononion gallowayi LOEBLICH and TAPPAN, 1953, p. 90, pl. 17, figs. 4–7.

Remarks: Rare. Found in shallow water and coarse sediments off Prince Patrick Island.

Genus NONIONELLINA Voloshinova, 1958

Nonionellina labradorica (Dawson)
Plate 3, figure 20a–b

Nonionina labradorica DAWSON, 1860, p. 191, fig. 4.
Nonion labradoricum (Dawson). – LOEBLICH and TAPPAN, 1953, p. 86, pl. 17, figs. 1–2.
Nonionellina labradorica (Dawson). – VOLOSHINOVA, 1958, p. 142.

Description: Test trochospiral in early coiling, later becoming planispiral and involute; wall calcareous, finely perforate; aperture a low slit at base of apertural face.

Remarks: The species is found in small numbers in Hecla and Griper Bay and in Hazen Strait at depths between 200 and 300 metres.

Family ANOMALINIDAE
Subfamily ANOMALININAE Cushman, 1927
Genus MELONIS de Montfort, 1808

Melonis zaandami (van Voorthuysen)
Plate 3, figure 21a–b

Nonion pompilioides (Fichtel and Moll). – CUSHMAN, 1930, p. 4, pl. 2, figs. 1–2 (not pl. 1, figs. 7–11).
Anomalinoides barleeanum (Williamson) var. *zaandamae* VAN VOORTHUYSEN, 1952, p. 681.
Nonion zaandamae (van Voorthuysen). – LOEBLICH and TAPPAN, 1953, p. 87, pl. 16, figs. 11–12.
Melonis zaandami (van Voorthuysen). – LOEBLICH and TAPPAN, 1964, p. C763, text-fig. 627, *2–3*.

Remarks: Found in Hazen Strait and in Hecla and Griper Bay, commonly at depths more than 190 metres. Station 8, where *M. zaandami* is found at 65 m., is an exception.

Family ROBERTINIDAE
Genus ROBERTINOIDES Höglund, 1947

Robertinoides charlottensis (Cushman)
Plate 3, figure 22

Cassidulina charlottensis CUSHMAN, 1925, p. 41, pl. 6, figs. 6–7.
Robertinoides (?) charlottensis (Cushman). – LOEBLICH and TAPPAN, 1953, p. 108, pl. 20, figs. 6–7.

Remarks: This species is rare in Hazen Strait and in Hecla and Griper Bay, and was found within the depth range of 43–391 metres.

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PLATE 1

1 *Astrorhiza arenaria* Carpenter
×20, Sta. 16,H azen Strait, N.W.T., Geol. Survey Canada No. 23326.

2 *Rhabdammina abyssorum* M. Sars
×20, Sta. 12, Hazen Strait, N.W.T., Geol. Survey Canada No. 23327.

3 *Bathysiphon rufus* de Folin
×25: a, Sta. 44; b, Sta. 5; Hecla and Griper Bay, N.W.T., Geol. Survey Canada Nos. 23328, 23329.

4 *Hyperammina elongata* Brady
×10, Sta. 43, Hecla and Griper Bay, N.W.T., Geol. Survey Canada No. 23330.

5 *Saccorhiza ramosa* (Brady)
×8, Sta. 31, Hazen Strait, N.W.T., Geol. Survey Canada No. 23331.

6 *Saccammina sphaerica* Brady
×15, Sta. 31, Hazen Strait, N.W.T., Geol. Survey Canada No. 23332.

7 *Glomospira gordialis* (Jones and Parker)
×100, Sta. 53, off Prince Patrick Island, N.W.T., Geol. Survey Canada Nos. 23333, 23334.

8 *Reophax fusiformis* (Williamson)
a, ×25, Sta. 10, Hecla and Griper Bay; b, ×60, Sta. 52, Ballantyne Strait; N.W.T., Geol. Survey Canada Nos. 23335, 23336.

9 *Reophax gracilis* (Kiaer)
×45, Sta. 55, Fitzwilliam Strait, N.W.T., Geol. Survey Canada No. 23337.

10 *Reophax guttifer* (Brady)
×75, Sta. 6, Hecla and Griper Bay, N.W.T., Geol. Survey Canada No. 23338.

11 *Reophax nodulosus* Brady
×15, Sta. 33, Hazen Strait, N.W.T., Geol. Survey Canada No. 23339.

12 *Reophax pilulifer* Brady
×15, Sta. 35, Hecla and Griper Bay, N.W.T., Geol. Survey Canada No. 23340.

13 *Saccammina atlantica* (Cushman)
×70, Sta. 13, Hazen Strait, N.W.T., Geol. Survey Canada No. 23341.

14 *Silicosigmoilina groenlandica* (Cushman)
a, ×75, side view; b, ×130, apertural view; Sta. 43, Hecla and Griper Bay, N.W.T., Geol. Survey Canada No. 23342.

15 *Adercotryma glomerata* (Brady)
×180, Sta. 12, Hazen Strait, N.W.T., Geol. Survey Canada No. 23343.

16 *Cribrostomoides crassimargo* (Norman)
×30, Sta. 47; a. apertural view; b. side view; off Emerald Isle, N.W.T., Geol. Survey Canada No. 23344.

17 *Cribrostomoides jeffreysii* (Williamson)
×30, Sta. 31; a, side view; b, apertural view; Hazen Strait, N.W.T., Geol. Survey Canada No. 23345.

18 *Cribrostomoides subglobosus* (Cushman)
×35, Sta. 18, Hazen Strait, N.W.T.; a–b, apertural views; Geol. Survey Canada Nos. 23346, 23347.

19 *Recurvoides turbinatus* (Brady)
a, ×100; b, ×140; apertural views, Sta. 9, Hecla and Griper Bay, N.W.T., Geol. Survey Canada Nos. 23348, 23349.

20 *Spiroplectammina biformis* (Parker and Jones)
×150, Sta. 4, Hecla and Griper Bay, N.W.T., Geol. Survey Canada Nos. 23350, 23351.

21 *Textularia earlandi* Parker
×140, Sta. 26, Hazen Strait, N.W.T., Geol. Survey Canada No. 23352.

22 *Textularia torquata* Parker
×120, Sta. 20, Hazen Strait, N.W.T., Geol. Survey Canada No. 23353.

23 *Trochammina nana* (Brady)
×100, Sta. 51, Ballantyne Strait, N.W.T.; a, ventral view; b, dorsal view; Geol. Survey Canada No. 23354.

24 *Trochammina quadriloba* Höglund
×300, Sta. 37, Hecla and Griper Bay, N.W.T.; a, ventral view; b, dorsal view; Geol. Survey Canada No. 23355.

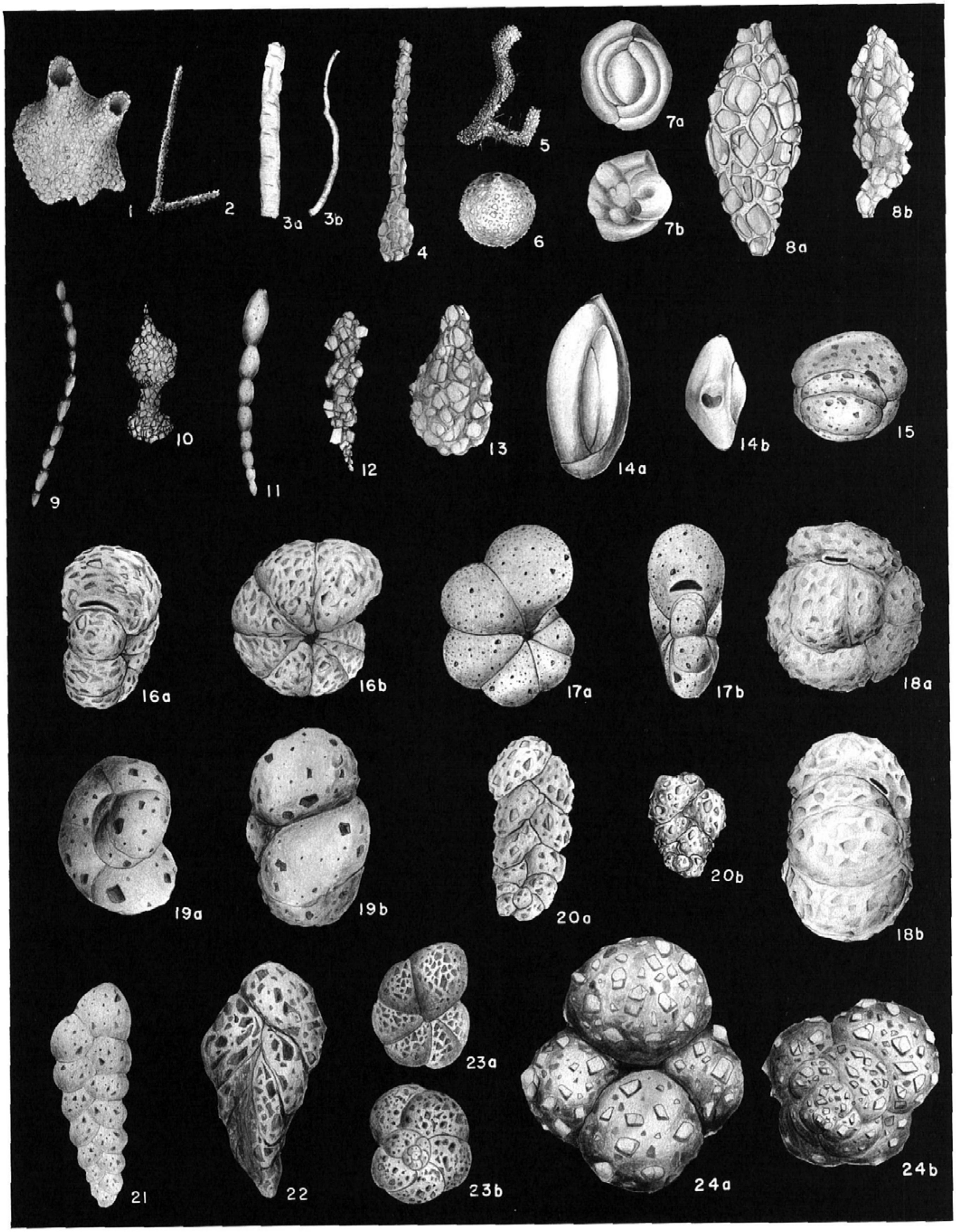
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PLATE 2

1 *Trochamminella atlantica* Parker
×100, Sta. 8, Hecla and Griper Bay, N.W.T.; a, dorsal view; b, ventral view; Geol. Survey Canada No. 23356.

2 *Trochamminella bullata* Höglund
×150, Sta. 29, Hecla and Griper Bay, N.W.T.; a, dorsal view; b, ventral view; Geol. Survey Canada No. 23357.

3 *Eggeralla advena* (Cushman)
×125, Sta. 53, off Prince Patrick Island, N.W.T., Geol. Survey Canada No. 23358.

4 *Planispirinoides bucculentus* (Brady)
×25, Sta. 18, Hazen Strait, N.W.T.; a, apertural view; b, side view; Geol. Survey Canada No. 23359.

5 *Cornuspira involvens* (Reuss)
×15, Sta. 13, Hazen Strait, N.W.T., Geol. Survey Canada No. 23360.

6 *Cruciloculina ericsoni* Loeblich and Tappan
×60, Sta. 5, Hecla and Griper Bay, N.W.T., apertural view, Geol. Survey Canada No. 23361.

7 *Pyrgo subsphaerica* (d'Orbigny)
×75, Sta. 35, Hecla and Griper Bay, N.W.T.; a, apertural view; b, side view; Geol. Survey Canada No. 23362.

8 *Quinqueloculina arctica* Cushman
×75, Sta. 40, Hecla and Griper Bay, N.W.T.; a, apertural view; b, side view; Geol. Survey Canada No. 23363.

9 *Quinqueloculina sadkovi* (Bogdanowicz)
a, ×40, apertural view; b, ×35, side view; Sta. 18, Hazen Strait, N.W.T., Geol. Survey Canada No. 23364.

10 *Quinqueloculina seminulum* (Linné)
a, ×35, apertural view; b, ×33, side view; Sta. 5, Hecla and Griper Bay, N.W.T., Geol. Survey Canada No. 23365.

11 *Triloculina trihedra* Loeblich and Tappan
×100, side view showing aperture, Sta. 13, Hazen Strait, N.W.T., Geol. Survey Canada No. 23366.

12 *Dentalina baggi* Galloway and Wissler
×23, Sta. 28, Hecla and Griper Bay, N.W.T., Geol. Survey Canada No. 23367.

13 *Dentalina frobisherensis* Loeblich and Tappan
×25, Sta. 14, Hazen Strait, N.W.T., Geol. Survey Canada No. 23368.

14 *Dentalina pauperata* d'Orbigny
×23, Sta. 18, Hazen Strait, N.W.T., Geol. Survey Canada No. 23369.

15 *Lagena apiopleura* Loeblich and Tappan
×100, Sta. 17, Hazen Strait, N.W.T., Geol. Survey Canada No. 23370.

16 *Lagena flatulenta* Loeblich and Tappan
×53, Sta. 27, Hecla and Griper Bay, N.W.T., Geol. Survey Canada No. 23371.

17 *Lagena gracilis* Williamson
×145, Sta. 17, Hazen Strait, N.W.T., Geol. Survey Canada No. 23372.

18 *Lagena gracillima* (Seguenza)
×43, Sta. 16, Hazen Strait, N.W.T., Geol. Survey Canada No. 23373.

19 *Lagena meridionalis* Wiesner
×85, Sta. 18, Hazen Strait, N.W..T, Geol. Survey Canada No. 23374.

20 *Lagena mollis* Cushman
×25, Sta. 29, Hecla and Griper Bay, N.W.T., Geol. Survey Canada No. 23375.

21 *Lagena nebulosa* Cushman
×35, Sta. 5, Hecla and Griper Bay, N.W.T., Geol. Survey Canada No. 23376.

22 *Lagena* sp. cf. *L. plumigera* Brady
×110, Sta. 14, Hazen Strait, N.W.T., Geol. Survey Canada No. 23377.

23 *Fissurina* sp. cf. *F. bradii* Silvestri
×125, Sta. 5, Hecla and Griper Bay, N.W.T.; a, apertural view; b, side view; Geol. Survey Canada No. 23378.

24 *Fissurina marginata* (Montagu)
×100, Sta. 23, Hazen Strait, N.W.T.; a, apertural view; b, side view; Geol. Survey Canada No. 23379.

25 *Fissurina ventricosa* (Wiesner)
×85, Sta. 5, Hecla and Griper Bay, N.W.T., Geol. Survey Canada No. 23380.

26 *Oolina apiculata* Reuss
×120, Sta. 13, Hazen Strait, N.W.T.; a, side view; b, apertural view; Geol. Survey Canada No. 23381.

27 *Oolina globosa* (Montagu)
×85, Sta. 17, Hazen Strait, N.W.T.; a, apertural view; b, side view; Geol. Survey Canada No. 23382.

28 *Oolina hexagona* (Williamson)
×120, Prince Gustaf Adolf Sea, N.W.T., long. 107°00′, lat. 78°45′, Geol. Survey Canada No. 23383.

29 *Oolina melo* d'Orbigny
×150, Sta. 17, Hazen Strait, N.W.T., Geol. Survey Canada No. 23384.

30 *Parafissurina arctica* Green
×185, Sta. 11, Hazen Strait, N.W.T., Geol. Survey Canada No. 23385.

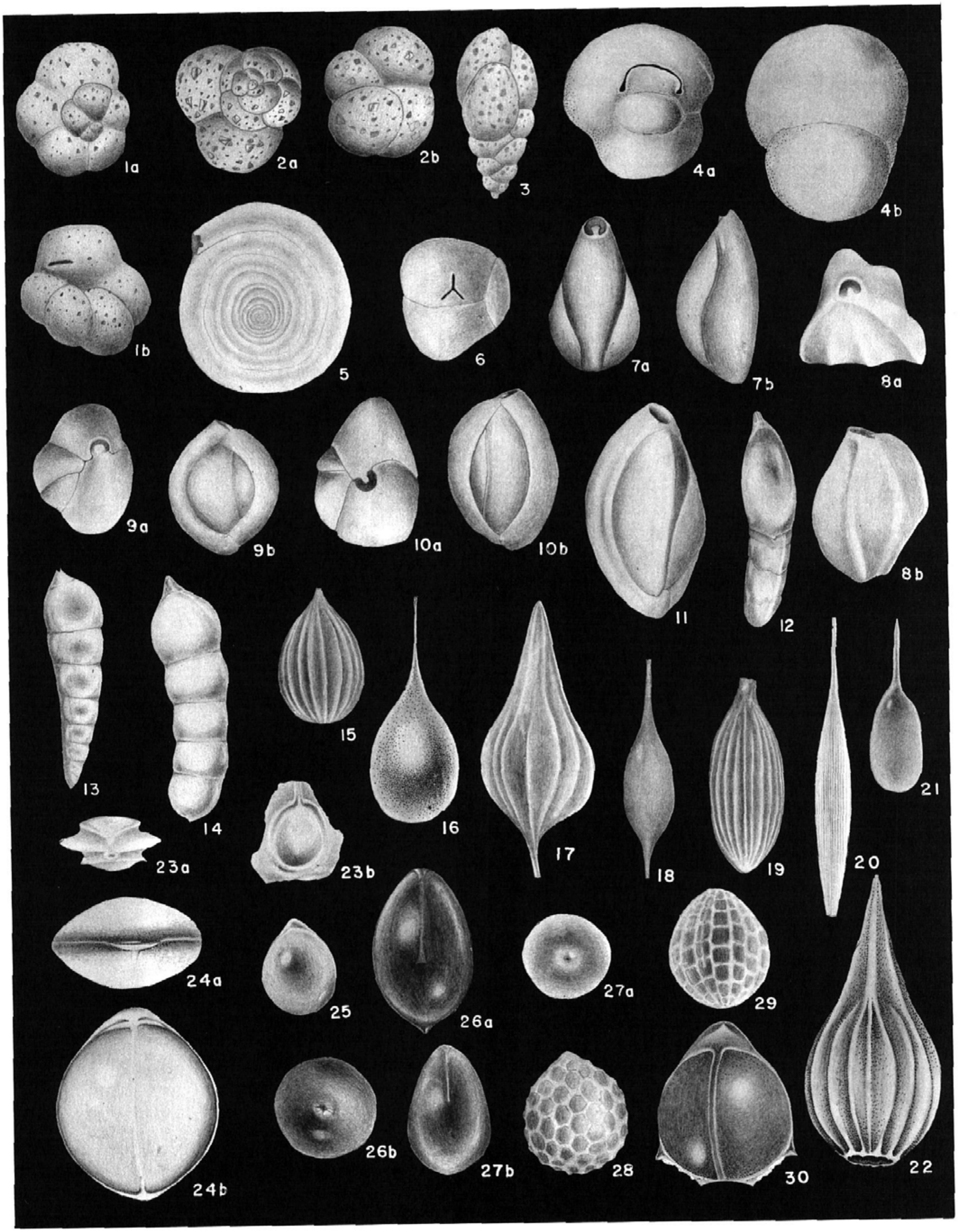
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PLATE 3

1 *Parafissurina tectulostoma* Loeblich and Tappan
×125, Sta. 18, Hazen Strait, N.W.T.; a, ventral view; b, side view; Geol. Survey Canada No. 23386.

2 *Bolivina* sp. cf. *B. inflata* Heron-Allen and Earland
×170, Sta. 17, Hazen Strait, N.W.T.; a, side view; b, apertural view; Geol. Survey Canada No. 23387.

3 *Islandiella islandica* (Nørvang)
×145, Sta. 23, Hazen Strait, N.W.T., Geol. Survey Canada No. 23388.

4 *Islandiella norcrossi* (Cushman)
×90; a, Sta. 4, Hecla and Griper Bay; b, Sta. 47, off Emerald Isle; N.W.T., Geol. Survey Canada Nos. 23389, 23390.

5 *Islandiella teretis* Tappan
×115, Sta. 18, Hazen Strait, N.W.T., Geol. Survey Canada No. 23391.

6 *Bulimina marginata* d'Orbigny
×105, Sta. 37, Hecla and Griper Bay, N.W.T., Geol. Survey Canada No. 23392.

7 *Buccella frigida* (Cushman)
×100, Sta. 10, Hecla and Griper Bay, N.W.T.; a, ventral view; b, dorsal view; Geol. Survey Canada No. 23393.

8 *Stetsonia horvathi* Green
×260, Sta. 17, Hazen Strait, N.W.T.; a, side view; b, apertural view; Geol. Survey Canada No. 23394.

9 *Valvulineria arctica* Green
a, ×130, ventral view; b, ×130, dorsal view; c, ×165, edge view; Sta. 11, Hazen Strait, N.W.T., Geol. Survey Canada No. 23395.

10 *Asterellina pulchella* (Parker)
a, ×230, ventral view; b, ×205, dorsal view; Sta. 52, off Prince Patrick Island, N.W.T., Geol. Survey Canada No. 23396.

11 *Patellina corrugata* Williamson
×80, Sta. 17, Hazen Strait, N.W.T., Geol. Survey Canada No. 23397.

12 *Elphidium bartletti* Cushman
×35, Sta. 58, Fitzwilliam Strait, N.W.T., Geol. Survey Canada No. 23398.

13 *Elphidium incertum* (Williamson)
×40, Sta. 53, off Prince Patrick Island, N.W.T., Geol. Survey Canada No. 23399.

14 *Protelphidium orbiculare* (Brady)
×90, Sta. 45, Hecla and Griper Bay, N.W.T., Geol. Survey Canada No. 23400.

15 *Globigerina pachyderma* (Ehrenberg)
a, ×150, Sta. 32; b, ×115, Sta. 23; c, x150, Sta. 18; Hazen Strait, N.W.T., Geol. Survey Canada Nos. 23401–23403.

16 *Eponides tener* (Brady)
×65, Sta. 17, Hazen Strait, N.W.T., Geol. Survey Canada No. 23404.

17 *Cibicides lobatulus* (Walker and Jacob)
×120, Sta. 46, off Emerald Isle, N.W.T.; a, ventral view; b, dorsal view; Geol. Survey Canada No. 23405.

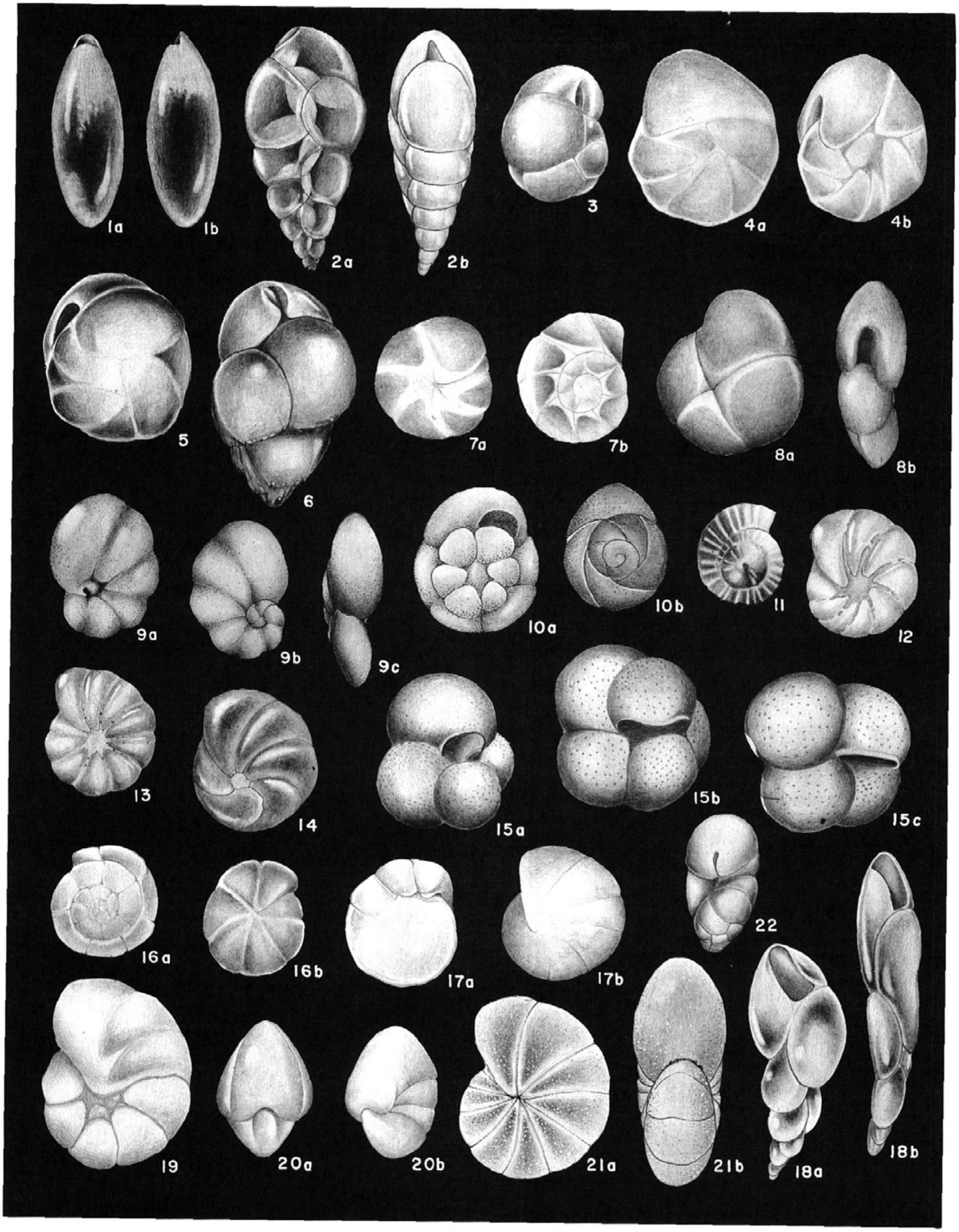
18 *Cassidella complanata* (Egger)
a, ×94, b, ×145; Sta. 17, Hazen Strait, N.W.T., Geol. Survey Canada Nos. 23406, 23407.

19 *Astrononion gallowayi* Loeblich and Tappan
×90, Sta. 52, off Prince Patrick Island, N.W.T., Geol. Survey Canada No. 23408.

20 *Nonionellina labradorica* (Dawson)
×45, Sta. 48, Hazen Strait, N.W.T.; a, apertural view; b, side view; Geol. Survey Canada No. 23409.

21 *Melonis zaandami* (Van Voorthuysen)
a, ×80, side view; b, ×100, apertural view; Sta. 23, Hazen Strait, N.W.T., Geol. Survey Canada No. 23410.

22 *Robertinoides charlottensis* (Cushman)
×80, Sta. 4, Hecla and Griper Bay, N.W.T., Geol. Survey Canada No. 23411.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