Relative sea level changes and ice sheet history in Finderup Land, North Greenland

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Supplementary information

Table S1. Overview of cores collected for this study.

Core name	Lake	Latitude (°N)	Longitude (°W)	Altitude (m.a.s.l.)	Lake depth (m)	Core length (cm)
I2-1	I2	81.45019	18.30312	19.6	7	158.5
I4-1	I4	81.40395	18.03681	34.6	20	161
I14-1	I14	81.42059	18.25471	59.2	22	78
I14-2	I14	81.42059	18.25471	59.2	22	64
T2-1	T2	81.41301	18.89223	42.2	6.5	143
T2-2	T2	81.41301	18.89223	42.2	6.5	161
T8	T8	81.31667	19.19438	81.2	18	104.5

Foraminiferal analyses: Method

A total of 73 samples from 6 cores in 4 lakes were analysed for their foraminiferal content (Tables S1-S4). Samples of app. 4 cm3 were weighed and wet-sieved into grain size fractions of <63µm, 63-100µm, and >100µm. Due to a relatively high content of clastic sand-sized sediment particles in some of the samples, the foraminiferal were here concentrated by heavy liquid separation using tetrachlorethylene (C2Cl4) with a specific gravity of 1.6 g/cm3 prior to the faunal analysis. In most samples both the 63-100µm and >100µm fractions were analysed for their foraminiferal content. When present, also the number of ostracod valves were counted.

In most instances both the 63-100 µm and the >100µm sediment fractions were analysed, but in some cased the 60-100 µm fraction was not available. Only few samples contained planktonic foraminifera and only one agglutinated specimen was found (Table S4, S5), the remaining benthic foraminifera belonged to calcareous species (Table S5). Almost specimens were identified to species level, although a few species were grouped (e.g. Polymorphidae). Ostracod valves were counted, but no detailed identification was carried out.

Foraminiferal assemblages: results and environmental description

Lake I14

Foraminiferal assemblages were analysed both in cores I14-1 and I14-2.
The assemblage in **core I14-1** is characterised by an assemblage dominated by large specimens of well-preserve *Elphidium clavatum,* and with *Cassidulina reniforme*, *Buccella frigida*, and *Haynesina orbiculare* as assesory species (Table S1a). In **core I14-2**, the foraminiferal assemblage is more diverse, dominated by *Elphidium clavatum*, but also with *Cassidulina reniforme*, *Stetsonia hovarthi*, *Astrononion gallowayi* and *Elphidium asklundi* as assessory species (Table S1b), decreasing in diversity upwards.

The foraminiferal assemblages indicate that marine interval of core I14-2 represent an Arctic central fjord environment with normal-marine conditions, albeit upwards shallowing. In contrast, the assemblage in core I14-1 indicate a more near-coast habitat. Likely, the foraminiferal samples in I14-1 represent the upper part of the foraminiferal interval in I14-2, i.e. the shallower section of the marine interval. The sandy sediments (main text Fig. 3) could have indicated the risk of reworking of foraminifera. However the well-preserved tests and the presence of several instars of ostracods, including many juveniles (Tables S1a,b), contradicts this.

Table S2a: Foraminiferal and ostracod valves were analysed in 7 samples in core I14-1 from Lake I14; only the >100 µm fraction was counted. For each level, the entire sample of ca 4 ml was analysed, and values are provided as actual counts in the entire ca 4 ml sample. The sediment only contained benthic foraminifera and ostracods; no planktonic foraminifera were found in this core. The benthic foraminifera in core I14-1 were overall very large and the ostracod valves in general encompass many different instars, with many juvenile specimens.

Sample depth (cm)	Buccella frigida	Cassidulina reniforme	Elphidium albiumbilicatum	Elphidium asklundi	Elphidium bartletti'	Elphidium clavatum	Eoeponidella pulcella	Haynesina nivea	Haynesina orbiculare	Lagena sp.	Oolina caudigera	Polymorphinidae	Miliolinella subrotunda	Triloculina trihedra	Total foraminiferal counts	Ostracods (single valves)	Ostracods (double valves)
17-18		1				44						1			*46*	2	
18-19	1	4				102			2						*109*	2	
19-20	3	5		1		112	1	1	2						*125*	6	
20-21	4	8				151			5						*168*	22	
21-22	3	5	1	2		177	1		4	1	2	4			*200*	10	
22-23	7	12		2	1	325	1	1	8				1	2	*360*		
24-25	9	2		2		185			3					1	*202*	30	2

Table S2b: Foraminiferal and ostracod valves were analysed in 9 samples form core I14-2 from Lake I14; both the 63-100 µm and the >100 µm fraction were studied. For each level, the entire sample of ca 4 ml was analysed, and values are provided as actual counts in the entire sample. The sediment only contained benthic foraminifera and ostracods; no planktonic foraminifera were found in this core.

Sample depth (cm)	Astrononion gallowayi		Buccella frigida		Cassidulina reniforme		Elphidium albiumbilicatum		Elphidium asklundi		Elphidium bartletti		Elphidium clavatum		Eoeponidella pulcella		Epistominella vitrea		Glabratella arctica		Haynesina nivea		Haynesina orbiculare		Oolina caudigera		Polymorphinidea		Stainforthia loeblichi		Stetsonia hovarthi		Triloculina trihedra		*Total foraminiferal counts*		Ostracods (single valves)
Fraction (µm)	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	
23-24	1				1	8				1				1								1											*2*	*11*	
24-25	3	1	1		27	5			1	2			6	1			1				1	1							2				*42*	*10*	
25-26	1	3	2		35	31			3	2			5	53	1						1	1							1	2	5		*54*	*92*	1
26-27	1	6	1	5	26	63			2	10			29	106	7	1			1		2	1		1			1	3		3	50		*120*	*199*	6
28-29	1	2	2	6	63	64				20		7	22	265			7				3	6		9				3		2	18	1	*116*	*385*	26
29-30		1		6	7	28				7		2	8	100		1						2					1	2		1	1		*17*	*150*	39
30-31		1		3		1				2			4	76	1							1		3						2		*7*	*87*	7
31-32		1	1	2	1	6		3				1	1	153										4		1		1				2	*3*	*174*	30
33-34		1		1		7				2		1	1	138										3				2		1			*1*	*156*	8

Lake T2

Foraminiferal assemblages were analysed both in cores T2-1 and T2-2. Foraminifera are abundant in several intervals of the marine unit of **core T2-2**, with the bottom intervals dominated by *Elphidium clavatum* with *Elphidium asklundi* and *Buccella frigida* as accessory species (Table S2a). Towards the top of the marine unit, the assemblage in core T2-2 is fairly diverse and characterized by *Elphidium clavatum, Elphidium asklundi, Buccella frigida, Cassidulina reniforme* and *Eoeponidella pulcella*, with *Haynesina nivea*, *Stainforthis loeblichi* and *Astrononion gallowayi* as accessory species. The presence of planktonic foraminiferal is noteworthy.

The foraminiferal assemblage of **core T2-1** is somewhat less abundant and less diverse, characterized by *E. clavatum, E. asklundi* and *B. frigida* (Table S6). The assemblage in T2-1 likely represents the top of the marine (foraminiferal) interval of T2-2. Presence of foraminifera concludes abruptly at the top of the lowermost unit.

This foraminiferal assemblage represents near normal-marine salinities in a relatively near-coast Arctic marine fjord or inner shelf environment. The influx of planktonic foraminifera indicate influx of marine waters of Atlantic source. The foraminiferal assemblages from Lake T2 show that the depth decreases upwards through this marine unit.

Table S3a: Foraminiferal and ostracod valves were analysed in 20 samples from core T2-2 from Lake T2; both the 63-100 µm and the >100 µm fraction were studied. For each level, the entire sample of ca 4 ml was analysed, and values are provided as actual counts in the entire sample. The sediment This core was the only one studied, which also contained planktonic foraminifera in addition to benthic foraminifera and ostracods. Planktonic foraminifera and ostracod valves were almost solely restricted to the >100 µm fraction, but data are provided for the entire sample combined. Notre that for the lower three samples the planktonic foraminifera were not divided into species, but the dominant species is *Neogloboquadrina pachyderma* (sinistral). The planktonic foraminifera indicate an increased influx of Atlantic-sourced water from the open ocean.

Sample depth (cm)	Part of sample analysed	Astrononion gallowayi		Buccella frigida		Cassidulina reniforme		Elphidium albiumbilicatum		Elphidium asklundi		Elphidium clavatum		Eoeponidella pulcella		Epistominella vitrea		Fissurina sp.		Glabratella arctica		Globocassidulina subglobosa		Haynesina nivea		Haynesina orbiculare		Islandiella norcrossi		Nonionellina labradorica		Oolina melo		Polymorphinidae		Tappanina sp.		Stainforthia feylingi		Stainforthia loeblichi		Trilocullina trihedra		*Total benthic foraminiferal counts*		Globigerinita glutinata w/bulla	Globorotalia inflata	Globorotalia scitula	Neogloboquadrina pachyderma (sinistral)	Turborotalita quinqueloba	*Total planktonic foraminiferal counts*	Ostracods (single valves)
Fraction (µm)		63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	*63-100*	*>100*	Both fractions combined						
60-61	1																																									*0*	*0*							
61-62	1																																									*0*	*0*							
62-63	1																																									*0*	*0*							
63-64	1																																									*0*	*0*							
64-65	1																																									*0*	*0*							
65-66	1																																									*0*	*0*							
66-67	1																																									*0*	*0*							
67-68	1																																									*0*	*0*							
68-69	1																																									*0*	*0*							
69-70	1																																									*0*	*0*							
70-71	1		4	2	26					2	56	2	56	17	1									6		10						**1**		2				9				*23*	*170*						***0***	
71-72	2/7		8	3	60	7	16		1	1	109	2	103	13	3		1							1	14		7						6				5				*27*	*333*						***0***	
72-73	1/5																																									*0*	*0*						***0***	0
73-74	2/5		2	12	65	30	48			9	96	16	70	45	3	1	2			1				1	12	1	11							1	12			1	10			*118*	*331*						***0***	0
74-75	1/3		4	23	76	30	55	2	4	8	58	37	85	75	7			2				1		2	14	2	12							2	6		2	1	1	1		*185*	*325*						***0***	6
75-76	1/3		4	21	108	32	39		1	10	61	10	86	62		1	1		1	3				12	19	1	3	2						3				3				*154*	*329*						***0***	2
80-85	1		3		28		9		1		47		68												8		1		1		1				4								*0*	*171*	5	1	1	13	2	***22***	31
120-125	1				5						5		85						1				1				3							1						2		*0*	*103*						***3***	16
158-159	1		1		30		7				2		64										1		4									1								*0*	*110*						***16***	
159-160	1		1		11	2	7				5		34		2				1				1				1							1								*2*	*64*						***13***	

Table S3b: Foraminiferal and ostracod valves were analysed in 5 samples form core T2-1 from Lake T2; both the 63-100 µm and the >100 µm fraction were studied. For each level, the entire sample of ca 4 ml was analysed, and values are provided as actual counts in the entire sample. The sediment only contained benthic foraminifera and ostracods; no planktonic foraminifera were found in this core.

Sample depth (cm)	Astrononion gallowayi		Buccella frigida		Cassidulina reniforme		Elphidium albiumbilicatum		Elphidium asklundi		Elphidium clavatum		Eoeponidella pulcella		Haynesina nivea		Haynesina orbiculare		Polymorphinidea		Stainforthia loebblichi		*Total foraminiferal counts*	
Fraction (µm)	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100
70-71				3		1						2				1		2					0	9
73-74		1		2																			0	3
74-75				4				4		1		10		1		2				2		2	0	26
75-76		9	2	34	3	2		3		31	1	49	2	1	1	4		4		2		4	9	143
76-77		6	3	16	1	7	1	1		20	4	40	9	1		1						1	18	93

Lake I4

Foraminiferal assemblages were analysed in the marine unit of core I4-1. The assemblage is dominated by *Elphidium clavatum* with *Buccella frigida* and *Cassidulina reniforme* as accessory species (Table S3), representing a typical arctic, fairly shallow-water environment with somewhat reduced salinities.

Table S4: Foraminiferal and ostracod valves were analysed in 13 samples in core I4-1 from Lake I4; only the >100 µm fraction was counted. For each level, the entire sample of ca 4 ml was analysed, and values are provided as actual counts in the entire ca 4 ml sample. The sediment only contained benthic foraminifera and ostracods; no planktonic foraminifera were found in this core.

Sample depth (cm)	Buccella frigida	Cassidulina reniforme	Elphidium albiumbilicatum	Elphidium asklundi	Elphidium clavatum	Eoeponidella pulcella	Epistominella vitrea	Haynesina nivea	Haynesina orbiculare	Polymorphinidae	Stainforthia loebblichi	*Total foraminfieral counts*	Ostracods (single valves)	Ostracods (double valves)
115-116												*0*		
115-117												*0*		
117-118					2							*2*		
118-119				1								*1*		
119-120	2	1		1	7			1				*12*	1	
120-121			1		8			2			1	*12*	6	
121-122	8	6		1	16			12			2	*45*	23	1
122-123	11	2			26			14				*53*	31	
123-124	13	4	3	4	19			13	1			*57*	22	
124-125	36	17	3		55			28	1		1	*141*	16	1
130-131	27	13	5		74	3	1	29		3	2	*157*	4	
159-160					1							*1*	0	
160-161		1			2			1				*4*	0	

Lake I2

Foraminiferal assemblages were analysed in core I2-1. They were only found in the lowermost parts of the core (Table S4). The assemblage was dominated by *Elphidium clavatum* and *Cassidulina reniforme*, with an upwards increase in *Elphidium albiumbilicatum* and *Elphidium bartletti* indicating an Arctic environment with an upwards drop in salinity.

Table S5: Foraminifera in core I2-1 from Lake I2. Both the 63-100 and the >100 µm fractions were analysed in 19 samples in the 78-158 cm section of the core. For each level the entire sample of ca 4 ml was analysed, and values are provided as actual counts in the entire ca 4 ml sample. The sediment only contained benthic foraminifera; no planktonic foraminifera or ostracod valves were found in this core. In the interval from 158-155 cm the foraminiferal tests were generally well-preserved, but from 154-152 cm the specimens were somewhat abraded either due to dissolution or re-working.

Sample depth (cm)	Astrononion gallowayi		Buccella frigida		Buccella hannai arctica		Cassidulina reniforme		Elphidium albiumbilicatum		Elphidium bartletti		Elphidium clavatum		Elphidium hallandense		Epistominella vitrea		Glabratella arctica		Haynesina nivea		Haynesina orbiculare		Islandiella helenae		Islandiella norcrossi		Stainforthia feylingi		Stainforthia loebblichi		Stetsonia horvathi		Cribrostomoides sp.		*Total foraminiferal counts*	
Fraction (µm)	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	63-100	>100	*63-100*	*>100*
79-80																																			*0*	*0*
80-81																																			*0*	*0*
81-82																																			*0*	*0*
82-83																																			*0*	*0*
83-84																																			*0*	*0*
84-85																																			*0*	*0*
85-86																																			*0*	*0*
86-87																																			*0*	*0*
87-88																																			*0*	*0*
88-89																																			*0*	*0*
98-99																																			*0*	*0*
145-146																																			*0*	*0*
151-152																																			*0*	*0*
152-153		1						1		5		1		3						1															*0*	*12*
153-154							1	7		21		29		23		1						1				1									*1*	*84*
154-155							42	63	4	131		73		13						1			1												*48*	*280*
155-156				2			29	112	1	73		74	1	26				1				8		3						1					*32*	*299*
156-157				3		1		143		19		26		84				2				3		1				10				3		1	*0*	*295*
157-158				4			17	99	1	25		10	3	106			1		1			3				1				4	1				*25*	*251*

Table S6. List of foraminiferal species found in this study; with author names and year of initial description.

Benthic calcareous foraminiferal taxa
Astrononion gallowayi Loeblich & Tappan, 1953
Buccella frigida (Cushman, 1922)
Buccella hannai arctica Voloshinova, 1960
Cassidulina reniforme Nørvang, 1945
Elphidium albiumbilicatum (Weiss, 1954)
Elphidium asklundi Brotzen, 1943
Elphidium bartletti Cushman, 1933
Elphidium clavatum Cushman, 1930
Elphidium hallandense Brotzen, 1943
Eoeponidella pulcella (Parker, 1952)
Epistominella vitrea Parker, 1953
Fissurina sp.
Globocassidulina subglobosa (Brady, 1881)
Glabratella arctica Scott & Vilks, 1991
Haynesina nivea (Lafrenz, 1963)
Haynesina orbiculare (Brady, 1881)
Islandiella helenae Feyling-Hanssen and Buzas, 1976
Islandiella norcrossi (Cushman, 1933)
Lagena sp.
Miliolinella subrotunda (Montagu, 1803)
Nonionellina labradorica (Dawson, 1860)
Oolina caudigera (Wiesner, 1931)
Oolina melo d'Orbigny, 1839
Polymorphinidea
Stainforthia feylingi Knudsen & Seidenkrantz, 1994
Stainforthia loeblichi (Feyling-Hanssen, 1954)
Stetsonia horvathi Green, 1959
Tappanina sp.
Triloculina trihedra Loeblich & Tappan, 1953

Benthic agglutinated foraminiferal taxa
Cribrostomoides sp.

Planktonic foraminiferal taxa
Globigerinita glutinata (Egger, 1893), with bulla
Globorotalia inflata (d'Orbigny, 1839)
Globorotalia scitula (Brady, 1882)
Neogloboquadrina pachyderma (Ehrenberg, 1861) (sinistral)
Turborotalita quinqueloba (Natland, 1938)