Glacial history and shoreline displacement on Erdmannflya and Bohemanflya, Spitsbergen, Svalbard

OTTO SALVIGSEN, ANNE ELGERSMA, CHRISTIAN HJORT, ERIK LAGERLUND, OLAV LIESTØL AND NILS-OLOF SVENSSON

Salvigsen, O., Elgersma, A., Hjort, C., Lagerlund, E., Liestøl, O. & Svensson, N.-O. 1990: Glacial history and shoreline displacement on Erdmannflya and Bohemanflya, Spitsbergen, Svalbard. *Polar Research 8*, 261-273.

Traces of former glaciation were studied on Erdmannflya and Bohemanflya. Both peninsulas were probably completely covered by glaciers during the Late Weichselian and the final deglaciation took place around 10,000 ^{14}C years BP. Esmarkbreen readvanced shortly after 9,500 BP, probably a local and shortlasting event. Raised beaches occur to about 60 m above sea level, and date back to about 10,000 BP. Initial land emergence was rapid, about 3m/100 years. It seems to have been followed by a marine transgression between 8,500 and 7,500 BP, which resulted in a large and distinct beach bridge and marine abrasion cliffs about 10–12 m above present sea level. *Mytilus edulis* lived in the area between at least 9,000 and 5,000 BP. Five thousand years ago relative sea level probably stood 3–4 m higher than today. Relative sea level has remained close to present during the last centuries. Different positions of glacier fronts in this century have also been mapped.

Otto Salvigsen, Anne Elgersma and Olav Liestøl, Norsk Polarinstitutt, P.O. Box 158, N-1330 Oslo Lufthavn, Norway; Christian Hjort, Erik Lagerlund and Nils-Olof Svensson, Dept. of Quaternary Geology, Lund University, Sölvegatan 13, S-223 62 Lund, Sweden; February 1990 (revised September 1990).

Erdmannflya and Bohemanflya are two low foreland peninsulas on the northern shore of Isfjorden (Figs. 1–5). They can be considered equivalents to the strandflat which is continuously developed along the west coast, outside the fjords. The bedrock is of Tertiary and Mesozoic age (Flood et al. 1971; Schaupeter & Struck 1988), and has a thin Quaternary sediment cover where raised beach features are prominent (Figs. 4 and 5). Only very small areas of Erdmannflya and Bohemanflya reach altitudes higher than 30 m and 50 m, respectively. A shallow, more than 1 km wide submarine platform exists outside the eastern shores of both peninsulas, which are separated by Borebukta, a bay about 5 km wide. The bay Ymerbukta delimits Erdmannflya towards the west, and Yoldiabukta Bohemanflya towards the north. The heads of the bays are occupied by calving glaciers which have retreated several km during the present century and left large lateral moraines along the shores. The mountains immediately to the west are more than 600 m high.

Fieldwork at Erdmannflya was done by Elgersma and Salvigsen during the Norwegian Polar Research Institute expedition to Svalbard in 1984. They also made some observations on the southeastern part of Bohemanflya. The major part of the fieldwork on Bohemanflya was done by Hjort, Lagerlund and Svensson during expeditions from the University of Lund in 1982 and 1984. Information about the position of glacier fronts was compiled by Liestøl.

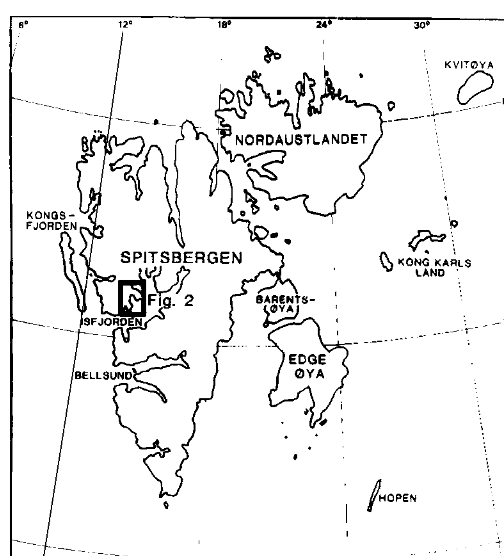

Fig. 1. Location map, Svalbard.

Glacial history

Glacial striae

The occurrence of glacial striae, glacial erratics and traces of till shows that both peninsulas have been completely glaciated at least once. Glacial striae are well developed and preserved on Cretaceous and Jurassic rocks of inner Erdmannflya and southeastern Bohemanflya. Mostly they show directions indicating movements of glaciers into the fjord, but some observations also indicate that a glacier front was located further out in Isfjorden. Directions of observed striae are shown in Fig. 2.

Bohemanflya has an area of glacially sculptured bedrock in its southern part, from the shore with its old mining buildings up to the hill with the large cairn at 65.5 m. Fine as well as more coarse glacial striae occur on many surfaces; directions vary and show ice movements from NNW to NNE. Crossing striae were found at several places but differences in direction are small and considered unimportant. Roches moutonnées and several crescentic gouges were also observed. The glacial striae and other glacial features are so numerous and so well preserved that they are supposed to be of Late Weichselian age.

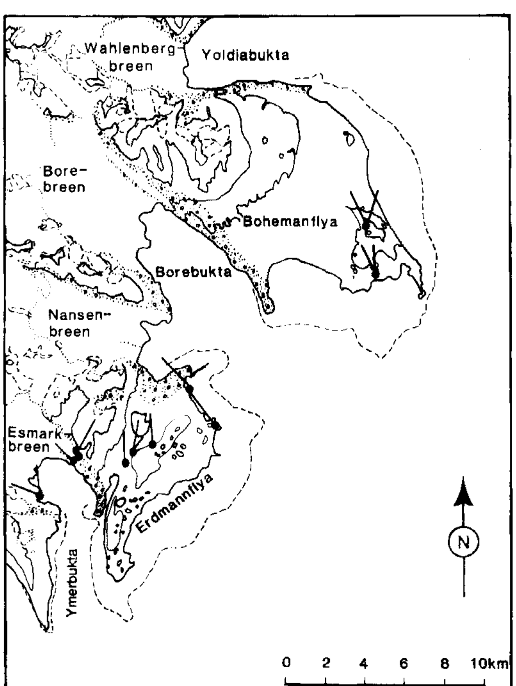

Fig. 2. Location map of Erdmannflya and Bohemanflya also showing direction of glacial striae. Movement towards the observation point. Contour lines: 10, 25, 50, 250 and 500 metres.

Glacially sculptured surfaces with striae were frequently observed also near the northeastern shore of Erdmannflya, from Henschenodden towards the front of Nansenbreen (bre = glacier). Directions from about NW show movements of a more extensive local glacier in Borebukta. A few glacial striae were observed further west on Erdmannflya along the low, rocky hill area in the middle of the peninsula. The predominant direction there is from NE, and the same direction was found on striated bedrock below the moraine near Esmarkbreen. These directions indicate that a large glacier filled Isfjorden and terminated west of Erdmannflya. The age of this glacier has not been determined, but the Late Weichselian alternative seems most probable. Younger striae were observed on a small island in Ymerbukta, so newly deglaciated from Esmarkbreen that it is in the position of the 1980 glacier front shown on Fig. 10. Directions of crossing striae were from WNW (oldest) and N (youngest).

Glacial erratics

Glacial erratics exist above the marine limit around the highest point on southern Bohemanflya. At least six different types of rocks were identified, all originating from the north (Ø. Lauritzen pers. comm.), thus showing a transport direction largely in accordance with the observed glacial striae. The rest of the peninsulas lie below the marine limit where erratics may also derive from drifting ice.

The glacial erratics are usually found along the riverbeds, where they have been gradually concentrated by melt water and solifluction. In the eastern part of Bohemanflya they include reddish and whitish granites, reddish augen gneiss, a coarse dark dolerite, a dark reddish-brown porphyry, whitish, bluish and reddish quartzites, mica schists, fossiliferous yellowish limestone, a bluish white marble and black dolomitic limestones. They represent both basement and younger Paleozoic rocks and indicate ice movements from the northeast and east.

Erratics were also found at several places on Erdmannflya, and especially two observations are worth mentioning. A bedrock cliff, up to 25 m high, occurs along the western edge of the peninsula. The bedrock is covered by some 3 m of unconsolidated sediments (Fig. 6) where small gullies have developed. Within them some cobbles and boulders with glacial striae occur, mostly Permian and Triassic rocks with their nearest occurrence to the north. The erratics probably come from a thin diamicton interpreted to be a till, which underlies fine grained, marine sediments with *Mya truncata* and *Hiatella arctica* shells dated to 9,680 ± 110 BP (T-6282). These erratics indicate a southflowing glacier in Ymerbukta during the Late Weichselian deglaciation period.

The central part of Erdmannflya, to the southeast of the inner part of Morenekilen (Fig. 3a), has a zone of big boulders and blocks. This zone has a well defined western limit, while the occurrence of blocks ceases gradually toward the east. Some blocks are $>1\ m^3$ and several rock types are represented. There are poorly cemented Cretaceous sandstones which outcrop on northeastern Erdmannflya and on southern Bohemanflya, e.g. stones from the Coquina limestone beds. There are also red sandstones and dolerites which outcrop to the north. The block zone may indicate that the glacier front was stationary in this area for a while, even though no marginal moraine was deposited. The Cretaceous sandstone boulders indicate glacial transport along Isfjorden.

Till

Over most of the peninsulas the bedrock is either exposed or covered by Holocene marine sediments. However, a very thin discontinuous sheet of diamicton, interpreted as a till, exists in a few places, for example above the marine limit on southern Bohemanflya. It is most notable in depressions and the 'washing limit' on this till marks the marine limit in the area (Fig. 7).

A thin (c. 0.1 m thick) diamicton is also found between the underlying weathered Cretaceous shale and the Early Holocene marine sediments along the river south of lake Vasskalven (Fig. 3b, Loc. B3). This diamicton is silty, stony and gravelly, and derives mainly from the underlying shale, but as it contains some erratics, it may be a till.

An Early Holocene readvance

The Esmarkmorena section is located on the eastern shore of Ymerbukta within the 'Little Ice Age' moraines of Esmarkbreen. It reveals evidence of a readvance of Esmarkbreen after the regional deglaciation. Glacial deposits mostly consisting of large boulders and stones cover a beach terrace

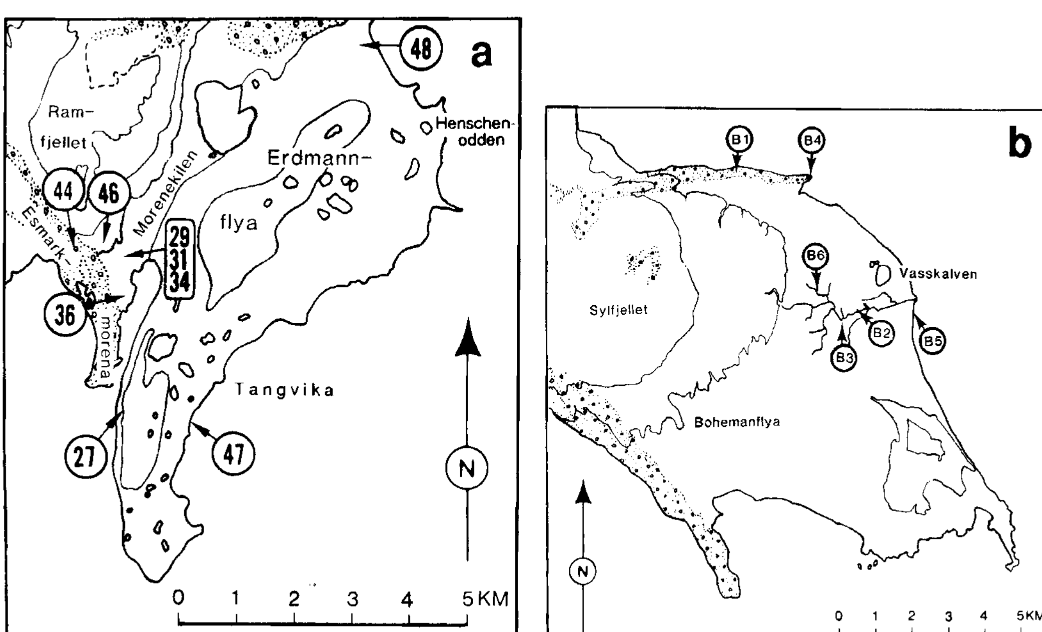

Fig. 3. Location map of dated samples on a) Erdmannflya and b) Bohemanflya. Contour lines: 25, 50, 250 and 500 metres.

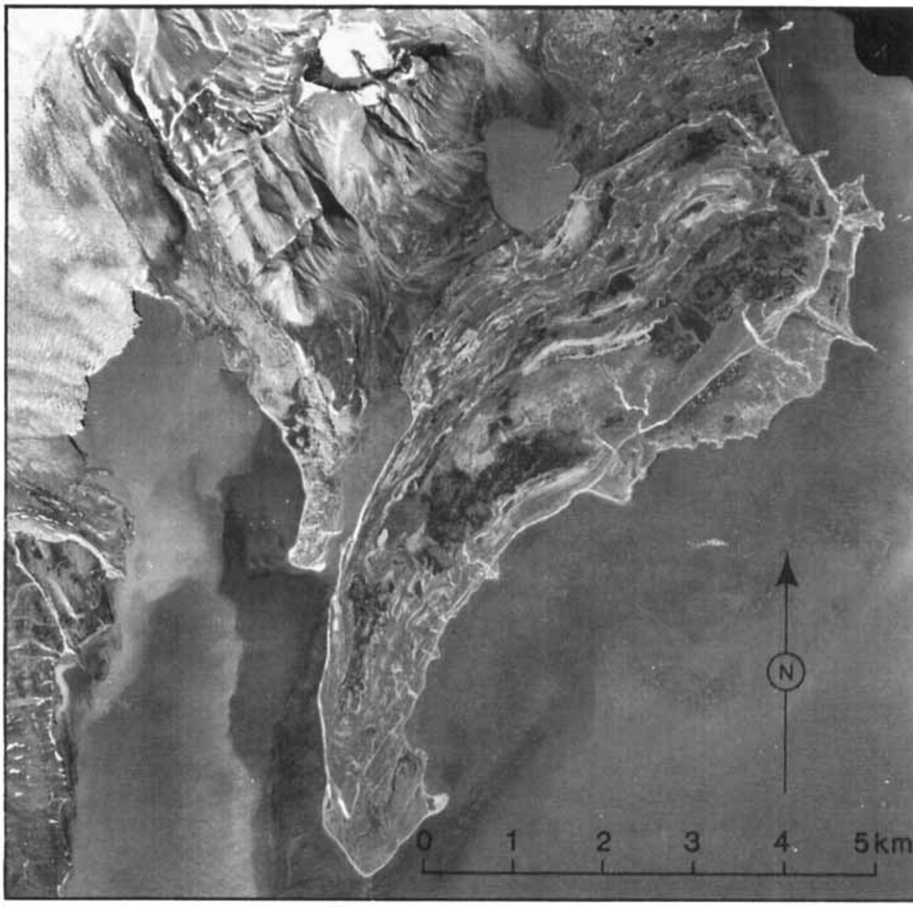

Fig. 4. Air photo of Erdmannflya. Norsk Polarinstitutt S 66V, 24 July 1966.

41–42 m above sea level. During the retreat of the glacier, meltwater eroded a deep gully in the beach terrace and in some places also into the underlying bedrock.

The bedrock in the section consists of southerly dipping, dark, sandy shales and light coloured sandstones, the latter forming minor hogbacks in the bedrock morphology. Thus, an asymmetrical depression about 8 m long and 1.3 m deep has been formed and is exposed in the northern part of the main gully. The lowest point in the depression is 30.5 m above sea level. The most complete sedimentary sequence was found here and the main units have been numbered as follows (see Fig. 8):

Unit 6. Upper gravel
5. Sand
4. Gravel and sand
3. Esmarkmorena till
2. Sand and gravel
1. Lower gravel

Unit 1. The lower gravel unit is up to 1.3 m thick and is interpreted as a littoral deposit. The clasts are generally well rounded and polished and the beds contain fragments of shells and some seaweed. The beds are strongly disturbed and folded, and steeply dipping bedding planes occur. A thrust fault transects the unit and continues upwards into the till (Unit 3). The shell fragments, some identified as *Hiatella arctica* and *Mya truncata*, have been dated to 9,500 ± 100 BP (T-6286).

Unit 2. Sand and gravel beds which can be divided into two subunits, both interpreted to be of glaciofluvial origin. The lower subunit measures 0.4 m and consists of numerous silty, sandy laminae which fine upwards. The upper subunit,

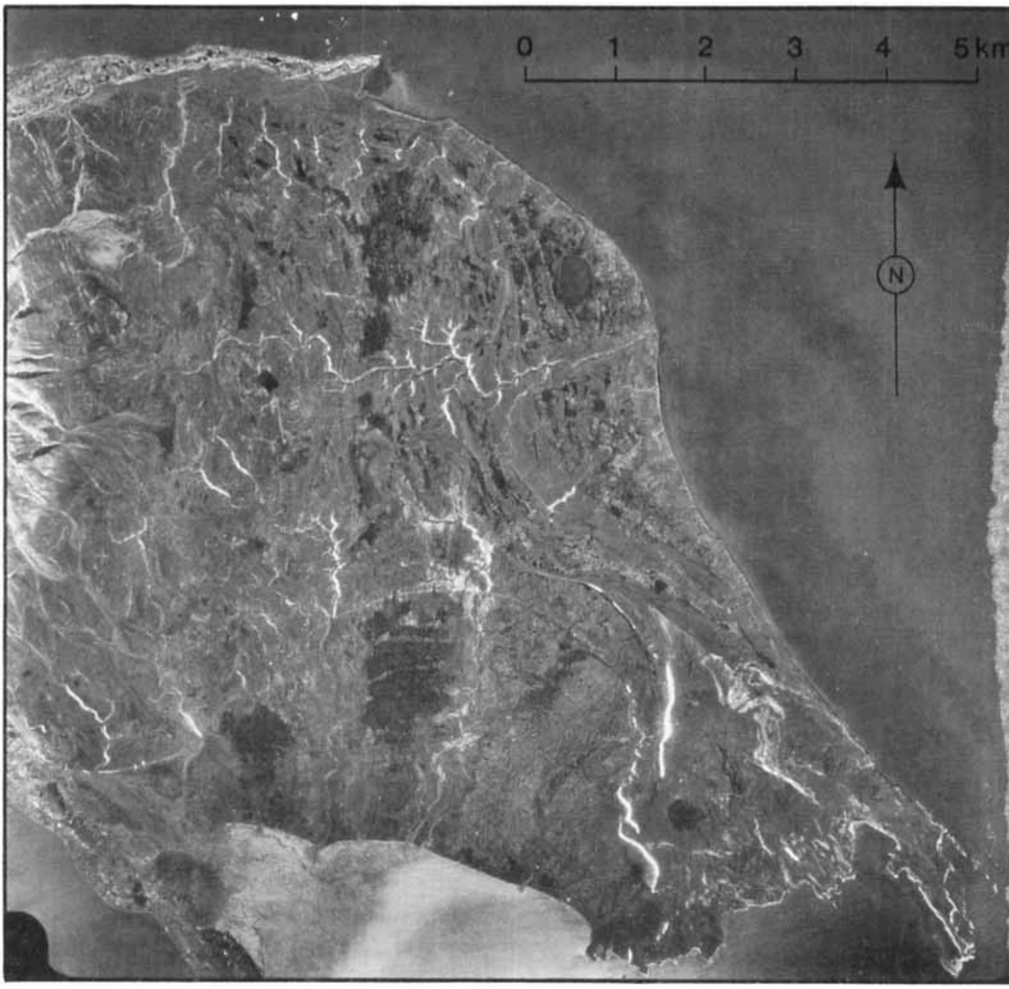

Fig. 5. Air photo of Bohemanflya. Norsk Polarinstitutt S 66V, 24 July 1966.

with a thickness of about 1 m, consists of gravel, occasionally with glacially striated stones.

Unit 3. A 2.5 m thick diamicton interpreted as a basal till is resting on the glaciofluvial gravels. At other sites along the gully it has been deposited directly on the bedrock. Its composition shows great variation. The lower part is loosely packed, clast supported with large angular stones and boulders in a sandy matrix. The upper part shows a sharp decrease in stone and boulder content, resulting in a gravelly deposit with a grey, sandy matrix supporting the clasts. A fabric analysis was performed in the upper part, and indicates a glacier movement towards ESE, thus suggesting an advance of Esmarkbreen. This glacier advance took place after 9,500 ± 100 BP (T-6286).

Unit 4. Beds of gravel and sand, interpreted as glaciofluvial in origin and divided into two subunits. The lower one has a maximum thickness of 1.5 m and consists of vaguely bedded gravels with a sandy matrix. The upper subunit is 0.4 m thick and consists of numerous sandy laminae which fine upward and are separated from each other by silty horizons.

Unit 5. Sand, which is interpreted as sublittoral and has a maximum thickness 1.5 m. The lower part is silty, occasionally with some paired, small *Macoma calcarea* valves. Ball and pillow structures demonstrate a high sedimentation rate.

Unit 6. Gravels with a thickness of 2.5–3.5 m which are interpreted as beach deposits. The lower part is bedded and contains shell fragments.

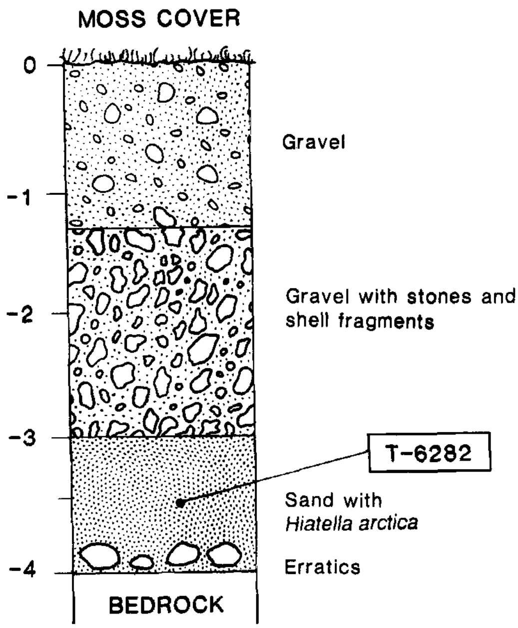

Fig. 6. Stratigraphy on top of the 25 m high cliff, western Erdmannflya.

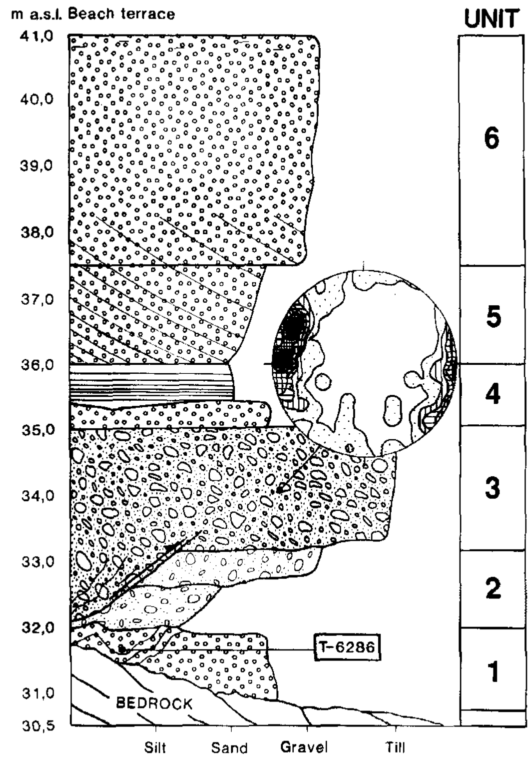

Fig. 8. Composite lithostratigraphy of the Esmarkmorena section.

The upper parts are homogeneous, mostly with angular pebbles. It has been influenced by frost processes in the active layer.

The main conclusion from this section is that Esmarkbreen readvanced after 9,500 BP.

Little Ice Age readvances

The glaciers in the bays which surround the peninsulas have deposited large lateral moraines along the inner shores of the peninsulas, Esmarkbreen and Nansenbreen on Erdmannflya and Borebreen and Wahlenbergbreen on Bohemanflya. These lateral moraines are conspicuous features, and continue into submerged terminal moraines running across their respective bays (Norsk Polarinstitutt 1978). They are ice-cored as far as they can be followed on land.

Fig. 7. The marine limit, about 60 m a.s.l., on Bohemanflya, showing a small benchmark in bedrock with washed till below and unwashed till above. Scale: Bending man in the background.

Records of the glacier front positions have been compiled, and are here shown in Figs. 9 and 10. Historical records (De Geer 1910) show that in 1910 the glaciers reached close to the maximum extension indicated by the moraines. There are no morphological, weathering or other reasons to believe that the outer parts of the moraines are much older than the inner parts. Thus, these glaciers probably had their largest Holocene extension late in the previous century. They are all surging glaciers and the ice-cored moraines are probably the result of more than one surge. The moraine of Wahlenbergbreen on Bohemanflya has been studied in some detail by us. It consists

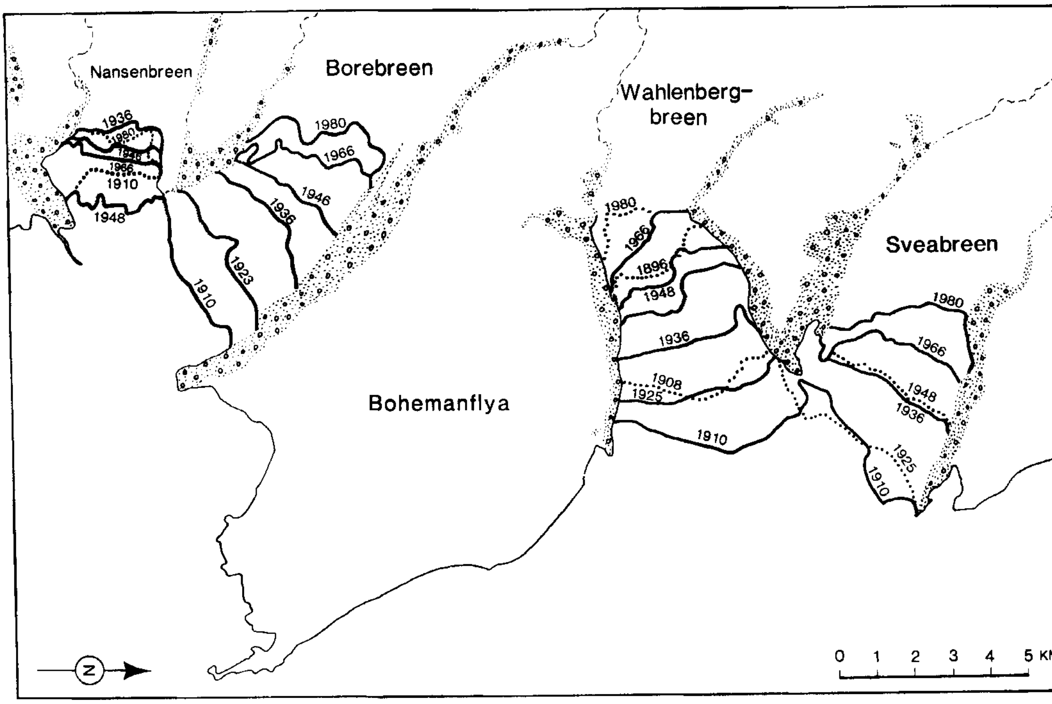

Fig. 9. Known glacier front positions in Borebukta and Yoldiabukta.

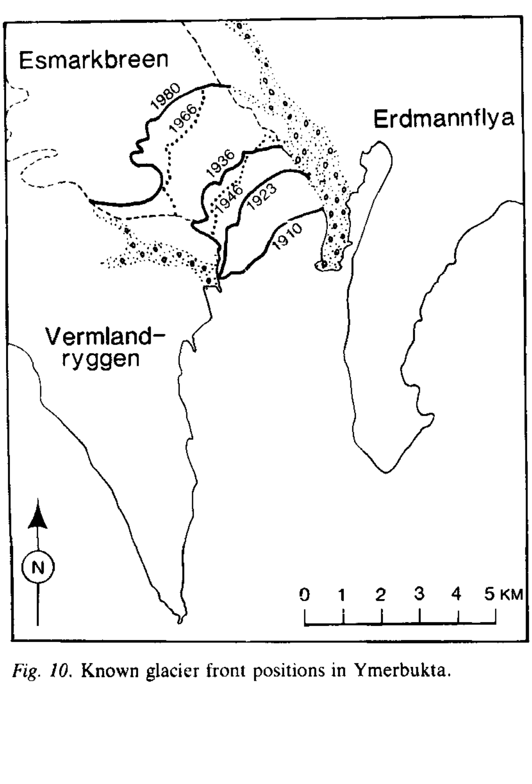

Fig. 10. Known glacier front positions in Ymerbukta.

of two generations. The older part of the moraine, here and there exposed on the distal (foreland) side of the ridge, has been markedly more affected by solifluction and other cryogenic processes, and its vegetation cover is much better developed than in the younger part of the moraine.

Mya truncata shells collected from the distal side (oldest part) of the Wahlenbergbreen moraine had a radiocarbon age of 9,000 ± 80 BP (Lu-2136). The sample also contained *Chlamys islandica* and *Mytilus edulis. Hiatella arctica* with both shells still together are incorporated in the younger part of the moraine at its very apex, and were dated to 4,180 ± 60 BP (Lu-2139). These dates are only maximum dates for the glacial advances and probably very far from the mark, but at least they show that Wahlenbergbreen was smaller around 9,000 BP and 4,000 BP than during the Little Ice Age. The mountain glaciers on Sylfjellet, immediately inland from Bohemanflya, have also retreated from an earlier maximum position, probably attained at the beginning of this century. But their frontal retreats amount only to a few hundred metres and the deglaciated surfaces are just now being colonized by pioneer plants, notably *Oxyria digyna*.

Shoreline displacement

The marine limit

The marine limit is best defined on southeastern Bohemanflya, where the slopes of the 'Cairnhill' (65.5 m a.s.l.) have been washed by the sea to about 60 m above present sea level. Higher up there is till in some depressions and perched stones and boulders. The site has been exposed to high energy waves from the east and the relative sea level corresponding to the observed washing limit is therefore interpreted as having been somewhat more than 55 m above present sea level, as judged from sea level/beach ridge relationships on similar high energy coasts today.

Slope processes (mainly solifluction) have destroyed the marine limit along the mountain sides. On northern Bohemanflya it is only possible to conclude that the marine limit is higher than 40 m. Marine deposits were found up to 53 m above present sea level east of Esmarkmorena on Erdmannflya. That is close to the expected marine limit here, since Erdmannflya and Bohemanflya probably lie on a similar isobase of emergence (Salvigsen 1989).

Whether the sea transgressed already ice-free land, or if the marine inundation followed in the immediate wake of the glacier breakup, can not be concluded from our data. The age of the marine limit has also been difficult to establish. The oldest radiocarbon date from Bohemanflya (B6; Fig. 3b and Table 1) is from shells in a frost boil 20 m above sea level, dated to 9,510 ± 90 BP (Lu-2364). Shell fragments on the surface of frost disturbed material at 47 m on Erdmannflya, near Esmarkmorena, yielded an age of 9,720 ± 110 BP (T-6287). Shells from a section about 30 m above sea level on western Erdmannflya were dated to 9,680 ± 110 BP (T-6282). Our best estimates for the age of the deglaciation and the marine limit in the area are thus around 10,000 ^{14}C years BP. This is similar to what was concluded by Forman (1989) about the deglaciation of the Forlandsundet area.

The first rapid uplift

Beach features are found all the way from the marine limit to the present shore. Beach ridges are the most frequently and continuously occurring forms, but are usually low and inconspicuous, at least when viewed from the ground. The relative uplift during the first part of the Holocene must have been rapid, as demonstrated by 8,970 ± 110 ^{14}C year old (T-6285) *Mytilus edulis* shells found in a small gully only 16 m above sea

Table 1. Radiocarbon dates from Bohemanflya and Erdmannflya. Corrections for deviations from $\delta^{13}C = -25‰$ PDB have been applied (Håkansson 1984, 1986). The original ages have been subtracted by 440 years, the standardized mean reservoir age used by the Radiocarbon Laboratory in Trondheim for Norwegian (including Svalbard) samples (Mangerud & Gulliksen 1975). This value is very close to the reservoir age 425 ± 25 years for marine samples from Svalbard suggested by Olsson (1980). Numbers in parentheses denote surface level of the actual section.

Field no.	Lab. no.	^{14}C years	Altitude (m)	Material
B6	Lu-2364	9,510 ± 90	20	*Hiatella arctica*
B5	Lu-2363	9,210 ± 90	0–1	*Mya truncata*
B3	Lu-2138	9,190 ± 90	18–20	*Mya truncata*
B1	Lu-2136	9,000 ± 80	(in till)	*Mya truncata*
B2	Lu-2137	7,690 ± 80	10	*Mytilus edulis*
B4	Lu-2139	4,180 ± 60	(in till)	*Hiatella arctica*
Sa84-46	T-6287	9,720 ± 110	47	Shell fragments
Sa84-27	T-6282	9,680 ± 110	26 (29)	*Hiatella arctica*
Sa84-44	T-6286	9,500 ± 100	32 (41)	*Mya t. and Hiatella a.*
Sa84-36	T-6285	8,970 ± 110	16	*Mytilus edulis*
Sa84-31	T-6535	8,670 ± 90	6.5	*Modiolus modiolus*
Sa84-34	T-6284	8,210 ± 90	5.0	*Mytilus edulis*
Sa84-47	T-6288	8,060 ± 100	9.8 (11.6)	*Mytilus edulis*
Sa84-33	T-8629	7,930 ± 100	7.0	*Mya truncata*
Sa84-29	T-6283	7,680 ± 90	8.0	*Mytilus edulis*
Sa84-48	T-6289	5,150 ± 80	3.5	Whale cranium

level near Morenekilen on Erdmannflya. Shells from the littoral/sublittoral *Mytilus edulis* are well suited for dating former sea levels (Donner & Jungner 1980) and another such date indicates that sea level was down to the 5 m level already around 8,200 BP (T-6284). This would mean an emergence rate of about 3 m/100 years during the first 1,500 years after the deglaciation (Fig. 11). Similar rapid uplift is seen in emergence curves from the west coast of Spitsbergen (Forman et al. 1987; Landvik et al. 1987). The initial uplift of inner Isfjorden seems to have been slower, probably about 2 m/100 years between 10,000 and 8,000 BP (Feyling-Hanssen 1965; Feyling-Hanssen & Olsson 1960; Péwé et al. 1982; Salvigsen 1984).

The Morenekilen section

A very distinct beach ridge and/or abrasion terrace occurs about 11 m above present sea level on both Erdmannflya and Bohemanflya. The beach ridge is up to 60–70 m wide and must have formed during a transgression and/or standstill of the sea.

A section through the beach ridge was located at the head of the narrow tidal-flat cove Morenekilen between Erdmannflya and Esmarkmorena. A rock outcrop along the northern shore is here connected with the mountain side by an approximately 100 m long beach ridge (tombolo) (Fig. 12). The ridge reaches 4–6 m above the fluvial plain and in the northwestern end it has a

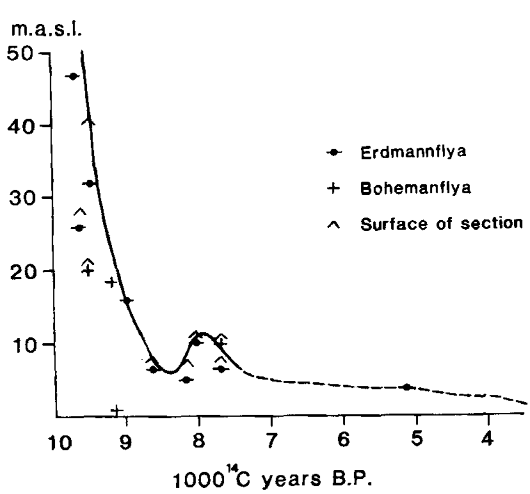

Fig. 11. Shoreline displacement curve for the Erdmannflya and Bohemanflya area. Time/elevation position of the dated samples which form the basis for the curve is also marked.

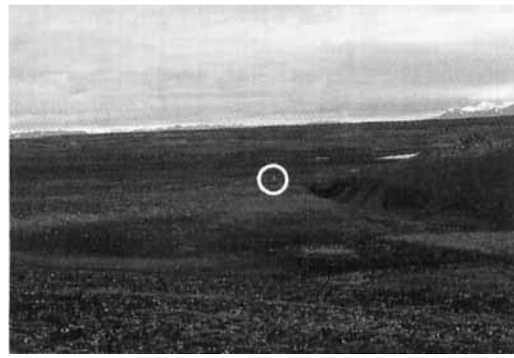

Fig. 12. The Morenekilen section seen towards the east. Scale: Man (in circle) to the left of the section.

well developed terrace about 10 m above sea level. Close to the rock outcrop an almost 4 m deep incision revealed the composite construction of the ridge. It was possible to recognize three units, counted from bottom to top (Fig. 13):

Unit C. Gravel (beach). The upper boundary of Unit C has the morphology of a beach ridge, with the crest reaching 5.5 m above present sea level. The ridge consists of gravelly sand with a weak stratification and the beds dipping eastwards. More rounded and sorted material and a decrease in particle size were observed towards the ridge-crest. A strong oxidation of the gravel

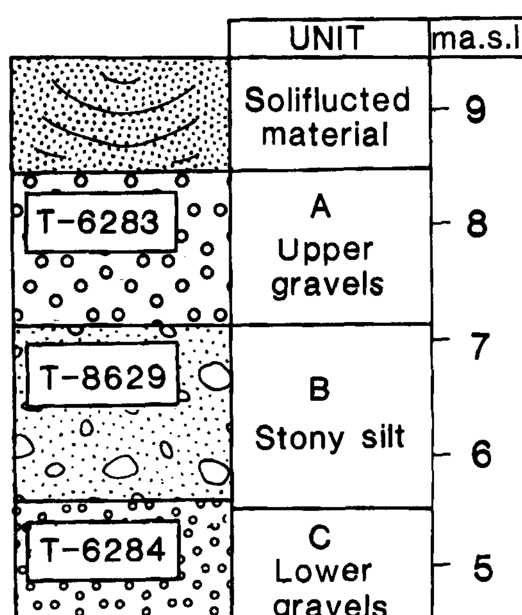

Fig. 13. Composite stratigraphy of the Morenekilen section.

has taken place close to the crest, giving it a bright orange/red colour.

In the lower part of Unit C a collection of shells (*Mya truncata, Hiatella arctica, Macoma calcarea* and *Mytilus edulis*) was made, all small and thin. However, *Astarte montagui* appeared as usual with thick shells. Some of the shells, notably those of *Macoma calcarea*, were paired and with well preserved periostracum. This indicates a reasonably low energy environment during the redeposition of the shells from deeper water onto the beach, much like present day conditions in Morenekilen. Morenekilen is now a well protected area where no high waves can be generated. Beach ridges are here only built up to a few decimetres above high tide level and silty sediments are trapped and deposited close to the beach gravel during high tide. Numerous pelecypods live in these sediments and after their death, many of their shells are deposited on the beach. *Mytilus edulis* shells from Unit C yielded the age 8,210 ± 90 BP (T-6284). The corresponding sea level was probably around 5 m above the present.

Unit B. Stoney, silty diamicton (marine). In the eastern part of the section the thickness of Unit B was measured to 1.5 m, but it wedges out at about 5 m above sea level toward the crest of the ridge in the underlying Unit C. The transition from Unit C is gradual, but still rather distinct, because of the appearance of fine sand and silt and the decrease in gravel content upwards. The middle part of Unit B (maximum thickness 0.6 m) is a rather homogeneous silt with only occasional gravel. Upwards the sand and gravel content increases again. The upper boundary is sharp and horizontal.

A dense population of *Mya truncata* shells in living position was found throughout Unit B, showing that it must have been deposited after sea level had risen and inundated the area. Shells from the upper part of Unit B were dated to 7,930 ± 100 BP (T-8629). The upward decrease of the gravel content in the lower part may demonstrate that the ongoing transgression gradually reduced the littoral element. The more silty middle part of the unit may have been deposited during the transgression maximum, with a sea level 10–12 m higher than the present, based on a combination of depth requirements of *Mya truncata* and the altitudes of the major erosional cliff. This indicates a transgression of at least 5 m.

Unit A. Gravel (beach). In the central part of the section the thickness of this unit measures 0.1–0.2 m but increases southeastwards to 0.8 m. In the same direction the upper boundary drops about 1 m, but this may have been caused by solifluction. The sediments are gravelly with a sandy matrix and they get less sorted, more stoney and with less rounded clasts northeastwards. Some stones have attached remnants of seaweed stems.

The sediments contain many small shell fragments and some single and paired *Mytilus edulis* shells. The latter have been radiocarbon dated to 7,680 ± 90 years BP (T-6283). The sediments are interpreted as deposited during a regression, when sea level stood about 8 m above its present level. Unit A is covered by silt-infiltrated gravel and stone stripes show that these sediments are soliflucted.

Some observations were also made outside the excavated section. A large fragment of *Modiolus modiolus* was found in sediments very similar to Unit B. It was dated to 8,670 ± 90 BP (T-6535), and is probably redeposited. *Modiolus modiolus* has only been found in a few Holocene deposits in Svalbard (Feyling-Hanssen 1955). The dating has climatic interest, as *Modiolus* is a boreal species which seems to have had only a short hypsithermal history in Svalbard. Another species dependent on a warmer climate was also observed, *Littorina littorea*, but at a site with no direct connection to the described units in the Morenekilen section.

The Vasskalven shoreline profile

In many places, especially on Bohemanflya, there is a distinct erosional cliff developed at about the same altitude as the best developed beach ridge system. In Fig. 5 it can be seen how the almost 10 m high cliff on northern Bohemanflya splits up southwards into two cliffs, with particularly distinct beach ridges just below them. Parallel to the river south of lake Vasskalven (Fig. 3b) the base of the lower cliff lies between 6 and 7 m and that of the higher cliff 11–12 m above present sea level.

In one of the small gullies branching northwards from the river a 1.5 m thick section through beach deposits was studied (Fig. 14). The lower 0.5 m, resting directly on Cretaceous shale, is a shell bearing coarse beach gravel containing fragments of *Mytilus edulis, Mya truncata, Astarte borealis,*

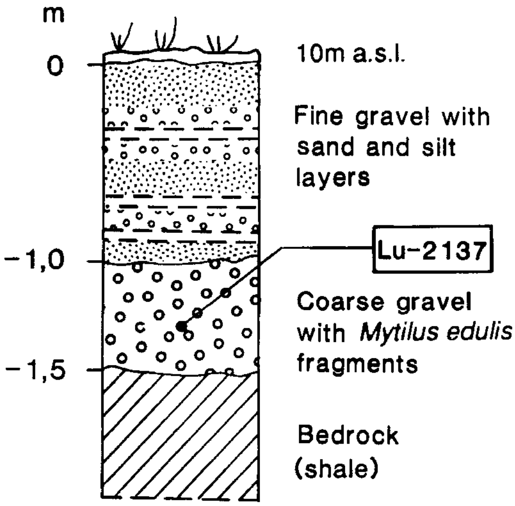

Fig. 14. Stratigraphy from section B2, Bohemanflya.

Table 2. **Bivalves, gastropods and algae in dated samples from Bohemanflya.**

Species	Sample	B1	B2	B3	B4	B5	B6
Mya truncata		+	+	+	+	+	+
Hiatella arctica		+	−	+	+	+	+
Macoma calcarea		+	−	+	+	+	+
Astarte borealis		+	+	−	+	−	−
Astarte elliptica		+	−	−	+	−	−
Astarte montagui		+	−	−	−	−	−
Mytilus edulis		+	+	−	−	+	−
Chlamys islandicus		+	−	−	+	+	−
Clinocardium ciliatum		+	−	−	−	−	−
Nuculana pernula		+	−	−	−	−	−
Leptea caeca		+	−	−	−	+	−
Littorina littorea		−	+	−	−	−	−
Emarginula fissura		−	−	−	−	+	−
Litothamnium		+	+	−	−	+	−

Corrected ^{14}C-ages BP 9,000, 7,690, 9,190, 4,180, 9,210, 9,510 (without standard deviation)

Littorina littorea and *Lithothamnion* (Sample B2, Table 2). The main component of the gravel is shale from the underlying rock. *Mytilus* shells from this bed were dated to 7,690 ± 80 BP (Lu-2137). Above follows c. 1 m of a finer beach gravel, with frequent layers of sand and silt, and on top of it all, c. 10 m above sea level, is a thin arctic brown soil horizon. At a few nearby sites the lower, coarse gravel is exposed at the surface. The more fine grained character of the upper gravel bed, with its sand and silt layers, may indicate deepening water (i.e. a transgression). However, it could also reflect only some lateral shift in the depositional environment. The ^{14}C dated shells, littoral/sublittoral *Mytilus edulis*, must either date or closely postdate the 11–12 m cliff. The marine silt above this cliff, from where the shells could theoretically have been washed down, does not contain *Mytilus*, and has been dated to more than 9,000 BP (Lu-2138 and Lu-2364).

***Fig. 15.* Shell rich sediments from a coastal cliff on Bohemanflya, B5.**

Discussion of the postulated transgression

The Morenekilen section indicates that an early Holocene transgression took place during a relatively short period of time, bracketed by the two *Mytilus edulis* dates 8,210 ± 90 BP (T-6284) and 7,680 ± 90 BP (T-6283). The dated *Mya truncata* (7,930 ± 100 BP) lived there shortly after the maximum of the transgression, showing that the transgressive phase only lasted about 300 years.

A stream-cut through the main beach ridge at c. 12 m in Tangvika on southeastern Erdmannflya reveals a c. 0.1 m thick *Mytilus edulis* layer below 1.8 m beach gravel. The *Mytilus* bed is overlying 0.2–0.3 m sandy gravel with thick fragments of *Mya truncata, Hiatella arctica* and *Astarte* sp. which have probably been resedimented. A sediment resembling a washed till occurs at the bottom of the section. Fragments from the *Mytilus* bed were dated to 8,060 ± 100 BP (T-6288), which gives the maximum age of the main beach ridge of Erdmannflya. The c. 7,700 BP (Lu-2137) old *Mytilus* shells in the upwards fining gravel on Bohemanflya indicate a slightly younger transgression, but fit into the general picture of a transgression on the northwest coast of Isfjorden between roughly 8,500 and 7,500 BP.

Holocene transgressions are known also from the coast of Norway. In Hordaland, western Norway, a transgression took place between 8,500 and 7,200 years BP (Kaland 1984). In northern Norway transgression started before 8,000 BP and culminated about 6,000 BP (Hald & Vorren 1983; Møller 1986). A vertical extent of about 10 m was suggested by Hald & Vorren (1983).

A very well developed shoreline at about 10 m occurs on the outer west coast of Spitsbergen north and south of Isfjorden (Landvik et al. 1987). Organic material within that beach ridge has indicated a younger age (6,000–5,000 BP) for that transgression than for the one here described from Erdmannflya and Bohemanflya. An age around 6,000 BP has also been suggested by Forman et al. (1987) for an inferred transgression on Brøggerhalvøya, further north on the west coast.

The most distinct shorelines in Northeast Greenland seem to date from approximately 6,000 BP (Hjort 1981), and coincide roughly with the so-called Vega transgression there (Hjort 1973). Whether this 6,000 BP transgression is recorded also in the central Isfjorden area is an open question, but the 6–7 m abrasion cliff on Bohemanflya may be a possible candidate.

Beaches below the 10 m level

There seems to be a continuous system of beaches between the 'main' ridge and cliffs and the present shore. However, material suitable for dating the lower beaches is very sparse on Bohemanflya and Erdmannflya. A whale cranium found on eastern Erdmannflya, 3.5 m above sea level and 100 m from the sea, had the age 5,150 ± 80 BP (T-6289), and may indicate that sea level 5,000 years ago was 3–4 m higher than at present. Fragments of *Mytilus edulis* were frequent around the dated cranium, showing that the climate 5,000 years ago still was warmer than today.

Most of Erdmannflya and Bohemanflya are surrounded by a zone of very shallow water (usually less than 2 m deep) and only low energy waves reach the shore today (Fig. 2). A sandy, stony beach in front of a low coastal cliff is the most characteristic shore type. It is an open question if a transgression is presently taking place on Bohemanflya and Erdmannflya. An ongoing transgression has been suggested for many areas of Svalbard (summarized by Rudberg 1986), and been thought to result either from neoglacial isostatic depression (e.g. Vogt 1932), or from the well documented present slow eustatic rise of sea level (e.g. Barnett 1983; Gornitz & Lebedeff 1987; Pettrer & Cushingham 1989), or from a combination of both. However, the volume of glaciers on Spitsbergen has been considerably reduced during this century (Liestøl 1988), which should begin to cause an isostatic rise of the land rather than a depression. Anyhow, relative sea/land movements are small today and it has been difficult to find convincing evidence for or against an ongoing transgression.

Acknowledgements. – Radiocarbon dates were performed by the Radiological Dating Laboratory in Trondheim under the supervision of Reidar Nydal and Steinar Gulliksen and by the Radiocarbon Dating Laboratory in Lund under the supervision of Sören Håkansson.

References

Barnett, T. P. 1983: Recent changes in sea level and their possible causes. *Climate Change 5*, 15–38.

De Geer, G. 1910: *A geological excursion to central Spitsbergen.* P. A. Norstedt & Söner, Stockholm. 23 pp., 21 pls.

Donner, J. & Jungner, H. 1980: Radiocarbon ages of shells in Holocene marine deposits. *Radiocarbon 22*, 556–561.

Feyling-Hanssen, R. W. 1955: Stratigraphy of the marine Late-Pleistocene of Billefjorden, Vestspitsbergen. *Norsk Polarinst. Skr. 107.* 187 pp.

Feyling-Hanssen, R. W. 1965: Shoreline displacement in Central Spitsbergen. *Norsk Polarinst. Medd. 93*, 1–5.

Feyling-Hanssen, R. W. & Olsson, I. 1960: Five radiocarbon datings of post glacial shorelines in central Spitsbergen. *Norsk Geogr. Tidsskr. 17*, 122–131.

Flood, B., Nagy, J. & Winsnes, T. S. 1971: Geological map of Svalbard 1:500,000. Sheet 1G Spitsbergen, southern part. *Norsk Polarinst. Skr. 154A.*

Forman, S. L. 1989: Late Weichselian glaciation and deglaciation of Forlandsundet area, western Spitsbergen, Svalbard. *Boreas 18*, 51–60.

Forman, S., Mann, D. & Miller, G. 1987: Late Weichselian and Holocene relative sea level history of Brøggerhalvøya, Spitsbergen. *Quaternary Research 27*, 41–50.

Gornitz, V. & Lebedeff, S. 1987: Global sea-level changes during the past century. Pp. 3–16 in Numedal, D., Pilkey, O. H. & Howard, J. D. (eds.): *Sea-level change and coastal evolution. SEPM Publ. 41.*

Hald, M. & Vorren, T. O. 1983: A shoreline displacement curve from the Tromsø district, North Norway. *Norsk Geol. Tidsskr. 63*, 103–110.

Hjort, C. 1973: The Vega Transgression. A hypsithermal event in Central East Greenland. *Bull. Geol. Soc. Denmark 22*, 25–38.

Hjort, C. 1981: Present and Middle Flandrian coastal morphology in Northeast Greenland. *Norsk Geogr. Tidsskr. 35*, 197–207.

Håkansson, S. 1984: University of Lund Radiocarbon Dates XVII. *Radiocarbon 26*, 392–411 (399–400).

Håkansson, S. 1986: University of Lund Radiocarbon Dates XIX. *Radiocarbon 28*, 1111–1132 (1123).

Kaland, P. E. 1984: Holocene shore displacement and shorelines in Hordaland, western Norway. *Boreas 13*, 203–242.

Landvik, J. Y., Mangerud, J. & Salvigsen, O. 1987: The Late Weichselian and Holocene shoreline displacement on the west-central coast of Svalbard. *Polar Research 5 n.s.*, 29–44.

Liestøl, O. 1988: The glaciers in the Kongsfjorden area, Spitsbergen. *Norsk Geogr. Tidsskr. 42*, 231–238.

Mangerud, J. & Gulliksen, S. 1975: Apparent radiocarbon age of recent marine shells from Norway, Spitsbergen and Ellesmere Island. *Quaternary Research 5*, 263–273.

Møller, J. J. 1986: Holocene transgression maximum about 6000 years BP at Ramså, Vesterålen, North Norway. *Norsk Geogr. Tidsskr. 40*, 77–84.

Norsk Polarinstitutt 1978: *Arctic chart 523, Svalbard Isfjorden 1:100,000.*

Olsson, I. U. 1980: Content of ^{14}C in marine mammals from northern Europe. *Radiocarbon 22*, 662–675.

Pettrer, W. R. & Cushingham, A. M. 1989: Global sea level rise and the greenhouse effect: might they be connected? *Science 244*, 806–810.

Péwé, T. L., Rowan, D. E., Péwé, R. H. & Stuckenrath, R. 1982: Glacial and periglacial geology of northwest Blomesletta peninsula, Spitsbergen, Svalbard, *Norsk Polarinst. Skr. 117*. 32 pp.

Rudberg, S. 1986: Present-day geomorphological processes on Prins Oscars Land, Svalbard. *Geogr. Ann. 68A*, 41–63.

Salvigsen, O. 1984: Occurrence of pumice on raised beaches and Holocene shoreline displacement in the inner Isfjorden area, Svalbard. *Polar Research 2 n.s.*, 107–113.

Salvigsen, O. 1989: Evolution of the coasts of Svalbard, Norwegian Arctic, during the Holocene. Pp. 76–78 in Raukas, A. (ed.): *Protection and evolution of seacoasts. Abstracts International meeting, Tallinn.*

Schaupeter, W. & Struck, U. 1988: *Flächenhafte kartierung der mesozoischen und känozoischen Sedimente auf Bohemanflya und Erdmannflya am nördlichen Isfjordenufer, Spitsbergen, Svalbard.* Diplomarbeit Christian-Albrechts-Universität zu Kiel. 96 pp., 2 maps, 2 appendices.

Vogt, T. 1932: Landets senkning i nutiden på Spitsbergen og Øst-Grønland. *Norsk. Geol. Tidsskr. 12*, 563–574.