

# Early Holocene land floras and faunas from Edgeøya, eastern Svalbard

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Early Holocene, near-shore marine sediments from Visdalen, Edgeøya, eastern Svalbard contain locally abundant allochthonous remains of land plants, notably bryophytes. Wetland species indicative of mineral-rich and calcareous soils are frequent, but upland plants are also well represented. The fossil assemblages are indicative of ecological and climatic conditions similar to those on Edgeøya today. The sediments contain one of the first fossil beetles reported from Svalbard. Apparently, the modern flora of Svalbard was already established in the earliest Holocene, probably following immigration from northern Europe. A few *Armeria scabra* remains are believed to be derived from interglacial deposits.

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## Introduction

Apart from exotic driftwood, pre-Holocene, Quaternary plant remains are rare in Svalbard (Ingólfsson et al. 1995); however, a number of Holocene lake and peat deposits have been investigated, mostly by means of pollen analyses. Only a few of these go back to the Early Holocene, and very little is known about the immigration history of Svalbard flora and fauna. An exception is the dwarf birch *Betula nana* that seems to have immigrated to central Spitsbergen around 6000 <sup>14</sup>C years BP (Surova et al. 1982). Nathorst (1883) was of the opinion that a few hardy species possibly survived the last glacial stage on Svalbard, but that by far the majority of the vascular plants immigrated after the last ice age via a land bridge joining Svalbard and Scandinavia. Other scientists, however, find support for the refugium hypothesis (Rønning 1965; Odasz 1991; Odasz et al. 1991). One argument is that the plants could not immigrate to Svalbard after the last ice age because no land bridge connected the archipelago with the European mainland. However, the fact that the small, isolated, volcanic island Jan Mayen, which has never been connected to any continent by a land bridge, has been populated by 62 species of vascular plants (Lid 1964) shows that long distance dispersal of plants does take place across oceans in the Arctic. Many studies of full and late-glacial phytogeography in northwest

Europe demonstrate the mobility of plants (Birks 1994).

Palaeoecological studies of Early Holocene terrestrial/limnic sediments have been carried out by Hyvärinen (1968, 1970, 1972), Surova et al. (1982), Göttlich & Hornburg (1982), van der Knaap (1989), Birks (1991) and Wohlfahrt et al. (1995). In addition, there is a find of *Polytrichum commune* Hedw. dated at 9870 ± 140 years BP (Salvigsen & Mangerud 1991). Surova et al. (1982) obtained a <sup>14</sup>C date of 10,360 ± 260 years BP (Tln-270) on basal peat from Reindalen on central Spitsbergen. They presented a rather crude pollen diagram from the peat section with only few pollen and spore types from indigenous plants. The oldest peat date appears to come from Agardhdalen, western Spitsbergen, from where Punning et al. (1978) reported a date of 10,570 ± 360 years BP (Tln-232). Van der Knaap (1989) obtained a <sup>14</sup>C date of 6710 ± 80 years BP on basal peat from a section in Rosenbergdalen, northwestern Edgeøya. Both macrofossil and pollen diagrams were published from the site. Only macrofossils of *Salix polaris*, Gramineae and five moss taxa were found in the section, but to this must be added 25 pollen and spore types. Van der Knaap concluded that the deposit and flora of the former mire indicated that the climate was warmer than today during peat accumulation. Palaeoecological studies of lake deposits from Svalbard are even fewer than those of peat

deposits. Hyvärinen (1968, 1970, 1972) studied lake sediments on northern Svalbard and Bjørnøya by means of pollen analysis. One of the sequences from northern Svalbard dated back to ca 10 ka, but the interpretation of the pollen diagrams is difficult due to a high content of long distance transported pollen. Birks (1991) presented a detailed macrofossil diagram from lake sediments from Skardtjørna, western Spitsbergen. The basal sediments were dated by accelerator mass spectrometry (AMS) on *Salix* and *Saxifraga* remains to 8 ka. There is no safe indication in Birks' study that any plants arrived after this date, whereas three taxa were found that do not presently grow in the area, and a mean July temperature about 2°C higher than today was inferred for the Early Holocene. Wohlfahrt et al. (1995) suggested that the mean July temperature on Bjørnøya may have been as much as 4–5°C higher than present in the Early Holocene, based on beetle data. Terrestrial plant macrofossils in near-shore marine sediments from Adventfjorden, western Spitsbergen, were studied by Heer (1870) and Andersson (1910). They found abundant fruit stones of *Empetrum nigrum* that no longer fruits in this area.

The aim of this paper is to describe and interpret some remains of terrestrial and limnic plants

and animals that throw light on the history of Svalbard flora and fauna. The remains come from sediment samples from Visdalen on the north-western part of the island of Edgeøya, eastern Svalbard (Fig. 1). A preliminary report on the present material that included some tentative moss identifications was published by Bennike (1992).

## Study area

Edgeøya covers 5150 km<sup>2</sup> and is the largest island in the southeastern part of the Svalbard archipelago; extensive areas are glaciated, although the island is relatively low (Norderhaug 1970). The bedrock is dominated by Triassic sandstone and mudstone with layers of limestones and thin coal seams in places, intruded by some dolerite sills (Lock et al. 1978). The northwestern part of the island supports the richest vegetation and belongs to the *Salix polaris* zone of Brattbakk (1986). Large areas are virtually barren, but the dwarf shrub *Salix polaris* is common in favourable sites. Ninety-three species of vascular plants are known from the island (Neilson 1970). From the flora and vegetation a mean temperature for the warmest month of around 2°C is suggested for the northwestern part of the island.

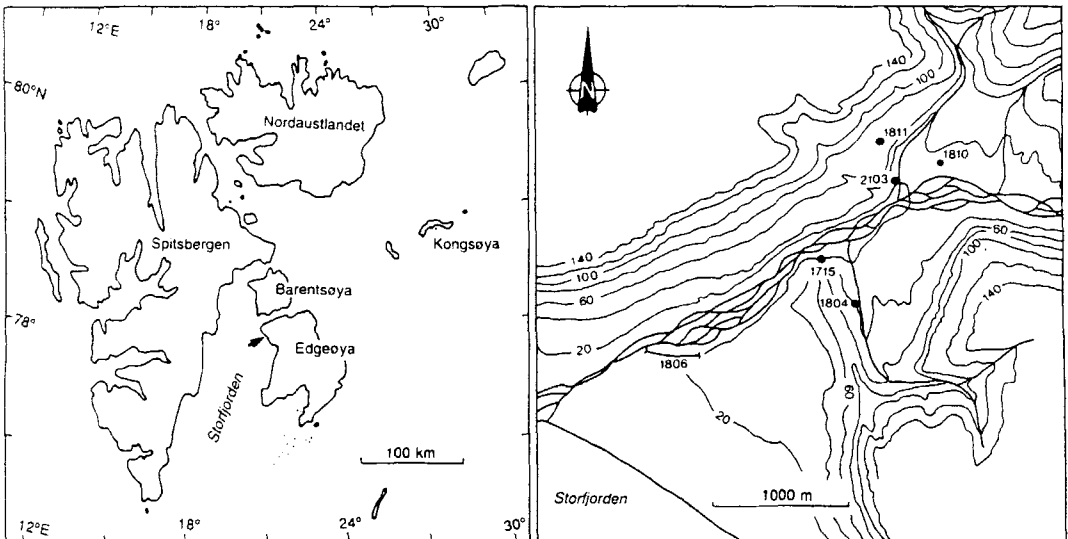


Fig. 1. Left: Map of Svalbard. The arrow shows the location of Visdalen on Edgeøya. Right: Map of Visdalen showing the location of the studied samples. Contour interval 20 m; contours only showed in Visdalen. For detailed description of the sites, see Möller et al. (1995).

## Material and methods

Seven samples were collected during the PONAM 1991 expedition to eastern Svalbard. For descriptions and interpretations of the sampled sediments, see Möller et al. (1992, 1995). The sediment samples consisted of fine sand and silt with allochthonous plant and animal remains, some of which were well preserved, indicating short transport. The samples were wet-sieved through 0.42 and 0.21 mm sieves, and the residue left on the sieves was sorted under a dissecting microscope.

Most of the bryophyte remains were well preserved, which made it possible to identify a large proportion of the material to a taxonomic level where a partial reconstruction of the paleo-environment becomes possible. The bryophyte material is deposited in the Department of Cryptogamic Botany, Swedish Museum of Natural History (No. 520644–620650). The other material is housed in the Geological Museum, Copenhagen. The bryophyte nomenclature follows Corley et al. (1981), with additions in Corley & Crundwell (1991) except for *Brachythecium coruscum* I. Hag. (*B. groenlandicum*), *Polytrichastrum alpinum* (Hedw.) G. L. Sm. (*Polytrichum alpinum*), *P. sexangulare* (Brid.) G. L. Sm. (*Popytrichum sexangulare*), *Pseudocalliergon angustifolium* Hedenäs (Hedenäs 1992b), *P. trifarium* (Web. & Mohr) Loeske (*Calliergon trifarium*), *P. turgescens* (T. Jens.) Loeske (*Scorpidium turgescens*), *Scorpidium cossoni* (Schimp.) Hedenäs (*Drepanocladus cossoni*), *Straminergon stramineum* (Brid.) Hedenäs (*Calliergon stramineum*) and *Warnstoftia sarmentososa* (Wahlenb.) Hedenäs (*Calliergon sarmentosum*). Tracheophyte nomenclature follows Rønning (1979).

## Identification

Seeds of *Melandrium apetalum* were identified from their wing which is broader than that of the related species *M. angustiflorum*, but the seeds only measured about 1.2 mm across. It is impossible to make species identification of *Armeria maritima* s.l. calyces (Godwin 1975), but from phytogeographical considerations the taxon represented must be one of the northern taxa that include *Armeria arctica* Wallr., *A. maritima* (Mill.) Willd. subsp. *arctica* (Cham.) Hult., *A. scabra* Pall., *A. labradorica* Wallr. and *A. sibirica*

Turcz. We use the name *A. scabra* which is the one currently in use in Greenlandic botany (Böcher et al. 1978). It is possible that some of the seeds referred to *Draba* sp. represent other Brassicaceae genera. All *Salix* remains (leaves, bud scales, fruit capsules, bark and wood) are referred to *Salix polaris*, to which the diagnostic leaves belonged, and which is the only willow species presently growing on Edgeøya. *Taraxacum* achenes were similar to *Taraxacum brachyceras* achenes which have smaller spines than *T. arcticum* (Trautv.) Dahlst. achenes, the only other *Taraxacum* species on Edgeøya today; but if the achenes are interglacial in age the species identification becomes uncertain.

*Lepidurus* was represented only by apodous segments. For climatic reasons the remains are referred to *Lepidurus arcticus*. *Olophrum* was represented by one elytron and possibly a tergite. The elytron can not be identified at the species level, but since *O. boreale* is the only species recorded from Svalbard at present (Fjellberg 1983), the fossil elytron has been referred to this species (J. Böcher, pers. comm. 1992).

## Results and discussion

### Non-bryophytes

Identified land and freshwater plants and animals are listed in Tables 1 and 2 and some remains are illustrated in Fig. 2. The samples were small (Table 1), but nevertheless some of the assemblages are diverse. Samples 87711, 87728 and 86251 contained marine fossils, showing that these assemblages were deposited in shallow water marine environments, probably near the mouth of a river. The marine fossils comprise the following animal groups: foraminifera, hydroids, serpulids, ostracodes, barnacles, malacostracans, molluscs, echinoids, bryozoans and fishes and the brown algae *Sphacelaria* sp. and *Laminaria* sp. In this context it should also be noted that the oribatid mite *Ameronothrus lineatus*, which occurred in similar samples not included in Table 1, lives at or near the sea shore (Hammer 1944). The other assemblages derive from lagoon sediments (88203) and glacio-lacustrine sediments (88651, 88655 and 86266) (Möller et al. 1995).

The radiocarbon dates range from 12.5 ka to 8.5 ka (Table 3). The 12.5 ka date on sample 87711 does not date the time of sedimentation

Table 1. Macrofossils (except bryophytes) from Edgeøya, Svalbard.

Sample No.	87711	87728	88203	86251	86266	88651	88655
C-14 age (ka) <sup>1</sup>	12.5	>9.8	10.0	9.9	8.6	8.7	8.5
Locality	1806	1715	1804	1811	1810	2103	2103
Sample size (liter)	0.5	0.35	0.1	0.7	1.0	0.2	1.1
PLANTS:							
<i>Cenococcum geophilum</i> Fries	+	+	1	1	+	+	+
?Pyrenomycetidae	-	+	-	-	+	+	+
<i>Equisetum</i> sp.	+	-	+	-	+	+	+
<i>Ranunculus sulphureus</i> Sol.	-	-	-	-	-	1	3
<i>Ranunculus</i> sp.	1	?	-	-	-	-	-
<i>Papaver dahlianum</i> Nordh.	+	3	+	-	+	++	++
<i>Melandrium apetalum</i> Fenzl	+	-	-	-	1	3	1
<i>Cerastium arcticum/alpinum</i>	+	-	+	2	+	++	++
<i>Minuartia rubella</i> (Wbg.) Hiern.	+	-	+	2	+	++	+
<i>Silene acaulis</i> (L.) Jacq.	2	-	+	-	+	+	+
<i>Oxyria digyna</i> (L.) Hill	++	-	+	2	++	+++	+++
<i>Polygonum viviparum</i> L.	-	-	-	-	-	+	+
<i>Armeria scabra</i> Pall.	2	-	-	-	-	-	-
<i>Draba</i> sp.	+	-	+	-	+	+	+
<i>Salix polaris</i> Wg.	+	+	1	-	+	+	+
<i>Potentilla</i> sp.	+	-	1	-	+	+	+
<i>Saxifraga oppositifolia</i> L.	+	3	+	-	++	++	+++
<i>Dryas octopetala</i> L.	-	1	-	-	-	-	-
<i>Taraxacum brachyceras</i> Dahlst.	5	-	-	-	-	-	-
<i>Juncus</i> sp.	+	-	-	-	-	+	-
<i>Luzula</i> sp.	+	5	1	-	+	+	+
<i>Carex</i> spp.	+	1	-	-	+	+	-
ANIMALS:							
<i>Lepidurus arcticus</i> Pallas	1	-	-	1	+	+	+
<i>Daphnia pulex</i> de Geer type	-	-	-	-	-	1	-
<i>Candona</i> sp.	3	-	-	-	-	-	-
<i>Olophrum boreale</i> (Paykull)	-	-	-	-	1	-	?
?Ichneumonidae	-	-	1	-	-	-	-
Chironomidae	-	-	+	-	+	+	-
?Lepidoptera	1	-	-	-	-	1	-
<i>Erigone</i> sp.	-	-	-	-	1	-	-
Oribatida	-	3	2	-	+	-	-

+/+ / +++: Relative frequency. 1-5: Absolute numbers. <sup>1</sup>The radiocarbon dates are presented in Table 3.

since the sample is underlain by in situ shells dated at 9.4 ka (the sea water corrected age is 9.0 ka) (Möller et al. 1995). The dated sample must therefore consist of older plus younger material. Sample 87728 lies just under in situ shells dated to 9.7 ka (Table 3). The samples with plant remains contained numerous small coal particles, and also a few pre-Quaternary trilete megaspores which could not be identified due to their simple morphology, but which are probably of Mesozoic age (S. B. Manum, pers. comm. 1992). It is possible that previously published peat and gyttja dates based on bulk samples from the region are too old due to contamination by coal particles, but on the other hand bulk peat samples

may also be too young due to contamination by intruding roots.

The assemblages are indicative of high arctic biotas similar to those on Edgeøya today. All vascular plants listed grow on Edgeøya today, except one, namely *Armeria scabra*, which does not occur on Svalbard at present. From its modern geographical range (Fig. 3), there seems to be no climatic reason for this since the plant grows in North Greenland and northernmost Canada where the climate is similar to that of Svalbard. Because the radiocarbon date shows that the sample from the same location from which the *Armeria* remains come includes some old plant material, it is possible that the *Armeria* remains

Table 2. Bryophytes from Edgeøya. S = shoot; B = branch; L = leaf.

Sample No.	87711	87728	88203	86251	86266	88651	88655
<i>Amblystegium</i> subg.	1S	-	-	-	-	-	-
<i>Hygroamblystegium</i> sp.	-	-	-	-	-	-	-
<i>Aulacomnium palustre</i>	-	-	-	-	-	-	1S
<i>A. turgidum</i>	-	1S	-	-	1S	-	-
<i>Brachythecium coruscum</i>	-	-	-	-	-	1S/B	1S/B
<i>B. turgidum</i>	-	-	1S	-	1B	-	-
<i>Bryoerythrophyllum recurvirostrum</i>	-	-	-	-	-	-	1S
<i>Bryum</i> cf. <i>pseudotriquetrum</i>	3S	-	6S	-	-	5S	8S
<i>Bryum</i> sp.	-	-	-	-	>10S	-	2S
<i>Calliergon</i> cf. <i>richardsonii</i>	-	-	-	-	1S	-	1S
<i>C. giganteum/richardsonii</i>	-	-	-	-	-	2B	-
<i>C. richardsonii</i>	-	-	-	-	-	1S	-
<i>Campylium polygamum</i>	-	-	-	-	-	1S	-
<i>Campylium</i> sp.	-	-	-	-	3S	-	-
<i>Ceratodon purpureus</i>	-	-	-	-	3S	-	-
<i>Dichodontium pellucidum</i>	-	-	-	-	2S	-	-
<i>Distichium</i> sp.	2S	-	37S*	-	6S	4S	-
<i>Ditrichum flexicaule</i>	4S	-	10S	2S	>10S	3S	11S
<i>Drepanocladus</i> s.str. sp.	-	-	-	-	-	-	1S/B
<i>Encalypta alpina</i>	-	-	-	-	4S	1S	1S
<i>E. procera/streptocarpa</i>	-	-	3S	-	2S + 1L	-	-
<i>Encalypta</i> sp.	-	-	1S	-	-	-	3***
<i>Isopterygiopsis pulchella</i>	-	-	-	1S	-	-	-
<i>Lophozia</i> s.l. sp.	-	-	1S	-	4S	1S	1S
<i>Oncophorus wahlenbergii</i>	-	-	-	-	-	-	1S
cf. <i>Orthothecium</i> sp.	-	-	-	-	1S	-	-
<i>Paludella squarrosa</i>	-	-	-	-	-	-	1S + 1L
<i>Philonotis fontana/tomentella</i>	-	-	-	1S	-	-	-
<i>Philonotis</i> sp.	-	-	-	-	-	1S	1S
<i>Pogonatum dentatum</i>	-	-	-	-	1S	-	-
<i>P. urnigerum</i>	2L	-	-	-	-	-	-
<i>Pohlia wahlenbergii</i>	-	-	-	-	2S	-	-
<i>Pohlia</i> sp.	1S	-	7S**	2S	5S	8S	4S
<i>Polytrichastrum alpinum</i>	-	-	-	-	3S	-	-
<i>P. sexangulare</i>	2S	-	2S	-	-	-	-
<i>Polytrichum juniperinum/strictum</i>	1S	-	-	-	-	-	-
<i>Polytrichum</i> sp.	3S	-	11S	-	-	1S	4S
<i>Polytrichum/Polytrichastrum</i> sp.	-	-	-	-	3S + 2L	-	5S
<i>Polytrichaceae</i> sp.	-	-	1S	-	-	2S	-
<i>Pseudocalliergon angustifolium</i>	-	-	-	-	-	-	1S
<i>P. turgescens</i>	-	-	-	-	5S	1S/B	7S
<i>Racomitrium canescens/panschii</i>	1S	-	-	-	3S	1S	4S/B
<i>Racomitrium</i> sp.	-	-	1S	-	1S	-	-
<i>Sanionia nivalis</i>	-	-	-	-	1S	-	-
<i>S. uncinata</i>	1S	-	4S	-	>10S	5S	3S
<i>Scorpidium cossoni</i>	-	-	1S	-	8S	-	4S
<i>S. scorpioides</i>	-	-	-	-	-	-	1S/B
<i>Sphagnum squarrosum/teres</i>	-	8B	-	-	-	-	-
<i>Timmia austriaca</i>	-	-	5S	-	-	-	-
<i>T. norvegica</i>	-	1S	1S	-	-	-	1S
<i>Timmia</i> sp.	-	-	-	-	1L	-	-
<i>Tomentypnum nitens</i>	1S/B	1S/B + >10L	2S	-	-	1S	-
<i>Warnstorfia sarmentosa</i>	-	-	-	-	-	1S	-
<i>W. tundrae</i>	-	-	-	-	1S	-	-
Indet.	-	1S + 1L	3S	1S	-	-	-
Indet. Amblystegiaceae	-	-	-	-	-	-	1S/B
Indet. acrocarp	-	-	-	-	-	-	8S
Indet. pleurocarp	1S/B	-	-	-	-	-	-

\*Of these, 18 and 5 shoots, respectively, were found in coherent tufts.

\*\*Of these, 5 shoots were found in one coherent tuft.

\*\*\*Calyptreae.

Table 3. AMS radiocarbon dates. For details of sediments and stratigraphy, see Möller et al. (1992, 1995).

Loc. No.	Sample No.	Altitude m. a.s.l.	Lab. No.	Age yrs BP <sup>1</sup>	Dated material
1806	87711	19.8	AAR-846	12470 ± 250	Plant remains
1806	87712 <sup>2</sup>	19.6	AAR-839	8960 ± 140	<i>Mya truncata</i>
1715	87721 <sup>3</sup>	32.6	AAR-842	9710 ± 160	<i>Mya truncata</i>
1804	88203	51.0	AAR-847	9965 ± 190	Plant remains
1811	86251	67.0	AAR-843	9475 ± 220	Plant remains <sup>4</sup>
2103	88651	50.8	AAR-834	8690 ± 250	Plant remains
1810	86266	52.0	AAR-844	8640 ± 170	Plant remains
2103	88655	47.1	AAR-833	8530 ± 190	Plant remains

<sup>1</sup>The dates have been corrected for isotopic fractionation by normalising to  $\delta^{13}\text{C} = -25\text{‰}$  PDB. Samples 87712, 87721, and 86251 have been corrected for a marine reservoir age by subtracting 440 years (Mangerud & Gulliksen 1975).

<sup>2</sup>Sample 87712 lies just below 87711.

<sup>3</sup>Sample 87721 lies just above 87728.

<sup>4</sup>Remains of marine plants.

are derived from interglacial sediments, in spite of the fact that they are well preserved. *Armeria* calyces are known from Last Interglacial deposits in central eastern Greenland (Böcher & Bennike 1991) and in northwestern Greenland (Bennike & Böcher 1992); in addition, there is an undated northern extralimital occurrence from the eastern part of northern Greenland (Bennike unpubl.). The *Taraxacum* achenes are another possible interglacial candidate since none of the other samples contained this taxon; but as the plant grows on Edgeøya today, the achenes may also be Holocene.

The rove beetle *Olophrum boreale* has been collected at Woodfjorden, northern Spitsbergen and on Bjørnøya (Fjellberg 1983) and may well be a member of the extant fauna of Edgeøya. It has also been recorded from Holocene lake sediments on Bjørnøya (Wohlfahrt et al. 1995). *Olophrum boreale* is a widely distributed northern Holarctic species although it has not been found in Greenland (Campbell 1983; Böcher 1988).

No limnic plants were found, but a few remains of the limnic animals *Lepidurus*, *Daphnia* and *Candona* indicate that ponds with mesotrophic waters existed in the area.

#### Bryophytes

Many of the bryophytes (Table 2) indicate calcium- or mineral-rich conditions. This is what would be expected in a periglacial environment or in an area where the ice has recently retreated (cf. Miller 1987), but the bedrock of the area probably also favours calciphiles.

Wetland species are often common in fossil bryophyte assemblages (e.g., Janssens 1983; Dickson 1973, 1986; Hedenäs 1992a; 1995) and in the present samples *Pseudocalliergon turgescens*, *Scorpidium cossioni* and *Tomentypnum nitens*, all occurring in mineral-rich to calcareous wetland habitats today, were frequent. Other species of more or less mineral-rich to calcareous wetlands include *Brachythecium turgidum*, *Calliergon* spp., *Campylium polygamum*, *Campylium* sp., *Scorpidium scorpioides*, *Warnstorfia tundrae* and *Pseudocalliergon angustifolium*. The last species was recently described (Hedenäs 1992b) and is known from only one extant Svalbard locality, on Bjørnøya (Frisvoll & Hedenäs unpubl.). In the Scandinavian mountain range it occurs mainly in moderate late snow beds in calcareous areas, but it occurs also in calcareous fens in the northern boreal zone in Finland. This species is otherwise known from Iceland, northern North America and the Chukotskiy Polustrov in easternmost Russia (Hedenäs unpubl.). *Aulacomnium turgidum* and *A. palustre* are also found in wetlands or on wet heaths, but these species are also found in intermediate (*A. turgidum*) or mineral-poor habitats (*A. palustre*). Spring-influence or moving water is indicated by *Paludella squarrosa*, *Philonotis* sp., *Pohlia wahlenbergii* and *Warnstorfia sarmentosa*. All these taxa are found in intermediate to rather mineral-poor places. Finally, some of the taxa found indicate probable nutrient enrichment (N- and P- compounds), namely *Calliergon* s. str. spp. (i.e., excluding *Pseudocalliergon trifarium*, *Warnstorfia sarmentosa*, *Straminergon stramineum*), *Campylium polyga-*

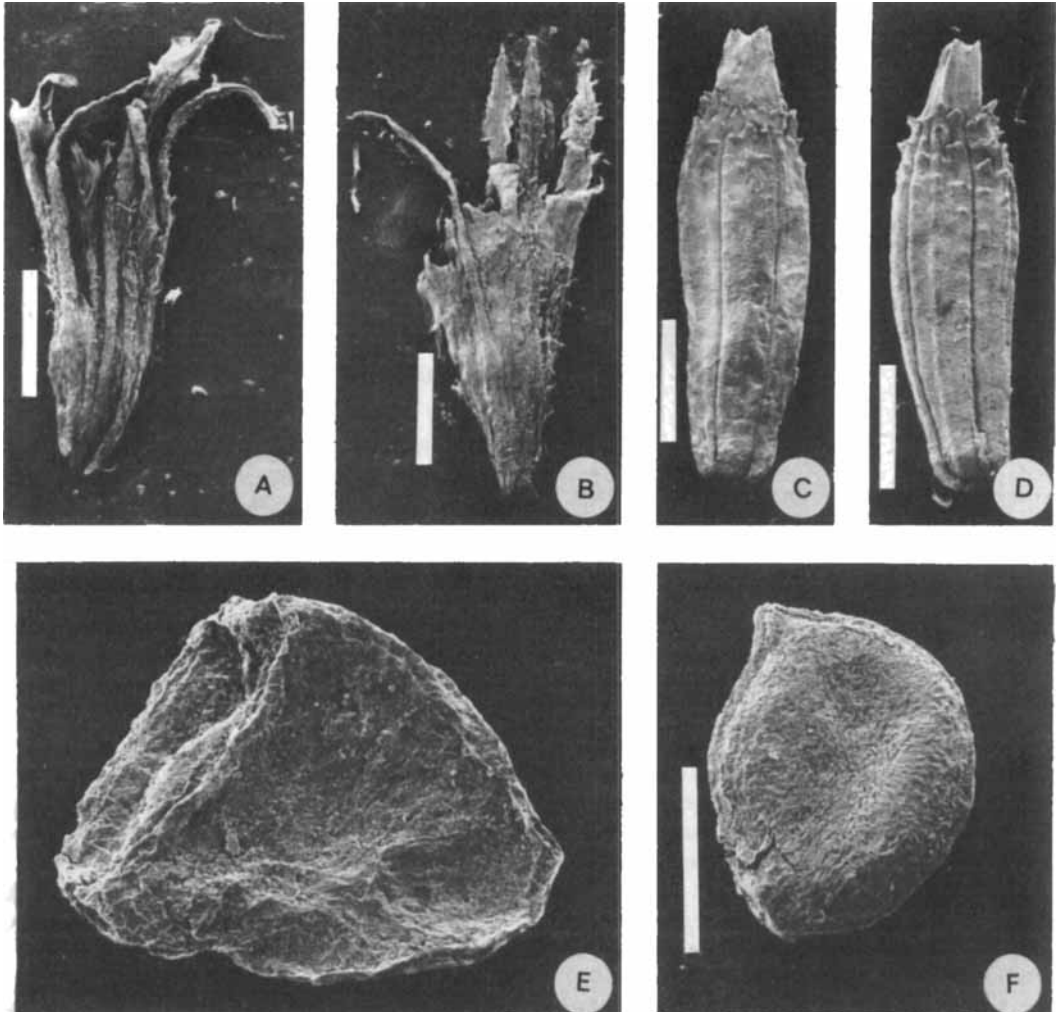


Fig. 2. SEM photographs of selected vascular plant macrofossils from Edgeøya. A–B. *Armeria scabra* calyces. C–D. *Taraxacum brachyceras* achenes. E. *Melandrium apetalum* seed. F. *Ranunculus sulphureus* achene. The figured specimens (MGUH 21272–21677) are deposited in the type collection of the Geological Museum, Copenhagen. Scale bars = 1 mm.

*mum*, *Drepanocladus* s. str. sp., *Sphagnum squarrosum/teres* and *Warnstorfia tundrae* (based on Kooijman 1993, van Wirdum 1991, Hedenäs & Kooijman unpubl. data, and own (Hedenäs) extensive field-work in Northern Europe).

Many of the terrestrial taxa are found today in more or less open (i.e., with sparse cover of vascular plants) and unstable environments. Examples include *Ceratodon purpureus*, *Pogonatum dentatum*, *P. urnigerum*, *Polytrichastrum alpinum*, *P. sexangulare* (often in late snow beds) and *Racomitrium canescens/panschii*. These taxa

are either indifferent as regards the mineral content, or occur in relatively mineral-poor habitats, whereas *Dichodontium pellucidum* and *Timmia norvegica* indicate somewhat richer and wetter environments. *Brachythecium coruscum*, *Bryoerythrophyllum recurvirostrum*, *Distichium* sp., *Ditrichum flexicaule*, *Encalypta* spp., *Isopterygiopsis pulchella* and *Timmia austriaca* all indicate mineral-rich habitats and can be found both on somewhat disturbed soil (often in crevices or when the soil surface is uneven) and in rock crevices in both dry and wetter situations.

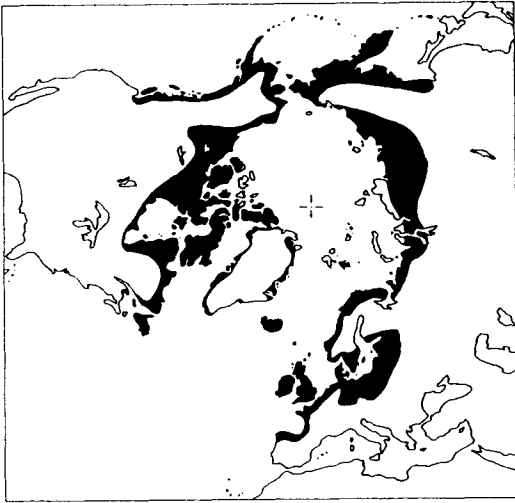


Fig. 3. Circumpolar map showing the modern geographical range of northern *Armeria* taxa (*Armeria arctica*, *A. scabra*, *A. labradorica*, *A. sibirica*, *A. maritima*), based on Hiltén & Fries (1986). The arrow indicates the fossil locality.

*Sanionia uncinata* occurs in a wide range of habitats in northern and arctic areas. On the other hand, *S. nivalis* is a species of extreme late snow-bed habitats or it may also grow along meltwater brooks from large late snow beds and glaciers. In Europe, this species is at present known from northern mountainous areas, where it is found mainly in the middle and high alpine regions and in the Arctic, including Svalbard (Hedenäs 1989). It is now also known from three northern North American and Greenland localities (Hedenäs unpubl.), but since the species was described rather recently (Hedenäs 1989), and since it seems to be common in its northern European distribution area, one would suspect that it is widely distributed in the Arctic.

The find of *Amblystegium* subg. *Hygroamblystegium* is interesting. The shoot resembles *Amblystegium fluviatile*, a species that is not very likely to be found in arctic areas. However, since the material does not permit identification to the species level, inferences regarding the habitat should not be made from this find. This shoot may derive from interglacial deposits.

Taken together, the bryophytes found indicate mineral-rich environments, with a well-developed wetland flora. The wetlands were probably surrounded by somewhat unstable dry ground, where

large areas had a rather sparse cover of vascular plants. The upland plants may also (partly) reflect the environmental conditions some distance away from the wetlands. Possible means of transport include flowing water and wind. The assemblage is similar to what can be found in Svalbard (Kuc 1963; Philippi 1973; Elvebakk 1982) or at high altitudes on mineral-rich Scandinavian mountains today, and indicates that the climate was probably similar to that in these environments today.

## Conclusions

Many of the plant and animal taxa reported are new to the fossil flora and fauna of Svalbard, but this mostly reflects the few studies of Quaternary macroscopical terrestrial plant and animal remains that have been carried out. In addition, nearly all records are the oldest known from Svalbard.

One of the results of this study is the possibility of finding interglacial plant remains on north-western Edgeøya, certainly not the most promising area of Svalbard to search for such remains considering that pre-Holocene Quaternary deposits are almost unknown from this island (Landvik et al. 1995). The data also show that the present flora, and the range of habitats and plant communities of Svalbard, were already well established in the earliest Holocene. We are inclined to follow Nathorst's view that only few vascular plants survived the Weichselian glacial maximum on Svalbard because most lowland areas were glaciated (Mangerud et al. 1992) and because the climate was colder than at present. If this is the case, the major part of the flora must have immigrated in the latest part of the Weichselian. Many radiocarbon dates between 13 and 10 ka from western Spitsbergen show that some areas were deglaciated by then (Mangrud et al. 1992). Deglaciation of lowland areas on Edgeøya began about 10.3 ka BP (Landvik et al. 1995). It should also be pointed out that virtually no clear endemic species occur on Svalbard, a fact which also testifies to the young age of the flora.

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