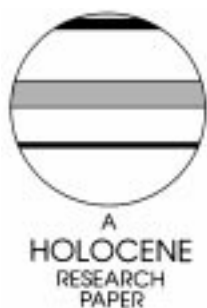


# Lateglacial and early-Holocene environments of Novaya Zemlya and the Kara Sea Region of the Russian Arctic

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**Abstract:** Pollen and radiocarbon data from Novaya Zemlya and the Kara Sea Region suggest that the hypothetical Panarctic Ice Sheet (Denton and Hughes, 1981) never existed in this area, at least during the last 16 000 years. Lateglacial tundra environments were slightly cooler and drier than the present ones, but there were also warmer intervals such as the Allerød, which were rather favourable for vegetation development. Better conditions existed during the early Holocene, when warm Atlantic air masses and sea currents gradually penetrated eastwards to the Kara Region.

**Key words:** Lateglacial, early Holocene, pollen analysis, radiocarbon dating, Panarctic Ice Sheet, Novaya Zemlya, Kara Sea, Russian Arctic.

## Introduction

The Quaternary evolution of northernmost Russia has been a subject of continuous debates, mostly due to the lack of empirical data. The speculative hypothesis that a huge Panarctic Ice Sheet (Denton and Hughes, 1981) covered this area for much of the late Quaternary has haunted studies of northern high latitudes for far too long and hindered scientific progress. Pollen and radiocarbon data recently obtained from several sites in the polar islands and mainland coastal areas (Figure 1) present a more realistic view of past environments in the Russian Arctic during the last 16 000 years.

The subdivision of high-latitude vegetation is given here according to the Russian traditional scheme (Isachenko and Shlyapnikov, 1989). The vegetation of polar deserts is sparse and consists of lichens, mosses and some vascular plants (Cyperaceae, Poaceae, herbs – up to 50–60 species in total). As one moves southwards, the vegetation cover becomes denser and more differentiated; the number of species of vascular plants attains 150–180 in Arctic tundra, and dwarf shrubs occur almost everywhere. Typical tundra is a realm of treeless assemblages with herbs, Poaceae, Cyperaceae and dwarf shrubs (*Salix*, *Betula*). The moss flora is enriched by several *Sphagnum* species. Southern tundra is characterized by an increased role of shrubs. This simplified division is rather clearly reflected in modern pollen rain and fossil spectra. Problems of correlation between modern plant cover and

pollen spectra in such polar archipelago as Sptisbergen (Svalbard) have been treated in other papers (Serebryanny *et al.*, 1985; 1993).

## Novaya Zemlya

Novaya Zemlya is a large polar archipelago that today is occupied by mountains, glaciers and ice caps. Northern coastlands and higher elevations (above 200–250 m) are polar deserts, whereas other areas support Arctic tundra. The only exception is typical tundra at the extreme southwest portion of the archipelago.

Extensive solifluction flows are common on the mountain slopes and coastal cliffs of Novaya Zemlya. Terrace units are often buried and therefore not distinguishable. Nevertheless, organic layers, mostly peat lenses, were identified *in situ* in some localities during geological surveys. One of these sections is located near Cape Nikolayevsky in the northern part of Gusinaya Zemlya – ‘goose land’ (72°10’N, 52°16’E, 1.3 m a.s.l.), a large peninsula in the southwest of the Southern Island. Two peat layers were exposed in lacustrine deposits with the lower peat being dated to 15 310 ± 610 yr BP (LU-1187).

Pollen spectra of this section (Figure 2) contain numerous grains of Cyperaceae, Poaceae and other herbaceous plants, including such relatively thermophilous species as *Rubus chamaemorus*, *Polemonium boreale*, *Valeriana capitata* and *Polygonum viviparum*. Dwarf birch (*Betula nana*) pollen attains 28%. Bryales spores are abundant (up to 35%). Single Ericales grains and a

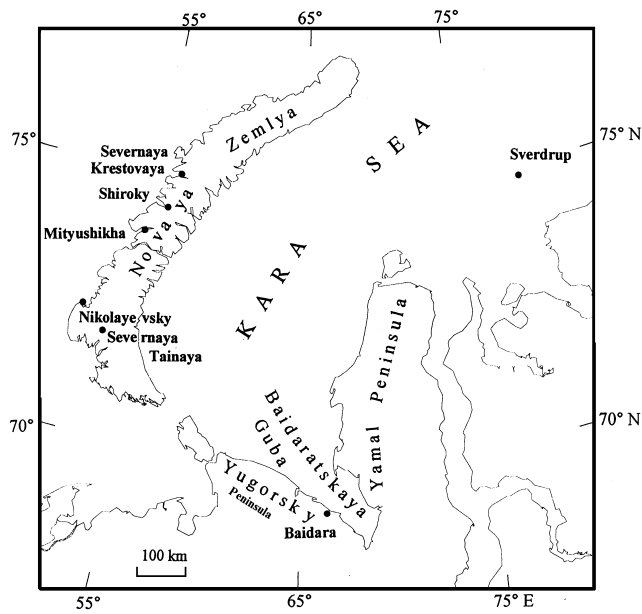
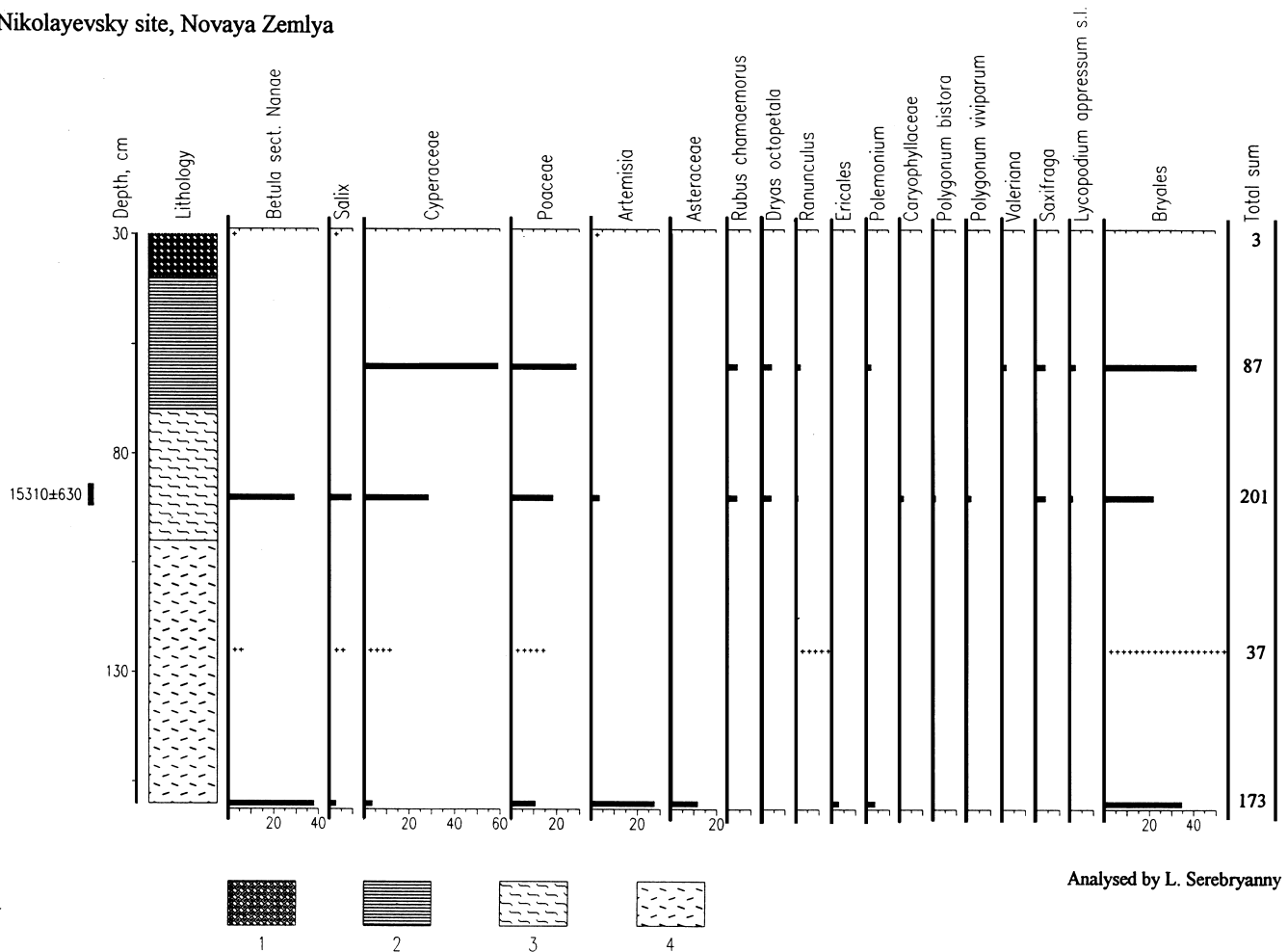


Figure 1 Location map of the area in study.

considerable amount of wormwood (*Artemisia*) pollen were found in the lowermost part of the section. These spectra are similar to subfossil spectra of typical tundra. It is remarkable that the present flora of Gusinaya Zemlya has a great abundance and diversity of flowering plants as compared to other regions of Southern Island (Yuriev, 1926). *Betula nana* grows commonly in this region now.

Nikolayevsky site, Novaya Zemlya



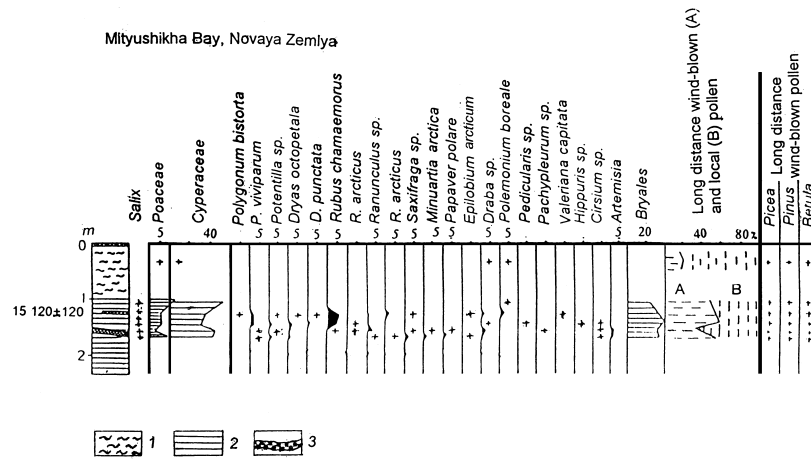
Analysed by L. Serebryanny

Figure 2 Pollen diagram of organogenic and littoral deposits near Nikolayevsky Cape, Gusinaya Zemlya, Southern Island of Novaya Zemlya. Pollen values are expressed as percentages of total pollen. (1) Gravelly loam; (2) clay; (3) highly mineralized peat; (4) sandy loam.

Similar information was obtained from a buried peat exposed along the coast of Mityushikha Bay (73°40'N, 54°48'E, 65 m a.s.l.). A single radiocarbon date of 15 120 ± 120 yr BP (LU-1446) was obtained. Here we found an assemblage dominated by Cyperaceae and Poaceae pollen and spores of Bryales (Figure 3). The floristic composition of nonarborescent pollen was very diverse: in addition to pure periglacial taxa (*Ranunculus arcticus*, *Dryas octopetala*, *D. punctata*, *Minuartia arctica*, *Epilobium arcticum* and others) pollen from more thermophilous plants (*Rubus chamaemorus*, *Polemonium boreale*, *Valeriana capitata*, *Polygonum viviparum*) was also present. The considerable admixture of long-distance wind-blown pollen (*Pinus*, *Picea*, *Betula*) indicates the northward migration of tree limit on the mainland. In all samples, single *Salix* pollen grains were identified. Dwarf *Salix*-herbaceous communities evidently characterized the coastal region, not far from the modern glacial limits, c. 15 000 yr BP.

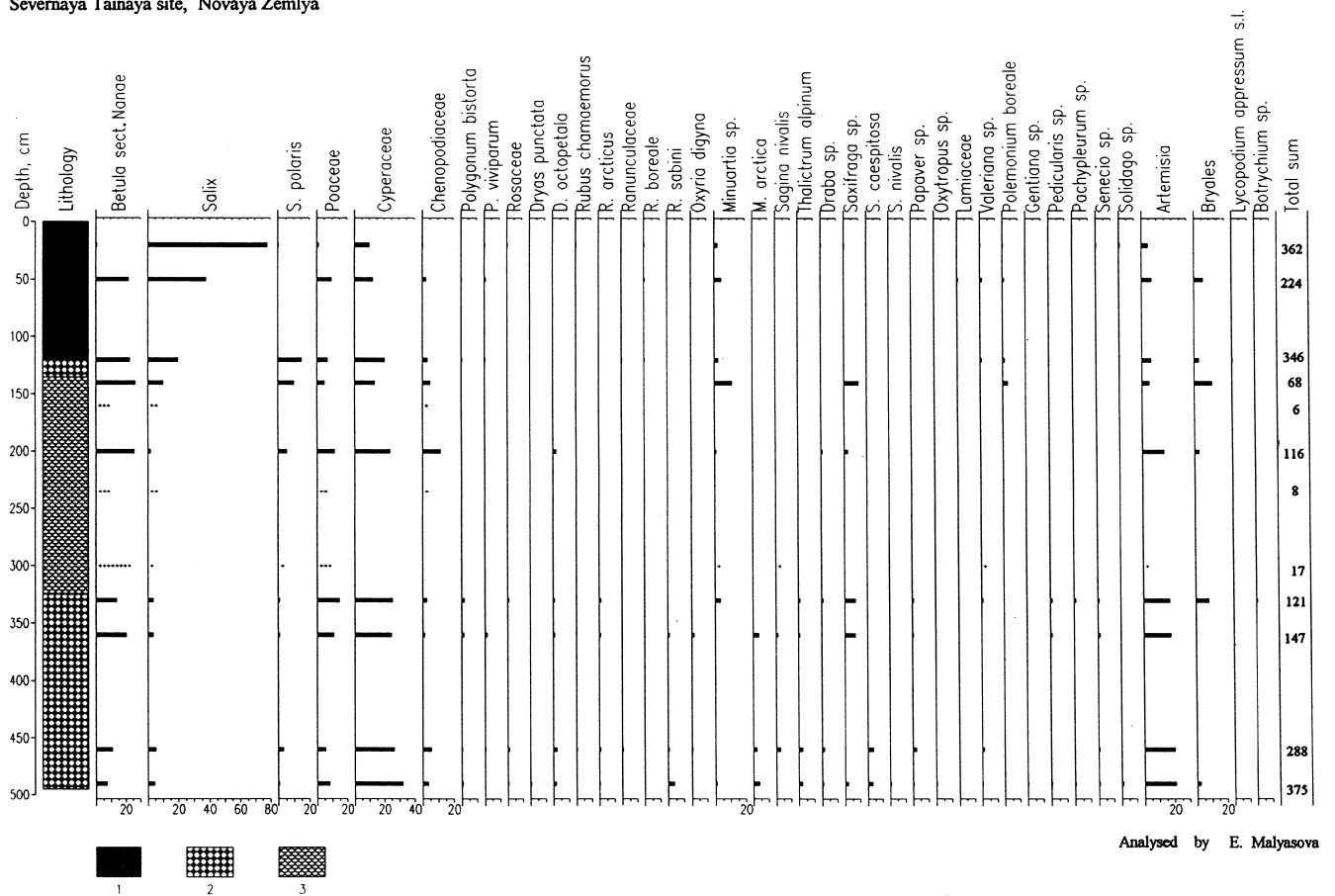
Nonglacial conditions existed in some inner areas of Novaya Zemlya as well. For example, in the Severnaya Tainaya River valley, Southern Island (site 3031, 71°46'N, 53°10'E), a peat horizon 2.2 m thick was found and investigated 22 km from the present-day sea coast. The basal gyttja is characterized by abundant pollen of Cyperaceae and herbs (Figure 4). Poaceae pollen is less abundant than in the above mentioned sites. However, this assemblage is typical of periglacial environments and therefore likely dates to glacial times.

The topmost peat layer was deposited during the Holocene. This pollen assemblage contains pollen of dwarf *Betula* (21%), *Salix*, including *S. polaris*, Cyperaceae (up to 20%) and Bryales spores. The herbaceous pollen is represented only by single



**Figure 3** Pollen diagram of organogenic deposits at the coast of Mityushikha Bay, Northern Island of Novaya Zemlya (Malyasova and Serebryanny, 1993). Pollen values are expressed as percentages of total pollen. (1) Loam; (2) clay; (3) peat.

**Severnaya Tainaya site, Novaya Zemlya**



**Figure 4** Pollen diagram of organogenic and littoral deposits in the valley of Severnaya Tainaya River, Southern Island of Novaya Zemlya. Pollen values are expressed as percentages of total pollen. (1) Peat; (2) sandy gyttja; (3) gravelly gyttja.

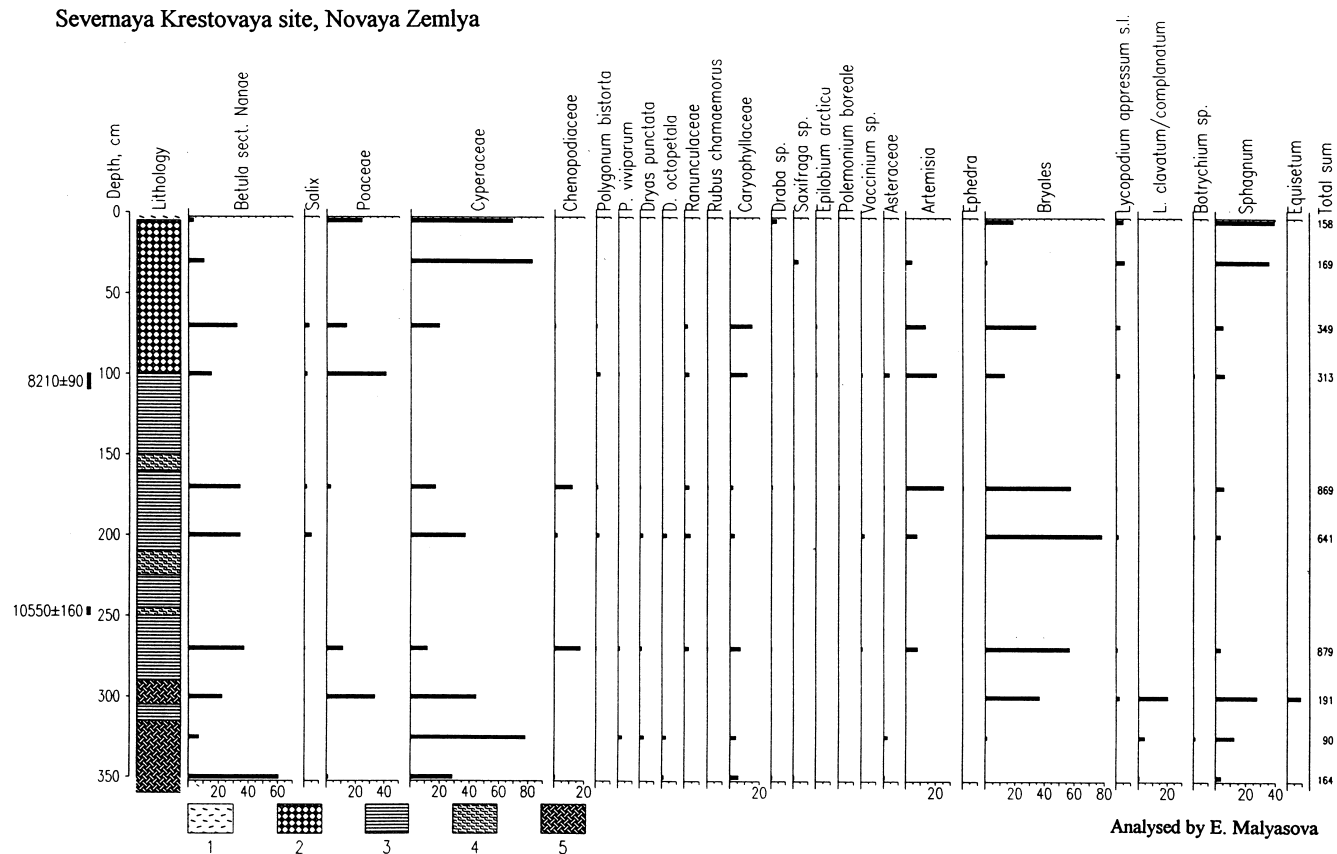
grains, which belong to mainly Arctic plants, such as *Polygonum viviparum*, *Ranunculus boreale*, *Minuartia* sp., *Saxifraga* sp. and *Polemonium boreale*. We suppose an early-Holocene age of these sediments due to their similarity with the basal layers of radiocarbon dated site 2573.

This site (2573), located in the valley of Severnaya Krestovaya River, Northern Island (74°08'N, 56°30'E), contains valuable information about early-Holocene palaeoenvironments in Novaya Zemlya. Silt with occasional pebbles and marine shells was exposed above basal gravel and sand and covered by peat layers with clay and loam, about 1.6 m thick. A considerable amount of pollen and spores was identified in the peat samples. Extremely

abundant Bryales spores are a typical feature of this section (Figure 5).

Dwarf *Betula* pollen is rather abundant in almost all the spectra (12–19%) and in the lowest one even up to 58%. The palynoflora of the lower peat samples represents a wide range of environments. Besides the Hypoarctic species *Betula nana*, other taxa groups, including Boreal (*Vaccinium* sp.) and Arctic (*Dryas octopetala*, *Rumex arcticus*, *Draba incana*) were identified here. The finds of Chenopodiaceae and *Artemisia* pollen indicates the occurrence of dry and coastal biotopes. A radiocarbon age of 10 550 ± 160 yr BP (LU-1466) suggests that these sediments are of Younger Dryas age.

## Severnaya Krestovaya site, Novaya Zemlya



**Figure 5** Pollen diagram of organogenic and littoral deposits in the valley of Severnaya Krestovaya River, Northern Island of Novaya Zemlya. Pollen values are expressed as percentages of total pollen. (1) Gravelly loam; (2) peat; (3) silt; (4) loam; (5) clay.

The middle peat layers contain pollen of different taxa: steppic (*Ephedra*, some *Chenopodiaceae* and *Artemisia*), Boreal (*Polygonum bistorta*), Hypoarctic (*Betula nana*, *Rubus chamaemorus*) and Arctic (*Draba incana*, *Saxifraga* sp., *Polemonium* sp.). These taxa suggest a possible correlation with sediments dated to the Preboreal period on the Kola Peninsula–White Sea Region (Malyasova, 1976).

The upper peat contains more *Cyperaceae*, *Poaceae* and *Artemisia* pollen than is typical for early-Holocene pollen assemblages from northeast Europe/northwest Asia. At the same time, quantity of long distance *Pinus* pollen suggests a considerable northward migration of trees on the mainland. A radiocarbon age of  $8210 \pm 90$  yr BP (LU-1462) indicates that deposition took place during the Boreal period.

A 4.5 m exposure of silts and clays covered by till is located near the margin of Shiroky Glacier at the coast of Mashigina Guba, Northern Island ( $55\text{--}60$  m above sea level,  $74^\circ 45'N$ ,  $55^\circ 10'E$ ). Wood fragments found in the uppermost part of this sequence are dated to  $8160 \pm 70$  yr BP (LU-1761). According to the pollen data (Figure 6), this time was characterized by high percentages of *Cyperaceae* pollen and *Bryales* spores, but pollen of *Betula nana*, *Salix*, *Poaceae* and *Caryophyllaceae* occurs in significant amounts. These spectra indicate that at least a typical tundra grew at the central western coast of Northern Island.

A till which overlies this silt was perhaps formed during a sudden, surge-like advance of Shiroky Glacier (there are morphological indications of several stages in this catastrophic process). Pollen of *Pinus* and *Betula* was found in six samples from the till section. Pollen spectra from the Vavilov Ice Cap, October Revolution Island, Severnaya Zemlya, also contain grains of *Pinus* and *Betula* as well as *Alnus* and *Corylus*. A. Andreev who analysed these samples supposes that such results are rather typical for recent spectra from the Kara Sea Region. Probably, the surge of Shiroky Glacier was very young.

In summary, Lateglacial and early-Holocene dwarf-shrub communities with abundant herbs and *Bryales* were distributed widely in the southern part of the archipelago. It was a typical tundra, although some floristic elements persisted from the full glacial. *Salix* and *Betula* were the dominant dwarf shrubs. At the same time, Arctic herbaceous-moss tundra was common in the northern regions of the archipelago. We hypothesize that the Lateglacial/Holocene transition was marked by a rather mild climate which was very favourable for vegetation development in high-latitude regions of Europe.

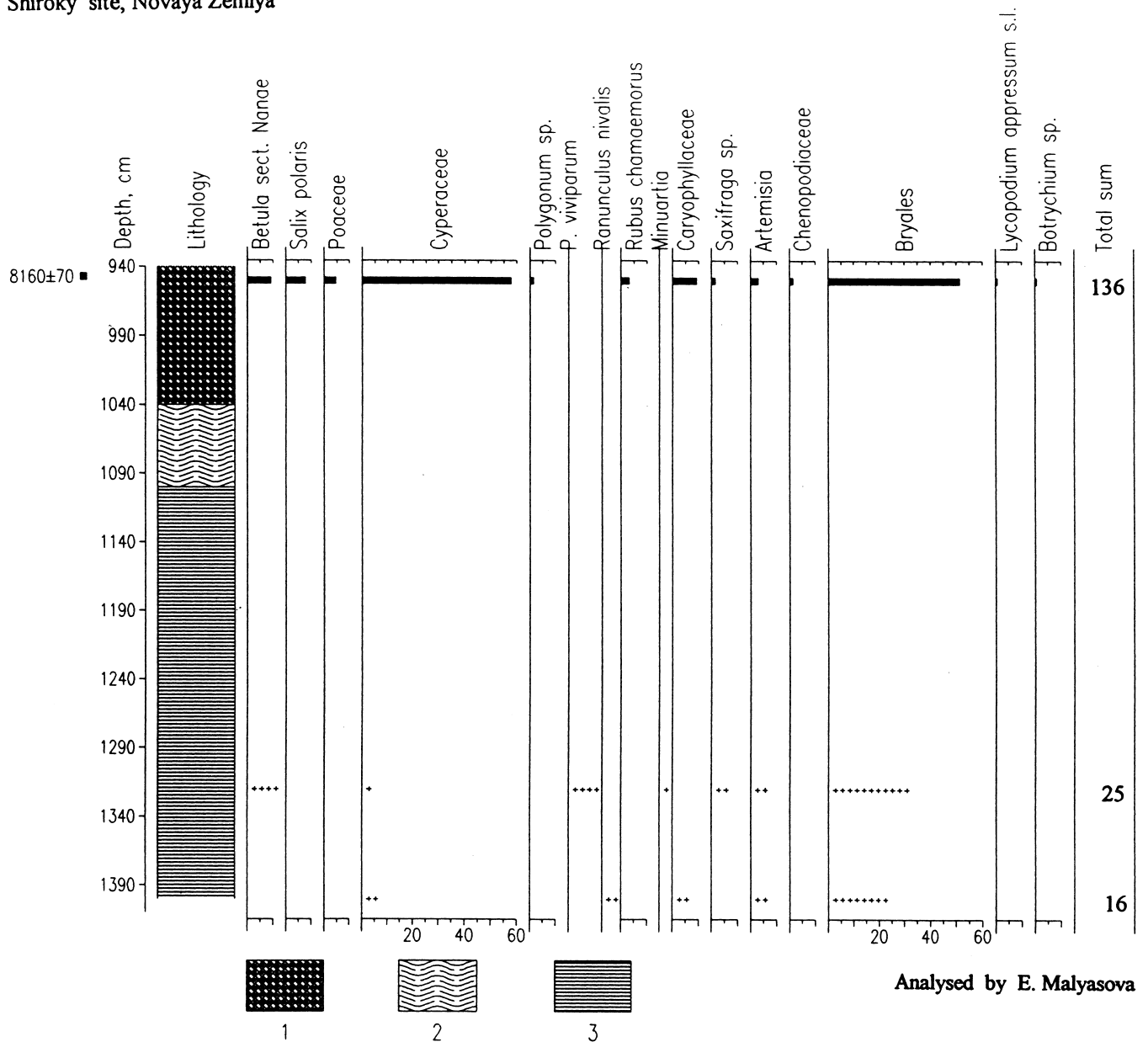
### Sverdrup Island, Kara Sea

Sverdrup Island ( $74^\circ 30'N$ ,  $79^\circ 30'E$ ) is located on the Kara Sea Shelf, 110 km from the mainland. It has area of  $70 \text{ km}^2$ , comprised mostly of sand spits with elevations to 2 m a.s.l. The highest point (33 m) is in the central part of the island. This surface consists of Quaternary terraces of gravels, sands and loams. Harsh climate limits vegetation growth and the island is dominated by polar deserts.

A buried peat horizon is exposed in the northern part of the island, 7–8 m a.s.l. and 6 m from the sea. It contains high concentrations of pollen in contrast to the over- and underlying sand layers where only very few pollen grains occur. The basal sands include ice veins that contain redeposited Mesozoic spores. These ice veins probably developed during the last ice age, when permafrost and aeolian processes were active on the dried Kara Sea shelves.

The bottom of the peat layer, 0.8–0.9 m, was radiocarbon dated to  $11\,640 \pm 40$  yr BP (GIN-7625). Therefore, the accumulation of *Cyperaceae* peat began during the Allerød. The composition of palynospectra (Figure 7) suggests the presence of typical tundra communities with *Poaceae*, *Cyperaceae*, *Salix*, *Ranunculaceae*, *Rosaceae*, *Polygonum*, *Valeriana*, *Caryophyllaceae* and *Bryales*.

## Shiroky site, Novaya Zemlya



**Figure 6** Pollen diagram of proglacial lacustrine deposits near Shiroky Glacier, Mashigina Guba, Northern Island of Novaya Zemlya. Pollen values are expressed as percentages of total pollen. (1) Silt with wood fragments; (2) loam; (3) clay.

Steppe-like associations indicated by *Artemisia*, *Chenopodiaceae* and *Asteraceae* also existed in some drier localities.

The Younger Dryas cooling is reflected in the increased share of *Artemisia*, *Chenopodiaceae* and *Salix* pollen and *Bryales* spores simultaneously. Peat from 0.55–0.65 m depth was radiocarbon dated to  $10\,490 \pm 380$  yr BP (GIN-7626). The greater admixture of *Artemisia* and *Chenopodiaceae* pollen indicates that the climate was much drier. Finds of pollen grains of *Salix* and *Betula* of the *Nanae* section as well as macrofossil remains of *Betula* indicate the importance of these shrubs on the landscape. The climate became less wet than in the Allerød. A cold and dry climate is confirmed also by the occurrence of pollen of *Betula* of the *Albae* section.

The early Preboreal warming was marked by a sudden change in the pollen spectra: pollen of trees and shrubs became dominant and pollen of *Artemisia* and *Chenopodiaceae* disappeared. Macroscopic remains of *Betula* are absent: probably the increased water-logging caused the decay of shrub coenoses on the swamp surface. Radiocarbon dating of the upper peat sample at  $9770 \pm 280$  yr BP (GIN-7627) as well as the above-mentioned dating of the lower

peat sample (GIN-7626) indicates the beginning of this warm interval.

The early Preboreal vegetation on Sverdrup Island area probably approximated modern southern tundra. Dwarf *Betula*, *Ericales* and even probably *Alnus fruticosa* were growing there in contrast to the present situation. Abundant pollen of arboreal *Betula* was totally long transported, and the tree-line may have occupied a more northerly position on the mainland in the early Preboreal than nowadays.

Climate was more favourable to plant growth compared to the above mentioned Novaya Zemlya conditions. Evidently, this climate amelioration was connected with the general sea-level rise and the penetration of Atlantic air masses and sea currents eastward to the Barents and Kara seas.

### Western coast of Baidaratskaya Guba, Yugorsky Peninsula

This coastland consists of five terraces uplifted to 0.5–2.5 m (laida), 4–8 m (1st level), 10–18 m (2nd level), 25–40 m (3rd level)

## Sverdrup Island site, Kara Sea

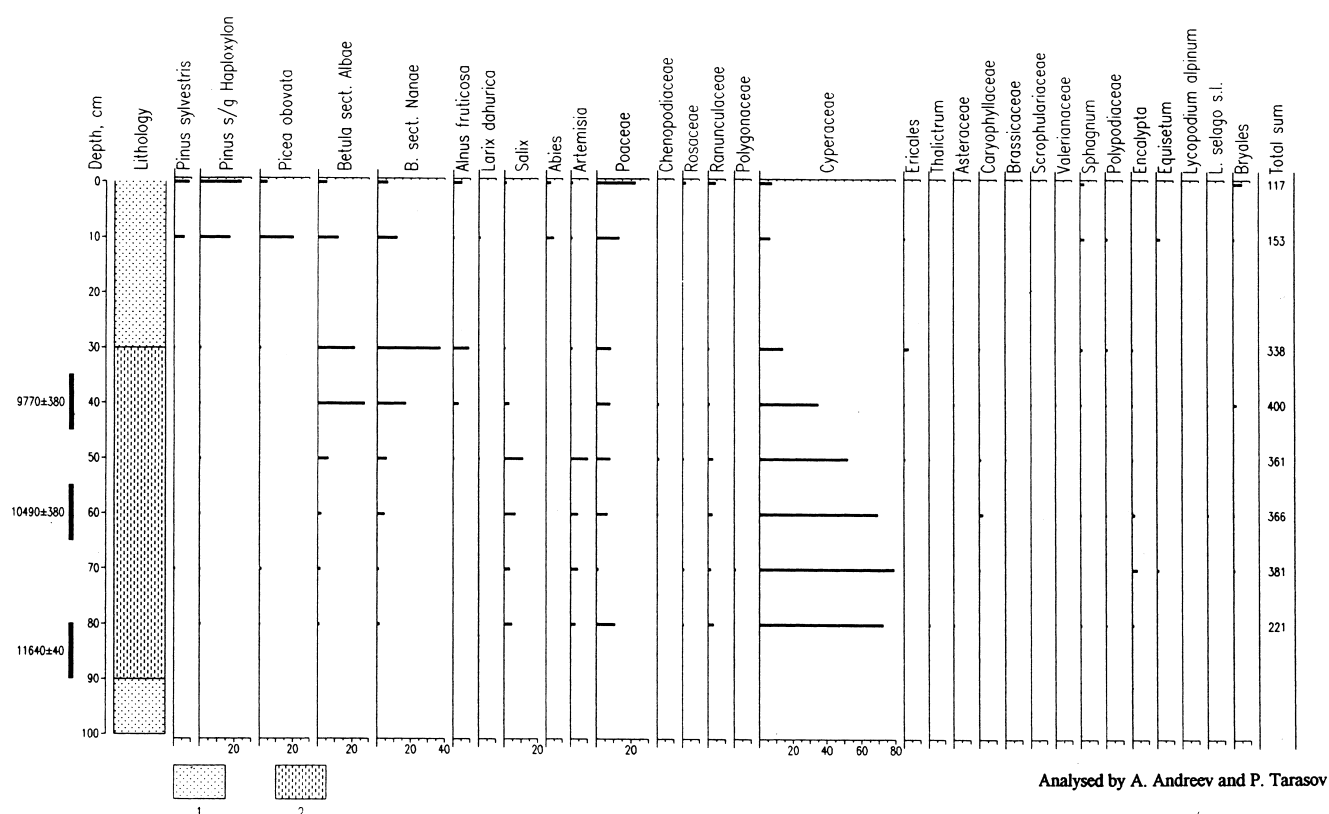


Figure 7 Pollen diagram of organogenic deposits in the Sverdrup Island. Pollen values are expressed as percentages of total pollen. (1) Sand; (2) peat.

and 45–65 m (4th level). The three lower terraces have a marine origin and developed during the Holocene. The relief of the third terrace is closely connected with permafrost: underground ice horizons and veins influence the character of the surface.

A peat horizon was exposed in the 3rd level terrace near Yary (69°00'N, 66°40'E). It overlies grey fine-grained sands with gravels. Diatom analyses of these sediments (by Z.V. Aleshinskaya) confirm their alluvial character. Pollen spectra of these deposits (depth 6.2–10.3 m) contain considerable amounts of redeposited pollen of *Abies*, *Picea*, *Pinus* subgenus *Haploxyloyn*, *P.* subgenus *Diploxyloyn*, *Tilia*, *Corylus* and *Juglans*. Similar spectra were assigned to the Mikulino (Riss-Wurm) Interglacial in the Pai-Khoi Range (Duryagina and Konovalenko, 1993), but some grains (*Juglans*) have a definite pre-Quaternary origin. The pollen of *Betula nana*, *Artemisia*, *Poaceae*, *Ericales* and other taxa do not occur frequently. Probably during the time of sedimentation there was an open landscape of polar deserts with very meagre and sparse vegetation in the area under study.

The middle part of this section (4.2–6.2 m) contains more fine-grained sediments (silts and clays with ice particles) which accumulated in shallow oxbows. The amount of exotic grains from *Alnus fruticosa* and *Betula* sect. *Albae*, and *Lycopodium alpinum* spores was considerable, but the occurrence of redeposited pollen and spores was less frequent. The deposition rates became relatively low when the nearby vegetation produced enough pollen and spores to dominate in spectra.

Palynological data (Figure 8) indicate that sparse *Betula* tree stands grew at the western coast of Baidaratskaya Guba. The presence of *Alnus fruticosa* and *Betula nana* as well as *Lycopodium alpinum* was considerable. The vegetation very much resembled the present forest-tundra with a dense lichen cover. The Late Pleistocene age of sediments is confirmed by radiocarbon dating. The upper layer of the section was covered by loamy and silty lenses enriched by wood remains, stumps and twigs, 4–6 cm in diameter.

One such enrolled branch of *Alnus fruticosa*, 6 cm in diameter, was radiocarbon dated at 10 900 ± 120 yr BP (MGU-1362). Sedimentation in an oxbow deposit took place in the Allerød and finished at the beginning of Younger Dryas.

The overlying peat consists of a series of lenses, each one up to several tens of metres in length and up to 4 m thick. Samples for pollen analysis were taken from the thickest lens. Radiocarbon datings of peat from the depth 4.10–4.15 m – 8000 ± 125 yr BP (WAT-2924) – and from the depth 3.70–3.85 m – 8210 ± 110 (GIN-7862a), 8120 ± 90 (GIN-7862b) and 8090 ± 40 yr BP (GIN-7862c) – indicate that peat accumulation began about 8000–8200 yr BP.

The results of the radiocarbon dating indicate a considerable break in sedimentation between 11 000 and 8000–8200 yr BP. Perhaps deposits did not accumulate since the Younger Dryas because of changes in the fluvial regime. Furthermore, climate perhaps was not favourable for peat growth during the Preboreal and early Boreal. The situation changed in the late Boreal and Atlantic, when the climate warmed and the processes of peat accumulation increased. This new stage was marked by forest-tundra development, but with less *Alnus fruticosa* followed by its almost complete disappearance around 7700 yr BP. *Cyperaceae* peat was deposited in the very humid environments of the thermal maximum.

## Conclusion

In the light of the available pollen and radiocarbon data it is possible to reconstruct the Lateglacial and early-Holocene environments in the western part of the Russian Arctic. There is no evidence that huge ice sheets existed there, but certainly the ice cap of Novaya Zemlya could have been slightly more extensive than today (Pavlidis, 1992). Nevertheless the present western

Baidara site, Yugorsky Peninsula

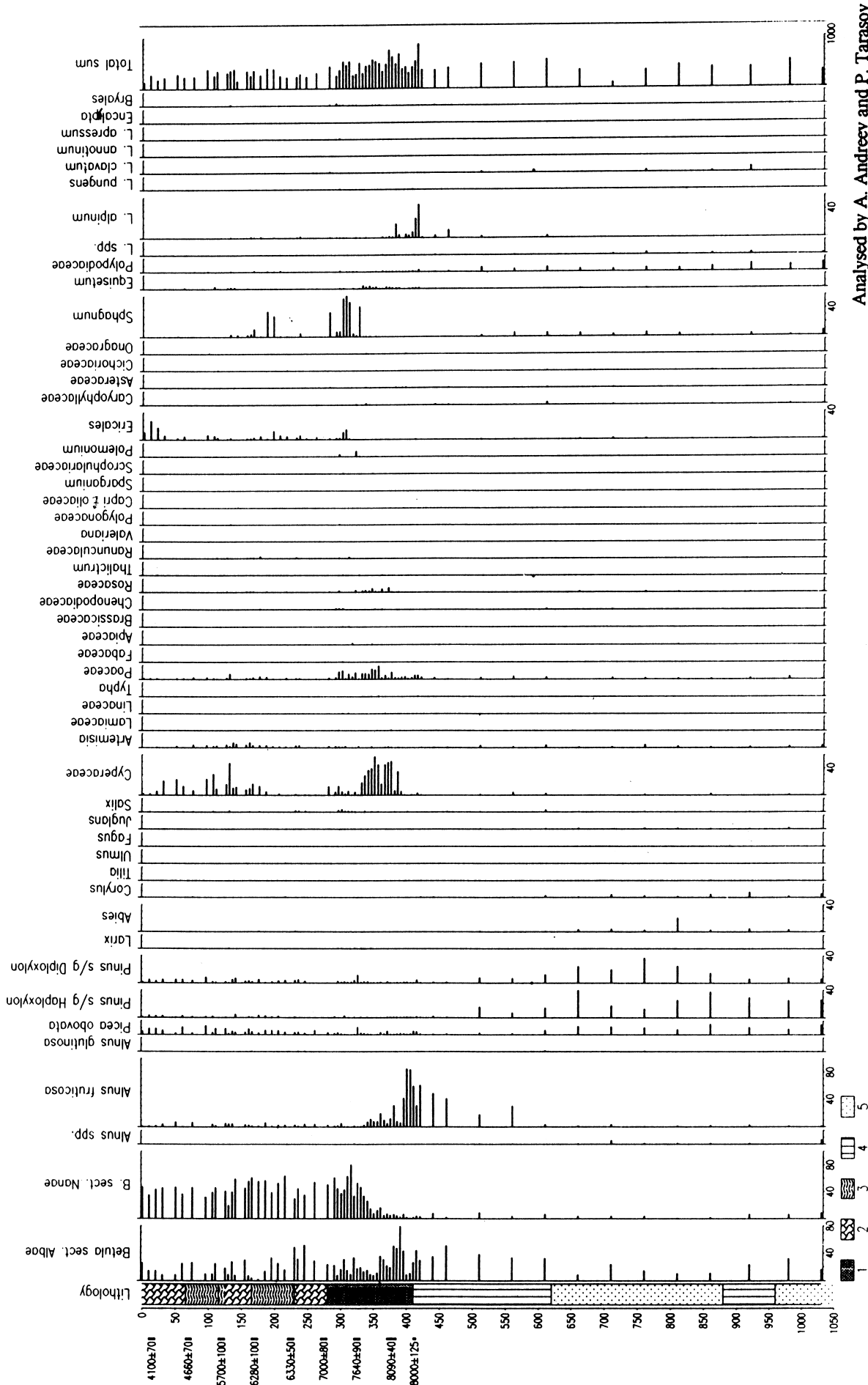


Figure 8 Pollen diagram of organogenic and river deposits at the western coast of Baidaratskaya Guba. Pollen values are expressed as percentages of total pollen. (1) Peat; (2) silt; (3) silty peat; (4) silty clay; (5) sand.

coastlands of this archipelago were ice-free and tundra communities with *Betula nana* grew in at least two areas under study 15 000–16 000 yrs BP. The Kara Sea shelf and southern coast lands were also ice-free and modified by intensive permafrost processes and erosion which caused the washing out of older pre-Quaternary layers.

The Lateglacial *sensu stricto* (13 000–10 300 yrs BP) was marked by the appearance of forest-tundra along the southern coast of Baidaratskaya Guba and tundra in Sverdrup Island. The large areas of the Kara Sea Shelf still had subaerial regime and were influenced by periglacial processes. Typical tundra existed even at the western coastlands of Novaya Zemlya in the Allerød.

We note the signs of a prominent climate amelioration in all the region under study during the early Holocene. Dwarf-shrub communities with abundant herbs and Bryales were distributed widely in Novaya Zemlya and the Kara Sea Shelf following the general rise in sea level. The early-Holocene thermal maximum was marked also in other high Arctic regions (Kaplina and Lozhkin, 1982; Ritchie *et al.*, 1983; Makeev and Ponomareva, 1988; Clague and Matthews, 1989; Nikolayev and Kolokolov, 1992; Ukraintseva, 1992).

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