QUATERNARY PALYNOSTRATIGRAPHY OF THE PECHORA SEA

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Abstract

By combining the lithologic, original palynologic and published micropaleonthological data we reconstructed paleogeographical events on the Pechora shelf during the Younger Dryas and Holocene time. Our paleoenvironmental reconstructions are based on the regularities in formation of pollen-and-spores assemblages in the surface sediments of the Pechora Sea. The main stages in paleogeography of the Pechora Sea during the Late Pleistocene were emphasized. The Late Valdai sediments in the Pechora Sea region were accumulated under the influence of fluvioglacial flows probably from the melting ice cap on Kolguev Island and, also, coastal glaciers. Climate deterioration considerably changed coastal vegetation as reflected in the depleted taxonomic and quantitative composition of palynospectra. The pollen data suggest that open steppe-like plant communities with *Artemisia, Poaceae, Asteraceae* and *Caryophyllaceae* dominated dry ecotopes on watersheds, whereas tundra-like communities with *Betula nana*, arctic *Salix, Dryas, Saxifraga, Carex* and *Brassicaceae* were common in more humid coastal lowlands.
The overlying silts and loamy sands are believed to have been accumulated during early deglaciation, i.e., Older Dryas and Alleröd. During this phase the glacial sedimentation was rather rapidly replaced by a glaciomarine deposition. Progressive climate warming caused prominent changes in coastal vegetation. Discontinuous treeless tundra-steppe associations were replaced by dwarf and shrub ernik tundra. A "complex vegetation cover" of forest-tundra apparently existed in the northern part of the Kola Peninsula and in the Northern Dvina Lowland. By the end of the Alleröd alder-bushes and horsetails occupied riverbanks, and spruce occurred in the forest-tundra communities on the adjacent hinterland.

Introduction

The Arctic is highly sensitive to climate variations and, consequently, it is an important region for understanding present and past climate changes. The Pechora Sea, which occupies the southeastern part of the Barents Sea shelf, is one of the key areas in the Eurasian Arctic for solving some cardinal problems of Quaternary stratigraphy and paleogeography. So far, existing conceptions about the Late Cenozoic stratigraphy of the Pechora Sea are based mainly on still debatable seismoacoustic profiling data (Gritsenko and Krapivner, 1989; Musatov, 1992; Lavrushin et al., 1985; Samoilovich et al., 1993) and scarce drilling data (Pavlidis et al., 1998; Polyakova, 1997; Lebedeva and Ivanova, 1987) and, thus, make detailed biostratigraphic investigations necessary. Among other biostratigraphic methods palynology is one of the most effective for this region, because of extremely low abundance of other microfossils in bottom sediments noted by many scientists (Polyakova, 1997; Kagan, 1989; Pogodina, 1994, among others).

However, implementation of this method for investigating marine and glaciomarine sediments demands special approaches dealing with regional peculiarities of aerial transportation of pollen and spores, transportation with rivers, and hydrodynamic conditions of sea basins. Nevertheless, the results of methodical investigations of subfossil palynospectra from surface sediments of the Barents Sea (Rudenko, 1999; Rudenko and Polyakova, 2001) and published data on the Laptev Sea (Naidina and Bauch, 1999), and Canadian Arctic (Mudie, 1982) show that the average composition of subrecent palynospectra gives an overview of zonal and even subzonal types of coastal vegetation.

The main goals of our investigations presented in this paper are:
1) to reveal downcore changes in taxonomic composition of spore-and-pollen spectra;
2) to carry out palynozonal subdivision of the Quaternary sequences;
3) to determine the local peculiarities in paleoenvironmental evolution of the Pechora Sea region.

Modern setting

The Pechora Sea occupies the southeastern part of the Barents Sea. Its western boundary runs along the Kolguev Island, its eastern boundary along Vaigach Island, and the northern one along Novaya Zemlya (Fig. 1). Within these bounds its total area is nearly 90,000 km^2. Southward from 70°N the Pechora Sea shelf represents a gently northward sloping submerged plain with maximum depth not much more than 80 m (Matishov, 1984). Processes of abrasion and accumulation together with currents control bottom topography down to the depth of 45-60 m (Pogodina and Tarasov, 2001). Silty sands and sandy silts predominate among surface sediments within the 50 m isobath contour.

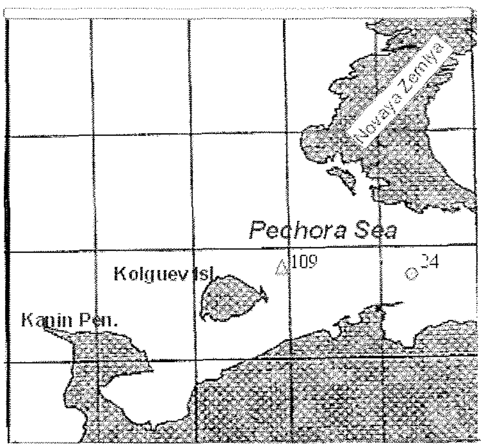

Fig. 1. Overview map of the Pechora Sea with investigated sites

The thickness of the Quaternary sediments in the Pechora Sea area exceeds 100 m (Gritsenko and Krapivner, 1989). Modern drilling and seismic data in the Pechora Sea revealed that deposits of the upper unit of Pleistocene sequence are represented by dark-greyish vaguely laminated sandy siltstone with abundant foraminifers, molluscs and ostracods in its upper part (Gritsenko and Krapivner, 1989; Epshtein et al., 1983). These sediments are regarded to be correspondent to the period of deglaciation of the Pechora Sea shelf (time span of 39-35 Ka according to Polyak et al., 2000). These modern data are in a good correlation with the results of radiocarbon dating of postglacial sediments of the Pechora Plain (Mangerud et al., 1999).

The Pechora Sea is distinguished by severe climatic conditions formed under the strong influences of Arctic anticyclone, while the impact of warm Atlantic air and water masses is negligible. The coastal areas are ice-covered from October until July. During a short summer season freshwater mainly belonging to the Pechora River supplies the marine basin with a huge amount of dissolved and suspended material including both spore and pollen grains and chlorophyte algae cysts (Tarasov et al., 2000).

According to the Russian traditional scheme of the high-latitudinal vegetation zonation (Yurtsev et al., 1978), the waterlogged coastal area lies within the northern moss-lichen-shrub tundra subzone. Vegetation covering most part of the Southern Novaya Zemlya Island as well as Kolguev Island and Kanin Peninsula corresponds to the subzone of southern arctic tundra dominated by polar shrubs – dwarf birch and polar willow. Berry-fields of cloudberry, bilberry and others are also widespread. Riverbanks are occupied by alder and horsetails. *Valeriana capitata* and other motley grass species are abundant among tundra plants of Novaya Zemlya.

Material and methods

The Late Glacial and Holocene stratigraphy and paleogeography of the Pechora Sea presented in this paper are based on the spore-and-pollen analysis of sediments from piston core 24 recovered by Marine Arctic Geologic-Research Expedition (MAGE) during cruise aboard RV "Professor Kurentsov" in 1994 and core 109 obtained by drilling vessel "Kimberlit" belonging to the Arctic Marine Geotechnical Expedition (AMIGE) in 1982 (Fig. 1, Table 1).

Table 1. Position and core length of piston core 24 and core 109

Core No.	Coordinates		Core length, m	Water depth, m
	Latitude	Longitude		
24	68º 40E	55º 56N	1.0	15
109	69º 20E	52º 22N	41.6	21

The piston core was sampled for palynological investigations with 5 cm intervals, and core 109 with 100-150 cm intervals. From every sample 100-200 g of sediment were taken for treatment. Standard heavy-liquid separation method of V.P. Grichuk (1966) without acetolysis and subsequent glycerin mounts was used to process samples and to extract pollen and spores.

Spore and pollen grains were examined under "Biolam R-15" microscope with x450 and x900 magnification. The first 300 specimens encountered in each representative sample were identified, and species abundance was converted to percentages. In some non-representative samples we did not count percentages, but used only quantitative registration. Spore-and-pollen percentages were calculated based on the total sum of registered grains. Pollen zonation is based on the changes in relative abundances of spores and pollen, and relative abundances of the main tree-line groups. Finally, palynozones established in diagrams were correlated with all-Europe Blitt-Sernander climate-stratigraphic scale (Mangerud et al., 1974; Khotinskii, 1977) and with Timan-Pechora regional biostratigraphical scale (Yakhimovich and Zarkhidze, 1993).

Results

Spore-and-pollen spectra from the surface sediments

The surface layer of the Pechora Sea bottom sediments contains numerous palynomorphs: subfossil and redeposited pollen and spores, freshwater algae (*P. kawraiskii, P. boryanum*), dinoflagellate cysts, foraminifera linings, plant and coal debris, and others (Table 2).

Table 2. Total percentages of different microfossils in the Pechora Sea surface sediments

Microfossils	Total percentage	
	Piston core 24	Borehole 109
Redeposited pollen and spores	18.2	28.7
Subfossil pollen and spores	68.7	60.7
Freshwater chlorococcalean algae	2.6	1.8
Dinoflagellate cysts	6.1	5.0
Diatom algae	1.3	1.0
Foraminifera linings	3.1	2.8

Satisfactorily preserved pollen of modern terrestrial plants dominates palynospectra at both sites. Pollen concentrations are low ranging from 50 to 150 grains per gram. All registered pollen grains were subdivided into local pollen and spores of coastal tundra zone and long-distance transported components. Long-distance transported components include mainly arboreal and shrub pollen, primarily *Alnus, Pinus, Picea, Abies, Betula*, as well as easy-floating spores of *Sphagnum* and *Polypodiaceae.* These long-distance transported components comprise more than 50% of the "pollen rain" (Table 3, Fig. 2).

Table 3. Averaged spore-and-pollen associations in surface sediments

Taxonomic composition	%	Taxonomic composition	%
<u>Arboreal and shrubs</u>		<u>Herbs</u>	
Pinus silvestris	20	Poaceae	2
P. sibirica	4	Cyperaceae	2
Picea obovata	6	Artemisia sp.	5
Abies sp.	2	Asteraceae	2
Betula sect. Albae	2	Ericales	2
Betula sect. Nanae	14	Varia (total sum)	5
B. sect. Fruticosae	4	<u>Spores</u>	
Alnus sp.	3	Polypodiaceae	7
Alnaster sp.	1	Lycopodiaceae	6
Salix glauca + S. polaris	2	Sphagnum	9
Carpinus sp.+ Corylus sp.	1	Bryales	2

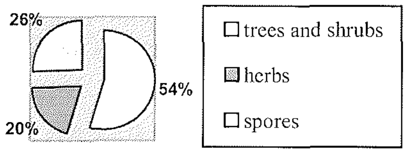

Fig. 2. Averaged total spore-and-pollen percentage composition in surface sediments

The major local pollen producers are *Cyperaceae, Poaceae, Salix, Asteraceae* (including *Artemisia), Saxifragaceae* and *Betula nana.* Other pollen types are found only occasionally, or, if counted, are not very abundant. However, in spite of the fact that well-floating pollen of conifers dominates palynospectra, local components are registered in such amounts that they might adequately reflect zonal and subzonal vegetation type. Re-deposited associations of the Pechora Sea surface sediments include pollen and spores of Quaternary, Paleogene-Neogene, Mesozoic and Paleozoic plants. Most of the re-deposited forms are poorly preserved; grains are crumpled, flattened, crushed and sometimes undeveloped. Among all re-deposited microfossils, only spores of Paleogene-Neogene plants are well preserved and have the specific orange color. Average percentage of re-deposited pollen and spores amounts to 28.7% of the total recorded palynomorphs. Their taxonomic composition is diverse and usually numbers 30-50 species in case the association is representative. Palynospectra are mainly represented by the Early Cretaceous and Triassic forms *Matoniaceae, Aratrisporites, Nevesisporites, Marattiaceae, Sphagnum, Gleichenia, Leiotriletes, Schizaeaceae* and pollen of *Cupressaceae, Pinus, Podocarpus,* and *Picea.* Single Permian forms include *Striatolebachiites,* and *Vittatina.* Ancient-looking pollen of angiosperms from the Upper Cretaceous-Paleogene beds (*Aquillapollenites, Mancicorpus, Oculopollis globosus, Trudopollis* and rare representatives of the Arctic-Tertiary flora – *Rhus, Nyssa, Carya, Pterocarya, Moraceae, Myricaceae)* were also found.

The group of aquatic palynomorphs is dominated by dinoflagellate cysts (mainly *Brigantedinium simplex, Algidasphaeridium minutum* and *Spiniferites*) and foraminifera linings thus indicating marine environments. At the same time, the presence of freshwater chlorococcalean algae (*Pediastrum cawraiskii, P. duplex* and *P. simplex*) provides evidence for considerable river runoff, mainly due to the Pechora River.

Distribution patterns of pollen-and-spore spectra in the Quaternary sequences Borehole 109

Borehole 109 is located in the deltaic part of the submarine valley eastward from the Kolguev Island (Fig.1). It penetrated a 5-m thick unit of clays and silts overlying the 36-m thick unit of loams and loamy sands with abundant gravel, pebbles, rock debris, and coal interlayer (core interval 24.5-24.6 m). The dark grayish color of the uppermost sediment layers indicates anoxic conditions.

Table 4. Spore-and-pollen assemblage zones (PAZ) in borehole 109

PAZ	Depth (m)	Description
1	0.8-3.3	Dwarf and shrub birch zone with AP (pine, spruce and alder) admixture
2	3.3-5.0	Dwarf and NAP zone with arctic-type clubmosses

Two upper units composed of clays and silts contain representative palynospectra, where pollen and spores of Quaternary age are dominant. Spore-and-pollen diagram of this part of the borehole is subdivided into two spore-and-pollen assemblage zones (PAZ) as shown in Table 4.

Taxonomic and quantitative composition of pollen and spores in PAZ 1 and PAZ 2 is rather poor. Dwarf *Betula* pollen is abundant in almost all spectra (>20-40%). Besides Hypoarctic species *Betula nana*, other taxonomic groups, including Boreal (*Vaccinium sp.*), Arctic (*Dryas octopetala, Rumex sp.*), and Arctic-Alpine ones (*Saxifraga sp., Lycopodium appressum*) are identified. Almost all registered spore-and-pollen spectra contain grains of long-distance transported wind-blown pollen from the taiga zone (*Pinus s/g Haploxylon, Picea*) – up to 15% in total. Alder, shrub alder (usually called *Alnaster*), and polar willow pollen grains are extremely rare. Water-drifted pollen of exotic broad-leaved plants, such as oak, hornbeam, and elm, are also scarce. Spores of *Sphagnum* mosses and *Polypodiaceae* ferns dominate the spore group.

Predominance of *Artemisia* pollen in NAP composition and occurrence of single *Ephedra* pollen indicate dry ecotopes and provide evidence for prominent climate amelioration in coastal regions. The floristic composition of non-arboreal pollen (NAP) is very diverse: in addition to pure periglacial taxa (*Ranunculus arcticus, Minuartia cf.arctica*), pollen of more thermophilic plants (*Polygonum viviparum, Polemonium boreale* and others) and different cereals is also present. At the same time, quantitative composition of NAP group is unrepresentative.

Core interval 5.0-11.0 m represented by moraine-like loams with numerous pebbles, gravel and rock debris is characterized by only sporadic occurrence of pollen and spores of the Quaternary age (mainly *Betula nana* and *Sphagnum*) contrary to abundant reworked pollen of Mesozoic conifers and Paleozoic spores of formal genus.

Laminated loamy sands and silts underlie moraine-like loams. This sediment unit does not contain any spores and pollen of the Quaternary age but only heterochronous Paleozoic-Mesozoic palynospectra dominated by Early Cretaceous *Classopollis,* pollen of different conifers (*Protopodocarpus, Pseudopicea* spp., *Pinus* spp. *Lebachia* sp. etc.) and spores (*Schizaeaceae* with typical Barremian-Aptian *Cicatricosisporites, Pilosisporites* as well as *Klukisporites, Aequitriradites, Sphagnum, Gleicheniaceae).* Sediments with Early Cretaceous palynospectra occur on the Pechora Sea coast (Gryazeva, 1980) and correlate with the above-described unit. These sediments were accumulated in aerial-subaerial environments.

Piston core 24

Piston core (PC) 24 was recovered at the base of the submarine coastal slope from 15 m water depth. Core section consists of 0.25 m of sandy silt underlain by an 0.55-m-thick layer of sandy-silty pelite, and ends with 0.2-m-thick layer of dense clayey silt with gravel and pebbles.

The percentage diagram of piston core 24 shows few changes in the abundance of pollen and spore taxa during the time of sedimentation and is subdivided into four pollen assemblage zones (PAZ) (Table 5, Fig.3).

Table 5. Spore-and-pollen assemblage zones (PAZ) in piston core 24

PAZ	Depth (m)	Description
1	0.0-0.25	Modern-like moss-lichen-shrub tundra zone
2	0.25-0.5	Sparse birch-wood zone with spruce, fir, pine and forester mosses
3	0.5-0.8	Dwarf-birch and polar willow zone with alder and humid motley grass
4	0.8-1.0	Dwarf and NAP tundra-steppe zone with arctic-type clubmosses

Pollen concentrations are lower than in the borehole section and decrease downcore. The *Betula sect. Nanae* curve in the percentage diagram shows maximum values in the lower part of the core (28%). Cool and dry climate conditions are reflected in considerable amounts of *Artemisia* and *Chenopodiaceae* pollen (up to 20 % in total) as well as xerophilous motley grass pollen: *Brassicaceae, Ephedra, Plantago* sp., and *Rumex* sp. The admixture of long-distance transported pollen from the taiga zone (*Pinus, Picea, Abies*) is negligible.

Palynospectra of PAZ-4 reflect an extremely unfavorable environment at a time when only sparse forest tundra with extensive open fields of dry-steppe communities were able to exist in the coastal zone. PAZ-4 closely resembles those recorded in adjacent areas: Sartan PAZ of the Taimyr Lowland (Andreev et al., 2002), and Younger Dryas PAZes of the Southern Novaya Zemlya Island (Serebryannyi et al., 1998), South-Western Barents Sea shelf (Okuneva and Stelle, 1986; Stelle et al., 1989) and Kolguev shelf (Baranovskaya et al., 1976; Veinbergs et al., 1995).

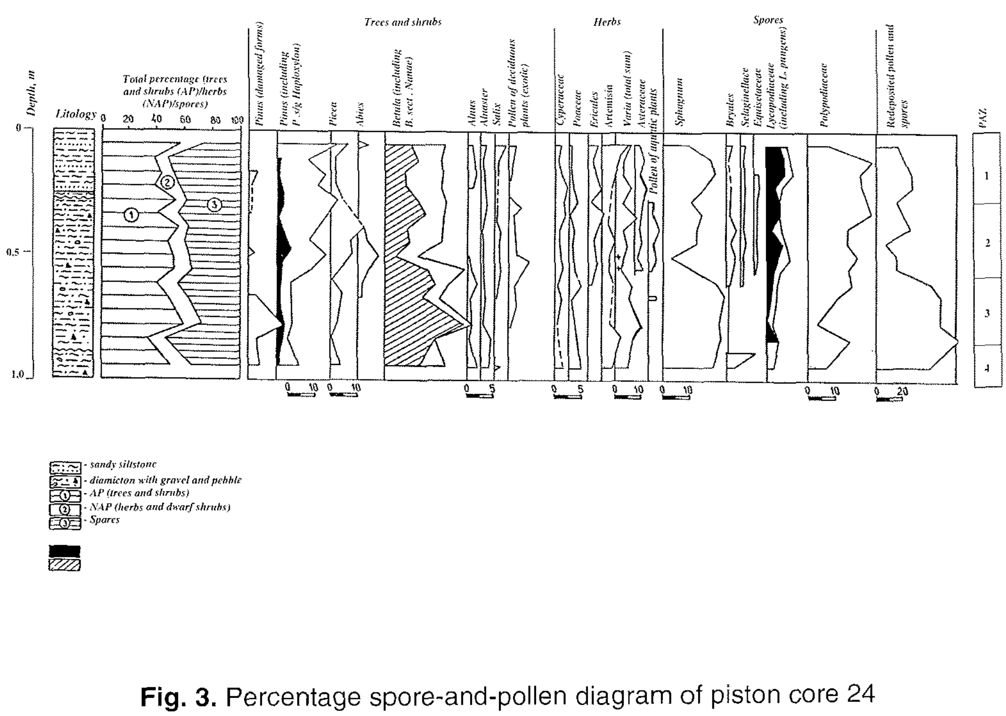

Fig. 3. Percentage spore-and-pollen diagram of piston core 24

PAZ-3 is characterized by increase in pollen concentration and considerable changes in spore-and-pollen composition, primarily, dramatic decrease in herb pollen percentage, especially steppe and tundra taxa (e.g. *Artemisia, Dryas, Poaceae, Asteraceae* and some others). In contrast, significant increase in *Betula sect. Nanae, Alnaster, Ericales* content as well as long-distance transported *Pinus* and *Picea* is noticeable.

PAZ-2 is distinguished by maximum percentages of conifer pollen. *Abies* and *Picea* percentages rise up to 10 and 14%, respectively, in 0.35-0.45 m interval. The peak in *Pinus s/g Haploxylon* percentage (5%) and considerable decrease in Hypoarctic elements percentage are recorded. Another peculiarity of PAZ-2 is presence of pollen belonging to thermophillous aquatic and nearshore aquatic plants such as *Typha latifolia, Alisma* sp., and *Potamogeton* sp. A visible increase in *Ericales* and herbs pollen percentage in the upper part of PAZ-2 and simultaneous dramatic decrease in conifer pollen suggest significant climate cooling during the final phase in sandy-silty pelite layer accumulation.

PAZ-1 reflects environmental deterioration in the area during the time of sandy silt accumulation. The Hypoarctic, Arctic, and Arcto-Alpine taxa dominate specta thus indicating modern-type vegetation of moss-lichen-shrub northern tundra. We consider *Betula* sect. *Nanae, Salix polaris, S. glauca, Polygonaceae* (including *Oxyria*), *Saxifragaceae, Cyperaceae, Sphagnum* and *Bryales* to be the main local producers of pollen and spores. It should be mentioned, however, that the long-distance transported conifers in association with arboreal *Betula* sect. *Albae* comprise more than 45% of palynospectra.

Climatostratigraphic interpretation

Unit 1

Bedrock recovered from borehole 109 is represented by 20-m-thick laminated loamy sands and silts with a coal interlayer at core depth of 24.5-24.6 m. According to palynological data, this unit was determined to be of the Early Cretaceous age, and its terrigenous lacustrine genesis was confirmed by geological and geomorphological data (Lavrushin et al., 1985). The depleted foraminiferal assemblages represented by Pre-Cenozoic species redeposited from continental sections (Kostin et al., 1988) are correlative to those studied in the northern Pechora Plain (Gryazeva, 1980) and in the area eastward from the Kolguev shoal (Baranovskaya et al., 1976).

Unit 2

The Early Cretaceous bedrock in borehole 109 section is unconformably overlain by 6 m thick moraine-like loam (core interval 5.0-11.0 m). According to our palynological and foraminiferal data (Kostin et al., 1988), the age of moraine-like loams was determined as the Late Valdai. We suppose that this unit was accumulated under the influence of fluvioglacial flows, perhaps, from the melting ice cap on Kolguev Island and, also, coastal glaciers. Glacial bottom sediments of this kind are widely spread at the periphery of the Barents and Pechora seas (Pavlidis et al., 1998; Tarasov et al., 2000; Samoilovich et al., 1993). They are characterized by extremely low concentrations of foraminifer tests and diatom valves (less than 20-50 specimens). The damaged shape of the valves suggests that they have been reworked from more ancient interglacial sediments. Numerous unvegetated areas on adjacent land formed by cryogenic processes could be possible sources for the reworked material. Diatom assemblages are dominated by sublittoral species – *Paralia sulcata, Diploneis subcincta, D. interrupta,* and *Trachineis aspera.* Such assemblages provide evidence for low surface water temperatures and low productivity of phyto- and zooplankton (Polyakova, 1997; Druzhinina and Musatov, 1992; Gudina, 1976; Pogodina, 1994; Polyak, 1985).

Climate deterioration considerably changed coastal vegetation as reflected by depleted taxonomic and quantitative composition of palynospectra. Such distribution pattern is quite typical for Late Glacial sediments (Rudenko, 1999; Polyakova, 1997; Sharapova, 1996; Baranovskaya et al., 1976; Lebedeva and Ivanova, 1989; Okuneva and Stelle, 1986; Serebryannyi et al., 1998; Andreev et al., 2002). One possible explanation for extremely low pollen concentrations might be low pollen productivity of plants in coastal areas due to extraordinarily severe climate conditions. Plant cover of the coastal areas was undoubtedly discontinuous and existed mainly in refuges. The pollen data suggest that open steppe-like plant communities with *Artemisia, Poaceae, Asteraceae* and *Caryophyllaceae* dominated dry ecotopes on watersheds, whereas tundra-like communities with *Betula nana*, Arctic *Salix, Dryas, Saxifraga, Carex* and *Brassicaceae* were common in more humid coastal lowlands.

Unit 3

The overlying silts and loamy sands with a thickness of 5 m are supposed to have been accumulated during early deglaciation in oceanic periglacial environments of the Older Dryas and Alleröd. Considerable climate warming resulted in rapid degradation of glaciers. During this phase the glacial sedimentation was rather rapidly replaced by glaciomarine sedimentation (Tarasov et al., 2000; Matishov, 1984). This unit is characterized by considerable increase in abundance of foraminifers. The relative abundance of the dominant species *Retroelphidium clavatum* is more than 80% (Kostin et al., 1988). This species is able to survive considerable freshening. The ecological structure of the foraminiferal assemblage with arctic and arctic-boreal *Elphidiella arctica, E. tumida, Retroelphidium hyalinum, Cassidulina barbara,* and *Islandiella norcrossi* provides evidence for extreme environments. At the same time, the remaining low total concentration of diatom valves as well as dinoflagellate and chlorophyte cysts allows assuming that this unit was accumulated under unfavourable environmental conditions with oscillating sea level and unstable hydrodynamic conditions.

Progressive climate warming caused prominent changes in coastal vegetation. Discontinuous treeless tundra-steppe associations were replaced by dwarf and shrub ernik tundra. Appearance of plants characteristic for waterlogged areas such as *Carex, Equisetum arvense* manifests some climate humidification. At the same time, steppe associations with *Artemisia, Ephedra, Chenopodiaceae* and *Poaceae* were still widespread. In northern Taimyr, Andreev et al. (2002) reconstructed such a "mixed" vegetation structure for the Alleröd epoch. "Complex vegetation cover" of forest-tundra apparently existed in the northern part of the Kola Peninsula (Rudenko, 1999; Sharapova, 1996) and in the Northern Dvina Lowland (Pleshivtseva, 1983). We suppose that by the end of the Alleröd alder-bushes and horsetails occupied riverbanks, and spruce occurred in the forest-tundra communities.

Unit 4

The Pleistocene-Holocene boundary corresponds to the core depth of 0.8 m in piston core 24. It is marked by considerable changes in composition of spores, pollen, foraminifers, and diatoms (Fig. 3).

Conclusions

By combining the lithologic, original palynologic and published micropaleonthological data we reconstructed paleogeographical events on the Pechora shelf during the Younger Dryas and Holocene. The main conclusions are as follows:
1) The Late Valdai sediments in the Pechora Sea region were accumulated under the influence of fluvioglacial flows, perhaps, from the melting ice cap on Kolguev Island and, also, coastal glaciers. Climate deterioration considerably changed coastal vegetation as reflected in depleted taxonomic and quantitative composition of palynospectra. The pollen data suggest that open steppe-like plant communities with *Artemisia, Poaceae, Asteraceae* and *Caryophyllaceae* dominated dry ecotopes on watersheds, whereas tundra-like communities with *Betula nana,* arctic *Salix, Dryas, Saxifraga, Carex* and *Brassicaceae* were common in more humid coastal lowlands.
2) The overlying silts and loamy sands are supposed to have been accumulated during early deglaciation in oceanic periglacial environments of the Older Dryas and Alleröd. During this phase the glacial sedimentation was rather rapidly replaced by glaciomarine sedimentation. Progressive climate warming caused prominent changes in coastal vegetation. Discontinuous treeless tundra-steppe associations were replaced by dwarf and shrub ernik tundra. "Complex vegetation cover" of forest-tundra apparently existed in the northern part of the Kola Peninsula and in the Northern Dvina Lowland. By the end of the Alleröd alder-bushes and horsetails occupied riverbanks, and spruce occurred in the forest-tundra communities on the adjacent hinterland.

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