Distribution of Pollen and Spores in Surface Sediments of the Laptev Sea

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Abstract - The palynological content of Laptev Sea surface sediments were studied. The pollen-spore spectra in these recent sediments are characterized by a predominance of coniferous pollen and moss spores. The pollen have been transported over long distances whereas the spores are of more local origin. The majority of these pollen and spore grains accumulate in the near-shore zone. The pollen-spore spectra in the eastern part of the Laptev Sea are characterized by a different taxonomical composition, which is linked to the huge perennial discharge of freshwater from the Lena and Yana rivers. Thus, the distribution of pollen and spores in the Laptev Sea, as well as their diversity, may be attributed to atmospheric and surface water circulation patterns but is mainly influenced by the intensity of freshwater runoff from the Lena river.

Introduction

The Laptev Sea is located at the northern Eurasian margin of Central Siberia. This shelf sea is bounded by the Taymyr Peninsula to the west and the New Siberian Islands to the east (Figure 1) and covers an area of about 660,000 km^2, most of which is relatively shallow water (less than 50 m deep). The recent Arctic vegetation on the adjacent land is characterized by rather treeless landscapes (Figure 2). However, tree pollen are very abundant in the pollen-spore spectra of continental as well as marine deposits. In general, it is established that pollen transportation into deposits of various origins is principally governed by aerial transportation (Semenov, 1973; Kabailene, 1976). A quantitative model of marine pollen transport, deposition processes (Mudie, 1984) as well as data from a coastal shelf box model (Mudie and McCarthy, 1994) shows that aerial transport is the main process by which pollen moves across the land adjacent to the western North Atlantic. These box model results indicate that wind is the most important marine pollen transport process off eastern Canada, where rivers are relatively small, have small runoff volumes and where strong westerly and southeasterly offshore winds prevail (Mudie and McCarthy, 1994). In regions where pollen grains are most abundant, i.e. in this case off the mouths of large rivers and particularly in near-shore marine sediments, however, fluvial transport is an important process for the accumulation of pollen (Cross et al., 1966; Heusser, 1985; Mudie, 1982; Muller, 1959; Traverse, 1988 and 1992).

The influence of fluvial pathway transport on the pollen distribution has been investigated in some large rivers: the Volga River (Fedorova, 1952), the Delaware River estuary (Groot, 1966) and the Mississippi River (Smirnov et al., 1996). Some investigators have concluded that the suspended pollen load in large rivers depends on the flow velocity, the concentration of pollen deposited aerially in surface waters, and the segregation of tributary water flow. Other studies (e.g. Smirnov et al., 1996) show no significant correlation between pollen load and velocity. Application of sediment mechanics to pollen grain transport demonstrates that such relationships should not be expected in a river and that pollen rain and resuspension of grains from the riverbed are more likely to control the distribution of pollen (Smirnov et al., 1996).

One of the main factors which shape the hydrography and, thus, the depositional environment

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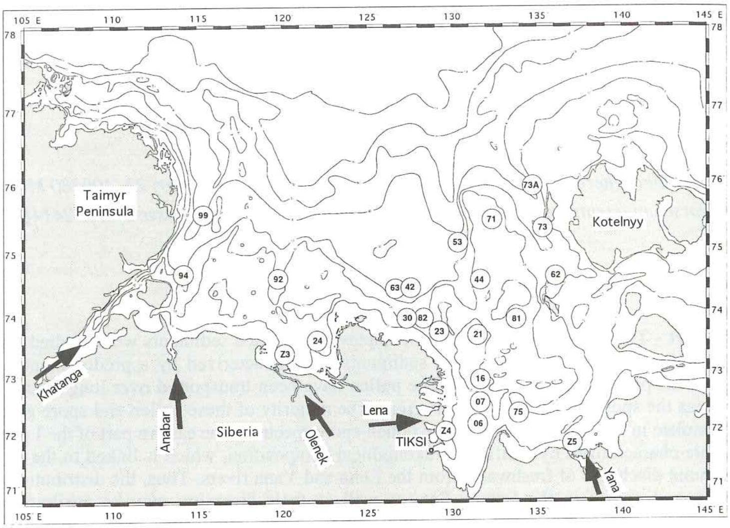

Figure 1: Location of studied surface sediments from the Laptev Sea containing sufficient numbers of pollen and spores grains.

of the Laptev Sea is the strong seasonal freshwater runoff by the main rivers (Figure 1) in the summer when the ice breaks (Timokhov, 1994). It is believed that sediment transport onto the Laptev Sea shelf during this time takes place either by ice or by suspension and that this material then accumulates mainly along the channels (Lindemann, 1994). The strong gradient in chlorophycean algae concentrations recorded by Kunz-Pirrung (this volume) suggests that the influence of freshwater is confined mainly to the shelf. The principal objective of this paper is to investigate the distribution of pollen and spores in surface sediments of the Laptev Sea, and to discuss their possible sources and transport pathways.

Material and methods

The palynological study was based mainly on surface samples taken during the Transdrift I and Transdrift II expeditions to the Laptev Sea on board the RV Ivan Kireyev (1993), RV Professor Multanovsky (1994) and RV Polarstern (1993).

The preparation of the samples for the study was carried out at the laboratory of the GEOMAR Research Center for Marine Geosciences in Kiel, Germany. Prior to the investigation, all samples were freeze-dried and then treated with cold acid (HCL, HF) to dissolve carbonates and silicates according to the method of Phipps and Playford (1984), Doher (1980) and Barss and Williams (1973).

For identification and quantification of the grains, a microscope was used at a constant magnification of 400x. A total of 86 slides from 45 surface samples were studied. Pollen and spore percentages were calculated based on the total number of grains.

Results

Pollen and spore diversity

In the sediments, a total of 20 palynomorph taxa were recognized. This number of taxa is quite typical for recent sediments of the high latitude regions of the Arctic (Kupriyanova, 1951). Among the arboreal plants, the pollen of spruce *Picea*, pine *Pinus sibirica*, cedar pine *Pinus pumila*, larch *Larix*, willow *Salix*, alder *Alnus*, and birch *Betula sect. Nanae* (*Betula exilis, B. middendorffii, B. nana)* were recorded. From the herbaceous plants, the pollen of Ericaceae, Gramineae, Cyperaceae, Asteraceae, Rosaceae, Saxifragaceae, Ranunculaceae, Caryophyllaceae were present. The spore plants were represented by green mosses *Bryales*, sphagnum *Sphagnales* and the fern Polypodiaceae.

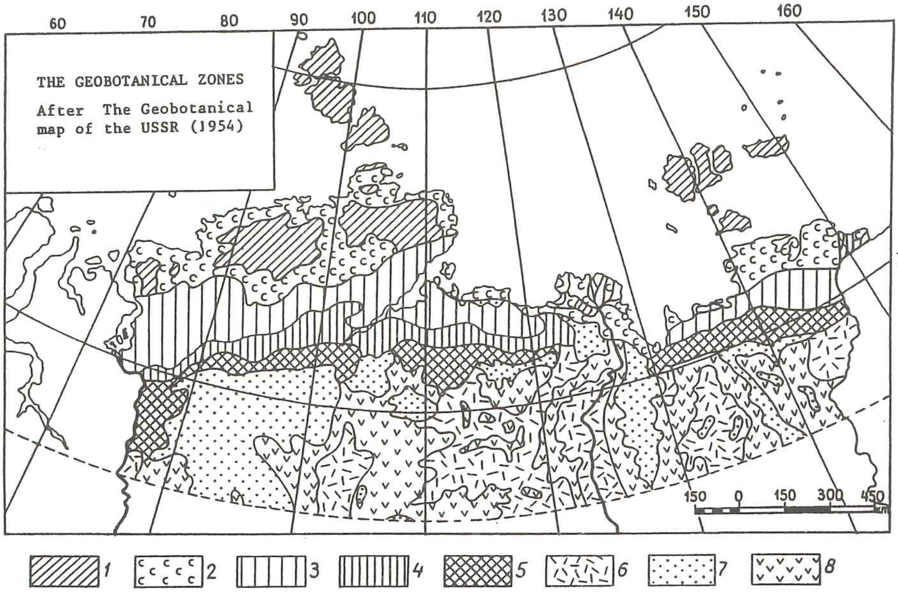

Figure 2: Map of geobotanical zones adjacent to the Laptev Sea (after Lavrenko and Sochava, 1954). 1) Arctic deserts and glaciers; 2) Arctic tundra; 3) typical tundra; 4) shrubs and tussocks tundra; 5) forest-tundra; 6) northern taigas; 7) mountain tundra and shrubs of the alpine taiga regions; 8) mountain forest-tundra of the northern taiga region.

Pollen and spores of Laptev Sea surface samples

From 45 investigated surface samples taken from the shelf, 24 samples (Figure 1) contained sufficient specimens to calculate percentage data. Pollen-spore spectra of these samples were dominated by arboreal pollen from coniferous trees (7-93%). Most of them belonged to *Pinus pumila*. The pollen of other conifers belonged to either *Pinus sibirica* or *Picea*. Occasionally, pollen grains of *Larix* were recognized. Deciduous trees comprised about 4% of the spectra and included *Salix, Alnus* and *Betula sect. Nanae* (*B. exilis, B. nana , B. middendorffii*). Among the herbaceous species, the pollen of Cyperaceae were dominant (up to 17%). The pollen of Ericaceae, Gramineae, Asteraceae, Rosaceae, Saxifragaceae, Ranunculaceae, Caryophyllaceae were observed, but remained low. Among the spore plants, *Sphagnales* (up to 40%), *Bryales* (up to 82%) and *Polypodiacea* (up to 4%) comprised the majority of most spectra.

The pollen-spore spectra of surface samples from sites nearer to the coast - sites 24, 23, 30 in the Lena Delta, sites Z4, 06, 07, 16 in Tiksi Bay and sites Z3 and Z5 in the estuaries of the Olenek and Yana rivers, respectively - are characterized by a decrease in the relative abundance of spores and an increase in arboreal coniferous pollen. In the sample from site Z5 at the estuary of the Yana river, the pollen-spore spectrum was characterized by the appearance of Ericaceae and birch dwarf shrubs. The composition of pollen-spore spectra in samples from site

82 just north of the Lena Delta showed the greatest quantity of coniferous tree pollen whereas the quantity of arboreal pollen was reduced in samples close to the coast of the Taymyr Peninsula (sites 94, 99). Pollen-spore spectra in these samples were characterized by a predominance of spores of the mosses *Bryales* and *Sphagnales*. The frequency of pollen grains decreased with increasing distance from the coast. In general, the special morphological texture of these pollen can be easily transported by wind and water. In the open sea, to the north of Kotelnyy Island (i.e. samples from sites 84, 73A, K1; Figure 1), pollen grains of pine are rare.

All 3 surface samples taken in the open sea (77°41´ - 78°22´ N; 125°00´-133°12´ E) contain only infrequent pollen grains of coniferous trees.

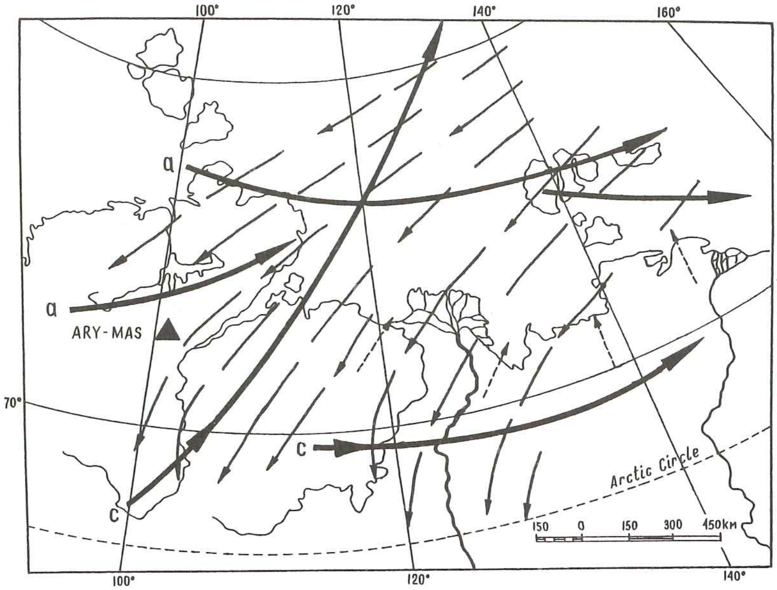

Figure 3: Atmospheric circulation over the Laptev Sea in July (Geographical Atlas of the USSR, 1983). Solid arrows represent prevailing surface winds, dotted small arrows indicate offshore winds; c - cyclones, a - anticyclones; Ary-Mas - northernmost forest in the world.

Summary of pollen-spore spectra

The overall distribution of the main components of the pollen-spore spectra is given in Figure 4. Based on this analysis, it follows that grains of pollen and spores concentrate in the off-shore as well as the near-shore zone. Pollen and spore distributions in the regions of the Lena Delta, Tiksi Bay and near the estuaries of the Olenek and Yana were characterized by a greater number of coniferous pollen grains (Figure 4a, b). In the area of Tiksi Bay, the summed percentage contents of *Pinus pumila* and *Pinus sibirica* reached values of up to 93%. Relatively high coniferous pollen contents were also found in the regions of the submarine valleys of the Olenek (up to 57%) and Lena (up to 74%) rivers.

Among the spore plants, the *Bryales* mosses were dominant and reached 82% in the submarine valley of the Lena (Figure 4c, d). *Sphagnales* percentages increased near the Taymyr Sea coast (up to 40%) and varied in the eastern part of the sea between 2-30% (Figure 4e).

Among the herbaceous plants, the amount of Cyperaceae varied between 1 and 17%. Frequency of Cyperaceae and the rest of the herbaceous species were higher in the western part of the sea and varied between 23-32% (Figure 4f, g).

Farther off the coast of the eastern Laptev Sea, there were still relatively high proportions of cedar pine pollen and sphagnum spores whereas the coastal zone yielded herbaceous pollen and spores of green mosses. The latter two are of local origin and therefore much more closely linked to the coastal vegetation. This implies that specific hydrodynamic processes which occur along the pathway of the main river runoff may be responsible for this distinction and, further, that along the coastal zones and away from the river mouths such processes have less influence on the distribution.

Discussion and conclusions

The composition of pollen and spore spectra in surface sediments of the Laptev Sea can be regarded as a result of transportation. This particularly applies to the occurrence of coniferous pollen grains which do not reflect the typical vegetation on land adjacent to the Laptev Sea. Therefore, these grains were brought into the shelf region either by offshore winds (Figure 3) or by the riverine freshwater runoff. Owing to their special morphology, pollen grains of pine are easily transported for longer distances by wind and rivers. It has been shown that the boundary of the forest-tundra zone in the Lower Yana region shifted northward in more recent times (Aleksandrova, 1953). As a result, forest tundra is now located in this area to within 50 km south of the coast (Figure 2). The flowering period for trees along this northern forest boundary is often accompanied by northerly directed winds. These winds may then account for the transfer of pollen to the Arctic from the forest-tundra and northern taiga. Interestingly in this context, the Ary-Mas forest as a major potential source is situated just along the pathway of the cyclones (Figure 3). Organic matter, which is made up of pollen, spores and other organic fibres, is one of the main components of aerosols over the Laptev Sea (Shevchenko et al. 1995). Previous studies of pollen-spore numbers and composition in Arctic Ocean surface water and seabed sediments (Mudie and Matthiessen, 1988) indicate a primary aeolian transportation, with the circum-Arctic and boreal-tundra vegetation being the main source.

Figure 2 shows that there are several other possible sources of pollen and spores from various tundra areas: 1) terraces along the Lena River valley, 2) plains and terraces of the Lower Khatanga River (the eastern part of the Northern Siberian Lowland), and 3) the mouth lowland of the Yana River (the western part of the Yana-Indigirka Lowland). In this area, the particular vegetation cover connected with the existence of the perennially frozen ground and specific thermokarst forms of tundra-relief, so-called alases, form favourable conditions for the accumulation and preservation of pollen (Naidina, 1995). But pollen preservation is not always perfect. In Northern Yakutia, one of the most widespread trees is *Larix*. Single undersized specimens of *Larix* grow in the tundra of the Yana lowland (Khotinsky et al., 1971) and together with *Betula exilis* and *Salix reptans* form the majority of the northernmost part of the Ary-Mas forest (Anonymous, 1978). But *Larix* pollen are practically absent in palynological spectra (Khotinsky et al., 1971; Kupriyanova, 1951; this study). This accounts for the complete decomposition of these pollen grains due to maceration.

Siberian rivers transport large amounts of dissolved and particulate material onto the shelf area, where it accumulates and/or from which area it is further transported towards the Arctic Ocean by, for example, sea-ice (e.g. Eicken et al., 1997). Due to the influence of the Lena River, the eastern Laptev Sea receives considerably higher amounts of freshwater than the western part (Timokhov, 1994). This distinction is also recognized in many other sedimentological, geochemical and biological proxy data (e.g. Dehn et al., 1995; Höleman et al., 1995; Létolle at al., 1993). Therefore, it is reasonable to conclude that the river runoff also accounts for the observed higher relative abundances of pollen and spore grains within the eastern Laptev Sea .

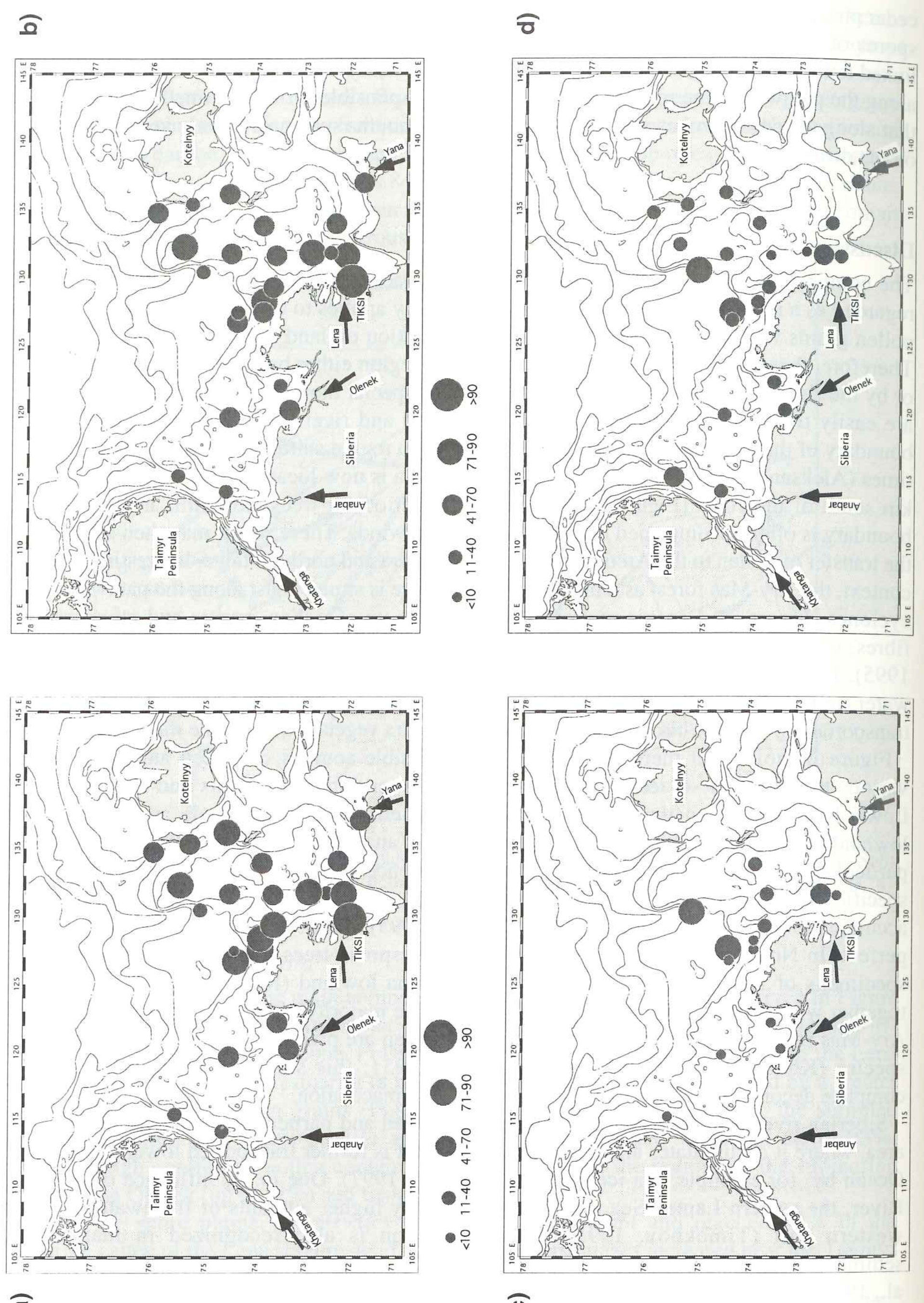

Figure 4: Relative distribution (%) of the main groups of pollen and spores in surface samples from the Laptev Sea. a) tree pollen (sum); b) tree pollen of *Pinus*; c) spores of *Bryales*; d) total spores (sum).

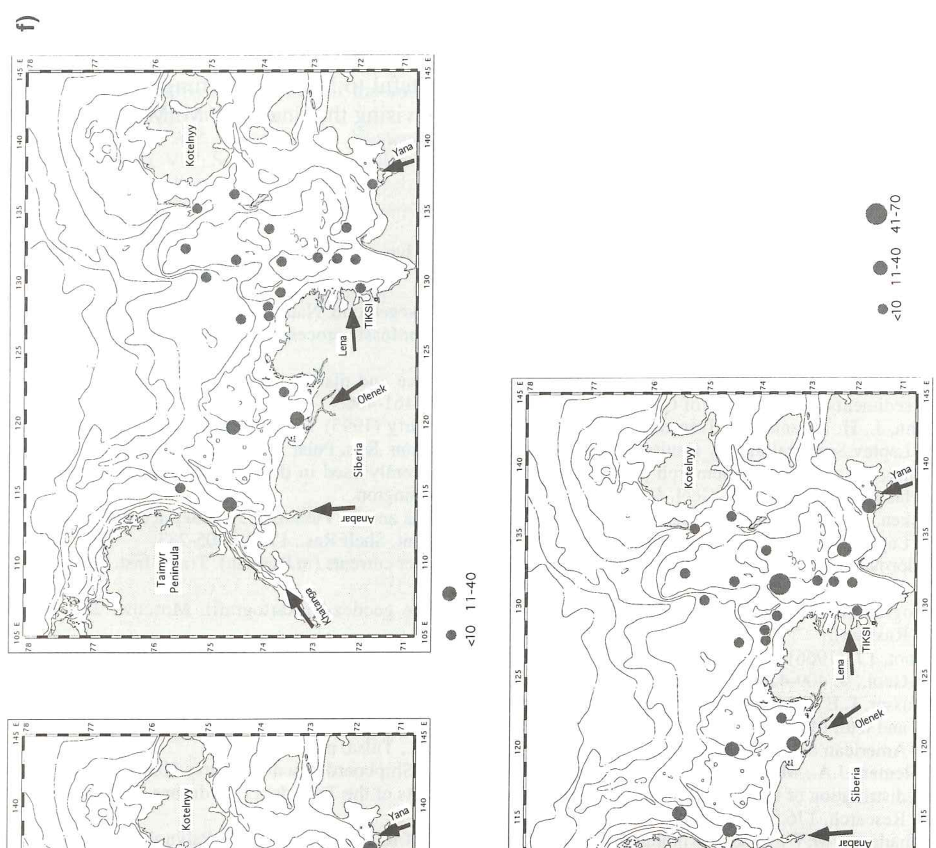

Figure 4 (continued): Relative distribution (%) of the main groups of pollen and spores in surface samples from the Laptev Sea. e) spores of *Sphagnales*; f) pollen of *Cyperaceae*; g) pollen of herbs (sum).

Acknowledgements

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