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Lithology of Upper Quaternary Veneer and Late Cenozoic Paleogeography of the Laptev Sea Margin

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THEME 11: Cenozoic Sedimentary Archives of the Eurasian Marginal Seas: Sampling, Coring and Drilling Programmes

Summary: Grain size and mineralogical analyses of bottom and uppermost subbottom sediments sampled by gravity corer, box corer and grabs were performed and interpreted in the light of scarce seismic acoustic data. It was found that the variability in lithology and mineral composition of sediments on the bottom and immediately below is controlled by topographic features of the shelf. Sands are common in near-coastal shallow marine environments. In the central part of the shelf the relative abundance of sand is associated with the ancient Lena River delta and/or the near-bottom position of pre-Quaternary(?) rocks. Fine deposits on the bottom surface occur predominantly in bathymetric lows and are characterized by the prevalence of clay and silt. Sandy silt becomes more abundant in the interval lying several meters beneath the bottom and reflecting the Late Weichselian(?) regression.

Quartz, alkaline feldspars, acidic plagioclases and weathered micas normally dominate among the light minerals. The distribution of heavy minerals allows to recognize Western and Eastern mineralogical provinces. The first is characterized by high contents of pyroxenes, while the Eastern province is dominated by epidote and amphiboles.

Hydromica is most common among clay minerals. Increased contents of kaolinite and montmorillonite are usual for shallow marine deposits near the Severnaya Zemlya archipelago, the Northern Taimyr Peninsula and the Central Laptev High due to the reworking of pre-Quaternary weathered rocks.

On the whole, paleoenvironments in the Laptev Sea Shelf during Late Pleistocene and Holocene time were predominantly influenced by modification of pre-existing (pre-Late Pleistocene) tectonic landscapes by sea level changes.

INTRODUCTION, MATERIALS AND METHODS

The overall aim of this work was to study the uppermost veneer of bottom deposits and major paleo-environmental features existing during its formation. The paper is largely based on mineralogical data published in Germany (STEIN & KOROLEV 1994, BEHRENDS et al. 1996, BEHRENDS 1999, BEHRENDS et al. 1999) and original grain size and mineralogical analyses of deposits penetrated by cores and grabs (Fig. 1) during Russian expeditions as well as the interpretation of scarce seismic acoustic data. We have investigated available data obtained from the Laptev Sea Shelf by joint German-Russian expeditions (KASSENS 1997, RACHOR 1997) as well as all relevant material collected from Russian research vessels during previous time (GRAMBERG & POGREBITSKIJ 1984, YASHIN & KOSHELEVA 1994). Grain size analysis was carried out according to methods accepted in VNIIOkeangeologia (ANDREEVA & LAPINA 1998). Samples were processed under ultra-sound and the content of fine grained fractions (0.001, 0.005 and 0.01) mm was defined using pipett. After the elutriation of clayey fraction samples were sieved to 10 fractions. Mineralogical composition of fraction 0.01-0.05 mm was analyzed using the immersion method. After dividing of minerals in the heavy liquid (specific weight 2.9) quantitative analysis of heavy and light minerals was carried out.

Content and distribution of organic carbon in bottom deposits samples were also studied based on results of German investigations (STEIN & NÜRNBERG 1995, STEIN 1996, FAHL & STEIN 1997, 1999) as well as our previouis measurements (DANUSHEVSKAYA et al.1990, ROMANKEVICH et al. 1977, 1982). The procedure developed involved: extraction of organic matter from sediments, group fractionation to separate hydrocarbons and HPLC analysis PAH. It was carried out through HPLC method under condition of the reverse-phase chromatography with chromatograph MILICHROM, column Separon SGX RP-18-S. The scanning spectrophotometric detector was applied to get multi-elemental chromatographic spectra and to use supplementary analytic signs during identification. Double-wave detection (280 nm) was coupled with the record of spectra of all components of the mixture under analysis in the range of 190-380 nm. Individual PAH were identified by the correlation of chromatographic (k'), chromato-spectrophotometric (h 254/h 280) and spectral ($\gamma_1$max/$\gamma_2$max; Amax1/A max2) characteristics of real samples and standards.

Thicknesses and spatial distribution of the Holocene veneer corresponding to seismic unit 1 were evaluated basing on results of Russian single channel seismic profiling (IVANOVA et al. 1989, GRAMBERG et al. 1990), PARASOUND HRS (FUETTERER 1994, RACHOR 1997, KLEIBER & NIESSEN 1999) and materials from long gravity cores. Investigation of clay mineral distribution was developed on the base of published German data (ROSSAK 1995, WASHNER 1995, WASHNER et al. 1999, ROSSAK et al. 1999) and unpublished Russian data.

DISCUSSION

Formation of Holocene deposits on the shallow water Laptev Sea shelf was controlled by general post-glacial transgression and local oscillations of the sea level. Spatial distribution of lithological types of recent deposits is extremely variable showing prevailing of mixed types of sediments (i.e., sandy-silty-clayey deposits, etc., Fig. 2). Sands occur predominantly in near-coastal shallow marine environments near mainland

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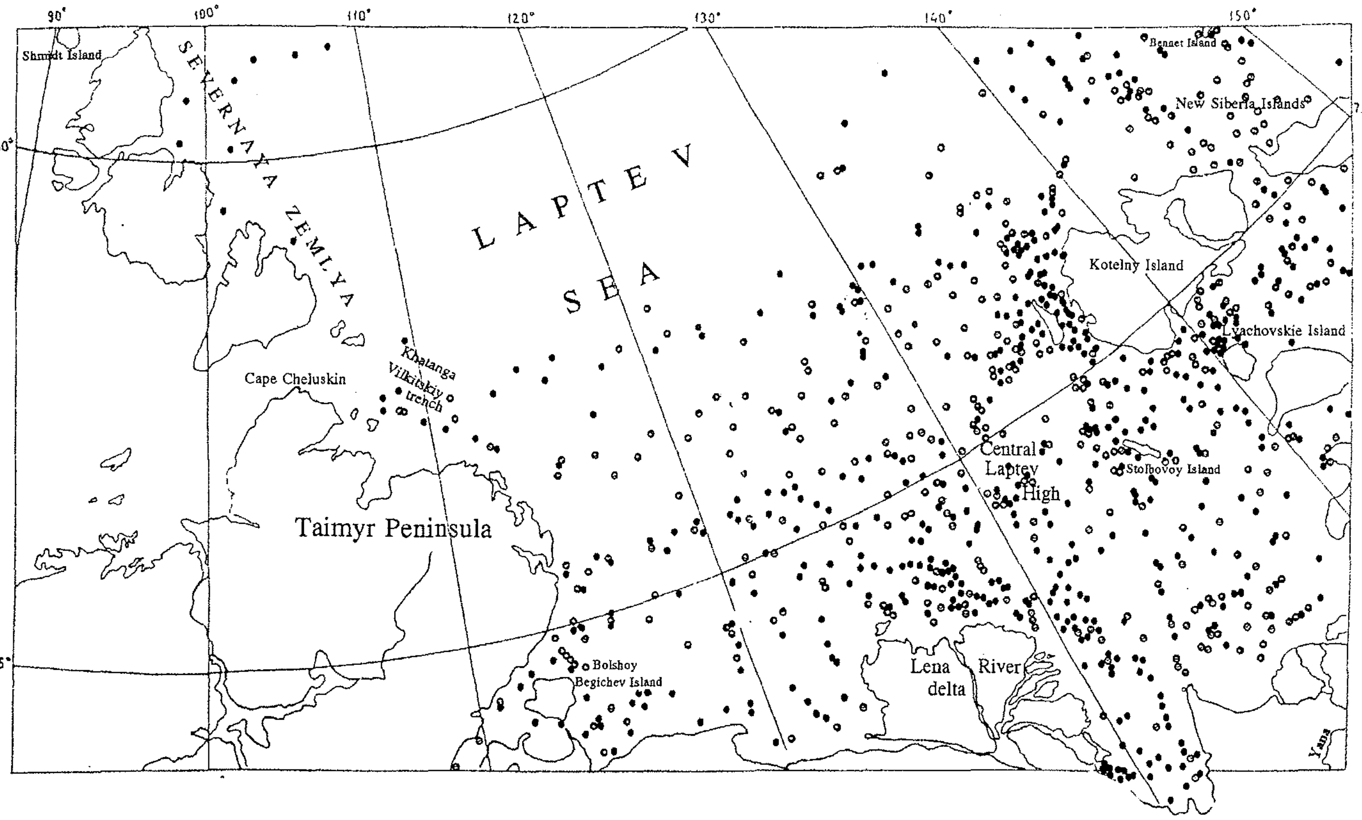

Fig. 1: Marine geological data coverage; circles = gravity cores; bold dots = grab samples.

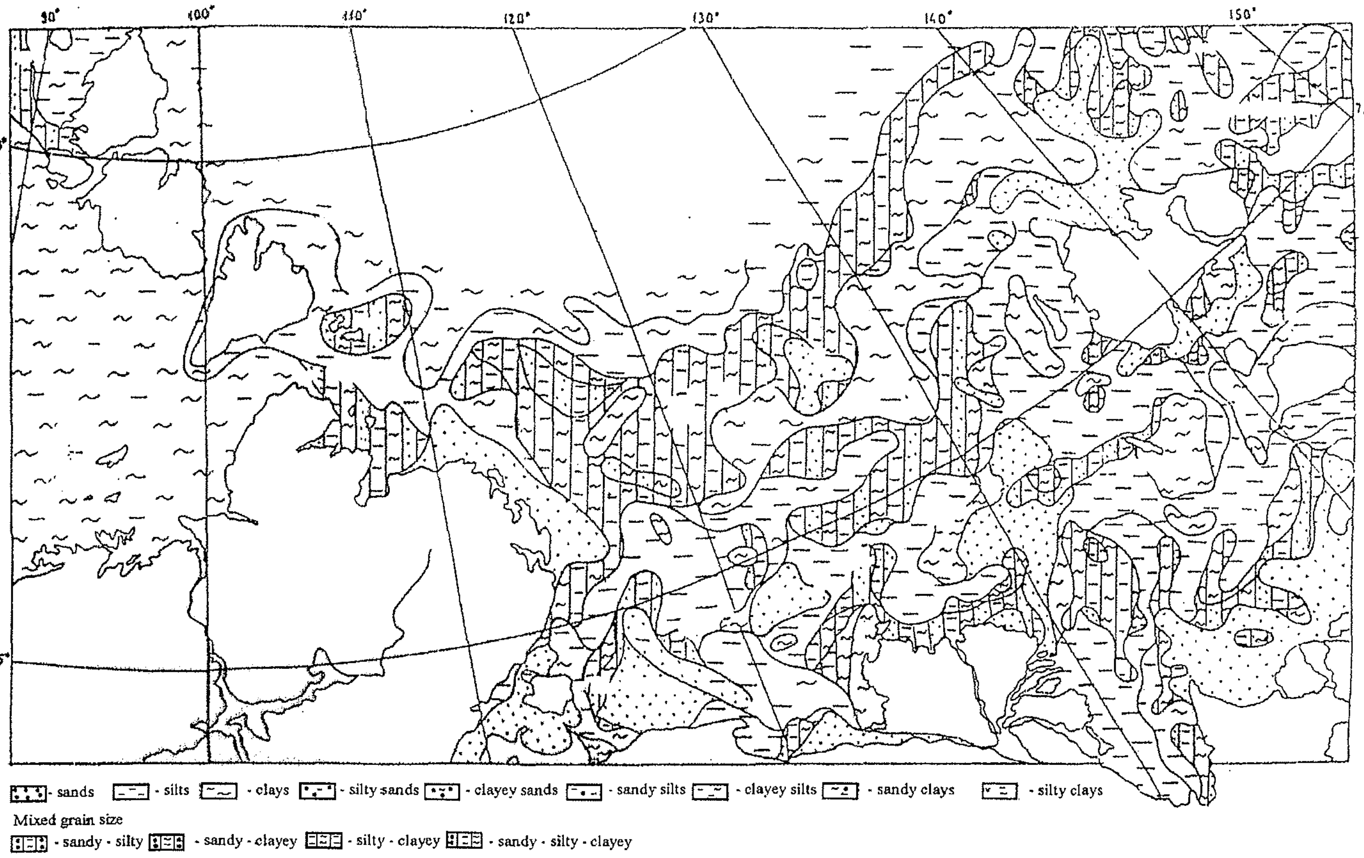

Fig. 2: Grain size distribution of upper Holocene deposits in the Laptev Sea.

and islands in the southern and eastern parts of the basin. In the central part of the shelf, the relative abundance of sands is associated with the ancient Lena River delta and/or the near-bottom position of pre-Quaternary rocks. Fine-grained deposits occur predominantly in bathymetric lows and they are characterized by prevalence of clay and silt. Silts prevail in bottom depressions of the inner and central parts of the shelf while clays are widespread near the shelf break and in the shelf areas adjacent to the Severnaya Zemlya archipelago.

The most remarkable feature of the grain size distribution of the Laptev Sea bottom deposits is their general mixed composition showing bi-modal character of distribution curves with two maxima at silty and clayey size. The basic matrixe of sediments usually is contributed by silt with considerable content of clay or, sometimes, sand.

Figure 3 illustrates the character of the distribution of seismic unit 1 corresponding to the Holocene veneer of terrigenous deposits overlying Pleistocene sediments of various ages. The bottom of seismic unit 1 usually shows an angular unconformity (toplap or erosion truncation) which was formed during the Late Weichselian (Sartansk) regression (GRAMBERG & POGREBITSKIJ 1984, KLEIBER & NIESSEN 1999) when sea level had been decreased up to depths 120 m and the entire Laptev Sea Shelf was exposed. Seismic unit 1 is present almost on the whole shelf and thicknesses of the Holocene veneer vary from 0.5-1 m on shelf highs, uplifts and abrasional surfaces to 5-10 m in maximum up to 25 m in local depressions and depocentres of modern accumulation. In the eastern part of the shelf the average thickness of seismic unit 1 is 4-5 m, maximum thickness is 5-10 m. The thickest (up to 20-25 m) Holocene cover was established in the axial part of the Khatanga-Vilkitskiy trench in the western part of the Laptev Sea shelf. In the upper part of the continental slope at modern depths less than 120 m the Holocene veneer is not underlain by an unconformable boundary and it is impossible to distinguish it from seismic unit 2 (Upper Pleistocene ?).

The mineral composition of the light fraction is characterized by dominating quartz, alkaline feldspars, acidic plagioclases and weathered mica minerals. Analysis of heavy minerals allows to recognize Eastern and Western mineralogical associations (Fig. 4). The former is characterized by prevailing pyroxenes, while amphiboles, epidote, garnets and black ore minerals dominate in the Eastern Laptev Sea. Distribution of pyroxenes and amphiboles is controlled by the position of major source areas. High contents of pyroxenes (20-40 %) are common for the Western part of the basin where terrigenous discharge is influenced by the erosion of ancient magmatic rocks from Anabar shield and Lower Cretaceous sediments enriched by pyroxenes on the Taimyr peninsula and in the North of Siberia (RONKINA 1965). The Eastern part of the shelf is characterized by increased content of amphiboles reflecting the erosion of metamorphosed diabases occuring on Vetckhoyansk range and New Siberian Islands as well as Lena river discharge which transports the products of weathering of the Upper Cretaceous-Paleogene sediments into the basin (RONKINA & VISHNEVSKAYA 1977).

The prevailing clay mineral in Holocene deposits of the Laptev Sea shelf in hydromica. Increased contents of kaolinite and montmorillonite are usual for shallow marine environments in the areas adjacent to the northern Taimyr Peninsula and the Severnaya Zemlya archipelago (Fig. 5) due to erosion and reworking of pre-Jurassic, Late Cretaceous and Paleogene crusts of weathering containing these clay minerals in the coastal areas of mainland and islands. Such crusts of weathering basically consist from kaolinite (20-55 %), hydromica (20-55 %) and chlorite (10-35 %) with admixture of montmo-

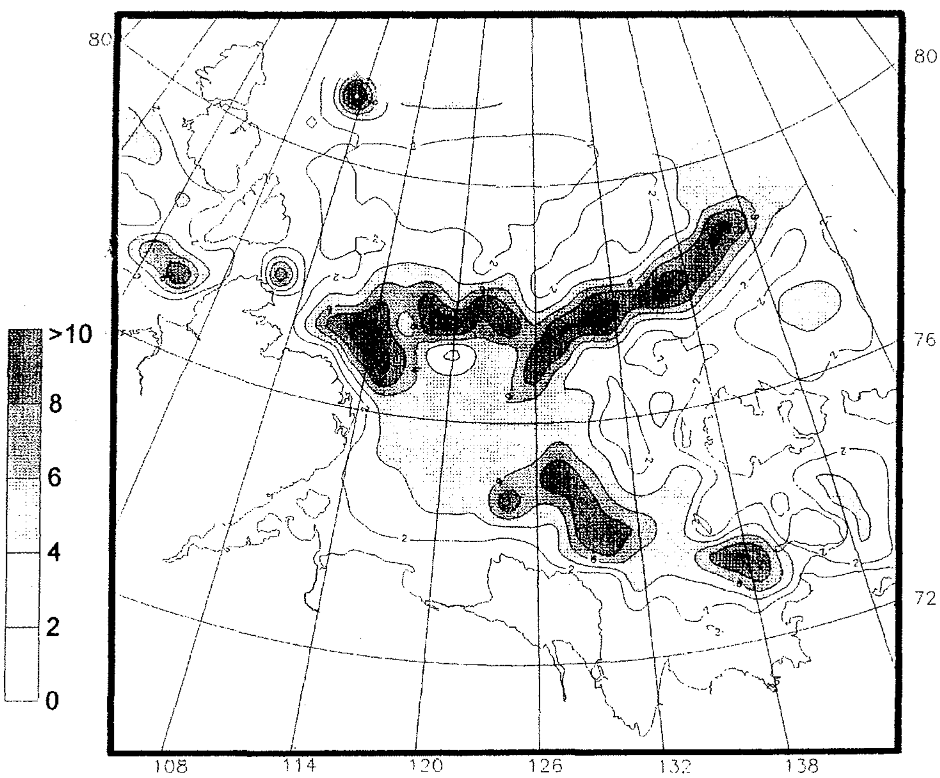

Fig. 3: Sediment thickness (m) of seismic unit (QIV?).

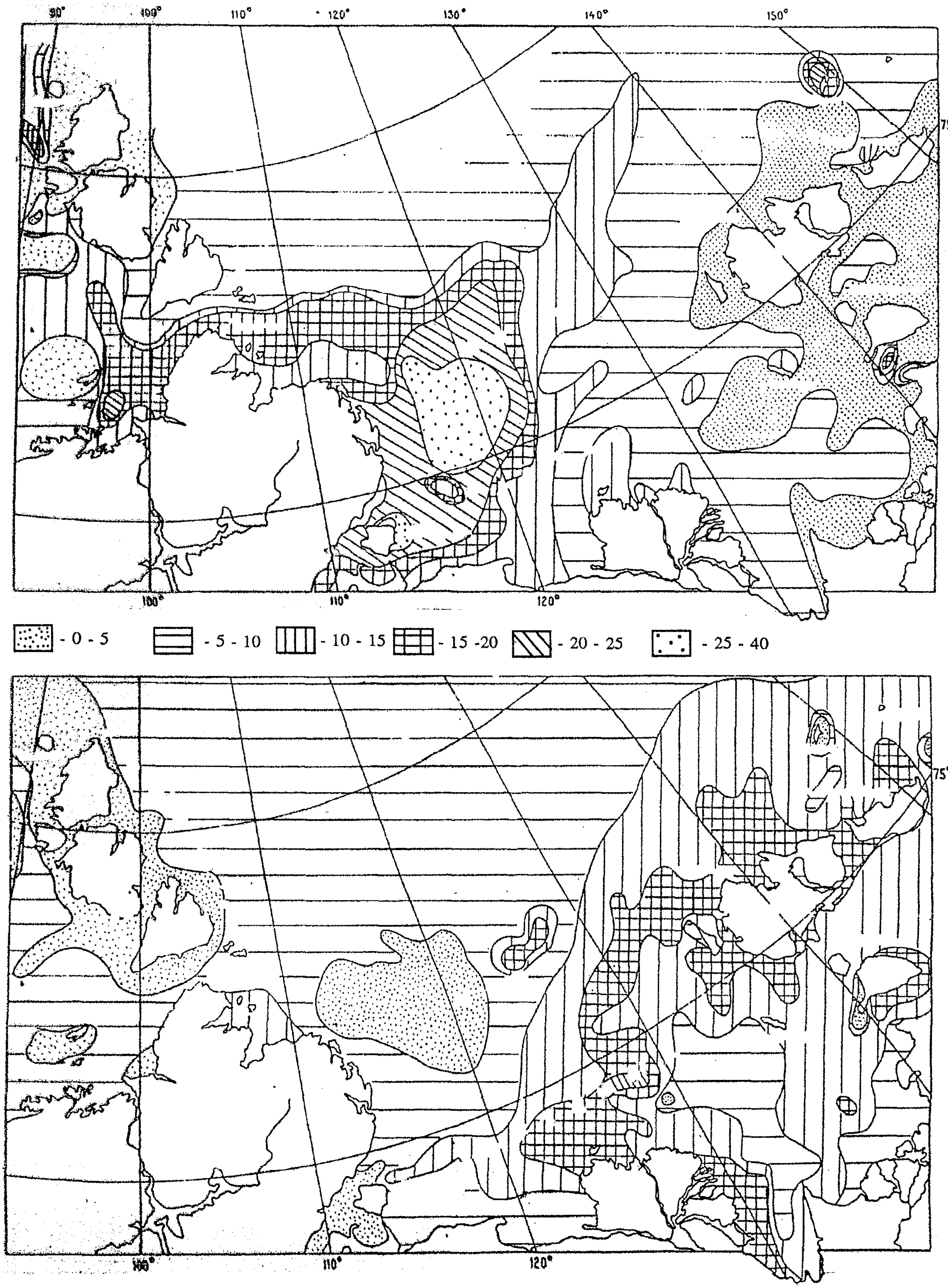

Fig. 4: Distribution of heavy minerals in upper Holocene deposits (%); top = pyroxenes; bottom = amphiboles.

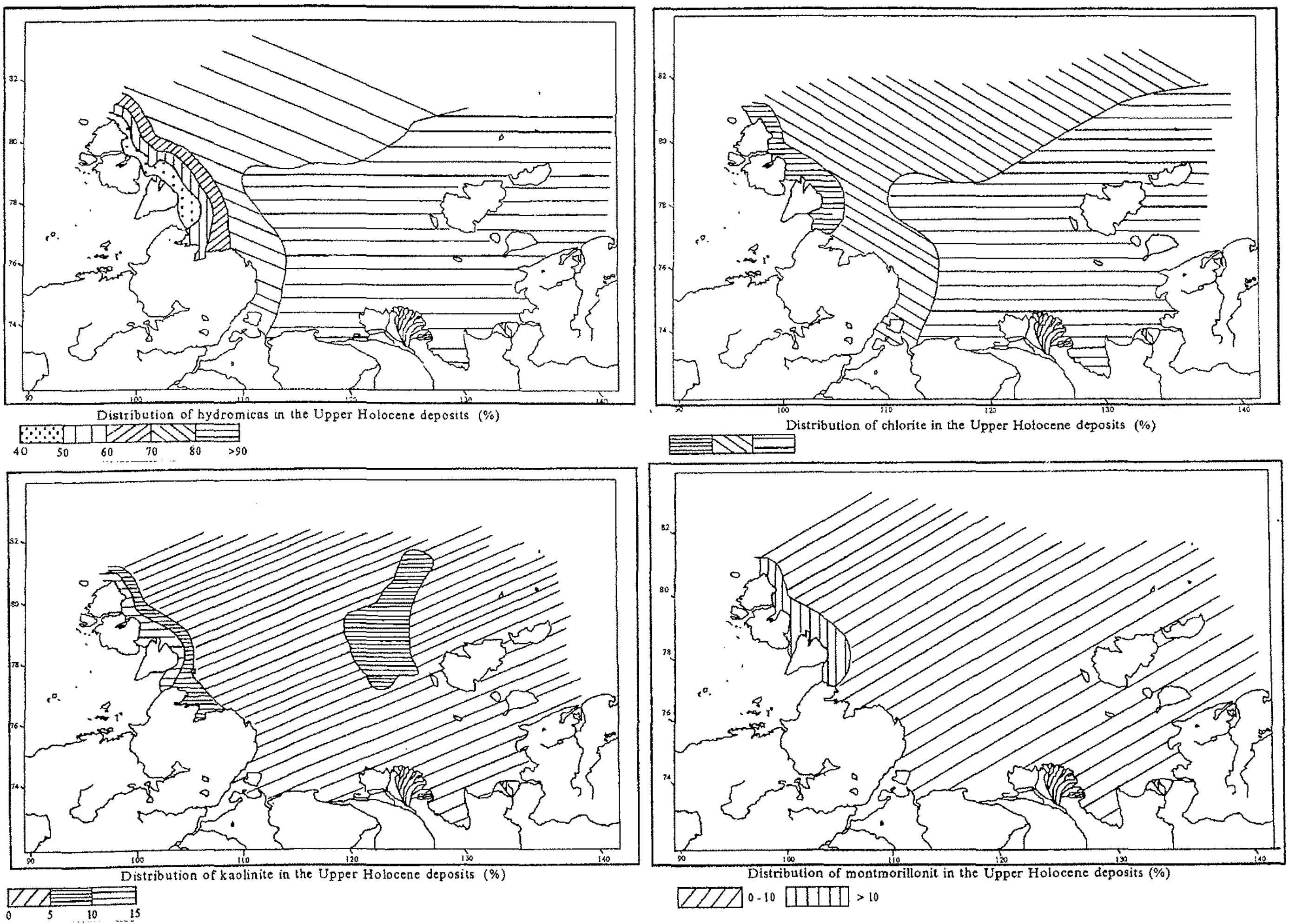

Fig. 5: Distribution of clay minerals in surface sediments of the Laptev Sea.

rillonite (up to 10 %). Crusts of weathering were developed mainly on sedimentary and metamorphosed Upper Proterozoic to Lower Paleozoic rocks and partly on Paleozoic intrusive rocks (AVDUNICHEV 1985, SHNEIDER et al. 1989). The main reason of kaolinite presence in bottom deposits of the central part of the Lapten Sea basin seems to be the erosion of the Upper Creataceous-Paleogene crust of weathering occuring onshore New Siberian Islands which were developed on effusive rocks. These crusts of weathering are characterized by kaolinite-Hydromica association of clay minerals (DOROFEEV et al. 1999).

The major geochemical feature of the organic carbon (Corg.) distribution is its circumcontinental zonation (ROMANKEVICH 1977). The mosaic-like distribution of organic matter and its heterogeneous composition are controlled by bioproductivity variations and differences of the volume and composition of suspended terrigenous material which serves as the main source for the organic matter input from the land as it was shown previously (ROMANKEVICH 1982).

The Laptev Sea water balance is characterized by the decreased contents of organic carbon (Fig. 6) in spite of the major significance of the solid terrigenous discharge. The content of organic carbon and organic matter corresponds to the grain size of deposits. For instance, the average content of organic carbon is 0.26 % in sands and 1.16 % in clayey muds (dispersion (D) = 0.201; average quadrat deviation (S) = 0.449; Coefficient of variation (V)x = 47.97). Deposits with an organic carbon content less than 1 % occur on the major part on the shelf. Maximum contents of organic carbon are fixed in the mouths of Lena, Yana, Khatanga and Olenek rivers. Increased organic carbon contents are established in certain areas of the central part of the sea bottom composed by fine grained deposits while low contents are located in northern and north-western parts and near Taimyr Peninsula due to more coarse grained character of bottom sediments and the composition of eroded rocks on the mainland.

Holocene deposits of the Laptev Sea Shelf are of a non-carbonate type (the content of $CaCO_3$ varies from 0.10 % to 8.5 %) due to the scarce occurrence of carbonate rocks in the hinterland and the poor character of the calcareous microfauna. Usually the content of $CaCO_3$ is less then 0.80 % and it increases only in estuaries. Clastic carbonates were revealed in the coastal zone of the New Siberian Islands.

The content of bitumens varies from 0.01-0.10 % constraining the evidence of a polygenetic origin of the organic matter, but the most common content is 0.01-0.03 %. Total bituminosity

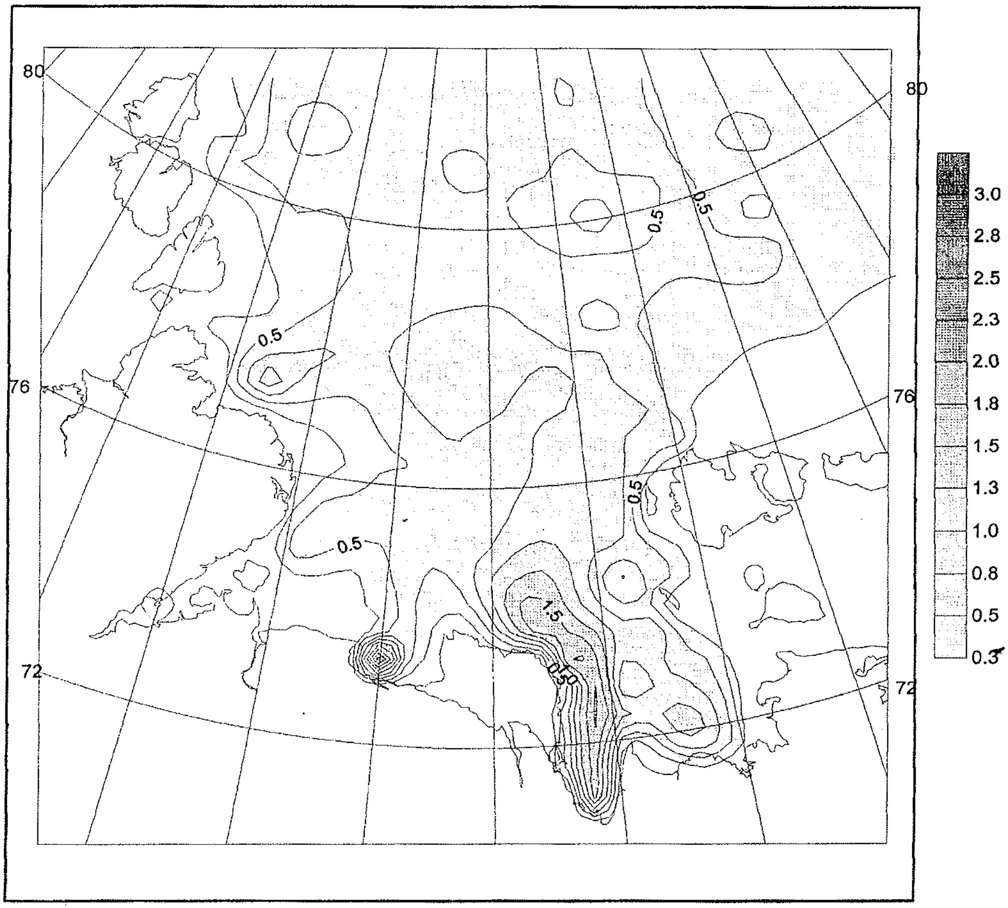

Fig. 6: Distribution of organic carbon in Holocene sediments of the Laptev Sea shelf.

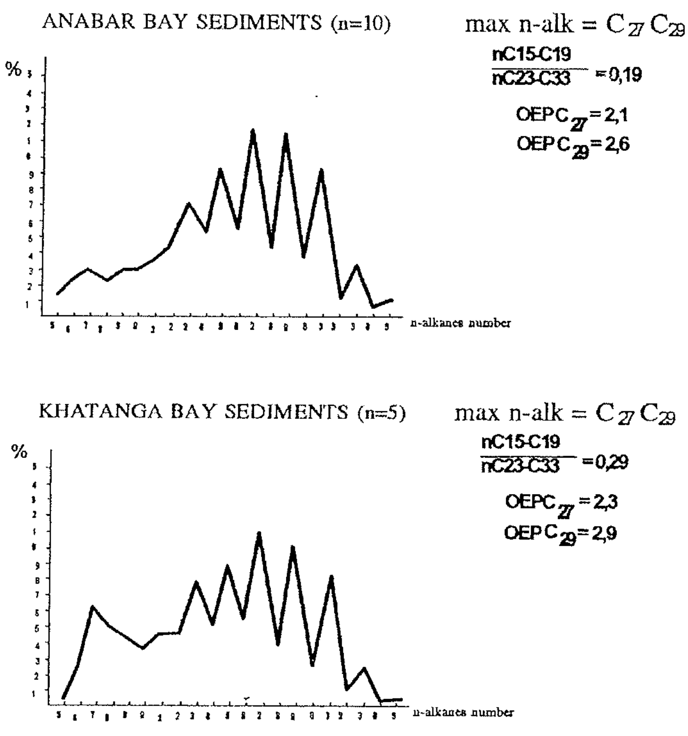

Fig. 7: N-alkane distribution in bottom sediments of the Laptev Sea shelf. OEP C27 and OEP C29: odd-even predominance ratio (SCALAN & SMITH 1970).

of organic matter is 4-5 %. The highest contents are fixed in clays of the major river estuaries. The contemporaneous background of hydrocarbon content is 0.002-0.006 % in recent deposits or 0.2-0.3% in the organic matter composition.

Three main genetic types of organic matter are present (ROMANKEVICH 1982, DANUSHEVSKAYA 1990) in the bottom deposits of Arctic shelves. The most widespread type is formed in the Laptev Sea predominantly by terrigenous remains of plants with a variable role of bottom population. Bitumens are characterized by an enrichment by carbon and resinaceous-asphaltene components and a depletion of hydrocarbons. Normal alkanes are composed basically by long-chain compounds (C25,27,29,31) and remains of terrigenous lipides (71-76 % of the total sum, Fig. 7). Good enough correspondence of molecular composition of polycyclic aromatic hydrocarbons (PAH) in the Laptev Sea shallow marine deposits and tundra macrophytes shows possible similar (predominantly humus) origin (YUNKER & MCDONALD 1995) of their organic matter.

CONCLUSIONS

The marine transgression since the beginning of the Holocene was likely responsible for the accumulation of the thin veneer not exceeding 5-10 m, in maximum 25 m in thickness, with higher values usually found in bottom trenches and depressions. The mineralogical composition of the Holocene deposits shows two different provinces on the Western and Eastern Laptev Sea shelf. These features apparently reflect the influence of terrigenous discharge from different provenances, the Taimyr Peninsula and Anabar Shield in the West, and Verchoyansk Range in the East.

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