Features of lithological and granulometric composition of bottom sediments in the northern part of Laptev Sea

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Abstract. Bed-sediment samples were collected from the northern part of the Laptev Sea to assess particle-size distribution, mineralogical composition as well as to examine organic matter content. The organic carbon distribution map is constructed to reveal the trends of C_{org} content and distribution in the surface of the bottom sediments.

1. Introduction

Since the 30-s of the 20th century the intensive development of oil and gas exploration industry has led to the necessity of exploration of such unique gas fields as Medvezhye, Urengoy, Yamburg, Zapolyarnoye, Bovanenko on the continental area of the Russian region of the Arctic. According to prospecting surveys, approximately a quarter (22 %) of the world oil and gas reserves is located within this territory.

It is obvious that the Arctic zone of the Earth will be the primary source of the oil and gas reserves, not only for Russia, but also for other countries. Thus, the interest of Arctic countries in the exploration of the Arctic natural resources tends to increase, and, according to experts' opinion, the competition for these resources among the countries will become stronger in future.

However, mineral resource development of the Arctic areas is associated with high risks, such as specific environmental conditions, lack of infrastructure and lack of experience in eliminating the impact of oil spill on the Arctic system, insufficient knowledge of the shelf. While organizing and performing the offshore drilling operations, a serious risk is represented by the gas-hydrates, which are underexplored in our seas in the Arctic. The Laptev Sea shelf is of primary interest in terms of hydrates [4]. The Laptev Sea is a submarine cryolithic zone [3], where the powerful and multiple methane releases [2, 3] (concentration up to 700 nM) in a form of flowing bubbles (known as plumes) were discovered. They rise from the bottom of the sea (from the depth of 60-110 m) through the water layer, and sometimes go up to the atmosphere. It is this depth interval in which the most significant thawing of the submarine cryolithic zone has been anticipated. Such an interval provides gas flow to gas outlet [2].

Gas hydrate is a solid clathrate compound in which a large amount of gas is trapped within a crystal structure of water, forming a solid similar to ice. It should be added that the methane content in gas hydrates is being lowered by a factor of about 200. In case of decreasing pressure or increasing temperature, the destruction of gas hydrates takes place and high gas volume is released. On the one hand, gas hydrates are involved in the process of oil and gas accumulation as they are considered to be impermeable layers. On the other hand, in case of fractured zones activation, the intense migration of the gas from gas hydrates deposits occurs, oil and gas pool collapse and decomposition of oil and gas bearing rocks take place. During the hydrate destruction, the gas flows through talik zones into the air and further to the atmosphere, which results in significant redistribution of hydrocarbon gases and gas hydrates formed at different times and at different depth. This fact poses a serious ecological problem of a global scale.

According to available data, seas of Eastern Arctic are the source of methane released into the atmosphere of the Arctic Region. Contribution of the latter is comparable with that of the entire global ocean, and it is conditioned by degradation of subsea and near-shore permafrost.

The facts of temperature jumps as compared to the past century (about 5°C) [1], the highest coastal erosion rate, annual methane discharge, enormously intense, in contrast with the other objects, have revealed ocean anomalies of the dissolved methane, including big gas plumes (up to 500 m in diameter) [2-4] and induced to perform a more detailed research.

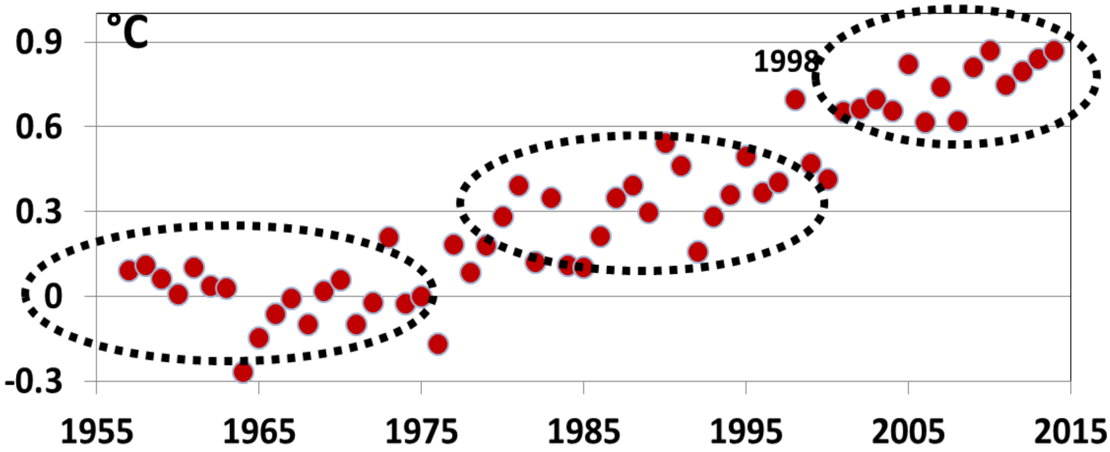


Figure 1. Global land-ocean temperature index (°C) [4]

2. Unit characteristics and methods

24 bed-sediment (0-5 cm) samples were collected from the northern part of the Laptev Sea to assess particle-size distribution and mineralogical composition as well as to examine organic matter content. The study area (figure 2) was explored by the Russian and US scientists in September-October 2011 on the board of research vessel Academician Lavrentiev.

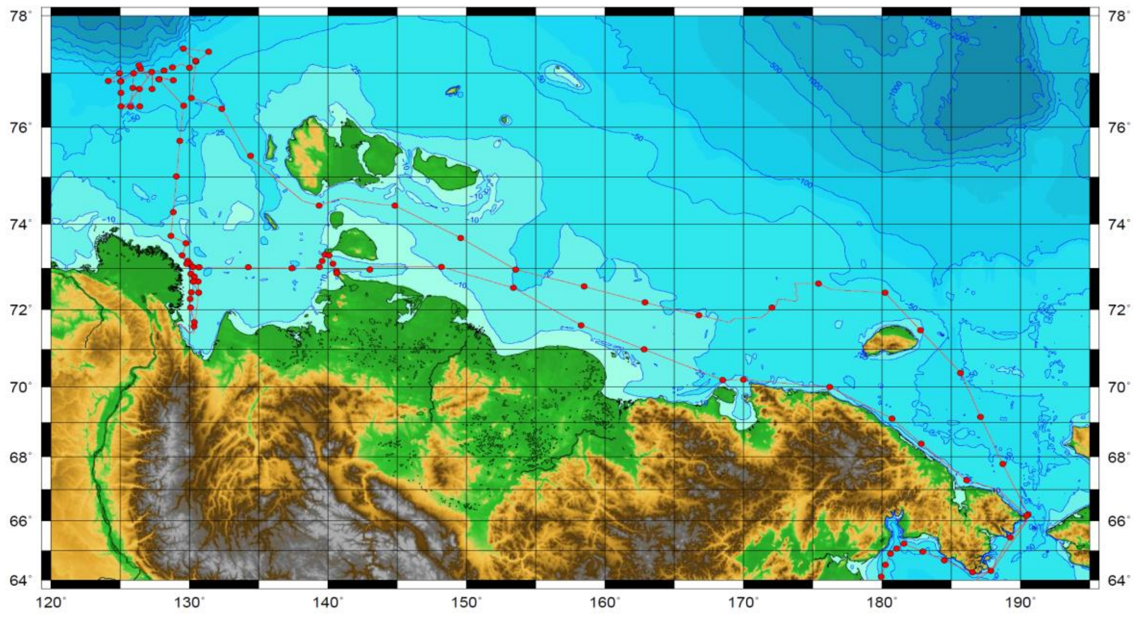


Figure 2. The map of study area

Particle size distribution was examined by laser diffraction method. Laser diffraction measures particle size distributions by measuring the angular variation in intensity of light scattered when laser beam passes through a dispersed particulate sample. Mineralogical analysis was carried out using the binocular microscope to reveal the different mineral species within sandy and silt fractions. Organic matter content was determined in the sediments by the Rock Eval pyrolysis. The analysis was carried out in the Arctic Sea's Carbon Research International Laboratory, Tomsk Polytechnic University.

In terms of the granulometric composition, the fractions with dimensions from 0.01 mkm to 3.08 mm were obtained. The range of fractions consisted of predominant pellite fraction (<0.01 mm) with the content from 24 to 77 %, aleurite (form 22 to 45 %), and psammitic (from 0.3 to 47 %) fractions were minor. According to the classification of clastic sedimentary rocks, the samples were primarily in the form of aleuritic-clays, less frequently in the form of silty clays and sands. Using the granulometry data, the cumulative curves were built (figure 3), the calculated sorting coefficient changed within the range of 1.18-3.65, which indicated the mean sorting ratio for aulerite clastic material, and good sorting ratio for sand clastic material.

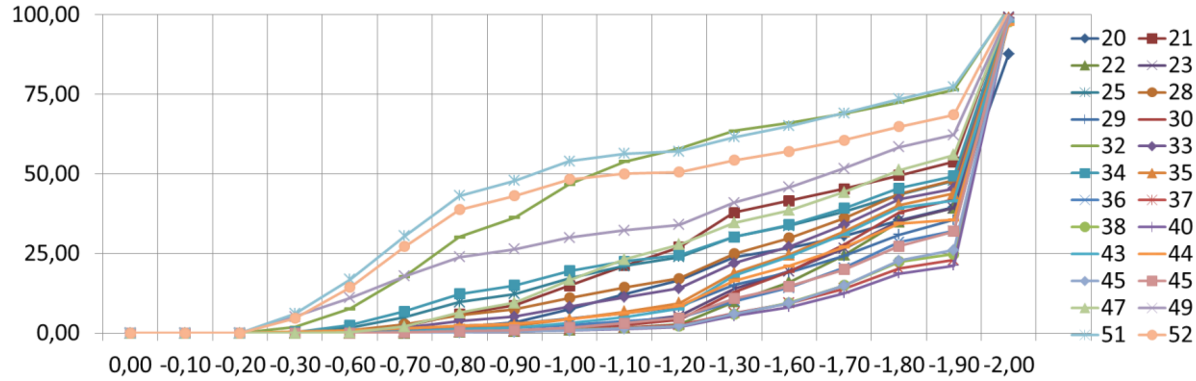
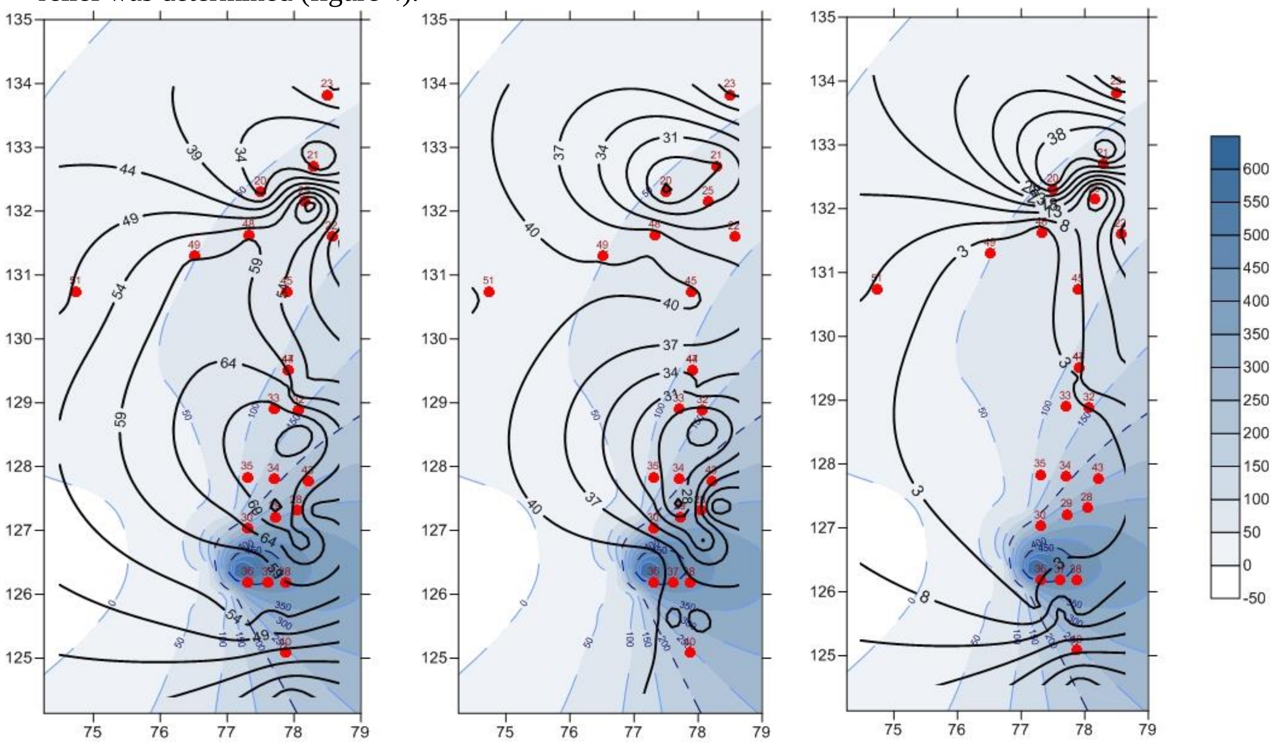
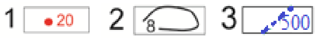


Figure 3. Particle-size accumulation curve

Using the granulometric analysis results, the distribution maps of pellitic, aleurite and sandy fraction content were constructed, and correlation between fractions content and surface of submarine relief was determined (figure 4).



a) b) c)

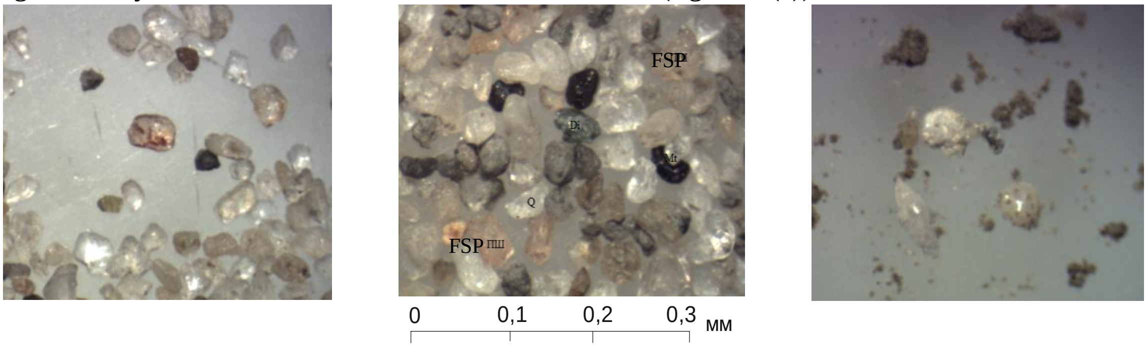


Note: 1 – № of the samples; 2 –a) pellitic fraction content, %; b) aleurite fraction content, %; c) sand fraction content, %; 3 – height contour, m.

Figure 4. Particle-size distribution map

Based on the information obtained in the course of study, the relation between water depth and grain size distribution has been established: pelitic sediments tend to the most low-lying areas, whereas the psammit depositions, on the contrary, are confined to the shallow part (figure 4).

Mineral analysis by physical method revealed the presence of quartz, feldspar, muscovite, biotite, garnet, and some of the other sediment minerals in sediment samples. Quartz and feldspars predominated in all samples. Quartz was the most common mineral which was found to be about 30-60% of total sediment, grains being colorless and transparent or translucent, ranging from rounded to angular. They were colorless with rare traces of hematite (figure 5 (a)).



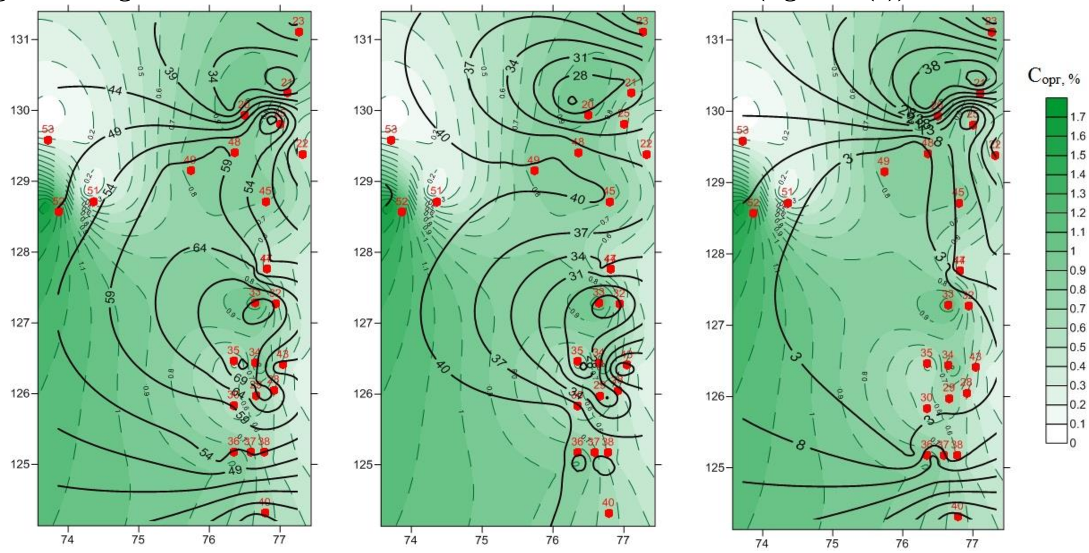
A) – The trace of hematite in quartz

B) – The grains of quartz (Q), feldspar (FSP), diopside (Di) and magnetite (Mt)

C) – The remains of clamshell of various forms

Figure 5. Features of the mineralogical composition of sands

Feldspar (25-35 %) is elongated, translucent, colorless, gray, pink, and pale yellow angular-rounded and angular fragments. Micas (biotite and muscovite) are found in small amounts (5-15 %) in all samples (figure 5 (b)). Carbonate minerals are presented by calcite brown siderite and are observed in samples No. 21, 22, 28, 30 in the amount of 10-15 %. The magnetite (to 10 %) is widespread among the ore minerals which has specific iron-black color and strong magnetic properties. Accessory minerals (to 5 %) include epidoty, diopside, apatite, chlorite, and grenades. Also, there are carbonized vegetable fragments and the remains of clamshell of various forms (figure 5 (c)).



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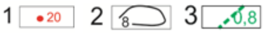

Note: 1 – № of the samples; 2 – a) clay fraction content, %; b) silt fraction content, %; c) sand fraction content, %; 3 – organic carbon content (C_{org}), %.

Figure 6. Organic carbon distribution map

Organic substance study is the most important aspect of hydrochemical, hydrobiological and geological research. Besides, organic carbon is its most primary characteristic. In the studied samples the C_{org} content varies from 0.03 to 1.61 %. The organic carbon distribution map is constructed to reveal the trends of C_{org} content and distribution on the surface of the north Laptev Sea's bottom sediments (figure 6). It is compared with the granulometric composition distribution map. Therefore, the relative saturation of north Laptev Sea's pelitic sediments with organic carbon is revealed. The correlation between organic carbon and sediment granulometry can be partly explained by the sorption of organic carbon by the thin pelitic fraction.

3.Conclusion

Based on the obtained data, it has been found that depositions of pelitic sediments tend to the lower areas, whereas the psammit depositions are confined to the shallow areas.

The concentration of north Laptev Sea's pelitic sediments with organic carbon is revealed. The probable reason for this process is the increased sorption of C_{org} by fine pelitic fraction.

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