the fracture is better when it intersects more with natural fractures, which creates more permeable inner surfaces, so a good study of the nature of the geological plates as well as natural fractures is necessary to determine the ideal dimensions.

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SPATIAL VARIABILITY OF ORGANIC MATTER IN SURFACE SEDIMENTS OF THE LAPTEV SEA SHELF (EASTERN PART)

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Increasing global warming in the Arctic leads to a significant rate of terrestrial and submarine permafrost degradation [6, 9]. A vast amount of remobilized organic matter (OM) is involved in the modern biogeochemical cycle. It was shown that an increased supply of remobilized ("old") OC may lead to severe acidification of the Arctic waters and significantly contributes to the greenhouse effect as a result of the OC to CO_2 transformation. Understanding of the fate of terrestrial OM moving from the land to the Arctic shelf is essential for predicting the potential feedback of Arctic ecosystems. Reliable identification of both OM sources and the mechanisms of its trans-formation within the "land – shelf" system is an important step towards a comprehensive understanding of the modern Arctic carbon cycle.

The East Siberian Arctic Shelf (ESAS), represented by the Laptev Sea, the East Siberian Sea, and the Russian part of the Chukchi Sea, is unique because it occupies a huge area (>$2*10^6$ km^2) and has a shallow average depth (~50 m). Moreover, the ESAS contains more than 80% of the world's subsea permafrost which is believed to store permafrost-related and continental slope methane hydrates [8, 9].

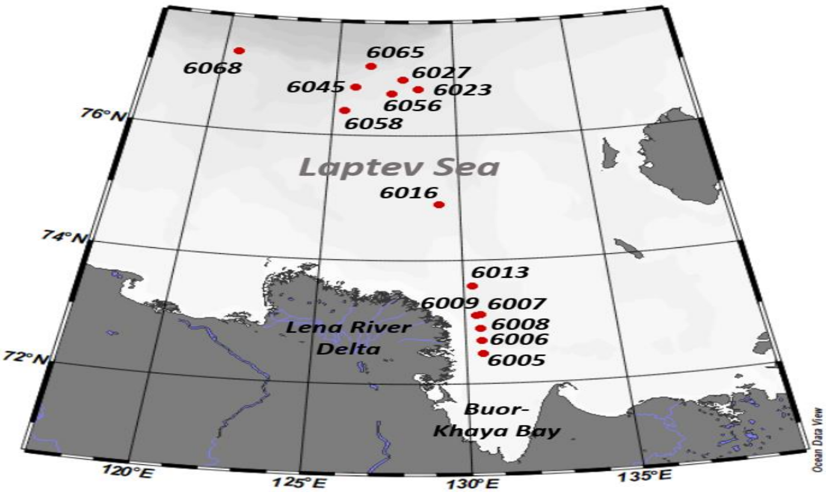

Fig. 1 Sample stations

The Laptev Sea is an Arctic sea dominated by terrestrial OM that receives a substantial contribution from both coastal erosion and Lena river runoff [7]. It was previously shown that accelerating coastal erosion acts as the main contributor to the terrestrial OM pool exported to the Laptev Sea [10]. About 25% of the Laptev Sea coastline is composed of ice-rich permafrost deposits known as the Yedoma Ice Complex which is highly susceptible to erosion. The retreat rate of the permafrost-dominated coast has been steadily increasing due to the combined action of thermal and mechanical forces [4]. The total input of the intense coastal erosion to the Laptev Sea and the East Siberian Sea is estimated at 4.0 – 22.0 ± 8.0 Tg/year (the submarine permafrost degradation is included) [6, 10]. Besides, the Lena River exports large volumes of the fresh water discharged to the Laptev Sea, being the main fluvial sediment source for the ESAS. During the land-to-shelf transport, exported organic matter undergoes aerobic biochemical decomposition, which can be re-mineralized to CO_2 or delivered to the deep-water part of the Arctic Ocean [1].

Our research attempts to characterize the modern OM stored in the surface sediments of the Laptev Sea in order to estimate its composition variability and attempt to identify the OM sources along the profile "coastline - outer shelf".

We analyzed 14 surface sediment samples (horizon 0 - 2 cm) collected across the Laptev Sea shelf during the Arctic expedition onboard the Russian R/V Academician M. Keldysh during fall 2018 (Fig.1). A box corer was used to collect sediment samples.

Grain-size (laser diffraction method; SALD-710, «Shimadzu»), pyrolytic (Rock-Eval 6 Turbo, VINCI Technologies), and GC-MS (Agilent 7890B (GC) – Agilent Q-TOF 7200 (MS)) analyses were performed. To provide relevant data for the modern OM an adapted Rock-Eval temperature program "Reservoir" has been applied.

According to the pyrolysis data, total organic carbon (TOC) varies from 0.4 to 2.71 wt%. Free hydrocarbons and low molecular weight OM, considered as lipid fraction (S_1), range from 0.11 to 0.73 mg HC/g. The predominantly higher TOC and S_1 values are found in the coastal zone (> 1 wt% and > 0.4 mg HC/g, respectively).

The contents of relatively thermo-labile hydrogen-rich OM or biopolymers (S_2) and CO/CO_2, released by oxygen-containing OM or geopolymers (S_3), correspond to 0.67 – 2.92 mg HC/g and to 1.18 – 5.4 mg HC/g, respectively. Consequently, the fraction of the lipid extractable component in the total OM yield is, on average, 13 times less than the fraction of biogeopolymers stored in the sediments ($S_2 + S_3$).

The sediment distribution suggests a relatively low HI (hydrogen index) and a higher OI (oxygen index). The HI of all samples is higher than 100 mg HC/g Corg and ranges from 103 to 181 mg HC/g Corg, which indicates the presence of a hydrobiont component in the OM. The maximum HI values are recorded in the samples taken from the outer shelf. The OI ranges from 199 to 309 mg HC/g Corg. The OI can reflect both the export of already oxidized OM with river runoff and coastal erosion and the subsequent degradation of allochthonous and autochthonous OM in the water column, as far as it is buried in sediments; therefore, it is important to separate these two processes. The ratio HI/OI < 1 may be compared to a mix of "Type 2" and "Type 3" kerogens for matured OM determining planktonogenic and terrestrial origin, respectively [5].

Sediments are dominated by clay (< 2 μm) and silt (2 - 63 μm) fractions. The sand fraction (> 63 μm) is almost absent. The significant HI and clay content correlation (r = 0,71) was also revealed.

The qualitative interpretation of n-alkanes (neutral non-polar fraction) and isoprenoids (pristane and phytane) distribution was conducted. Obviously, terrestrial input is a main contributor to the OM of the studied sediments. Overall dominance of the high molecular weight (HMW) odd C_{25} – C_{31} n-alkanes indicates a significant portion of terrestrial OM exported with river discharge and thermo abrasion material [2, 3, 4]. However, for many outer shelf samples both the hydrobiont markers of the autochthonous nature (C_{15}-C_{19} n-alkanes) and the terrestrial markers mentioned before are contrastingly expressed.

Such classic geochemical indices were calculated based on the peak exit areas on received chromatograms: CPI (Carbon Preference Index), OEP_{17}, OEP_{19} (Odd Even Predominance) indexes, K_i, TAR (terrigenious to aquatic ratio), Paq, and Pr/Phy ratio.

High values of the CPI (>> 3) indicate a prevalence of vascular land plants as a source of OM and low microbial degradation state. The average K_i (0.46) and OEP (1.28) indexes also confirm low diagenetic transformation of OM. The TAR traces an increasing supply of autochtonous OM with increasing distance from the coast. In the zone of coastal sediments, the terrestrial component is clearly pronounced (TAR = 31.6), while for the outer shelf sediments, the index is 4 times lower (TAR = 7.6). The Paq index points out a low contribution of macrophytes (Paq = 0.31) with increasing values in the coastal part. The Pr/Phy ratio confirms the suboxidative environment revealed by the pyrolysis data (HI/OI ratio).

The GC-MS records are directly comparable to Rock-Eval data. The terrestrial OM contribution is clearly traced despite the great distance from the coast. This is a distinctive feature of the Laptev Sea biogeochemical regime, which was previously noted by other researchers. Our results confirm and enhance their findings with new geochemical data providing a deeper understanding of the modern biogeochemical carbon cycle in the Arctic.

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ANALYSIS OF THE CURRENT STATE OF THE ZAPADNO-MALOBALYKSKOYE OIL FIELD DEVELOPMENT (KHMAO-YUGRA)

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The full-scale development of the Zapadno-Malobalykskoe oil field began in 1999, with produced water re-injection being started in 2000. Since then, the production history has been determined by wells of highly porous and permeable development targets (AS_4, BS_2, BS_8). Over the first four years, oil and fluid production was marked by its low rate due to the very moderate field development of the main BS_8 formation. Having reached its peak in 2005, the oil production stabilized at the level of 2.4 to 2.6 million tons up to 2007, with the rate of putting wells on production significantly reducing from 45 to 10 to 20 wells per year (Fig. 1) [3].

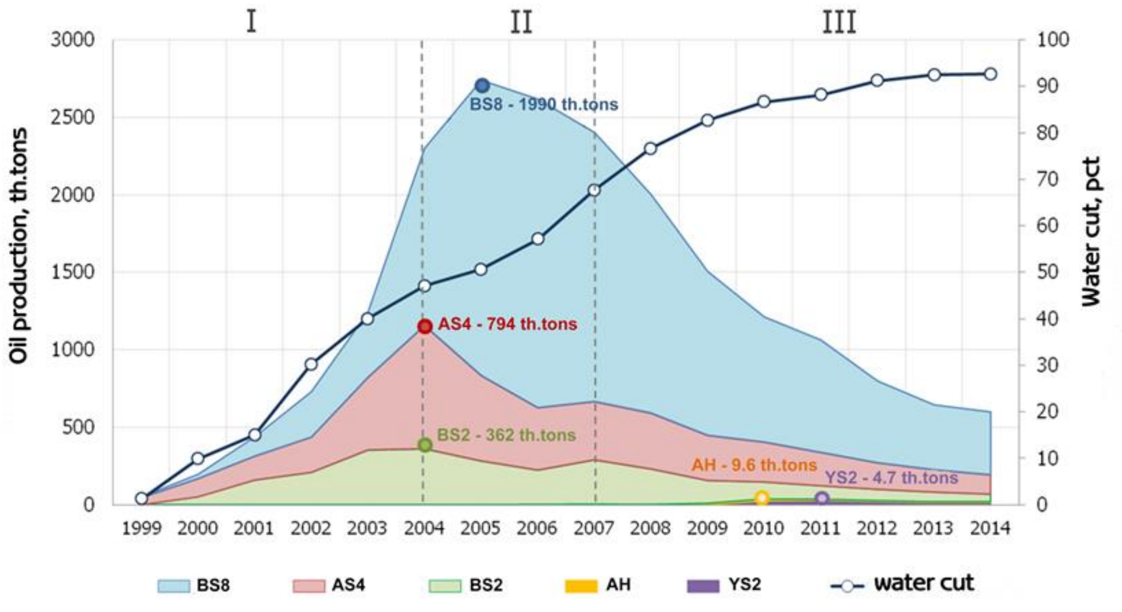

Fig. 1 Production history (1999-2014) of the Zapadno-Malobalykskoe development targets AS_4, BS_2, BS_8

During the entire field development period, the water cut was expanding at a high rate: 6-10% per year reaching 82.7% in 2009, with the withdrawal of 39.6% of recoverable reserves in compliance with the industrial categories. Over 2010-2014, well drilling at the main BS_8 formation enabled water cut rate to be stabilized at 0.5-2.0%. In 2014, the fractional water content amounted to 92.6 %, with only 46.6% of all recoverable oil reserves being withdrawn. The main reason for the withdrawals discrepancy is the advancing water production of the main development target AS_4 (extensive self-induced fracturing network) and BS_2 (putting into operation under-saturated oil bottom intervals) [1].

Since the production history began, the field has produced 20,509 th.tonnes of oil and 88,274 th.tonnes of fluids, with the accumulated water injection amounted to 91,617 thousand cubic meters. 46.6% of them were drawn from the initial recoverable reserves. Remaining recoverable reserves are estimated to 23,492 th.tonnes. Reserves-to-production ratio is 39 years.

The formation AS4 is represented by three oil deposits. Almost all recoverable oil reserves are concentrated in the main deposit, that is 99.4% (9,059 th.tonnes). The formation well stock has been developed by 70%. Well drilling is planned in the marginal areas of the main deposit. The current 3-line drive system is aimed at maintaining reservoir pressure [2]