Methane in Tabular Massive Ground Ice as a proxy of Late Pleistocene environmental conditions in Western Sector of Russian Arctic

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Methane emission triggered by permafrost degradation are important consideration in climate change debate in the Arctic making studies of origin and distribution of methane in permafrost of a considerable interest. Study of methane origin and content was performed at the Marre-Sale key site (69043'N/66049') at the western coast of Yamal Peninsula.

The study area is in the continuous permafrost zone with low ground temperatures. Geological section of the base of the coastal bluff is represented by lower saline silty clay unit of marine and coastal-marine origin and presumably associated with Marine Isotope Stage (MIS) 5. The eroded surface of marine and coastal-marine clayey sediments is overlaid by continental non-saline silts and sands formed during MIS 3 - MIS 1. Tabular massive ground ice (TMGI) bodies are represented by two types. The first type TMGI (3-10 m thick) was detected at the boundary between the marine and continental units. The ice contains uniformly distributed silt and sand inclusions. This type of TMGI can be described as ice-soil mix with layers of clear ice. The second type of TMGI (more than 10 m thick) was detected within the saline clayey unit of marine origin.

We collected 42 1-kg samples of TMGI and frozen soils for methane concentration analysis. The samples were disintegrated to a particle size of less than 0.25 mm with RETSCH mill at temperatures below freezing. Degassing of disintegrated ice was performed with SUOK-DG apparatus using a dynamic method of degassing. This method is based on diffusion of water containing gas to sub-micron level simultaneously with creation of high vacuum in diffusion zone. The gas volume obtained from 200 to 300 g of ice reached 10 to 33 ml depending on gas saturation of samples. Gas composition was determined by a method of gas chromatography using apparatus with plasma ionization detector SHIMADZU 2014.

For the samples with a high methane concentration, content of $\delta^{13}C(CH_4)$ isotopes (eight analyses) was determined in the Vernadskiy Institute of Geochemistry and Analytical Chemistry RAS (Moscow, Russia) using isotopic mass-spectrometer (GC-C-IRMS configuration). Content of the Hydrogen isotope in methane D vs. SMOW was determined for air bubbles obtained from six ice samples in the laboratory ISOLAB B.V. (The Netherlands). The highest level of methane saturation was typical of the samples of TMGI (6197 ppmv), while the lowest gas content was typical of frozen continental sands (115 ppmv) (Vasiliev et al., 2015).

Analysis of isotope composition of methane in the TMGI samples showed that according to ratio between $\delta^{13}C(CH_4)$ and D vs. SMOW, methane was produced by activity of anaerobic bacteria (Fig 1).

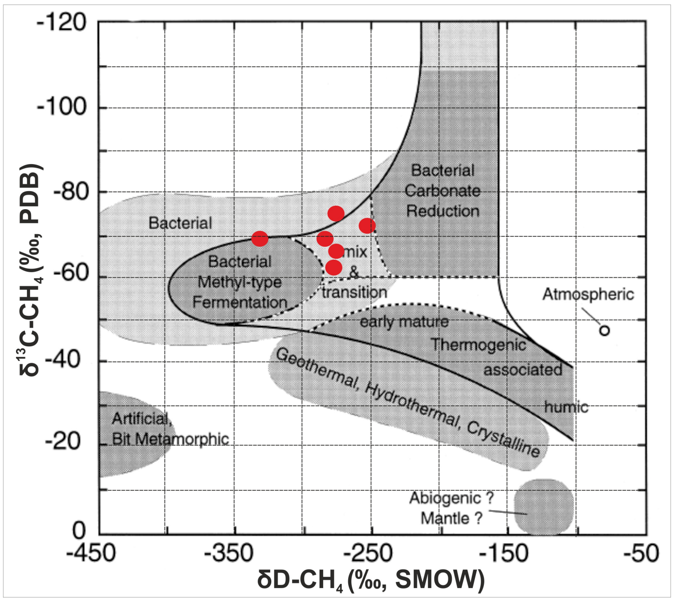

Figure 1: The red dots - the value of carbon isotope composition of methane (13C, ‰) and deuterium methane (D, ‰) of gas bubbles in TMGI and the diagram the ratio of the isotopic composition of methane, depending on the genesis of gas by Whiticar, 1999.

Results show that isotope composition of methane in ground ice and frozen soils is substantially different than that of atmospheric methane and methane from gas bearing strata of Senomanian and Neokomian age in West Siberia used in gas production. The isotopic values of ^{13}C in methane in TMGI are close to the values of the carbon isotopes of methane in permafrost at depths of 46-52 and 114-120 m in the Bovanenkovo gas field, West Yamal, and characterized of isotope composition of methane (^{13}C, ‰) -70.4 to -76.8 ‰(Chuvilin et al., 2007). The high methane content in TMGI is a result of methane migration from the adjacent soils and accumulation inside ice bodies. Extremely high methane concentration in TMGI is a strong evidence of its intrasedimental and not atmospheric origin. It is difficult to select potential sources of gas bubbles trapped in TMGI. This heterogeneous medium, rich in organic matter, might have favored the anaerobic micro-environment necessary to explain the abnormally high methane content. Marshy coasts near shallow seas may have contributed to such conditions. The isotopic content of marsh gas in TMGI excludes the glacial origin of this ice.

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