Available online at www.sciencedirect.com

ScienceDirect

Russian Geology and Geophysics 58 (2017) 600–610

RUSSIAN GEOLOGY AND GEOPHYSICS

www.elsevier.com/locate/rgg

Input of organic matter to the Buor-Khaya Gulf (*Laptev Sea*)

T.V. Pogodaeva [a,*], T.V. Khodzher [a], N.A. Zhuchenko [a], M.N. Grigoriev [b], V.S. Panov [c], G.T. Maksimov [b]

[a] *Limnological Institute, Siberian Branch of the Russian Academy of Sciences, ul. Ulan-Batorskaya 3, 664033, Russia*
[b] *Melnikov Permafrost Institute, ul. Merzlotnaya 36, Yakutsk, 677010, Russia*
[c] *Institute of Archeology and Ethnography, Siberian Branch of the Russian Academy of Sciences, pr. Akad. Lavrentieva 17, Novosibirsk, 630090, Russia*

Received 27 October 2015; accepted 6 July 2016

Abstract

We present results of study of organic matter in the coastal and bottom sediments of the Laptev Sea (Buor-Khaya Gulf). The study has shown the regularities of organic-matter distribution in the shelf zone adjacent to the glacial coast. The coast composed of a glacial rock complex supplies the largest amount of organic material to the sea as compared with other types of the coast. The average content of organic matter in these strata is ~2–3%. The bottom sediments of the shallow littoral zone are significantly depleted in organic carbon (0.1–0.3%) as a result of their active rewashing and the transition of finely dispersed material (mainly organic one) toward the deep sea zones. The content of organic carbon in the bottom sediments increases to 1–2% as the sea deepens to 7–10 m at 5–12 km from the coast. There are frequent local anomalies of organic-carbon contents (up to 4–5%) in the deltaic zones of the sea. The highest contents of organic carbon (up to 3%) have been found in the recent marine sediments in the central, relatively deep zones of the bays.

Keywords: bottom sediments; organic carbon; organic nitrogen; carbon isotopes; nitrogen isotopes; Arctic; Laptev Sea

Introduction

In recent years, the forecasted climate warming in Arctic has triggered great interest to data on the input of organic carbon, the source of greenhouse gases, to the Arctic basin (Achberger et al., 2013; Bense et al., 2009; Frey and McClelland, 2009; Guo and Macdonald, 2006; Gustafsson et al., 2011; Naidu, 1985; Richter-Menge and Overland, 2010; Romankevich and Vetrov, 2001; Schuur et al., 2008). Solid river and coastal runoff was established to be the major terrigenous source of organic carbon for Arctic seas (Are, 1999; Charkin et al., 2011; Eicken, 2004; Grigoriev, 2004; Grigoriev and Kunitskii, 2000; Grigoriev and Rachold, 2003; Grigoriev et al., 2001, 2004a; Guo et al., 2007; Rachold et al., 2000, 2004; Reimnitz et al., 1988; Shuiskii, 1983; Stein and Macdonald, 2004). The large part of the Arctic coast, especially in the east of the Russian Federation, is formed by glacial rocks (so-called glacial complex) and deposits of thermokarst depressions (Grigoriev, 2004; Grigoriev and Kunitskii, 2000; Grigoriev and Rachold, 2003; Grigoriev et al., 2001, 2004b). They are rich in organic carbon owing to the presence of abundant plant remains, e.g., peat accumulations. The active erosion of the coast, particularly the glacial complex, resulted in suspension flows on the large part of the nearby shelf, which are well visible in satellite images (http://www.visibleearth.nasa.gov). Coastal sediments (and organic carbon) are supplied by bottom currents to deep sea zones as suspensions and bottom material, in compliance with the bathimetric parameters and relief of the bottom. According to Rekant (2001) and Treshnikov and Sal'nikov (1985), the main waterways involved in the transportation of most of the bottom sediments are paleoriver valleys formed during the Zyryanian, Sartanian, and preceding sea regression.

The Buor Khaya Gulf located in the central part of the Laptev Sea is the best object for studying the above processes. The solid runoff of the long Siberian Lena River here forms an underwater extension of its delta. About a third of the gulf coast is steep cliffs up to 40 m in height, composed of the glacial-complex rocks. The latter are intensively eroded by thermal abrasion, whose rate reaches 10–20 m/year, as, for example, on Muostakh Island (Grigoriev and Kunitskii, 2000). In recent 10–15 years, the rate of the glacial-coast disintegration has considerably increased (Grigoriev et al., 2006). The reason is an increase in the regional summer surface air

* Corresponding author.
E-mail address: tatyana@lin.irk.ru (T.V. Pogodaeva)

1068-7971/$ - see front matter © 2017, V.S. Sobolev IGM, Siberian Branch of the RAS. Published by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.rgg.2017.04.002

temperature, a slight increase in the thickness of seasonally thawing layer on the coastal slopes, and growth of the storm activity in Arctic because of the considerable expansion of the water area zone free of close ice in summer.

The Lena delta also has a glacial coast; the average annual rate of the coast retreat there is 2–3 m/year (Grigoriev, 1993). Terrigenous material supplied to the sea water area contains much organic matter (OM). The coast erosion intensifies the flow of this material. It is necessary to elucidate the distribution of OM throughout the coastal area and the regularities of its distribution and deposition on the coastal shelf.

Materials and methods

Field works on the coast and shelf of the Buor-Khaya Gulf of the Laptev Sea were carried out by the Permafrost Institute (Yakutsk) in 2010–2013 (Fig. 1). Drilling for studying bottom sediments in the central zone of the gulf was performed by the researchers from this institute together with their colleagues from the Pacific Oceanological Institute (Vladivostok), Moscow State University, and Alfred-Wegener-Institut für Polar-und Meeresforschung (Bremerhaven, Germany).

In August of 2010, 137 samples of surface sediments were taken along seven profiles in the thermal-abrasion zone of the western coast of the Buor-Khaya Peninsula. This zone is formed by rocks with thick wedge ice. In each profile, the samples were collected in the coastal zone and within a continental slope, at 10 km from the coast. Some samples were taken in the Orto-Stan River and its mouth.

In April of 2011, drilling from marine ice on the coastal shelf penetrated a 50 m thick section of bottom ground at a distance of 17.5 km to the northeast from Muostakh Island (71°41′33.4″ N, 130°22′00.2″ E). Sixty-two samples were taken from the extracted bottom sediment core. Eleven samples were collected in the coastal deposit exposure on Cape Muostakh (Bykovskii Peninsula) (71°42′18.67″ N, 129°35′45.57″ E).

In April 2012, a core of thawed and permafrost bottom sediments was extracted from the 50 m long column of the well drilled near the western coast of the Buor-Khaya Gulf (71°25′20.4″ N, 132°05′04.9″ E). Thirty-four samples were taken from this core.

In August of 2012, twenty-eight samples of surface deposits were taken from a 19 m high sea cliff of Muostakh Island (on its northeastern coast), formed by a rock complex with thick wedge ice, and from the adjacent beach (section M-11-2012, 71°35′41,9″ N, 129°59′41.7″ E) (Fig. 1).

In April of 2013, two wells were drilled along the profile running from the northern cape of Muostakh Island to the Bykovskii Peninsula (Fig. 1), 30 m deep well II D-13 and 20 m deep well IV D-13, and 23 and 12 samples, respectively, were taken from them. Also, a 40 m deep well V D-13 was drilled on the Bykovskii Peninsula, at the center of the Ivashka lagoon, a former thermokarst lake subject to the sea influence. Eighteen samples were taken from its bottom deposits.

In August of 2013, the bottom surface ground was sampled in the strait west of Muostakh Island (Fig. 1). The samples were examined by different analytical methods, including analysis for organic carbon, nitrogen, and C/N.

The contents of total organic carbon (TOC) and total organic nitrogen (TON) were determined in the certified Laboratory of Hydrochemistry and Atmosphere Chemistry (Certificate ROSS RU. 0001.513855) of the Limnological Institute, Irkutsk. The analyses were made by catalytic high-temperature oxidation of samples at 950 °C, followed by the determination of CO_2 content on a high-temperature Vario TOC cube carbon analyzer with an IR detector. All samples were treated with 10% HCl (prepared from concentrated HCl of high purity and deionized water with TOC < 1 ppb) for removal of carbonates and then were dried at 80 °C to a constant mass (GOST 23740-79). The average over three measurements for a sample was taken as the final result. Standard deviation was no more than 0.01%.

Isotope ratios were measured by gas isotope mass spectrometry at the Institute of Archeology and Ethnography, Novosibirsk. Standard deviation of isotope measurements for the standard sample (citric acid, Aldrich) did not exceed 0.12‰. The average over two measurements for a sample was taken as the final result.

Results

The littoral zone of the western coast of the Buor-Khaya Peninsula is formed mostly by Pleistocene glacial rocks, which are loams with a high content of organic material (plant remains and peat inclusions). The ice content of the rocks is >50%. The sediments near the water line and in the shoal (a depth of ≤2 m) are medium- and fine-grained sand. The surface bottom sediments at a depth of >2 m are sandy loam. The rock sample from the Orto-San River is sandy loam, and the sample from the mouth zone is sand.

The glacial complex rocks and the deposits of alas depressions of the sea cliffs (sampled along several profiles) contain 0.82–5.8% TOC (loams) and up to 48% TOC (peat intercalates), whereas the sands of the littoral shoal are poor in organic carbon, 0.04–0.18% TOC (Fig. 2). Along all studied sea profiles, the sandy loams replacing sands as the sea deepens (to 7–10 m at a distance of 5–12 km from the coast) have low contents of TOC, 0.14–0.63%, which slightly increase with the sea depth. In sea depressions, the TOC content in sediments reaches 5%. Along all the profiles, high contents of TOC are observed in sediments consisting mostly of fine fractions.

In the 50 m thick bottom sediment section of the well drilled 17.5 km northeast of Muostakh Island, the ~6 m thick upper member is the richest in OM, with the maximum content of TOC (up to 3%) observed in the upper 33 cm thick mud bed (Fig. 3*b*). Throughout the core, the sediments are dark gray silt-argillaceous, with horizontal lamination. Lower in the section, in the horizons lying 18, 23, and 38 m below the sea bottom, there are a few more sediment members rich in OM (up to 2% TOC). The minimum content of OM has been found