Available online at www.sciencedirect.com

ScienceDirect

Russian Geology and Geophysics 58 (2017) 322–331

RUSSIAN GEOLOGY AND GEOPHYSICS

www.elsevier.com/locate/rgg

Molecular geochemistry of organic matter of Triassic rocks in the northeastern part of the Barents Sea: the influence of tectonic and magmatic processes

V.I. Petrova *, G.I. Batova, A.V. Kursheva, I.V. Litvinenko, I.P. Morgunova

Federal State Budgetary Institution "Academician I.S. Gramberg All-Russian Scientific Research Institute for Geology and Mineral Resources of the Ocean" (FSBI "VNIIOkeangeologia"), Angliiskii pr. 1, St. Petersburg, 190121, Russia

Received 28 July 2016; accepted 1 September 2016

Abstract

Samples of Triassic sediments were collected from cores of parametric boreholes drilled on the Admiralteiskii Rise, Franz Josef Land Archipelago, and Fersman structure in the northeastern part of the Barents Sea sedimentary basin. The composition and distribution of hydrocarbon biomarkers (*n*-alkanes, isoprenoids, cyclic alkanes, and polyaromatic hydrocarbons) were studied using the GC–MS method and provided information about the genesis, facies conditions of sedimentation, and catagenetic maturity stage of dispersed organic matter (DOM). The Late Mesozoic–Cenozoic uplifting of the region and active magmatic processes significantly influenced the thermal transformation of sediments. The revealed trend is best observed in the sediment section of the Franz Josef Land Archipelago, where the thermal effects led to a radical increase in DOM transformation, up to the AC_1 stage.

Keywords: hydrocarbon biomarkers; dispersed organic matter; catagenesis; Triassic deposits; Barents Sea; Arctic

Introduction

Triassic deposits are the thickest unit in the sedimentary cover of the Barents Sea region. Parametric and prospecting boreholes penetrated Triassic deposits both on the Franz Josef Land (FJL) Archipelago and in the water area, namely, in the South Barents Sea depression and on the Admiralteiskii Rise (Gramberg et al., 2004). The Triassic section is a terrigenous stratum with local tuffaceous rocks (and basalt bodies, in the Barents Sea depression) in the bottom. The northern part of the shelf is formed mostly by marine sediments, and the southern part, by lagoon and continental ones. Correspondingly, the genotypes of dispersed organic matter (DOM) show a zonal distribution, with accumulation of humic–sapropelic DOM in the north of the region and sapropelic–humic one in the south. The catagenetic maturity of DOM of synchronously accumulated strata varies over the area and reaches an abnormally high degree in some sections (Gramberg et al., 2001).

Regional catagenesis of DOM depends on many factors, namely, the intensity of heat flow, pressure, geologic time, lithologic composition of the host rocks, sedimentation environments, etc. (Fomin, 2011). Most researchers, however, consider temperature as the major factor controlling the above process. This is evidenced by a drastic increase in the degree of DOM catagenesis in zones of contact between sedimentary rocks and igneous bodies (Bishop and Abbott, 1995; Jones et al., 2007; Kontorovich et al., 1987; Melenevsky et al., 2008).

Catagenetic anomalies within the Triassic Barents Sea rock complex are observed not only in the sections of test-parametric boreholes drilled on FJL, with abundant intrusive bodies, but also in the Admiralteiskii Rise area, where the high degrees of DOM catagenesis are explained by the influence of the Meso-Cenozoic uplifting (Gramberg et al., 2001). According to known concepts (Astaf'ev, 1993), the Upper Permian–Triassic deposits of the Novaya Zemlya shelf subsided to a depth of about 5 km during the regional evolution. Correspondingly, the degree of DOM catagenesis in the Triassic deposits varies from MC_1 to MC_4, with the Lower Triassic deposits (T_1) showing the maximum vitrinite reflectance R^0_{vt} (>0.6).

* Corresponding author.
E-mail address: petrovavi@mail.ru (V.I. Petrova)

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.2016.09.008

Bro et al. (1989) processed results of parametric drilling and comprehensively studied and described the core material, including the chemical composition of rocks and the hosted DOM and its bitumens. These data were partly included into the collective Russian–Norway research monograph on the geologic evolution of the northern Barents Sea region (Solheim et al., 1998). The lithologic-facies conditions of accumulation of DOM, its genesis and maturity, and some aspects of the influence of intrusion processes on the oil potential of Triassic rocks of the Arctic islands are reported elsewhere (Danyushevksya, 1995; Gramberg et al., 2001; Suprunenko et al., 1998).

Indeed, transformation of DOM of rocks during the intrusion of igneous bodies into a sedimentary stratum, which is accompanied by thermal, emanation, and dynamic impacts (so-called contact metamorphism), leads to a significant transformation of kerogen structure (Melenevsky et al., 2006, 2008; Reverdatto and Melenevsky, 1986). Sheet intrusions (sills) of basic rocks and large dikes exert the strongest influence on organic matter (OM). The joint contact and regional catagenesis of OM can shift oil and gas generation zones and change the phase composition and conditions of preservation of hydrocarbons (Kontorovich and Khomenko, 2001; Kontorovich et al., 1987, 1996; Othman et al., 2001).

Modern investigation methods based on analysis of the molecular composition of DOM make it possible to consider the above problems at a new information level. Study of the influence of cutting dikes on the distribution of hydrocarbon markers in sedimentary rocks of the near-contact zones showed the local impact of these dikes, touching no more than 15% of the intrusion thickness (Bishop and Abbott, 1995; Farrimond et al., 1999). The lateral gradient of transformation of aliphatic, cyclic, and aromatic chemofossils matches the general tendency for an increase in the degree of catagenetic maturity toward the contact zone.

It is no doubt that the impact of sills on the Triassic FJL rocks must be accompanied by similar processes, as indirectly evidenced by petrographic studies of the catagenetic maturity of DOM of the core material from parametric boreholes (Gramberg et al., 2001). It was shown that along with the regular increase in R^0_{vt} values with depth, its abnormally high values (up to stage MC_5) are observed near igneous bodies. The boundary between stages MC_2 and MC_3 in the Triassic section of the Admiralteiskii Rise lies significantly higher than that in the Barents Sea megadepression. Joint contact metamorphism and tectonic processes must inevitably be reflected in the specific molecular composition of DOM of the regional Triassic rocks. It is worthwhile to assess the influence of each of these factors.

Materials and methods of study

The object of our study was Triassic FJL rocks sampled from the section of the Severnaya (Graham Bell Island) and Nagurskaya (Alexandra Land Island) boreholes. The Severnaya borehole core is composed of Middle–Upper Triassic silty mudstones of the Anisian, Ladinian, Carnian, and Norian Stages. The Nagurskaya borehole core is formed by Lower–Middle Triassic silty mudstones of the Induan, Olenekian, Anisian, and Ladinian Stages. The core of the Triassic deposits of the Admiralteiskii Rise was sampled from the Admiralteiskaya-1 and Krestovaya-1 boreholes; this is Lower Triassic sedimentary rocks of the Olenekian and Induan Stages. The core samples were compared with the core from the Fersmanovskaya-1 borehole drilled in the area of the Central Barents Sea rises and exemplifying a typical regional Triassic section (T_1–T_3) including rocks of the Olenekian, Anisian, Ladinian, and Carnian Stages. The similar lithologic compositions of the studied and Fersmanovskaya-1 samples (mudstones and silty mudstones) give grounds to consider their comparative study correct.

Analysis of DOM included determination of kerogen composition and contents of total organic carbon (TOC) and carbonate carbon, extraction of chloroform (A_{chl}) and alcohol–benzene ($A_{alc–benz}$) bitumens and humic acids (HA), and identification of the group and hydrocarbon compositions of A_{chl}.

Fractions of saturated and aromatic hydrocarbons (HCs) were separated on a gas chromatograph and then were examined on an Agilent 5973/6850 gas chromatograph–mass spectrometer system with a quadrupole mass detector and data processing software.

Analysis of aliphatic and cyclic HCs: HP DB capillary column (30 m × 0.25 mm), stationary phase 5% phenyl/95% methyl silicone; helium as a gas carrier, a flow rate of 1.2 mL/min; and injector temperature of 320 ºC. The thermal regime of analysis: The temperature was increased from 50 to 320 ºC at a rate of 3 ºC/min and then was maintained at 320 ºC for 7 min. Total ion current (TIC) detection was made in the full scan mode (50 to 500 *m/z*, 70 eV). *n*-Alkanes and isoprenoids were analyzed using selected ions *m/z* 71 and 183; triterpanes, using ions *m/z* 191, 370, 398, 412, 426, 440, and 454; and steranes, using ions *m/z* 217, 218, 372, 386, and 400.

Analysis of polycyclic aromatic HCs (PAHs): HP DB capillary column (30 m × 0.25 mm), stationary phase 5% phenyl/95% methyl silicone; helium as a gas carrier, a flow rate of 1.2 mL/min; and injector temperature of 290 ºC. The thermal regime of analysis: The temperature was increased from 60 to 200 ºC at a rate of 20 ºC/min, then to 300 ºC at a rate of 10 ºC/min, and was maintained at 300 ºC for 5 min. TIC detection was made in the full scan mode (50 to 500 *m/z*, 70 eV). Unsubstituted and alkylated PAHs were analyzed using selected ions *m/z* 128, 152,154, 178, 192, 202, 206, 228, 252, 276, and 278.

Discussion

Brief lithologic description

The Triassic FJL deposits penetrated by parametric boreholes are a thick gray rock unit mostly of marine genesis with