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Organic geochemistry of the Lower Cambrian Sinyaya Formation (*northern slope of the Aldan anteclise*)

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Abstract

We investigated organic matter (OM) of the Lower Cambrian Sinyaya Formation in the southeast of the Siberian Platform. The studied collection of rocks was divided into groups according to the contents of organic carbon, bitumens, and sulfur and lithologic characteristics. The content and distribution of saturated biomarkers were examined. Lanostanes C_{30}, norlanostanes C_{29}, 28,30-bisnorhopanes, and 2α- and 3β-methylhopanes have been identified in the bitumens. Relationships between the content of organic carbon and the distribution of hopanes, hopane ratios, and 2α-methylhopane index have been established. The conditions of sedimentation, diagenesis, and catagenesis of OM and the generation potential of the rocks have been estimated. It is shown that lanostanes, 28,30-bisnorhopanes, and methylhopanes can be used as biomarkers of the source rocks of the Sinyaya Formation and thus can help to determine the source of bitumens on the northern slope of the Aldan anteclise of the Siberian Platform.

Keywords: organic geochemistry; bitumens; biomarkers; source rocks; Lower Cambrian; Siberian Platform

Introduction

Carbonate sediments enriched in organic matter (OM) accumulated on the northern slope of the Aldan anteclise and composed the Sinyaya Formation in the Early Cambrian. The formation sections were studied by geologists along the banks of the Lena, Sinyaya (left tributary of the Lena), and Botoma Rivers in the southeast of the Siberian Platform. The Sinyaya Formation is localized in the Sinyaya–Botoma facies area of the Anabar–Sinyaya facies region (Bakhturov et al., 1988; Kontorovich, 1976; Kontorovich et al., 1981; Savitskii et al., 1972; Shabanov, 1983; Zelenov, 1957).

Geochemistry of OM of the Lower Cambrian Sinyaya Formation was long judged from analysis of few samples. Earlier publications reported the contents of OM and bitumens in its rocks (Zelenov, 1957) and results of study of porphyrines, the elemental and group compositions of bitumens (Kontorovich, 1976; Kontorovich et al., 1981; Savitskii et al., 1972), and the properties of kerogen (Bogorodskaya et al., 2005). The rocks of the Sinyaya Formation are a facies analog of the rocks of the Lower–Middle Cambrian Kuonamka, Inikan, and Shumnaya Formations. They are regarded as source rocks and a hydrocarbon (HC) and mineral raw materials in the east of the Siberian Platform (Gurari et al., 1984; Kashirtsev, 2003; Kontorovich, 1976; Kontorovich et al., 1981; Savitskii et al., 1972; Zelenov, 1957). In recent years, geochemistry of biomarkers of the Sinyaya Formation has come under study (Parfenova, 2011a,b; Parfenova et al., 2010).

This work is aimed at a complex investigation into organic geochemistry of the Sinyaya Formation. The goal is to elucidate the regularities of formation of the Lower Cambrian rocks abnormally enriched in OM in the southeast of the Siberian Platform and to refine the diversity and biochemical composition of the biota that was the source of OM, the conditions of OM accumulation and transformation during diagenesis, the degree of OM catagenesis, and the generation potential of the formation rocks.

Material and methods

The Lower Cambrian carbonate rocks were sampled on the right bank of the Sinyaya River in 2004 (Fig. 1). Thirty-four

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samples were studied: Thirty-one from the Sinyaya Formation, one from the Kutorgina Formation, and two from the Perekhodnaya Formation. The rocks were crashed to a fraction of 0.25 mm. The content of rock-forming oxides was determined by X-ray fluorescence analysis on a Kompleks SRM-25–Elektronika-60 XRF spectrometer. The total contents of iron, sulfur (S_{tot}), their species, and CO_2 were evaluated by the chemical method. The contents of clay and carbonate minerals (calcite and dolomite) and authigenic silica in the rocks were estimated by norm computation. The content of total organic carbon (TOC) was determined on an AN-7529 express analyzer by oxygen combustion of insoluble residues (IR) preliminarily decarbonatized with 10% HCl. Pyrolysis of the rocks (23 samples) was performed on SR Analyzer–POPI (Pyrolytic Oil Productivity Index). The bitumen (S_1, %) and kerogen (S_2, %) components of OM, productivity index ($PI = S_1/(S_1+S_2)$), hydrogen index (HI, mg HC/g TOC), and temperature of the maximum release of HCs (T_{max}, ºC) were determined. Bitumen was extracted with chloroform from 50 g specimens (a total of 31) in a centrifuge at the room temperature. After mercury cleaning of the extract from elemental sulfur, asphaltenes were extracted with petroleum ether from the bitumen. Then, malthenes were separated into fractions of saturated HCs, aromatic HCs, and resins (26 specimens). Saturated HCs were examined on 5890 series II Gas Chromatograph with a capillary copper column filled with Apiezon L at the starting and final temperatures of 60 and 280 ºC, respectively. Twenty-six HC specimens were studied on Agilent 5973N (gas chromatograph 6890 with a highly efficient mass-selective detector and computer recording) at 100–320 ºC; twenty-three of them were examined from TIC chromatograms. The chromatograph had a capillary column (length 30 m, i.d. 0.25 mm) with impregnated phase HP-5MS. The rate of carrier gas (He) was 1 ml/min. Hydrocarbons were identified from their retention time, which was compared with the data for known compounds and with earlier published data. The carbon isotope composition of the carbonate-free substance of 14 IR specimens was determined on an MI 1201V mass spectrometer by the relative method, i.e., by alternating measurements of *m*/*z* 44 and *m*/*z* 45 ion currents for the samples under study and the standard sample (CO_2).

The section structure

The section of the Sinyaya Formation was described earlier by Bakhturov et al. (1988) and Zelenov (1957). Our recent field and laboratory studies have yielded additional information about the composition and structure of its Lower Carboniferous deposits. The studied section is located on the right bank of the Sinyaya River, at 6 km from its mouth (61º10′437″ N, 126º52′640″ E). The Sinyaya Formation rests conformably upon light brown massive and fractured dolomite-containing limestones (with TOC ≈ 0.1%) of the Perekhodnaya Formation (Fig. 2). It comprises three members. We describe them from bottom to top. The member thicknesses (Fig. 2) are given after our and literature data.

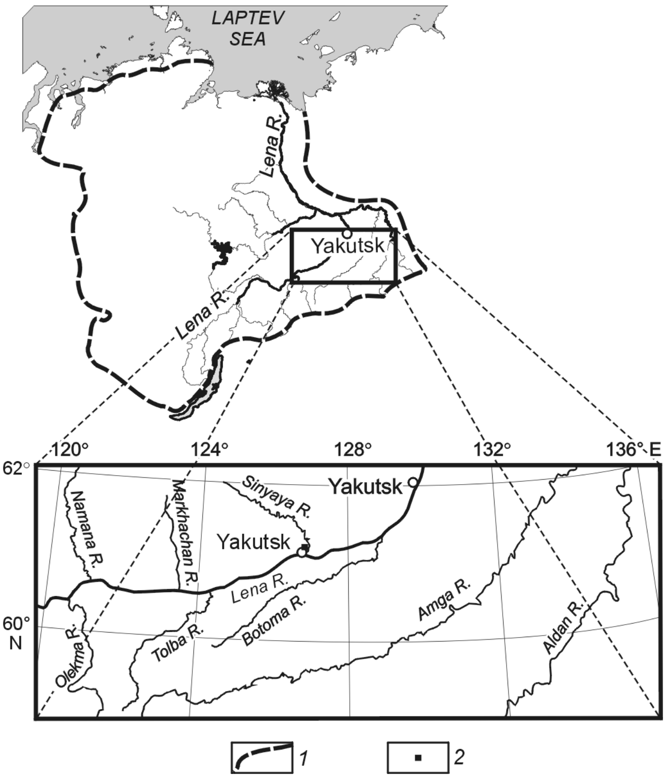

Fig. 1. Map of sampling. *1*, borders of the Siberian Platform; *2*, sampling locality.

Member I. Alternation of thin-laminated black and dark brown limestones, often dolomite-containing, and light brown massive coarse-platy limestones and dolomites. In the lower and middle parts of the member, the thickness of foliated-rock beds varies from 0.05 to 0.20 m, locally reaching 0.40 m. In the upper part, there is a frequent alternation of thin-laminated (0.01–0.05 m) and massive limestones with vertical fractures and bioclastic material. Calcite is predominant among the rock-forming minerals (>80%). The content of dolomite is usually lower than 5–10%, seldom reaching 30.52% (sample 3) and 54.54% (sample 6). The content of authigenic silica varies from 0 to 4.7%, reaching 6.07% (sample 9) and 9.75% (sample 13). Total organic carbon in the rocks amounts to 0.22–6.84%. The bedding surfaces are even. The member thickness is 8 m.

Member II. Brown massive limestones, often dolomitic or dolomite-containing, of spotty structure occur as lenses and irregular-shaped buns. They are enveloped by thin-laminated (≤0.01–0.05 m) dolomitic and dark brown siliceous–dolomitic limestones. Calcite is the main rock-forming mineral (up to 90.93% in sample 14). The upper part of the member (sample 17) is the richest in dolomite (26.58%) and authigenic silica (6.38%). The content of TOC in the rocks varies from 0.65 to 5.06%. The bed surfaces are uneven, wavy. The member thickness is 5.5 m.

Member III. In the lower part of the member, there is a frequent alternation of dark brown thin-laminated dolomite-containing limestones with brown and light brown coarse-platy massive limestones. The interbed thickness varies from 0.01–