
GEOLOGY

Prerequisites for Development of the Oil and Gas Potential of Pre-Jurassic Rocks in the Kara Sea

G. S. Kazanin^a, G. A. Tarasov^b, and T. A. Kirillova-Pokrovskaya^a

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Geological–geophysical studies performed in the 20th century demonstrated a genetic relationship between the structure of the Kara Sea bottom with its main structural–tectonic elements and petroliferous formations of the northern West Siberian petroliferous province. This major petroleum production region of Russia is entering the late stages of hydrocarbon extraction. Therefore, prospecting for oil and gas in relatively less studied Arctic shelf areas is a pressing issue. Moreover, the discovery of unique (in terms of reserve) gas condensate deposits in the South Kara shelf suggests that the Arctic region is most promising for the discovery of hydrocarbon traps, conversion of their resources into commercial reserves, and their industrial development in the near future.

The present paper is based on materials of geological–geophysical investigations conducted by the Murmansk Arctic Geological–Prospecting Expedition in the Kara Sea in 2004. Approximately 6000 km of CMP profiles accompanied by aerial gravimetric and differential hydromagnetic surveys were carried out on the Yamal shelf during the cruise of the R/V *Professor Kurentsov* in 2004 (Fig. 1).

The main purpose of these geological–prospecting works was to specify the geological structure of the Yamal shelf of the Kara Sea and to define hydrocarbon traps. In order to solve the issues formulated above, the geological section of the region was divided into three structural–tectonic stages: crystalline basement, intermediate complex, and plate cover.

The *Pre-Jurassic basement*. The new 2D seismic exploration data obtained for the Yamal part of the shelf made it possible to specify some structural features of the pre-Mesozoic basement and to compile geological–

geophysical sections. Figure 2 demonstrates different interpretations of CMP records that illustrate specific features of the pre-Jurassic basement structure and relationships between seismic complexes in the study region.

The near-latitudinal and near-meridional seismogeological sections across the region distinctly demonstrate that the basement structure includes two structural–tectonic stages: a crystalline basement and volcanosedimentary sediments of the intermediate complex. The Pukhuchan Depression is filled with Paleozoic sequences up to 4 km thick in its axial part (Fig. 2). The bedded pattern of the seismic record of the intermediate complex indicates the heterogeneous composition of Paleozoic sediments, i.e., alternation of sandy and clayey sequences (reservoirs and caprocks, respectively) with effusive interlayers (Fig. 2b). In the remainder of the area, sediments of the intermediate complex form Paleozoic and Triassic sequences. Their thickness ranges from 3 to 8 km (up to 11 km at the junction of basement blocks of the Pai Khoi Monocline and Yamal Monocline) (Fig. 2c). The seismic record pattern implies that the study region can include stratal and lithological hydrocarbon traps related to downlap of beds to the eroded surface of the crystalline basement. The high hydrocarbon potential of Paleozoic rocks is supported by the discovery of a large gas condensate deposit associated with oil pools in Silurian metasandstones of the Bovanenkovo petroleum field located in the adjacent land. The geological reserves of gas and oil in this deposit are estimated at $160 \cdot 10^9$ m³ and $55 \cdot 10^6$ t, respectively.

Fractures in the pre-Jurassic basement. Evolution of the pre-Jurassic basement structure was completed in the course of Hercynian and pre-Jurassic orogenic processes. They were marked by reorganization of an extensive system of large-scale strike-slip faults, most of which were active during almost the entire Paleozoic. In the study region, mobile strike-slip and normal fault zones make up systems mainly oriented along the

^a Marine Arctic Geological–Prospecting Expedition, ul. Sof'i Perovskoi 26, Murmansk, 183072 Russia

^b Murmansk Marine Biological Institute, Kola Scientific Center, Russian Academy of Sciences, ul. Vladimirskaia 17, Murmansk, 183010 Russia; e-mail: tarasov@mmbi.info

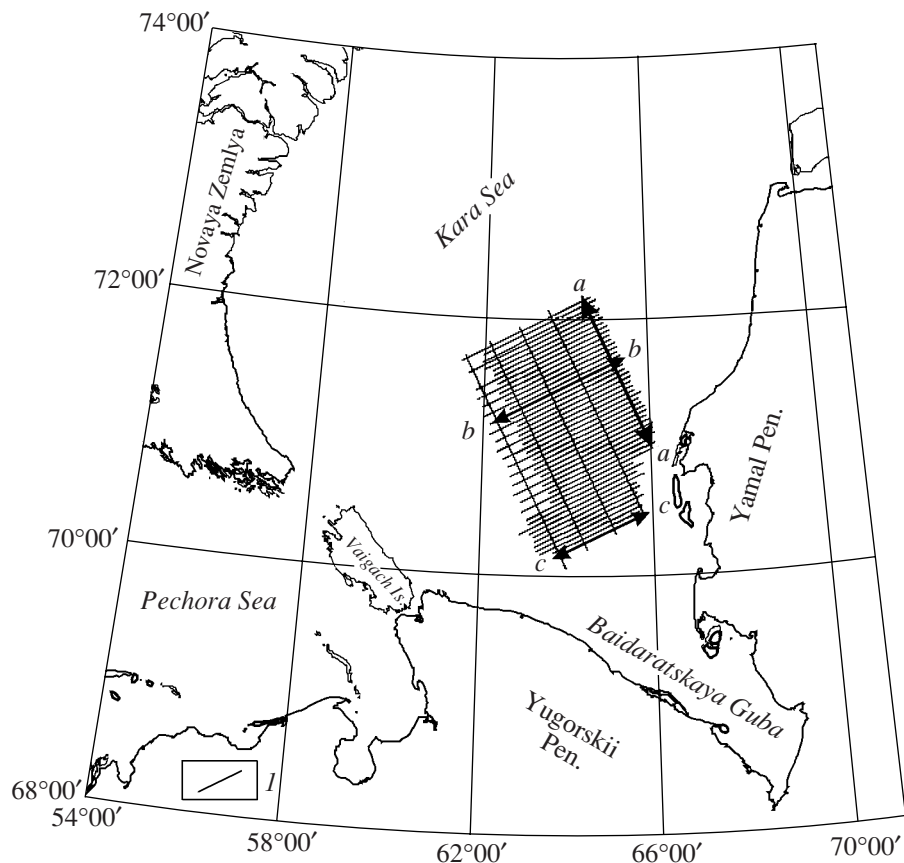


Fig. 1. Schematic map of the geological–geophysical investigation area in the Kara Sea. (I) CMP seismic profiles of 2004 (multiplicity 84, record length 8.192 s).

northeastern (NE), northwestern (NW), and near-meridional (A, B, C) directions (Fig. 3).

In addition to down-dip–strike-slip faults, fractures in the pre-Jurassic basement are also recorded. In the Mesozoic–Cenozoic sedimentary cover, the fractures are accompanied by zones with a vague seismic record. Such anomalies (“gas columns”) in the seismic record complicate the Yamal flank of the Pukhuchan Depression. Some anomalies are confined to local swells of Aptian–Albian–Cenomanian sediments.

The tectonic structure of the pre-Jurassic basement. Using materials of complex geological–geophysical studies and taking into consideration new data on the structure of anomalous physical fields, we compiled the schematic structural-tectonic map of the pre-Jurassic basement.

With respect to tectonics, the study region is located at the junction of first-order structures: the South Kara Syncline (II), the Pai Khoi Monocline (I), and the Yamal–Gydan Megasaddle (III). They include subordinate structural elements. The Pukhuchan Depression, the main geodynamic structure of the region, which governed the Late Paleozoic and Mesozoic tectonic plan in the studied part of the South Kara Syncline. The subordinate structural elements are complicated, in

turn, by local anticlines, which are reflected in the heterogeneous basement as low-amplitude small uplifts. It should be noted that local uplifts of the plate cover are practically unrecognizable in the structure of the heterogeneous basement, while the influence of the pre-Jurassic basement structure on the distribution of local uplifts in the sedimentary cover is distinct.

Thus, the results of complex geological–geophysical studies in the Kara Sea in 2004 indicate that introduction of new technologies and processing methods into the practice of seismic exploration increases sharply the reliability of forecast of the hydrocarbon potential of the Mesozoic–Cenozoic plate cover and pre-Jurassic rocks of the South Kara Syncline. The hydrocarbon potential of pre-Jurassic rock complexes is supported by the following fact: (i) wave fields of the South Kara Syncline suggest the presence of hydrocarbons and the influx of gas from deep levels of the Earth’s crust; (ii) calculations performed for the northeastern West Siberian Geosyncline suggest that Paleozoic rocks of the Gydan–Yenisei Depression alone can contain billions of cubic meters of gas [1].

The new approach to the hydrocarbon potential of lower complexes of the sedimentary cover and, particularly, to the study of the pre-Jurassic basement as an

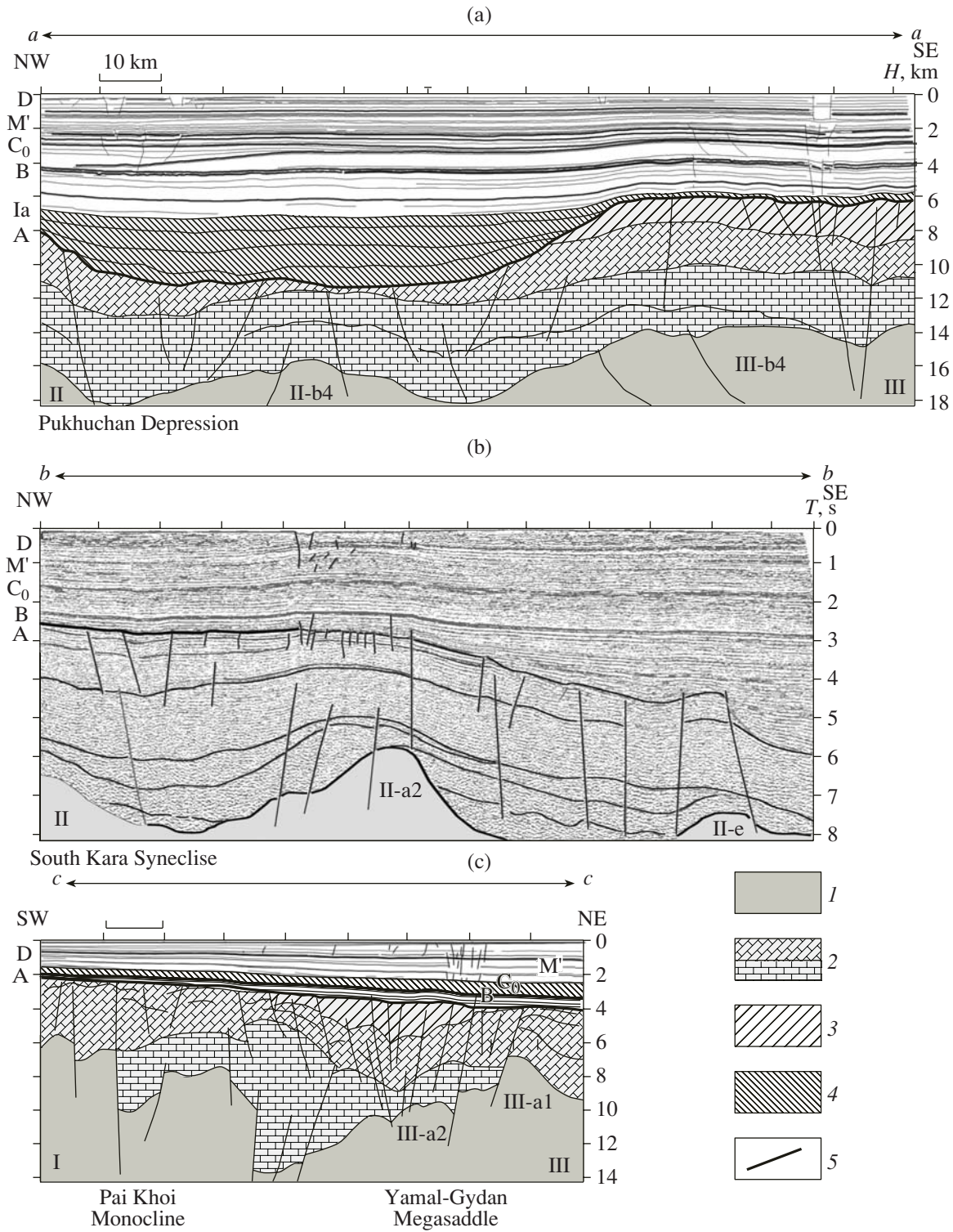


Fig. 2. Seismostratigraphic sections (CMP profiles): (a) profile a-a; (b) profile b-b; (c) profile c-c. (A, B, C₀, M', D) Reference reflectors and their indices; (1) crystalline basement and indices of first-order and subordinate structures; (2) Paleozoic volcanosedimentary rocks of the intermediate complex; (3) Triassic (?) sequences of the intermediate complex; (4) Triassic (?) sequences of sedimentary cover; (5) fractures.

autonomous oil- and gas-bearing stage with specific features of the distribution of hydrocarbon pools dictates the formulation of principally new requirements

on the information characteristics of geological prospecting carried out for oil and gas exploration purposes.

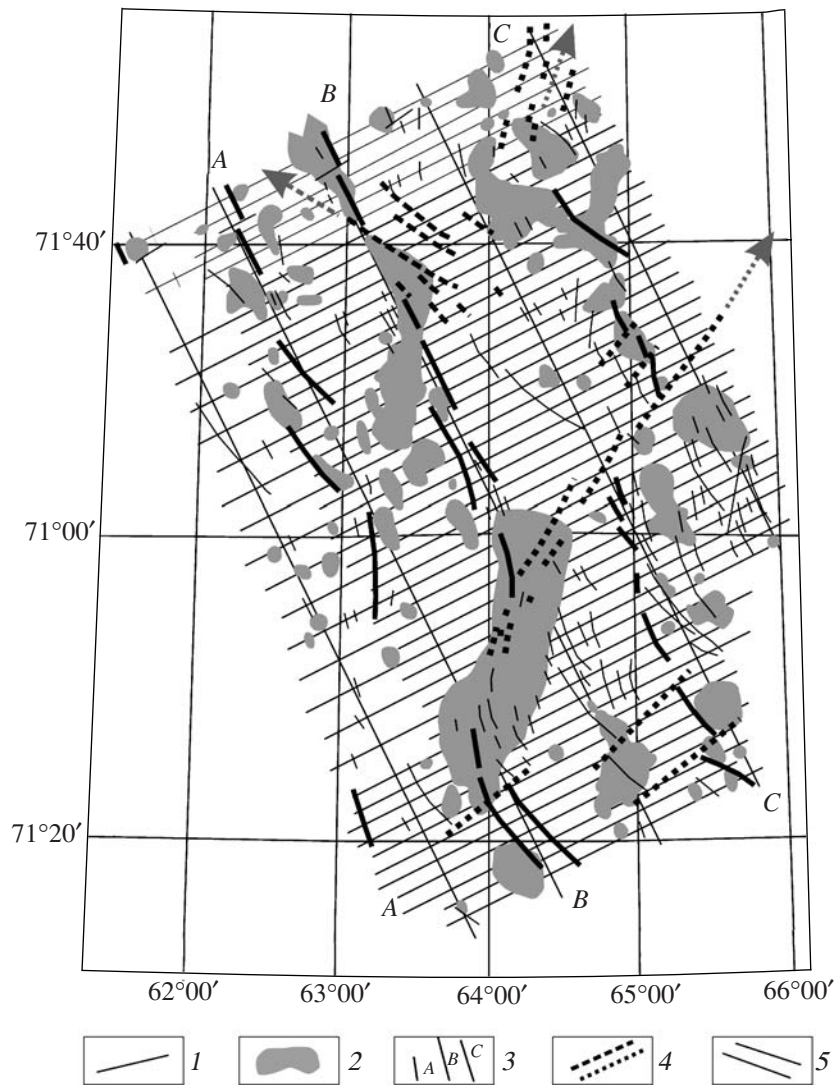


Fig. 3. Schematic map of fractures in the pre-Jurassic basement of the Yamal shelf. (1) CMP profiles; (2) local uplift; (3) near-meridional normal faults; (4) strike-slip faults; (5) other fractures (see text for explanations).

The program of geological-prospecting works aimed at development of the hydrocarbon potential of the Jurassic and pre-Jurassic rocks in the South Kara Syncline in the nearest future should include a complex of seismic exploration, drilling, and special works, including the following top priority tasks: (a) revision and reinterpretation of previous seismic exploration profiles with a record length of >6 s; (b) creation of a

system of new regional profiles and processing of fragments of previous regional profiles; (c) creation of a network of regional profiles; and (d) parametric drilling.

REFERENCES

1. V. V. Kharakhinov, S. I. Shlenkin, V. N. Nesterov, et al., *Geofizika*, Spec. Issue, 78 (2001).