

Seismogeological characteristics and oil-and-gas content of the Kara Sea shelf (South Kara, North Kara sedimentary basins)

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Abstract. On the basis of a comprehensive analysis of geological and geophysical materials, seismogeological models of sedimentary complexes in the South Kara oil-and-gas province (OGP) and in the North Kara potential oil-and-gas province (POGP) were constructed. The conclusion is drawn that the South-Kara OGA is the northern end of the West Siberian oil-and-gas province and the Jurassic and Cretaceous deposits are of the greatest interest here. North-Kara POGP is the continuation of the Barents Sea province and Triassic and Jurassic rocks have the biggest petroleum potential. On most of the POGP, the main prospects of oil production are associated with the Neoproterozoic-Paleozoic sedimentary complex.

1. Introduction

Two separate sedimentary basins are allocated in the Kara Sea. South, located to the south of the Novaya Zemlya Archipelago, part of the water area is identified as part of the South Kara Regional Depression, which is the northern end of the West Siberian sedimentary basin [1].

In the respect of oil and gas content, the southern part of the Kara Sea is separated as part of the South Kara oil and gas province (OGP), which is part of the West Siberian oil and gas province, the northern one is an independent North Kara prospective oil and gas province (POGP).

The South Kara and North Kara sedimentary basins are separated by the North Siberian sill, a large contrast erosion-tectonic basement high. The presence of this barrier does not allow comparison of seismogeological complexes in the South Kara regional depression and the North Kara POGP (figure 1).

2. South Kara OGP

At the north of Western Siberia the five seismogeological megacomplexes were identified in the Mesozoic-Cenozoic deposits: Triassic, Neocomian (Berrias-Lower-Aptian), Aptian-Albian-Cenomanian, Turonian-Maastricht and Cenozoic. All sedimentary seismogeological complexes that developed in the north of Western Siberia continue to the southern part of the Kara Sea and were developed in the South Kara OGP.

Triassic-Jurassic (T_{2,3}-J), Neocomian (Berrias-Lower-Aptian) (K₁) and Aptian-Albian-Cenomanian (K₁-K₂) megacomplexes are the main oil and gas bearing complexes on the territory of the West Siberian oil and gas province.



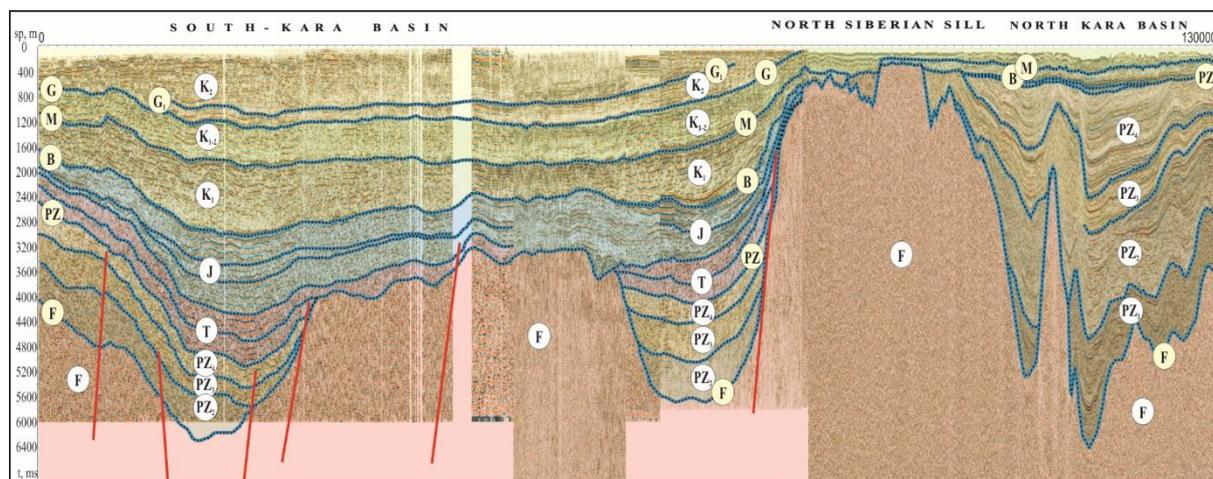


Figure 1. Seismogeological cross-section of the composite regional profile “South Kara Regional Depression – North Siberian sill – North Kara Basin”.

All Mesozoic-Cenozoic sedimentary megacomplexes are controlled in the top by regionally developed marine clay packs - mega-regional impermeable beds which are characterized by abnormally low acoustic characteristics and the most energetically expressed reflecting seismic horizons are confined to them.

The Mesozoic-Cenozoic sedimentary cover lies on a Paleozoic basement. In most of Western Siberia Paleozoic deposits have undergone the processes of Hercynian folding and Early Triassic rifting. In these regions, the dislocated and metamorphosed Paleozoic rocks serve as the basement. In the east of the West Siberian basin and in the Yenisei-Khatanga regional trough, the Neoproterozoic-Paleozoic platform sediments, similar to the complexes of the Siberian Platform, lie beneath the Mesozoic-Cenozoic deposits.

The analysis of the time cross-sections allows to assume that the Vendian-Cambrian platform deposits of the Yenisei-Khatanga trough continue to the northeast of Western Siberia and are developed in the Gydan Peninsula and continue to the southern part of the Kara Sea as separate blocks. In the South Kara regional depression, two large submerged massifs are allocated, within which the thickness of platform sediments increases to 12000 m. These submerged blocks located in the western and eastern parts of the South Kara regional depression are separated by a large basement high, within which the thickness of platform deposits is reduced to 5000 m.

In the Arctic regions of Western Siberia, the most prospecting gas content is the Aptian-Albian-Cenomanian rock complex, which is associated with the unique gas fields of the Nadym-Pur, Yamal and Gydan oil and gas areas (OGA). In the South Kara OGP three oil and gas fields were discovered on the shelf: Rusanovskoe, Leningradskoe and Pobeda. The main reserves of the Leningradskoe and Rusanovskoe fields are concentrated in the Aptian-Albian reservoirs, at the Pobeda field the gas is concentrated in the Cenomanian reservoir, yje light oil is in the Upper Jurassic reservoir.

Based on the results of the researches carried out at IPGG SB RAS in the southern part of the Kara Sea, 35 structures have been identified - potential traps for hydrocarbon reservoirs. The most perspective for liquid hydrocarbons in Western Siberia and in the southern part of the Kara Sea are the Neocomian and Middle-Upper Jurassic reservoirs. In particular, the light oil reservoir is discovered in the Upper Jurassic sandstones of the Pobeda field. The Neocomian complex of rocks with more than 80% of the oil reserves in the territory of Western Siberia has a cliniform structure in the South Kara OGP as well as in Western Siberia, and hydrocarbon deposits, controlled both by anticlinal structures, and lithological traps.

3. North Kara POGP

The North Kara basin has not been studied by drilling and the model of the geological structure of this region can be constructed only from the analysis of seismic materials, potential fields and geological survey data for the islands. At the present day, a network of regional seismic profiles has been worked out in the northern part of the Kara Sea, the interpretation of which has formed the basis for the present studies.

In the northwest, the North Kara basin borders on the Barents Sea basin, which has been well studied by seismic exploration and deep drilling. Comparison of wave fields at the regional composite time cross-section along the profile passing through the Barents Sea-Kara Sea line makes it possible to note that the Barents Sea sedimentary basin has been extended in the northwestern part of the Kara Sea.

In this zone, a series of Paleozoic, Triassic, Jurassic and Cretaceous sedimentary seismic complexes are identified on the cross-sections, which are well joined to the Barents Sea complexes. In the southern and southeastern directions, the Mesozoic seismogeological complexes are regionally rising, their thicknesses are sharply reduced, and they are wedged to the erosion surface of the Paleozoic top.

In most of the North Kara basin, the erosion surface separating the Paleozoic and low-thickness Mesozoic deposits, with which a large break in sedimentation is associated in this region, is clearly recorded on the cross-sections. The analysis of time seismic cross-sections makes it possible to identify in the Paleozoic platform deposits of the North Kara POGP 4-5 seismogeological complexes, according to the overlaying, controlled by energetically expressed reflecting horizons.

In the Arctic sector, the Paleozoic deposits are located everywhere at big depths and are almost not drilled. As a result, when stratifying seismogeological complexes, as a rule, data on islands are used [2,3].

The composite section of the Novaya Zemlya archipelago includes a complete sequence of Paleozoic deposits from the Cambrian to Permian inclusive. If we operate with the average thickness of the sediments composing the various complexes, then in the presence of a complete sequence in the section, the average thickness of the Paleozoic deposits on the Novaya Zemlya archipelago will be about 10,000 m. On the islands of the Severnaya Zemlya, the composite section of the Paleozoic deposits includes the Cambrian-Devonian interval, the average thickness of which is about 8500 m. Considering that in the most submerged parts of the North Kara basin the maximum thickness of Paleozoic sediments estimated according to seismic data is 13,000 m, it can be assumed that a complete Paleozoic section was developed in these zones. In this case, the basal seismic complex can be conditionally dated by the Cambrian, and the seismic complexes overlapping it Ordovician-Silurian, Devonian-Carboniferous and Permian, respectively.

The analysis of the time cross-sections allows us to conclude that in the central part of the basin under the erosion surface overlapped by the Mesozoic, the youngest deposits appear, while in the direction to the side parts under the Mesozoic, more ancient seismic complexes are emerging. Thus, in different parts of the basin in the top of the Paleozoic, there will be layers of different ages, probably from the Ordovician to the Permian. The basal complex, composed of supposedly Cambrian deposits, is developed only in contrasting depression zones and does not come out under the erosion surface, but wedges out onto the contiguous basement highs.

Within the researches, a complex interpretation of the CDP seismic data for the South Kara Regional Depression and the North Kara basin was carried out, the set of the structural maps were constructed, including united structural maps for the Paleozoic top and the basement of platform deposits-the basement top (figure 2). On the cross-sections the Paleozoic top, to which the reflecting horizon A is confined, identified quite confidently, the correlation of the basement top (horizon F) was carried out along the envelope of the reflecting horizons, which emphasize the platform appearance of the sediments. Below this horizon, on the cross-sections are fixed chaotic seismic images.

With the use of these materials, maps of thicknesses of Paleozoic and Mesozoic deposits were also constructed on the Kara Sea, and a structural map on the top of the basement served as the basis for

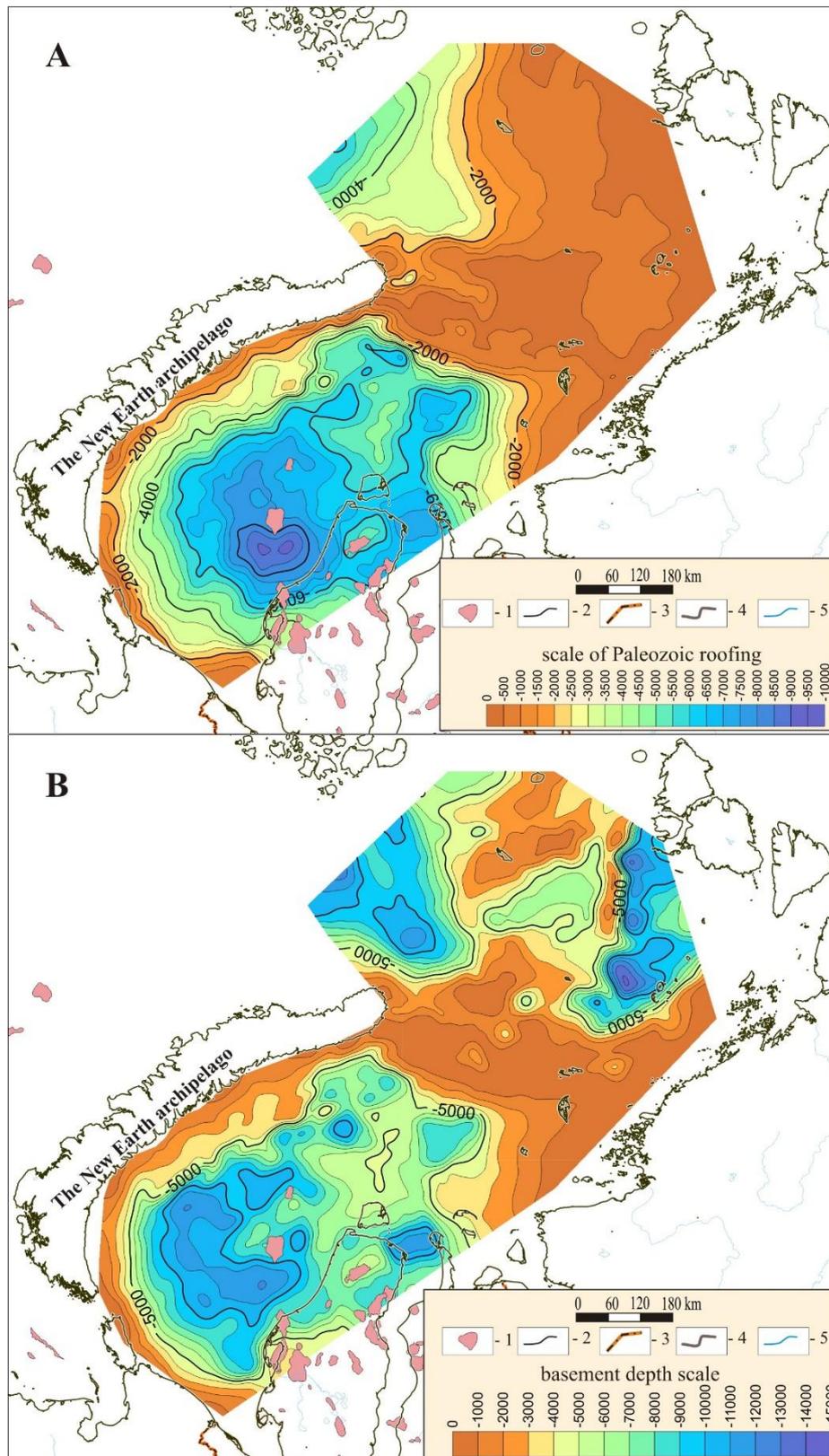


Figure 2. Structural maps of the top of the Paleozoic (A) and the basement (B). Legend: 1 - oil and gas fields; 2 - isohypses; 3 - administrative boundaries; 4 - coastline; 5 - rivers.

constructing a scheme for tectonic zoning of the Kara Sea (the South Kara OGP, the North Kara POGP). The analysis of structural maps on the tops of the Paleozoic and the basement showed that in the South Kara Regional Depression these surfaces are largely similar. In the western part, there is a large depression zone - the South Kara megasineclise, in the east there is a large, semi-closed positive structure in the latitudinal direction - the Northern megascarp, complicated by smaller closed uplifts. In the North Kara basin, structural plans for the tops of the Paleozoic and the basement differ fundamentally. In this part of the shelf in a relief of the Paleozoic top, a monocline is plunged in the northwestern direction, practically uncomplicated by positive and negative structures. The relief of the basement top, on the contrary, is strongly dissected and a series of large positive and negative structures is identified here.

The analysis of the thickness maps of the Paleozoic-Mesozoic platform deposits in general, and also of the thickness maps of the Paleozoic and Mesozoic deposits, showed that in the South Kara and North Kara sedimentary basins, the areas of which are 410000 km² and 335,000 km², the sedimentation volume is 2300000 km³ and 1550000 km³, respectively. At the same time, Paleozoic platform deposits in the South Kara OGP account for 23%, in the North Kara POGP - 71%.

4. Conclusions

The analysis of geological and geophysical materials in the Kara Sea suggests that the sedimentary basins in the South Kara and North Kara sedimentary basins are of undoubted interest in relation to oil and gas potential.

The oil and gas potential of the South Kara OGP is proved by the discovery of the Leningradskoe, Rusanovskoe and Pobeda oil and gas fields. In this part of the shelf there are 35 uplifts - potential traps for hydrocarbon reservoirs, Neocomian clinoform complex is developed, with more than 80% of oil fields in Western Siberia, and the oil and gas content of the Upper Jurassic is proved.

The analysis of time cross-sections and the results of structural constructions allows to draw a conclusion that from the seismostratigraphic and structural-tectonic positions the North Kara basin is also perspective in terms of oil and gas potential. Here, anticline, structural-tectonic, structural-stratigraphic, structural-lithological, tectonically screened traps are identified in sedimentary complexes. According to a number of researchers, salt-dome structures can also be developed in the Ordovician-Silurian complex of the North Kara POGP [4].

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