Estimation of prospects of oil and gas production of Barents Sea shelf by results of seismic measurement by 3D common dept point method

V N Borodkin¹,²; A R Kurchikov¹; V I Samitova¹; A S Nedosekin³, A V Lukashov³ and O A Smirnov³
¹ West Siberian Branch of Institute of Petroleum Geology and Geophysics of the Russian Academy of Sciences, Tyumen, Russia
² Industrial University of Tyumen, Tyumen, Russia
³ LLC "INGEOSERVIS", Tyumen, Russia
E-mail: Samitova_vi@mail.ru

Abstract: The article shows the tectonic confinement of the research area and its position from the point of view of petroleum geological classification, and the main oil and gas bearing complexes are identified. According to the Triassic, Jurassic-Barremian and Aptian-Albian-Cenomanian oil and gas bearing complexes, a seismic-geological model was given, the conditions for the formation of deposits were considered, prospective objects were identified, and the optimal volume of exploratory drilling was planned. The complex of features indicates the presence of vertical migration of hydrocarbons, which contribute to the formation of secondary hydrocarbon deposits in the Cretaceous section.

1. Introduction
Resources of hydrocarbons are concentrated at about 80 billion tons of equivalent fuel [1-3] on the shelf in the Arctic region of Russia. Among the Arctic territories of Russia and other countries, the water areas of Karsky [4-6] and the Barents Sea [7-10] are the richest in hydrocarbons.

2. Research
Our research area is located in the eastern part of the Barents Sea, within the Ludlowskoye license area, where 3D seismic survey was conducted (Figure 1).

According to the scheme of tectonic classification, the work area is a part of the Barents Sea megadepression, which is a huge one of the northeastern strike, within which boundaries the South Barents and North Barents synclises are distinguished, the Shtokmanovsko-Luninsky and Albanovsko-Gorbovsky rapids, and the St. Anne trench (Federal State Unitary Enterprise Arcticmornftegeologorazvedka, 2009).
The work area is confined to the Shtokmanovsko-Luninsky knickpoint, which separates the South-Barents and North-Barents syneclises.

From the point of view of oil geological classification, the research area is located within the Shtokmanovsko-Luninskaya oil and gas area, which is located within the East Barents Oil and Gas Province. Within the work area, a large Ludlowskoye gas field, as well as the unique

**Figure 1.** A survey map of the research area.
Shtokmanovskoye and Ledovoye gas condensate deposits in the immediate vicinity, was discovered (Figure 1).

Productivity is established in the stratigraphic range from Aalenian to Callovian stage.

In the sedimentary deposits of the Barents Sea region, two oil and gas bearing complexes and four perspective oil and gas bearing complexes are located: Ordovician-Lower Devonian, Lower Permian-Upper Devonian, Upper Permian, Triassic, Jurassic-Barremian and Cretaceous ones.

3. Results and discussion

3.1. Geological history of the region development

Three major developmental stages are distinguished in the geological history of the Barents Sea region: Pre-Ordovician (foundation formation), Caledonian-Hercynian-Early Cimmerian (the formation of platform covers of the Barents and Timan-Pechora platform and the folded structure of the Paihoysko-Novaya Zemlya system) and the Jurassic-Cenozoic (platform one) [11].

There is a point of view that the East Barents paleo-ocean was a dead branch of the Iapetus paleo-ocean and can be considered as an "interrupted" one, which had appeared as a result of short-term spreading after the split of the continental crust in the rifting zone. The time of opening the paleo-ocean was estimated by the late Vendian, in the interval of 580-540 million years ago. The subsequent sustained sustainable deflection of the oceanic crust of the East Barents paleo-ocean, accompanied by repeated tectono-magmatic activations in the region, led to the formation of the eponymous mega-depression in the Phanerozoic. Until the end of the Jurassic era, this mega-depression had also experienced stretching. As a result of the stretching phase, there is the large amplitude of deflection and activation of the introduction of the intrusive bodies. From the beginning of the Cretaceous era, the stretching is replaced by compression.

In the Cretaceous period, the inversion phase begins, which became the main factor of the structure-forming movements which led to the formation of many structures, including the Ludlovskaya one.

The seismic geological structure of the Triassic, Jurassic-Barremian and Cretaceous oil and gas bearing complex is considered in the context of the investigated area.

3.2. Seismogeological model of sedimentary formations

The formation of Triassic oil and gas bearing complex deposits occurred during the active deflection of the Barents Sea shelf and the arrival of a large amount of terrigenous material carried down from Western Siberia and the East European platform.

On the temporary seismic sections in the Triassic seismic complex interval, bright, high-amplitude reflecting horizons are clearly distinguished, which do not agree in the form with the structural plan. It is assumed that they correspond to the areas of intrusions distribution.

As a result of the work carried out in the Triassic oil and gas bearing complex interval, there were revealed no seismic anomalies indicating a possible saturation with hydrocarbons.

Jurassic-Barremsky oil and gas bearing complex is currently the main productive complex in the Russian part of the Barents Sea water area.

In the context of the Jurassic part of the complex, the oil and gas content was established in the Aalenian-Biocian (reservoirs YU3, YU2, YU1) and the Bat-Callovian (YU0) sediments of the Middle Jurassic, in the Oxford-Volga formations of the Upper Jurassic, according to the drilling data of the collectors, no clayey incision in the eastern part of the region, as in the Kara Sea, sandy-siltstone deposits, analogues of the Nurmin suite can be developed [12]. In favor of this thesis on the temporal seismic sections against the background of a regional increase in the temporal thicknesses between the mirror B-B in the eastern direction, a splitting of the positive phase below the mirror B is noted in the wave pattern (Figure 2), which may be due to the appearance of sandy material in the section of the Upper Jurassic deposits. In the Neocomian component of the oil and gas bearing complex, as noted above, the industrial oil and gas content has not yet been confirmed, but during the wells drilling, intensive gas manifestations took place.
Figure 2. An example of a wave pattern in the interval of Upper Jurassic and Neocomian deposits.
The Aalenian-Bajocian deposits are productive in the Shtokmanovskoye (reservoirs YU3, YU2, YU1) and Ledovoye (reservoirs YU2, YU11, YU1) deposits. On Ludlovskoye license area deposits are interpreted as water saturated according to field geophysical logging.

The lower part of the Aalenian-Bajocian deposits is represented mainly by sandy differences. The formation of sediments occurred in the conditions of the delta flat land, sometimes flooded by the sea. For the purpose of forecasting the perspective objects, a dynamic analysis was carried out. In the zone of contrast reflections according to the AVO analysis [13] no effects associated with gas saturation were detected.

Bat-Callovian deposits are represented by interbedding of mudstones, siltstones and sandstones, the latter are clayed in the northern direction. In the section, the main oil and gas exploration interest is represented by the sand layer YU0, where a large gas deposit has been discovered within the investigated territory.

In order to determine the formation conditions for the YU0 layer within the 3D work contour, a litho-facies analysis of sediments was performed, based on the method of facies identification according to the shape of the gamma-ray logging curve together with the core data. The establishment of the facies nature of the deposits was carried out by comparing the logging characteristics of the investigated interval with the electrometric characteristics of facies of the classification made by V.S. Muromtsev [14], according to which facies of shallow-marine sedimentation accumulation are established within the work area.

On the seismic sections, anomalies of the "bright spot" type are observed in the investigated interval. AVO-technologies are used to clarify the geological model of the gas reservoir, as well as to search for new promising targets.

It should be noted that in the joint analysis of seismic sections, maps of the amplitude characteristics of the mirror B and the results of the AVO analysis, it is established that the "bright spot" anomaly is much larger in its area than the charted gas-water contact contour of the deposit. On the temporary seismic sections within the deposit contour, "funnels" with a low parameter, values are distinguished, which are relatively narrow zones of the absence of an acoustic signal (Figure 2), and according to a number of researchers [15, 16, etc.] they are identified with channels of vertical migration fluids, including the hydrocarbons. Such areas can although be associated with tectonic disturbances, also contributing to the vertical migration of fluids. In the area under study, the channels are distributed mainly in the Jurassic-Cretaceous and Cenozoic deposits. There are also single channels extending from the Triassic complex of sediments up to the seabed. On the surface of the seabed, there are recorded pockmarks – relatively small, isolated depressions filled with acoustically layered sediments, partially saturated with gas. As practice shows, their presence proves the existence of active processes of vertical migration of hydrocarbons.

In the upper part of the channels, numerous bright spot anomalies are revealed identified with gas "pockets" formed as a result of migration of hydrocarbons and concentrations in the area of local seals propagation. Thus, as a result of the conducted studies, the geological model of the gas deposit of the YU0 reservoir was refined as well as series of structural-tectonic and structural-lithological traps of hydrocarbons were mapped.

The Neocomian component of the Jurassic-Barremsky oil and gas bearing complex on temporary seismic sections in terms of structural features includes two intervals - the lower one, which has a clinoform structure (OG Gn-1-B') and the upper one, characterized by the cover development of deposits (OG Gn-1-Gn) (Figure 2).

On the basis of the investigations carried out, a series of structural-tectonic traps was isolated in the Neocomian part of the section. Most of traps, according to dynamic analysis (amplitude maps and AVO analysis), were interpreted as saturation with hydrocarbons.

The relevance of the study of the structure of the Aptian-Albian-Cenomanian oil and gas bearing complex (Cretaceous) is due to the discovery of gas-condensate deposits in this interval of the section in the Kara Sea water area [5, 6]. The formation of deposits took place under continental conditions,
which caused a sharp change in the thickness of deposits, their inconsistency and variability at short distances.

In order to search for promising targets, a dynamic analysis was carried out. All the identified anomalies were confirmed by AVO studies for the presence of effects due to gas saturation.

4. Conclusion

As a result of the conducted studies, drilling of 7 prospecting wells, laid in various tectonic blocks, is planned. There will be prospecting wells for the Middle Jurassic deposits (layer YU0) with a passing estimation of the Neocomian (mirror Gn-1, Gn) horizons, including the clinoform part of the section.

Thus, the results of the conducted studies prove high prospects of oil and gas potential of the investigated territory, which should be confirmed by the planned list of exploratory drilling.

References

[1] Gramberg I S and Suprunenko O I 1994 The oil and gas potential of the sedimentary cover of the Arctic seas of Russia Papers of the First Int. Conf. "Development of the Shelf of the Arctic Seas of Russia" (Moscow: Nuclear Society)

[2] Grigorenko Yu N et al 2006 Hydrocarbon potential of Russia's continental shelf: state and development problems Mineral Resources of the Russian Shelf (Special Issue of the Journal Mineral Resources of Russia, Economics and Management) (Moscow)

[3] Kontorovich A E et al 2010 Geology, hydrocarbon resources of the shelves of the Arctic seas of Russia and prospects for their development Geology and Geophysics 1, 51 7-17

[4] Bogoyavlensky V I and Polyakova I D 2012 Prospects of oil and gas potential on large depths of the South Kara region Arctic: Ecology and Economics 3, 7 92-103

[5] Borodkin V N et al 2015 Refinement of the boundaries of seismic-facies complexes of the Neocomian within the Kara Sea water area Geology, Geophysics and Development of Oil and Gas Fields 11 14-24

[6] Borodkin V N et al 2017 Assessment of the prospects of oil and gas content of the Jurassic-Cretaceous deposits of the South Kara region according to the data of the area seismic surveys 2D Geology of Oil and Gas (Moscow)

[7] Margulis E A 2014 History of the formation of the sedimentary cover of the Barents-Kara region Oil and Gas Geology. Theory and practice. (St. Petersburg: FGUP VNIGRI)

[8] Norina D A 2014 Structure and Oil and Gas Potential of Perm-Triassic Terrigenous Deposits of the Barents Sea Shelf Author's abstract of the PhD in Geological Sciences (Moscow)

[9] Stupakova A V 1999 Development of the basins of the Barents Sea shelf and their oil and gas content Geology, Methods of Prospecting, Exploration and Evaluation of Deposits of Fuel and Energy Raw Materials. Background Information (Moscow: Geoinformmark)

[10] Tkachenko M A 2015 Geological structure and prospects of oil and gas potential of the Jurassic complex of the central part of the East Barentsev mega depression Report at the IV Int. Conf. of Young Scientists and Specialists of the Memory of Academician A P Karpinsky (Moscow: FGUNPP Geologorazvedka)

[11] Zhiravlev V A et al 2014 State geological map of the Russian Federation North-Karsko-Barents Sea Sheet R 39, 40 Isle Kolguev – Kara Strait (Explanatory letter) (St. Petersburg: Karpinsky Russian Geological Research Institute)

[12] Kurchikov A R and Borodkin V N 2015 Characteristics of the Geological Structure and Oil and Gas Content of the Jurassic Oil and Gas Bearing Complex of Western Siberia (Novosibirsk: Publishing house of SB RAS)

[13] Nedosekin A S, Smironov O A, Shestakova N M, Kurchikov A R and Borodkin V N 2016 Use of AVO-attributes in forecasting the oil and gas potential of the Jurassic-Cretaceous deposits of the Iusky oil and gas bearing region of Western Siberia Geology, Geophysics and Development of Oil and Gas Fields 12 4-11
[14] Muromtsev V S et al 1989 Local forecast of the sand bodies of oil and gas traps by combining methods of electrometric geology and seismic stratigraphy in deposits with a clinoform occurrence Complex of Geological and Geophysical Methods in the Search for Non-Water Traps and Hydrocarbon Deposits in Western Siberia (Leningrad)

[15] Bembel R M, Megerya V M and Bembel S R 2002 Geosolitons and degassing of the Earth Proc of the Int. Conf. Degassing of the Earth: Geodynamics, Geofluids, Oil and Gas (Moscow: GEOS)

[16] Belyaev B M and Kropotkin P N 1992 Classification of oil and gas accumulation and deep hydrocarbon degassing in sedimentary basins (in connection with their geodynamic evolution) Proc. of the Int. Symp. Geodynamic evolution of sedimentary basins (Moscow)