Regional model of the geological structure of the Yamal and Gydan oil-and-gas areas

E S Surikova\textsuperscript{1,2}, A E Solmin\textsuperscript{2} and S M Guseva\textsuperscript{1}

\textsuperscript{1}A.A. Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of the Russian Academy of Sciences, pr. Akademika Koptyuga 3, Novosibirsk, 630090, Russia
\textsuperscript{2}Novosibirsk State University, Pirogova st. 2, Novosibirsk, 630090, Russia

Abstract. Despite the fact that a number of hydrocarbon fields have been discovered on the Yamal and Gydan Peninsula, including large gas fields, there is still no generalized regional model for geologists. In connection with the appearance in recent years of new geological information (2D, 3D seismic, logging, drilling of well Gydanskaya № 130), the authors believe it makes sense to reinterpret seismic data using new information too.

1. Introduction
In recent years, special attention has been paid to both the state geological programs and oil and gas companies to the industrial and resource base of the Northern and Arctic territories, the gas production centers of West Siberia are shifting to the Far North. It is here, within the Yamal and Tazov districts of the Yamal-Nenets Autonomous District, that the research area is located. According to modern schemes of oil and gas zoning, the region covers the Yamal and Gydan oil-and-gas areas (OGA). 32 hydrocarbon fields (HCF) were discovered on the Yamal Peninsula, the largest of which are the South Tambey, Bovanenkovo, Kharasaveyskoe, Krusenstern, Arctic, etc., 17 HCF were discovered on the Gydan Peninsula, including Salmanov, Gydanskoe, Geophysical, West-Messoyakh (Figure 1).

In all fields of the region, the traps are structural anticline, the reservoirs are mainly stratified or massive, limited by faults or impermeable lithology.

The stratigraphic interval of the industrial oil-gas content of both OGA includes the section from the Cenomanian top to the Jurassic bottom deposits, while in Yamal Paleozoic rocks and weathered contact zone of the top of Paleozoic are productive too, which are not exposed by drilling in Gydan. The main hydrocarbon resources are concentrated in the permeable Aptian-Cenomanian complex. There is a change down the section from the pure gas uncondensate deposits to pure condensate, while the oil rims are found in the interval Barremian - Middle Jurassic [2, 7, 10, 11].

In the tectonic map of the top Jurassic rocks, the territory of the Yamal peninsula is megamonoclysis (Paikhoi-Novaya Zemlya), complicated by positive closed high-amplitude structures of 2-3 ranks; the territory of the Gydan Peninsula is according to the Antipayutin-Tadebyakh megasineclise (Figure 2).
Figure 1. Yamal and Gydan oil-and-gas areas of the West Siberian oil-and-gas basin [13] Legend: 1 - regional seismic cross-sections; boundaries: 2 - administrative, 3 - West Siberian plane, 4 - West Siberian oil and gas basin, 5 - oil and gas areas, 6 - oil and gas subareas; fields: 7 - oil and gas, 8 - gas oil, 9 - oil and gas condensate, 10 - gas condensate, 11 - gas.

Figure 2. Tectonic map of the Jurassic structural stage of the West Siberian petroleum province northern part [6].
2. Methods of study
The paper deals with a comprehensive interpretation of seismic materials based on stratigraphic interpretation of seismic data [4, 5, 8, 12]. Analysis of regional time cross-sections and deep drilling data of the region made it possible to identify all the seismic geological complexes traditionally allocated in West Siberia: Paleozoic, Triassic, Jurassic, Berriasian-Lower-Aptian, Aptian-Cenomanian and Turonian-Cenozoic, which are limited in the top and bottom by seismic reflectors: A (the bottom of the sedimentary cover), Kt (the Kiterbut formation), B (the top of the Bazhenov formation), M (the Neitytin clay unit), and G (the Kuznetsov formation) (Figure 4). Structural maps for all reflectors, maps of thicknesses of seismic complexes were built.

Using paleosections, the reconstruction of the positive structures development during geological time was carried out using the thickness method [1, 3, 9]. Thus, for example, the section aligned along B reflector is the paleorelief of the lower horizons at the time of the formation of the reflector B.

3. Structural and tectonic characterization
Structural maps analysis on seismic reflectors showed that the sedimentary cover structure of all reflectors in the Yamal peninsula is a monoclysis complicated by high-amplitude positive structures of 2 and 3 ranks which amplitudes increase upward the section. The sedimentary cover structure of the Gydan Peninsula changes upward the section – landscape of the Jurassic and Lower Cretaceous subsurfaces is a megasineclise complicated by the Gydan, Geophysical and Messoyakh uplifts; landscape of the Upper Cretaceous and Cenozoic reflectors - monocline. The structures of the Yamal OGA are more contrasting in the Cenozoic subsurfaces, in comparison with the structures of the Gydan OGA. The positive tectonic structures of the Gydan Peninsula are flattened upward the section, since the Cenozoic structure formation processes within the Gydan OGA passed less intensively.

The main hydrocarbon reserves are concentrated in the Aptian-Cenomanian deposits, so we pay special attention to the structural plan for the Cenomanian top, where positive structures are marked (Figure 3). All the allocated structures are productive.

![Figure 3. Structural map of senomanian top subsurface with allocated positive structures. Legend: 1 – boundaries of the megasynclises, 2 – positive structures.](image-url)
Figure 4 shows a modern time section and paleosections runs in the southern parts of the Yamal and Gydan OGA and crosses the Novii Port uplift, the Nizhnenemessoyask and the Gydan uplifts. Within both OGA, the same Jurassic, Cretaceous and Cenozoic reflectors are traced. Within the Gydan OGA, the total time thickness of the sedimentary cover is much larger than in the Yamal OGA (here we can distinguish extra 3-4 well-traced reflectors) due to a thick complex of sediments of pre-Toarcian age. It can be assumed that on the Yamal peninsula sedimentary deposits under the reflector Kt are represented by the Jurassic and Triassic, and on the Gydan Peninsula, possibly, in addition to the sedimentary deposits of the Triassic, Upper Paleozoic sediments are also widespread.

The paleosections analysis shows (Figure 4) that at the sedimentation time of the Bazhenov formation, the gentle relief of the Jurassic subsurfaces was complicated only by the contrasting Messoyakh uplift of the basement. During Berriasian-Aptian time the Novii Port uplift began to form and the Nizhnenemessoyakh arch grew due to the basement block upward movement. During Aptian-Turonian, the South-Gydan uplift began to form. During post-Turonian time, the final formation of all structures, the maximum growth of the Novii Port uplift, the inherited development of the Nizhnenemessoyakh arch take place.

It can be concluded that all 3 positive structures crossed by the line developed in different ways: Novii Port uplift formed due to the basement block upward movement mainly in Cenozoic time, Messoyakh inclined ridge formed over the basement block gradually throughout the whole Mesozoic-Cenozoic time, South-Gydan uplift is a rootless structure, which does not confined to the basement block, the formation of it took place mainly in Cenozoic time.

Figure 5 shows a section that also passes through the territories of the Yamal and Gydan Peninsulas, but considerably to the north. The line crosses the North-Arctic, East-Zelenomysovsky, Paesedskii uplifts.

The paleosections analysis shows the Paesedskii and the East Zelenomysovsky uplifts gradually grow throughout the whole Mesozoic-Cenozoic tectonic history, but the North Arctic uplift is formed over the basement block mainly during the Cenozoic period.

Each of the tectonic development stages is accompanied by faults formation. In the research, four types of faults were identified: separating basement blocks; penetrating into the Jurassic rocks, penetrating into the Cretaceous rocks, cutting the entire sedimentary cover.

The Cenozoic type of faults is important in terms of oil and gas potential, since they could serve as channels for migration of hydrocarbons from source rocks to the reservoirs upward the section.

Paleotectonic analysis shows before the early Cretaceous, the Mesozoic-Cenozoic sediments of the Gydan OGA tended to a relative subsidence, in the Cretaceous-Cenozoic time - to a relative uplift; the sediments of the Yamal OGA during the development history tend to a relative uplift, with the maximum growth and the formation of the modern uplifts (anticlinal structures) in Cenozoic.

During the research three formation models of positive structures of the 2-3 ranks, which the HCF are associated with, were identified. The first type is “root” (formed over the basement block) structures that have been growing gradually from early Cretaceous time. The second type is “root” structures, which grow maximum intensive in the post-Turonian period. The last type is “rootless” structures with predominantly Cretaceous-Cenozoic development time. The second and third types of uplifts, for which the most important post-Turonian stage of tectonic development, are common for structures located on the Yamal Peninsula, and the first type with a gradual growth of anticlines throughout the Mesozoic-Cenozoic history of tectonic development is common for the Gydan Peninsula.

It should be noted that the coincidence in the Cenozoic era of factors contributing to the formation of HCF, predetermined the extremely high gas potential of the studied region. Favorable factors for the formation of a large number of HCF in the study area are:

1) the presence of beds with good reservoir properties in the Jurassic-Cretaceous rocks;
2) the presence of reliable thick reservoir cap rocks;
3) gas generation by Jurassic oil-producing source formations and by gas-producing source coal layers of the Pokur formation;
4) the formation of high-amplitude structural traps in the Cenozoic;
5) the formation of faults cutting almost the whole sedimentary cover (from Triassic to Cenozoic deposits), contributing to the migration of hydrocarbons from source rocks to the Aptian-Cenomanian reservoirs.

Figure 4. Present-day (A) and paleoseismic sections flattened on the G (B), M (C), B (D) reflectors along line Reg_5.
Legend: 1 – reflector, 2 – seismogeological complex, 3 – faults.
Figure 5. Present-day (A) and paleoseismic sections flattened on the G (B), M (C), B (D) reflectors along line Reg_2. Legend: 1 – reflector, 2 – seismogeological complex, 3 – faults.
4. Conclusion
As a result of paleotectonic analysis, we can draw the following conclusions:

- Before the early Cretaceous, the Mesozoic-Cenozoic sediments of the Gydan OGA territory tended to a relative subsidence compared to the Yamal OGA territory. The sedimentary cover of the Gydan Peninsula tends to relative uplift, mainly in the Cretaceous-Cenozoic time, and the Yamal OGA territory tends to relative uplift throughout the history of development. Despite the difference in the history of tectonic development in the Yamal and Gydan OGA, the maximum growth and formation of the modern appearance of anticlinal structures in both regions occurred in the Cenozoic.

- Messoyakh inclined ridge tends to a relative uplift throughout the whole history of tectonic development.

- Most of the positive structures of the Yamal Peninsula are confined to the basement blocks and tended to grow relatively throughout the Mesozoic-Cenozoic history of tectonic development. At the same time, the most intensive growth of positive closed structures of this region took place in the Berrias-Aptian and Cenozoic.

- The formation of the depression zone separating the structures of the Yamal and Gydan peninsulas began in the middle Triassic and continues to this day.

- Analysis of Mesozoic-Cenozoic tectonic processes made it possible to distinguish four main stages of tectonic activation, accompanied by the faults formation: pre-Jurassic, early Jurassic, early Cretaceous and post-Turonian (Cenozoic), which allow us to distinguish five main classes of faults:

  - Separating of basement blocks, penetrate the deposits of the sedimentary cover, but do not cut Jurassic deposits (the time of formation is pre-Jurassic, presumably Perm-Triassic);
  - penetrates into the Jurassic (the time of formation of the Gettang-Aalen);
  - penetrating into the Cretaceous deposits (Berrias-Valanginian);
  - penetrating into the Cenozoic deposits (Late Paleocene) - cutting the entire sedimentary cover.

The last type of faults is important in terms of oil and gas potential, since they could serve as channels for migration of hydrocarbons from oil and gas source rocks upwards along the section to the reservoirs.

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