Seismogeological analysis and petroleum potential of the Achimov Formation of the Gydan Peninsula

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Abstract. Considered questions of structure and formation conditions of the Berrias–Lower Aptian deposits of the Gydan Peninsula of Western Siberia. Their seismogeological characteristics are given. Recognized eight seismic sequences, most of which have a wedge shape and correspond to third-order sequences. The main prospects for the search for hydrocarbon traps are associated with the Achimov petroleum complex, lenticular sandy-aleuritic beds of which have deep-water genesis. Two types of promising zones are identified for the search for lithological traps in the deposits of the Achimov Formation. One of them is associated with depocenters accumulation of clinoforms, the second – with the regional wedging distal Achimov strata in the direction of the Taimyr paleolandmass.

1. Introduction
The Gydan Peninsula, located in the Arctic regions of Western Siberia, is a promising area in search of hydrocarbon deposits. A number of large oil and gas fields such as Salmanovskoe, Geophysicheskoe, Tota-Yakhinskoe, Gydanskoe, and Solentskoe, with deposits in the Jurassic and Cretaceous sediments, have already been discovered on this territory. Nevertheless, the study drilling remains extremely low. A little more than 180 wells were drilled, which are mainly concentrated on a small number of areas. Most of them are located near the coast of the Ob and Taz Bays. A significant part of the wells uncover the Cretaceous deposits on the bottom hole and only about twenty wells reached the Jurassic complex.

In recent years, seismic exploration works become more intense in the Arctic regions. On the territory of Gydan, the total length of seismic profiles is currently about 60 thousand linear kilometers, and their average density is about 0.60 km/km².

In the Jurassic and Cretaceous of Western Siberia is allocated a number of petroleum complexes. Each of them has its own features of geological structure, litho-facies composition of rocks, regularities in the allocation of hydrocarbon deposits, etc. One of such promising petroleum complexes in the territory of Gydan is Achimov petroleum complex. The huge reserves of oil and gas of the Priobskaya and East-Urengoy oil and gas bearing zones of Western Siberia are associated with the Achimov Formation. On the territory of the Gydan Peninsula hydrocarbon deposits in the Achimov strata were found at the Deryabinskoe field. However, most of the resources of this complex remain undetected.
2. Seismogeological characteristics

The Gydan peninsula is located in the north-east of the West Siberian plate. In the section of the Mesozoic sedimentary cover, five seismogeological megacomplexes can be recognized: Triassic, Jurassic, Berrias–Lower Aptian, Aptian–Cenomanian and Turonian–Maastrichtian. Of special interest is the Berrias–Lower Aptian megacomplex. Its distinctive feature is the clinoform structure of the section, which was caused by the lateral filling of a relatively deep-water basin as a result of avalanche sedimentation. At the time seismic sections, the Berrias–Lower Aptian megacomplex of Gydan is defined by reflecting horizons B (top of Bazhenov and Gol’chikha Formations) and M (bottom of Neite shale member).

To construct a seismogeological model of the Berrias–Lower Aptian deposits, including the Achimov Formation of the Gydan Peninsula, the authors carried out a complexation of geophysical and geological methods. First of all, they include seismic and sequence-stratigraphic methods, paleogeomorphological reconstructions, interpretation of the results of well logging (WL).

The principle of selection seismic sequences (SS) was based on comparison of wavefield features of seismic sections, WL data, spatial location of plug shale member, boundaries of second- and third-order sequences, maximum flooding surfaces. Segregation and correlation of SS controlled by paleontological data. Stratigraphic finding of reflecting horizons assign to bottom of regional shale
members was carried out by comparing WL data embedded in temporary seismic sections through vertical seismic profiling and seismic logging.

Within the Gydan Peninsula, eight seismic sequences of the Valanginian–Lower Aptian age have been identified: Savui (sv), Cheuska (ch), Sarman (srm), Urengoi (urn), Pim (pm), Seakha (sh), Arkticheskiy (ark) and Lower Alym (nal) (figure 2). The names are given by the name of regional shale members lying at the base of seismic sequences. All SS except for the Lower Alym are wedge-shaped bodies (clinoforms), which correspond to third-order sequences. The time of their formation varies from 0.4 to 2.5 million years. The formation of the Lower Cretaceous clinoforms of Western Siberia should be considered in terms of the Depositional Sequence III model [1].

In the transgressive phases of SS formation, mainly shale sediments accumulated, regressive–sandy-aleuritic horizons. The boundaries of SS are controlled by reflecting horizons at the base of the sequences of the third-order and are marked by the extremum of the negative phase.

The clinoform part of the Berrias–Lower Aptian megacomplex is displayed on the stacked data by a series an oblique reflective horizons, which are flattening as the horizon B approaches (figure 2). In the regressive part of the wedge-shaped seismic sequence (WSS), an oblique boundaries stop tracing up the uprising according to the pattern of toplap, downwards by the type of downlap. In the zone of greatest thickness, a wave pattern with a chaotic, low-amplitude form of recording is singled out. The transgressive parts of WSS represented mainly dynamically expressive negative extremes of seismic recording.

![Figure 2](image_url)

Figure 2. Seismogeological paleosection Berrias–Lower Aptian along composite profile.

The upper part of the section of the Berrias–Lower Aptian megacomplex is a cover horizontally layered formation. In the regressive parts of seismic sequences, the wave pattern has a low-amplitude, chaotic form of recording, with an increase in thickness, a weak oblique can be appear. The transgressive, mainly shale part of seismic sequence is characterized by a dynamically expressed wave pattern.
3. Formation conditions of the clinoform complex

The accumulation of the Berrias–Lower Aptian deposits of Western Siberia occurred under the conditions of a relatively deep-water paleobasin regressing. According to paleobathymetric reconstructions conducted by one of the authors of the article [2], the depth of the Early Berrias basin to the beginning of the formation of the Lower Cretaceous clinoform complex in the territory of Gydan did not exceed 160 m. During the Berriasian, Valanginian and Hauterivian as a result of tectonic subsidence of the bottom of the basin in areas of uncompensated sedimentation, the depths of the paleobasin continued to increase.

In the Cretaceous period, there were two source of terrigenous material, which formed two systems of clinoforms on Gydan, respectively. For the first system of clinoforms, the Siberian Platform was the source area. The second system of clinoforms was formed due to terrigenous material carried down from the Taimyr landmass. However, the volumes of sediment drifted from the Siberian platform were many times higher than similar amounts of material carried from the northern source area. This was the reason for the asymmetry of the structure of the clinoform complex of the Yenisei-Khatanga regional depression and adjacent areas of the West Siberian plate.

The relatively deep-water environments in the area under investigation existed almost until the late Hauterivian [3]. The West Siberian clinoform complex was progradated cyclically, interrupted by short-duration transgressions, during which regional shale members were formed. On the territory of the Gydan peninsula, the compensation of the paleobasin by sediments occurred during the late Valanginian and the Hauterivian. In the extreme north of the peninsula, this process also affected the beginning of the Barremian. The rate of progradation of the sedimentary complex was irregular in time. The maximum value it reached in the early Hauterivian. The authors associate this with the time of compensation of precipitation in the basin of the adjacent Yenisei-Khatanga regional depression from the east. As a result of which sedimentary material coming from the Siberian platform to the western regions of the depression began to move by rivers in transit to the territory of Gydan.

4. Seismogeological model and oil and gas prospects

Within the Gydan Peninsula, the depths of the Berrias-Lower Aptian megacomplex top reach 2400-2500 m. The maximum value are recorded in depressions along the southern and western coasts of Gydan. In general, for the relief there is a tendency of uplift in the eastern and northeast directions towards Taimyr. In the relief, we can conditionally distinguish two zones, differing in the gradients of the submergence of the top of the megacomplex. The outer Pritaymyr zone is characterized by elevated gradients, averaging 10–20 m/km, and the presence of small-scale local structures that can be mapped only with a dense network of seismic profiles. In the inner zone, the gradients of immersion of the top of the Berrias–Lower Aptian megacomplex decrease several times and a number of positive structures of the second-, third- and lower-orders appear in the relief.

The maximum thickness of the Berrias–Lower Aptian deposits is noted in the southeast of Gydan and reaches 1800–1900 m. If to consider each WSS separately, it is possible to allocate three zones. The first two are zones of reduced thickness, associated respectively with its undatheme and fondotheme. The third zone, within which WSS depocenter are allocated, is represented primarily by the elinotheme and, to a lesser extent, by unda- and fondothem.

In the formation of the Gydan clinoform complex, the depocenters of the clinoforms along the Valanginian, the Hauterivian and the Barremian were successively displaced in the north-west direction. In figure 3, as an example, a map of the thickness of the Pim WSS of the Lower Hauterivian age is presented. During its formation, source area participated, located both on the Siberian platform and on the Taimyr. As a result, on the seismic profiles it is possible to observe counter clinoforms [4]. At the time of accumulation of the Pim WSS, the precipitation of the Yenisei-Khatanga sedimentary basin was compensated and the clinoform breakpoint acquired a submeridional orientation.

In the structure of the clinoforms, two levels of sandy-aleuritic bodies are distinguished. The first level is associated with the uppermost bed of shallow-marine and continental genesis. The second is
confined to the distal relatively deep-water deposits of the Achimov Formation. Sandy-aleuritic bodies of shallow and deep-water sediments have different morphology and reservoir properties, differ in structural plans. These and a number of other factors have caused the dominance of various types of trap in different parts of the clinoforms, which requires a differentiated approach to their study.

The structural plan of the Berrias–Lower Aptian megacomplex of Gydan is not very favorable for the search for anticline oil and gas traps. Large structures have now been drilled. Further search for anticline deposits of hydrocarbons can be attributed only to small and small-amplitude traps. Therefore, the search for lithological traps is of particular relevance. From this point of view, one of the prospective intervals is the Achimov Formation lying at the base of the Cretaceous. It represents a series of lenses relatively deep-sea genesis, rejuvenating in the north-west direction. The lenticular form of the sandy bodies of the Achimov Formation allows to consider both positive and negative structures as promising for discovering new deposits of oil and gas.

The degree of exploration of the resources of the Achimov Formation remains extremely low. Its deposits on Gydan have uncovered about 40 wells at depths from 2380 to 3440 m. All wells except Gydanskaya well 130 drilled along the perimeter of the peninsula.
There are two types of promising zones for the search for lithological traps in the deposits of the Achimov Formation. The first type of zones is confined to the depocenter of clinoforms. As the practice of oil and gas prospecting in Western Siberia has shown, the increased effective thicknesses of Achimov sandstones and zones with improved reservoir properties are usually confined to the depocenter of clinoforms [5]. On the territory of the Gydan Peninsula in the Lower Cretaceous clinoform complex, two major depocenters of accumulation of sedimentary material are allocated, confined to the sediments of the Pim and Seakha WSS (figure 4). Within the depocenters, the most promising are the areas raised in the structural sense.

The second type of zones is associated with the regional attenuation of the distal strata of the Achimov Formation toward the Taimyr paleolandmass. This zone includes the Deryabinskoe gas condensate field, discovered in the east of the Gydan Peninsula. East within the area identified gas deposits in Khabeyksko field.

The selected prospective oil and gas accumulation zones require further detailed study. These areas should be given priority in setting up prospecting for hydrocarbon deposits on the territory of the Gydan Peninsula.

Figure 4. Map of prospective oil and gas accumulation zones of the Achimov Formation.
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