Evolution of Hydrocarbon Systems Within the Eastern Part of the Scythian Plate

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Abstract. On the basis of the performed 2D modeling, the authors established the main spatio-temporal regularities of the development of the processes of generation, migration and accumulation of hydrocarbon fluids in the platform part of the Eastern Ciscaucasia. The modeling results showed the saturation with hydrocarbons of the terrigenous strata of the Anisian and Landian stages, terrigenous sediments of the Middle Jurassic, Lower Cretaceous, as well as a single saturation of carbonates of the Upper Cretaceous and Lower Maikop, probably associated with the development of areas of abnormally high reservoir pressures. The degree of rock saturation is relatively high and reaches 80% for the sandy strata of the Middle Jurassic. For carbonate-terrigenous sediments of the Middle Triassic, saturation varies from 45-65%.

1. Introduction
In the sedimentary cover of the Eastern part of the Scythian plate, 4 generation-accumulation hydrocarbon systems are distinguished: lower-middle Triassic, lower-middle Jurassic, Cretaceous-Eocene and Oligocene-Miocene. To reconstruct the evolution of hydrocarbon systems was modeled a regional profile that intersects the following tectonic elements in the Eastern part of the Scythian plate: the Nogai zone, the Prikum system of elevations, the zone of Manychsky deflections, the southern part of the Karpinsky ridge (Fig. 1).

Figure 1. Regional profile across the eastern part of the Scythian plate and location of calibration wells.
2. Study techniques and results
The distribution of lithological types by section is presented on the lithological-facies model of the profile under consideration (Fig. 2). To characterize the lithotypes was used reference data for the Eastern Pre-Caucasus and the "default" parameters of the "Temis" software package. Each lithotype is characterized by a set of petrophysical parameters that are used in calculations.

![Figure 2. Lithological model along the line of 2D modeling.](image)

On the basis of the conducted studies of rock types in the studied area, four oil and gas-mater formations were identified: mudstones (argillites) of the Demyanov formation, middle Jurassic Bat-Bayos clay deposits, Apt-Albian clays and deposits of the Khadum formation (Fig. 3).

![Figure 3. Position of oil source strata along the profile line.](image)

The average geochemical parameters used in the model are shown in table 1.
Table 1. Geochemical characteristics of oil-bearing rocks.

| Formations (OPRs, oil-producing rocks) | Organic carbon content, % | HI (hydrogen index), mg hydrocarbon/g organic carbon content | Type of organic matter (kerogen) | Energy, m |
|--------------------------------------|---------------------------|------------------------------------------------------------|---------------------------------|-----------|
| Demyanov                             | 1.3                       | 160                                                        | III                             | 80        |
| Bat-Bayos                            | 1.5                       | 250                                                        | II                              | 70        |
| Apt-Albian                           | 1.2                       | 290                                                        | II                              | 50        |
| Khadum                               | 2.8                       | 440                                                        | II                              | 60        |

One of the most important parameters that determines the time and speed of kerogen decomposition and formation of hydrocarbons from it is the activation energy. Activation energy (Ea) is the minimum energy that a molecule (or pair of reacting molecules) must have to enter a chemical reaction. Activation energy is usually measured in joules and is not attributed to a single molecule (this is a very small value), but to the mole of a substance and expressed in units of J/mole or kJ/mole.

Kinetic schemes of activation energy distribution were determined for the considered oil-producing strata (Fig. 4).

![Figure 4](image-url)

**Figure 4.** Kinetic schemes of the distribution of partial potentials from the activation energy for the types of kerogen used in the model. A-demyanovsky, B-hadumsky, V-bat-bayossky, G-apt-albsky.
To restore the geological and geochemical history of hydrocarbon systems, the following reconstructions were performed: reconstructions of the stages of sinking, the thermal history, and the history of oil and gas generation for the main oil and gas-producing formations. Based on the obtained modeling results, was estimated the degree of transformation of oil-bearing rocks, as well as the stages of generation and emigration of hydrocarbon fluids.

According to the reconstructions carried out, Demyanov oil-producing rocks (OPRs) in the zone of the Manychsky deflections began to generate hydrocarbons (HC) at the end of the late Jurassic. The period of generation at the moment is not completed. The maximum generation of HC is dated to the end of the Eocene, migration to the middle of the Eocene, and emigration to the middle of the Miocene. At present, Demyanov OPRs have generated 16 t/m².

The Bat-Bayos oil-producing pores began generating hydrocarbons in the middle of the Eocene. The generation period is not completed. The maximum generation of HC is dated to the middle of the Miocene. The migration process began at the end of the Oligocene, and emigration at the end of the middle Miocene. At present, the Bat-Bayos oil-producing rocks have generated 6 t/m².

Lower Cretaceous oil-bearing rocks in both the more submerged and the more elevated part of the trough began to generate hydrocarbons in the middle of the Eocene. The generation period lasted for a long time. The maximum generation of hydrocarbons was reached at the end of the Miocene, and the emigration of hydrocarbons from this oil-producing rock at the beginning of the Pliocene. At present, the lower Cretaceous oil and gas producing rocks (OGPRs) in the submerged parts generated 8 t/m², in the more elevated - 2 t/m². The generation of oil-bearing rocks of the Khadum formation both in the more bent and in the more elevated part of the territory began at the end of the Eocene; and it continues to the present day. The peak generation of all parts of the studied territory is probably at the present time, since the migration of hydrocarbons began in the late Miocene. At present, Khadum OGPRs generated no more than 2 t/m². The upper boundary of the "oil window" for the Eastern part of the Scythian plate on the southern slope of the Karpinsky ridge and the Manychsky deflections zone runs at a depth of about 1,200-1,600 m, for the Nogai zone it is submerged and averages 2,400 m. The depth of the transition from the oil and gas generation zone to the gas generation zone at the Nogai is located at 4,400-4,600 m, for the Manychsky deflections zone and the southern slope of the Karpinsky ridge – 3,000-3,600 m.

The entry of the lower Triassic OPRs into the oil-generation zone in the Eastern part of the Scythian plate began at the end of the Eocene (54 million years ago), later the main zone included oil-producing rocks of the middle Jurassic - 48 million years ago (Fig. 5).

Figure 5. Dive Curves and Position of Generation Zones.
At the beginning of the Eocene (42 million years), the main zone of oil formation included oil-bearing rocks of the lower Cretaceous (Apt-Alb), rocks of the lower Maikop entered the main zone at the end of the Miocene (24 million years).

Currently, lower-middle Triassic (Demyanov) oil-producing rocks have developed their generating potential by 70% in the zone of the Manychsky deflections. Oil-producing rocks of the middle Jurassic are developed in the zone of the Manychsky deflections by 60-70%, on the southern slope of the Karpinsky ridge - by 20-30%. Oil-producing strata of the lower Cretaceous (Apt-Alb) in the Central part of the studied section are developed by 70%, on the Nogai zone by 80%, on the southern slope of the Karpinsky ridge by 40-50%. The oil-producing strata of the lower Maikop in the most submerged part of the deflection developed a potential of 75-80%, in the raised parts of the deflection – by 20%. The focus of oil formation is confined to the southern, most submerged part of the section, as well as to the zone of the Manychsky deflections.

To date, OGPRs of the lower Triassic (Demyanov) in the submerged area of the Manychsky troughs, are the gradations of apocatagenesis, OGPRs of the middle Jurassic (Bat-Bayos) is converted to the gradation MC1-MC2 (meso catagenesis), rocks of the lower Cretaceous in the Nogai zone are at the bottom of main zone of oil generation (MZOG) (gradation of catagenesis – MC3, in the most elevated areas – In the middle of MZOG – gradation of catagenesis - MC2. Rocks of the lower Maikop are located in the upper part of the MZOG – gradation of catagenesis - MC1.

The value of the formation rise angle controls the direction of fluid flow; liquid hydrocarbons migrate along the formation rise, aiming to occupy the highest position in the sediment section. From the southern, most submerged part (the Nogai zone), which is associated with the center of oil formation, the flow of fluids is directed to the southern slope of the Karpinsky ridge.

The results of 2D modeling showed hydrocarbon saturation of the terrigenous strata of the anisian and landian tiers, terrigenous deposits of the middle Jurassic and lower Cretaceous, as well as a single saturation of carbonates of the upper Cretaceous and lower Maikop, probably associated with the development of the regions of abnormally high stratum (pore) pressure. The degree of saturation of rocks is relatively high and reaches 80% for sandy strata of the middle Jurassic. For carbonate-terrigenous deposits of the middle Triassic, saturation varies from 45-65% (Fig. 6).

Thus, based on the 2D modeling were established the main spatial and temporal patterns of the development of the processes of generation, migration and accumulation of hydrocarbon fluids in the platform part of the Eastern Pre-Caucasus.

Figure 6. The nature and degree of saturation with hydrocarbon fluids in the eastern part of the Scythian plate.
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Acknowledgments

The studies were carried out with the financial support of the Ministry of Education and Science of the Russian Federation as part of Assignment №075-00069-20-00-PR for research work (the basic part of the state assignment in the field of scientific activity).