Evolution of Hydrocarbon Systems in the Tersk-Caspian Trough

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Abstract. The article analyzes the evolution of hydrocarbon systems in the Tersk-Caspian trough. In general, the modeling results confirmed the existing distribution of oil and gas content across the sedimentary cover of the region. Thus, according to modeling data, confirmed hydrocarbon deposits are located in reservoirs of upper Cretaceous chemogenic limestones in the areas: Andreevsk, Starogroznensk, Khayan-Kort, Pravoberezhsk, etc. The degree of reservoir saturation, excluding field development, is high – up to 80-90%. Subsalt bundles of the upper Jurassic may become promising objects for searching for hydrocarbons. According to the results of geological and geochemical modeling, there are significant volumes of hydrocarbons in the advanced anticline folds in the upper Jurassic subsalt deposits. The oil saturation here can reach 80% or more.

1. Introduction
The Tersk-Caspian advanced trough is bordered to the North with the Scythian epipleoneura stove, on which it imposed its outer Board. Its inner parts overlap the outer zones of the Alpine folding structure of the Greater Caucasus. In the West, the deflection is framed by the Mineralovodsky ledge. The surface of the Paleozoic basement lies in a trough at depths from 2-6 to 12 km. 48 oil and gas fields have been discovered in the Tersk-Sulak depression and the Tersk-Caspian oil and gas-producing region, including 3 gas, 8 gas condensate and 37 oil fields. The main oil-producing strata are the middle Jurassic terrigenous, lower Cretaceous terrigenous, Kuma terrigenous – carbonate, and Maikop terrigenous. Productive complexes are: lower Cretaceous terrigenous-carbonate, upper Cretaceous carbonate, and middle Miocene terrigenous.

One of the important indicators is the degree of catagenesis of rocks of oil and gas-producing strata. The selection of catagenesis zones is based on measurements of vitrinite reflection index (Ro) and colloalginite reflection index (Nka). To determine the level of conversion, a set of indirect indicators was used: the degree of bituminization of OM, the composition of bitumoids, hydrocarbon maturity coefficients, reservoir temperature measurements, and Rock-Eval pyrolysis data.

To construct and correlate the catagenetic model, were used fairly accurate definitions of borehole temperature measurements for the Sunzhensk and Burun areas located in the southern and northern parts of the research area, as well as measurements of vitrinite reflectivity (Ro, %) for these areas. The vitrinite-based maximum paleotemperatures for warming up the Jurassic strata also proved to be very close to the current reservoir temperatures in this area. Pale - and modern geothermal gradients are
also close, making up 28-35°C/km for different areas of this structural zone. The current temperature zoning along the profile line is shown in Fig. 1.

2. Modeling results

As evidenced by the results of modeling in the Tersk-Caspian trough, four generation-accumulation hydrocarbon systems (GAHCSs) are distinguished: middle Jurassic, lower Cretaceous, Eocene and Maikop GAHCSs. To reconstruct the evolution of the processes of generation, migration and accumulation of hydrocarbon systems, a basin modeling was carried out based on the regional seismic profile crossing the Siberian-Caspian trough from South to North. As a rule, the foci of HC formation are confined to the most submerged parts of the sedimentary basin, where deposits are located in more severe thermobaric conditions. This is due to the beginning of emigration processes and migration of hydrocarbons from these areas to the reservoir horizons.

In the profile (see Fig. 1), the most submerged area is the Chechen basin, which can be the main focus of hydrocarbon generation. More local sub-areas can be identified in the basins that separate the Sunzhensk and Tersk anticline zones.

According to the modeling results, the upper boundary of the main zone of oil generation passes at a depth of about 2,000 m, which corresponds stratigraphically to the roof of the upper Miocene-the sole of Pliocene deposits. The lower limit of the oil window is traced at a depth of about 5,000 m that in the Chechen basin to the base of the Maikop series, as in the Sunzha and Terek areas – the roof of the upper Cretaceous -that leads to the generation of petroleum hydrocarbons of the Kuma and Maikop OGPRs up to the present day (Fig. 2).

The gas window is timed to the intervals of depths of 5,000 – 8,000 m. Within the Chechen basin in the main gas generation zone there are Cretaceous-Paleogene deposits, in the Sunzhensk and Tersk structural zones – inter-salt deposits of the upper Jurassic-Cretaceous deposits, in this connection, the upper Jurassic and Aptian OGPRs today should be considered as the main sources of gas in the region, which can contribute to the transformation of previously formed oil deposits into gas-condensate, and with further conversion – into gas. The middle Jurassic sediments are of catagenetic overripe, but can still generate small amounts of "dry" methane.

In addition to modern estimates of the boundaries of the main zone of oil generation and main gas generation zone, to understand the formation of petroleum in the region we need to consider the catagenetic evolution of the main petroleum source strata within the main source of hydrocarbon generation.

According to the simulation results, the processes of hydrocarbon generation within the Tersk-Caspian trough began at the turn of the Aptian and Alb centuries (about 110 million years ago), when
the Bayos-Bat and upper Jurassic OGPRs entered the main oil formation zone. Their generation of oil fluids continued until the Oligocene period, which was facilitated by the stable tectonic regime of the region's development and the smooth sinking of precipitation.

![Figure 2. Catagenetic zoning of the sedimentary cover.](image)

During the Oligocene period, the accumulation of a thick layer of clay deposits of the Maikop series began, which contributed to the transition of the middle-upper Jurassic OGPRs to the gas window region. The continued arrival of abundant precipitation and active deflection of the territory in the early Miocene led to a sufficient catagenetic transformation of the Apt-Albian OGPRs for HC generation. By the end of the early Miocene, the deposits of the Kuma formation were also involved in the processes of petrogenation. At the turn of the middle / late Miocene (about 10-15 million years ago) the middle-upper Jurassic OGPRs came out of the gas window, around the same time the Apt-Albian OGPRs reached it and are in the main gas generation zone to the present day. At the end of the late Miocene, the deposits of the Kuma formation entered the gas generation zone. At the same time, oil formation processes begin in the oil-producing horizons of the Maikop series.

To forecast and evaluate the possibility of HC generation, in addition to the qualitative and quantitative characteristics of OGPRs and the level of their catagenetic transformation, it is necessary to take into account the degree of OM depletion (Fig.5), which characterizes the residual potential of OGPRs.

![Figure 3. the degree of depletion of the OM potential of OGPRs.](image)
To date, the middle-upper Jurassic OGPRs have fully developed their potential almost everywhere within the Tersk-Caspian trough. Their generation of hydrocarbons is possible only within the Monteneigrin structural zone, where they are located at the MC4 catagenesis gradation and have retained 20% of their generation potential. The degree of development of kerogen Apt-Albian OGPRs decreases from 90% in the depots of the Chechen depression to 40-70% to its sides. In the Sunzha and Terek zones, it is 70-90%. The potential of deposits is almost completely preserved in the elevated Chernogorsk zone.

A similar trend can be observed for the deposits of the Kuma formation. The clay strata of the Maikop series have almost completely preserved their potential within the deflection, only in the depocenter of the Chechen depression, the degree of depletion is 40-50%.

Thus, based on the specifics of the organic matter and the degree of catagenetic transformation of the isolated OGPRs, the main sources of oil fluids can now be the deposits of the Maikop series of rocks, the lower Cretaceous and the Kuma formation, within the raised blocks. Gas HC generation is provided by OGPRs of Apt-Albian and Kuma formation, within the submerged sections. Jurassic oil-producing strata do not make a significant contribution to the formation of oil and gas content of the Terko-Caspian trough, since the late Miocene. However, they are probably still capable of generating any volumes of "dry" gas.

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![Figure 4](image_url)

Figure 4. Predicted phase composition of hydrocarbon fluids.

As the results of modeling show, the emigration of hydrocarbons from the oil-producing strata of the Bayos-Bat age began in the Alb time (about 130 million years ago). At that time, the migration processes were local and occurred only within the depots of the Chechen depression, the predominant direction of migration was vertical. By the Campanian time (81 million years ago), migration processes were occurring throughout the Jurassic thicket in the Chechen basin. The direction of migration changes from a purely vertical to a lateral direction, controlled by the angles of incidence of strata. The gradual sinking of sediments during the Paleogene did not affect the nature and direction of migration processes. The most active migration processes within the Tersk-Caspian trough began in
the Miocene. In the Burdigalian age, migration processes in the Jurassic thicket became more active in the Sunzha and Tersk zones. It is likely that potential hydrocarbon deposits in the Jurassic subsalt complex could have been formed at this time. In the middle Miocene (Serravalian age), HB emigration begins from the Apt-Alb and Kuma OGPRs within the Chechen basin, and by the end of the Neogene – from the Maikop deposits, the direction of migration here is controlled by the angle of fall of the layers.

Today, due to the peculiarities of the tectonic structure and the presence of "squeezing" folds in the Mesozoic complex, migration processes in the Tersk-Caspian trough are multidirectional. The flow of fluids from the main centers of oil formation located in the bent part of the region is mainly directed towards the platform and southern sides of the deflection. Thus, the main hydrocarbon deposits were formed in the anticline structures of the Central part of the Meridian section of the forward deflection. According to the completed constructions, the main natural reservoir is chemogenic limestones of the upper Cretaceous age, in which hydrocarbon fluids came mainly from the oil-producing deposits of Bat-Bayos and Apt-Alb. However, at the moment, deposits in the upper Cretaceous deposits of the Tersk and Sunzhensk zones are fed both by the inflow of fluids from the lower OGPRs, mainly through faults, and by lateral and descending flows from the OGPRs of the Kuma and possibly Maikop formations (Fig. 5).

3. Conclusion
In general, the modeling results confirmed the existing distribution of oil and gas content across the sedimentary cover of the region. Thus, according to modeling data, confirmed hydrocarbon deposits are located in reservoirs of upper Cretaceous chemogenic limestones in the areas: Andreevskaya, Starogroznenskaya, Khayan-Kort, Pravoberezhnoye, etc. The degree of reservoir saturation, excluding field development, is high – up to 80-90%.

Subsalt bundles of the upper Jurassic may become promising objects for searching for hydrocarbons. According to the results of geological and geochemical modeling, there are significant volumes of hydrocarbons in the advanced anticline folds in the upper Jurassic subsalt deposits. The oil saturation here can reach 80% or more (Fig. 6).

The simulation results of a possible accumulation of this complex were detected at Datykhsk, Zakanovsk, Andreyevsk, Han-Koltovsk, Akhlovsk, Malgobek-Voznesensk and Gudermes structures. According to the nature of saturation and conditional estimation of the size of the potential deposit, the Zakanovsk and Andreyevsk structures can be considered the most promising. The main risks of searching for deposits in this complex should be associated with the presence of high-capacity
reservoirs, since the geochemical potential of the Jurassic OGPRs has been confirmed by analytical studies, and the salt-bearing strata are the most reliable fluid barriers.

Figure 6. The degree of hydrocarbon saturation of the sedimentary cover.

The prospects for oil and gas potential of the inter-salt Jura are difficult to assess unambiguously. Due to the complex tectonic structure of zones of advanced folding, the existence of fault zones that can be channels of interformational flows of reservoir fluids, as well as the heterogeneity of the lithological composition of salt strata, it is quite possible to form hydrocarbon accumulations in inter-salt carbonate horizons. The results of drilling operations confirm these forecasts. The source of HC for them could be the middle Jurassic and upper Jurassic subsalt OGPRs. However, the size of these likely clusters cannot be estimated from 2D modeling results.

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