Results of Modeling of the Processes of Generation, Migration and Accumulation of Hydrocarbons in the Eastern Part of the Scythian Platform

V Yu Kerimov¹, R N Mustaev¹, N S Yandarbiev², D D Ismailov¹

¹Sergo Ordzhonikidze Russian State University for Geological Prospecting, Moscow, Russia
²M. Lomonosov Moscow State University, Moscow, Russia

E-mail: vagif.kerimov@mail.ru

Abstract. Basic spatial and temporal regularities for development of the processes of generation, migration and accumulation of hydrocarbon fluids in the eastern part of the Scythian platform are determined and particularities of the generation and accumulation hydrocarbon systems in the northern platform boundary – Karpinsky ridge-Mangyshlak and Eastern Ciscaucasia oil and gas producing rocks are studied on the basis of application of the techniques for basin analysis and modeling of the hydrocarbon systems. The results of studying and modeling of the hydrocarbon systems prove that five hydrocarbon systems – Triassic, Jurassic, Cretaceous, Paleocene-Eocene and Oligocene-Miocene generation and accumulation hydrocarbon systems (GAHS) – can be defined within the sedimentary mantle of the eastern part of the Scythian platform. Two-dimensional models based on the regional seismic profile crossing the tectonic elements in the eastern part of the Scythian platform were created using the Temis Suite software package. Main directions for further performance of prospecting and appraisal works in the eastern part of the Scythian platform were determined on the basis of the performed investigations and modeling of GAHS. Differentiation of the investigated area is performed in terms of the type of predicted oil-and-gas content, age of the promising oil and gas complexes and their confinedness to the tectonic structures and zones.

1. Introduction

The objective of the present paper is to determine basic spatial and temporal regularities for development of the processes of generation, migration and accumulation of hydrocarbon fluids in the eastern part of the Scythian platform and studying of characteristics of the generation and accumulation hydrocarbon systems of the northern platform boundary – Karpinsky ridge-Mangyshlak and Eastern Ciscaucasia oil and gas producing rocks on the basis of application of the techniques for basin analysis and modeling of the hydrocarbon systems.

The results of studying and modeling of the hydrocarbon systems prove that 5 hydrocarbon systems - Triassic, Jurassic, Cretaceous, Paleocene-Eocene and Oligocene-Miocene GAHS – can be defined within the sedimentary mantle of the eastern part of the Scythian platform.
2. Modeling techniques
Modeling of the hydrocarbon systems for the territories in the eastern part of the Scythian platform was performed on the basis of the regional seismic profile crossing the tectonic elements in the eastern part of the Scythian platform with application of the Temis Suite software package.

Initial values of the following geochemical parameters: \( C_{\text{org}} \) is the percentage of organic hydrocarbon content in the sedimentary rocks; HI (the hydrogen index) is the ratio between the amount of the generated hydrocarbons (peak S2 on the Rock-Eval pyrolysis diagram) and \( C_{\text{org}} \); type of the OM (organic matter) is the type of kerogen, which is determined primarily on the basis of the chemical and carbon and petrographic characteristics of the kerogen; were used as the basic parameters for modeling of the process of generation of the hydrocarbons within the oil and gas producing rocks (OGPR).

3. Modeling results and discussions
To restore the geological and geochemical history of the hydrocarbon systems it is performed the 2D modeling based on the regional seismic profile crossing the following elements in the eastern part of the Scythian platform – the Nogay zone; the Priukum system of tectonic elevations; the zone of Manychsky deflections and the southern part of the Karpinsky ridge [1].

Based on the studies performed with the OM of the rocks in the investigated area four oil and gas genetic formations – argillites of the Demianov formation, Middle Jurassic Bat-Bayos argillaceous sediments, Apt-Alb argillites and Khadum section sediments – were identified (Figure 1).

![Figure 1](image-url)

**Figure 1.** Location of oil producing rocks along the profile line. Oil producing rocks: A – Apt-Alb argillaceous erosions; B – Khadum section; C – Bat-Bayos argillaceous erosions; D – Demianov formation.

4. Generation and migration of hydrocarbons from the oil-producing sections
The extent of transformation of the oil producing rocks along with the stages of generation and migration of the hydrocarbon fluids were estimated on the basis of the obtained results. In accordance with the performed reconstructions the Demianov oil-producing rocks (OPR) in the zone of Manychsky deflections started generation of hydrocarbons at the end of the Late Jurassic [2], [3]. The generation period is not completed by the present moment. Maximum generation of hydrocarbons is dated by the end of Eocene, migration – by the Middle Eocene, and emigration – by the Middle Miocene. The Demianov OPR have generated 16 tons/m² (Figure 2) as of the present moment.

Lower Cretaceous oil producing rocks both in the more submerged and in the more elevated parts of the trough started generation of hydrocarbons in the Middle Eocene. The generation period has
lasted till the present moment. Maximum of generation of hydrocarbons was attained at the end of the Miocene, emigration of hydrocarbons from the given oil producing rock started at the beginning of the Pliocene. By the present moment the Lower Cretaceous OGPR have generated 8 tons/m² in the more submerged areas and 2 tons/m² – in the more elevated area [4].

Generation in Khadum oil producing rocks both in the more submerged and in the more elevated parts of the territory had started in the Late Eocene and lasted till the present time. The peak generation of all the parts of the territory under investigation is probably at the present moment. The emigration of hydrocarbons started in the Late Miocene.

By now, Khadum OGPR have generated not more than 2 tons/m².

Figure 2. Dynamics of generation of liquid hydrocarbons within the oil producing sections in the eastern part of the Scythian platform.

5. Centers of generation and migration routes of the hydrocarbons

Location of main zones of oil generation within the section of the sedimentary mantle of the region (Figure 3) is determined on the basis of catagenetic reconstructions [5].

The upper boundary of the “oil window” for the eastern part of the Scythian platform on the southern slope of the Karpinsky ridge and in the zone of Manychsky deflections stretches at the depths of approximately 1200…1600 m, for the Nogay zone it is submerged constituting on average 2400 m. The depth of transition from the zone of oil generation to the zone of gas generation within the Nogay zone is located at the level of 4400…4600 m; for the zone of Manychsky deflections and the southern slope of the Karpinsky ridge it is 3000 to 3600 m. Depths of depositing of main generation zones of hydrocarbons for various oil producing sections are provided in Figure 4. Entry of the Lower Cretaceous OPR into the zone of oil generation in the eastern part of the Scythian platform started at the end of the Eocene (54 million years ago), later on (48 million years ago) the oil producing rocks of the Middle Jurassic entered the main zone of oil generation. The oil producing rocks of the Lower Cretaceous (Apt-Alb) entered the main zone of oil generation at the beginning of Eocene (42 million years ago), and the rocks of the Lower Maikop entered the main zone of oil generation at the end of the Miocene (24 million years ago). Presently, the generation potential of the Lower Triassic (Demianov) oil producing rocks is developed for 70% in the zone of Manychsky deflections. The
Middle Jurassic oil producing rocks are developed for 60…70% in the zone of Manychsky deflections, and for 20…30% on the southern slope of the Karpinsky ridge. The oil producing rocks of the Lower Cretaceous (Apt-Alb) in the central part of the section under investigation are developed for 70%, within the Nogay zone – for 80%, and at the southern slope of the Karpinsky ridge – for 40…50%. The generating potential of the oil producing rocks of the Lower Maikop is developed for 75…80% in the most submerged parts of the trough, and for 20% – in the most elevated parts. The center of oil generation is confined to the southern – the most submerged – part of the section, as well as to the zone of Manychsky deflections. As of the present moment, the Lower Triassic OGPR (the Demianov ones) in the submerged zone of Manychsky deflections are positioned on the gradations of apocatagenesis (AC), the Middle Jurassic OGPR (the Bat-Bayos ones) are converted to the gradations of MC1…MC2 (meso catagenesis). The Lower Cretaceous rocks in the Nogay zone are located within the bottom part of MZOG (gradation of catagenesis MC3), gradation of catagenesis MC2 is in the most elevated parts located in the middle of the MZOG. The Lower Maikop rocks are in the upper part of the MZOG – gradation of catagenesis MC1.

![Figure 3](image.png)

**Figure 3.** Location of main zones of oil and gas generation in the eastern part of the Scythian platform

### 6. Accumulation and degree of saturation with the hydrocarbons

The results of the 2D modeling showed saturation with hydrocarbons of terrigenous strata of the Anisian and Landian tiers, terrigenous sediments of the Middle Jurassic, the Lower Cretaceous as well as single saturation of the Upper Cretaceous and Lower Maikop carbonates that was associated probably with development of the regions having abnormally high pore pressures (AHPP). The degree of saturation of rocks is relatively high and attains 80% for sandy sections of the Middle Jurassic. The value of saturation varies from 45 to 65% for carbonate and terrigenous sediments of the Middle Triassic (Figure 4).

Modeling of the processes of accumulation and saturation with the hydrocarbons allowed determining promising directions for exploration and prospecting of oil and gas accumulations.

The perspectives for oil and gas content of the most ancient Triassic complex of the sedimentary mantle are related to the Prikum ridge and the Eastern Manychsky deflection in the Eastern Ciscaucasia [6], [7].

As far as the Eastern Ciscaucasia is concerned, it relates primarily to the eastern part of the Prikum system of elevations (to the east from the Russky Khutor Severny field) and the southern slope of the Eastern Manychsky deflection, where the sections of the Triassic sediments are the most complete. The Triassic sediments in the western part of the Prikum system of elevations are strongly eroded and contain deposits in the residues of the paleorelief covered with the sandy-argillaceous Jurassic formations. Active processes of biothermal formations are related to the paleo-protrusions. The expressed in structural terms sections having the signs of erosion or stratigraphic discontinuities are
the most promising ones in terms of formation of the hydrocarbon traps. The perspectives of discovery of the oil deposits are related to finding of stratigraphically and lithologically screened traps within the boundaries of the Eastern Zimnestavkinsky ridge and the slopes thereof, as well as within the limits of the southern submerged boundary of the Eastern Manychsky deflection, where discovery of the gas condensate deposits within the Lower and Middle Triassic sediments similar to the Yuzhno-Buynaksky gas condensate field is predicted. The perspective in terms of the oil content Ozemensky-Darginsky zone can be noted in the eastern part of the Manychsky deflection. The Ozernoe oil field is discovered within the limits of the zone concerned [8].

The Lower Jurassic complex of terrigenous sediments is the basic oil producing section in the Eastern Ciscaucasia. Several areas of cropping out of separate sandy parts of the formations in the direction of regional elevation of the strata are defined as promising in terms of their oil-bearing capacities. One of them is located to the north of Khoperskaia, Zarikovskaia and Ozernaia areas, and the other stretches to the south of the Prymanych area across the Arbalinskaia and Dzhuzgunskaja areas.

![Figure 4. Type and degree of saturation with the hydrocarbon fluids in the eastern part of the Scythian platform.](image)

The Upper Jurassic and Lower Cretaceous complex of sediments is another promising direction of further searching for oil and gas in the region. The main gas producing horizon of this zone is represented by the Apt sediments, which contain the gas condensate deposits. The oil deposits in the Apt and Middle Jurassic deposits are explored on the western and eastern boundaries of the zone, beyond the zone of influence of the lateral fluid flow [9]. The oil-bearing capacity of an industrial scale is determined within the sediments of the same age on the assumed continuation of the zone to the Trans-Caspian area, which is an additional confirmation of high perspectives of the offshore part of the Kamyshev-Caspian zone, primarily in the terms of oil extraction.

Despite for more than a century long history of development, the Cenozoic trend for performance of geological prospecting for oil and gas in the region still remains promising. Searching for hydrocarbon accumulations in the Pliocene sediments at the northern platform boundary of the Tersky-Caspian front deflection can be noted as a separate direction of geological prospecting. The problem of searching for new hydrocarbon accumulations within relatively shallow depositing Maikop sediments is worth special attention [10]. As the result of the performed researches it is possible to define two various directions of search and prospecting for oil and gas in the investigated area. The first of them can be defined as “searching for traditional reserves of hydrocarbons in granular collectors of the Khadum formation” and the other one as “searching for non-traditional reserves of hydrocarbons in high-carbon low-permeability carbonate-argillaceous formations of the Paleogene”. It is recommended to focus the geological prospecting works under the first traditional direction in the
north-eastern part of the Prikum system of elevations, and in the eastern part of the Eastern Manychsky deflection. Northern part of the Prikum system of elevations is another zone of development of sandiness of the Maikop sediments.

The areas of crossing the deep-seated faults of various orientation, where the maximum density of the disjunctive fracture of rocks is observed, can be recommended as local objects for performance of prospective drilling. According to the data provided by the seismic survey and drilling such areas can be found in the Eastern Manychsky deflection and in the Dovsun deflection in the western part of the Prikum system of elevations.

7. Conclusion
Therefore, basic spatial and temporal regularities of development of the processes of hydrocarbon fluids in the eastern part of the Scythian platform were determined on the basis of modeling; and separate characteristic of the generation and accumulation hydrocarbon systems were provided for the northern platform boundary – Karpinsky ridge-Mangyshlak and Central Ciscaucasia oil and gas producing rocks. The results of studying and modeling of the hydrocarbon systems prove that 5 hydrocarbon systems – Triassic, Jurassic, Cretaceous, Paleocene-Eocene and Oligocene-Miocene – can be defined within the sedimentary mantle of the eastern part of the Scythian platform. Main directions of further performance of exploration and appraisal works in the eastern part of the Scythian platform were determined on the basis of the performed investigations and modeling of GAHS. Differentiation of the investigated area is performed in terms of the type of predicted oil-and-gas content, age of the promising oil and gas complexes and their confinedness to the tectonic structures and zones.

8. References
[1] Gordadze G, Kerimov V, Giruts M, Poshibaeva A, Koshelev V 2016 Genesis of the asphaltite of the Ivanovskoe field in the Orenburg region Russia Fuel 216 pp 835–842
[2] Guliev I S, Kerimov V Y, Mustaev R N, Bondarev A V 2018 The estimation of the generation potential of the low permeable shale strata of the Maikop Caucasic series SOCAR Proceedings 1 pp 4–20
[3] Kerimov V Iu, Mustaev R N, Serikova U S, Lavrenova E A, Krugliakova M V 2015 Hydrocarbon generation-accumulative system on the territory of Crimea Peninsula and adjacent Azov and Black Seas Oil Industry 3 pp 56–60
[4] Kerimov V Iu, Gorbunov A A, Lavrenova E A, Osipov A V 2015 Models of hydrocarbon systems in the Russian Platform–Ural junction zone Lithology and Mineral Resources 50(5) pp 394–406
[5] Kerimov V Iu, Gordadze G N, Lapidus A L, Zhagfarov F G, Zakharchenko M V 2018 Physicochemical Properties and Genesis of the Asphaltites of Orenburg Oblast Solid Fuel Chemistry 52(2) pp 128–137
[6] Mustaev R N, Kerimov V Iu, Shilov G Y, Dmitrievsky S S 2016 Modeling of thermobaric conditions formation of the shale hydrocarbon accumulations in low-permeability reservoirs of the Khadum formation Ciscaucasia Geomodel 18th Science and Applied Research Conference on Oil and Gas Geological Exploration and Development
[7] Kerimov V Iu, Gordadze G N, Mustaev R N, Bondarev A V 2018 Formation conditions of hydrocarbon systems on the Sakhalin shelf of the Sea of Okhotsk based on the geochemical studies and modeling Oriental Journal of Chemistry 34(2) pp 934–947
[8] Kerimov V Iu, Mustaev R N, Osipov A V 2018 Peculiarities of Hydrocarbon Generation at Great Depths in the Crust Trans. Earth Sciences 483(1) pp 1413–1417
[9] Kerimov V, Rachinsky M, Mustaev R, Serikova U 2018 Geothermal conditions of hydrocarbon formation in the South Caspian basin Iranian Journal of Earth Sciences 10(1) pp 78–89
[10] Lapidus A L, Kerimov V Iu, Mustaev R N, Salikhova I M, Zhagfarov F G 2018 Natural Bitumens: Physicochemical Properties and Production Technologies Solid Fuel Chemistry 52(6)