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GEODYNAMIC EVOLUTION OF THE CASPIAN MEGADEPRESSION AND ADJACENT TERRITORIES

(Представлено членом редакційної колегії д-ром геол. наук, проф. О.М. Карпенком)

The objective of this study is to establish links between the features of the geodynamic evolution of the complex, heterogeneous in its geological structure of the Caspian megadepression and adjacent regions – with the issues of assessing the prospects for the oil and gas potential of this entire territory.

For this purpose, the data of published works on the geodynamic evolution of the above territory were analyzed and, based on this analysis, a summary map of the geodynamic evolution of the Caspian megadepression and adjacent regions was compiled, combined with the optimal systemic oil and gas geological zoning of this territory, previously developed by the authors of this work. The analysis of oil and gas resources for individual large links of the optimal zoning system with the features of their geodynamic evolution showed that in the studied area, there is mainly a direct dependence of the amount and density of hydrocarbon (HC) resources on the number of stages of geodynamic evolution of the earth's crust that have passed here, and also the presence or absence of paleospreading zones (rifts) and paleosubduction zones (island arcs).

Keywords: Caspian mega-depression, Azerbaijan, geodynamics, complex regions, optimal systemic oil and gas geological zoning, hydrocarbon resources, oil and gas potential, organic matter (OM), dispersed organic matter (DOM).

Formulation of the problem. To predict the prospects for oil and gas content in the complex regions of the Caspian megadepression and adjacent territories, one of the important criteria is the analysis of the features of the geodynamic evolution of the earth's crust on this great territory.

In a number of works devoted to this problem (*Kucheruk et al. 1983; Sokolov, 1985; Kucheruk et al., 1983*) certain regular relationships between oil and gas potential and global tectonics have been identified, in particular, a relationship has been established between the location of elevated hydrocarbon concentrations in areas of high heat flux from the Earth's interior, as well as the relationship of hydrocarbon accumulations with ancient rift (spreading) and subduction (convergent) systems in the earth's crust. Thus, in paleorift systems, favorable conditions for oil and gas formation could be created, since after the split and expansion of the earth's crust, the approaches to the surface of the highly heated mantle substance were created, on the one hand, high heat flows, and on the other hand, large graben-like depressions – sedimentary-rock basins with huge thicknesses of sediments filling them, in which large hydrocarbon deposits can be concentrated.

According to (*Kucheruk et al., 1983; Sokolov, 1985; Kucheruk et al., 1983*) the most favorable conditions for oil and gas formation and oil and gas accumulation existed on the continental margins – due to the accumulation of thick sedimentary strata and a favorable thermodynamic regime. Modern passive margins were formed at the end of the Paleozoic and in the Mesozoic. In the initial period, these margins experienced rifting, which subsequently gave way to intense subsidence with the accumulation of thick (up to 12-14 km) sedimentary strata. Oil and gas formation in sedimentary strata on the passive margins of the continents was favored by the presence of carbonate and argillaceous oil source strata enriched in organic matter, as well as thick terrigenous and carbonate reservoirs, high geostatic load, which ensures the extraction of formation waters from hydrocarbons and their migration into reservoirs (*Kerimov et al., 2016*). Within active continental margins characterized by high tectonic activity, seismicity and volcanism, which is due to the presence of deep inclined faults (Benioff zones), along which plates are thrust (subduction zones) there are also very favorable conditions for oil and gas formation and oil and gas accumulation (*Kerimov et al., 2014; Kerimov, 2021*). In these zones, during the process of subduction, a significant bowing of the earth's crust and the accumulation of huge strata of rocks in the zones of troughs, often immediately in front of mountain structures, also occur. In this case, thick sedimentation prisms are formed in the troughs, in which sediments rich in organic matter accumulate. As the sedimentary rock basins deepen and the thickness of the sediments increases, the geostatic load causes the squeezing of reservoir fluids and the formation of a reservoir pressure gradient towards the mainland, and also contributes, due to the huge lateral pressure, to additional heating of rocks and fluid migration in the lateral and vertical directions (*Khaustov, 2011*).

Thus, there is an exceptionally powerful mechanism for the generation of hydrocarbons from organic matter drawn along with oceanic sediments into plate underthrust zones.

Analysis of recent research and publications. According to (*Gavrilov, 1988*) the lithosphere in its development goes through a number of stages and phases, of which the phases of rift, partial and complete subduction (obduction) are the most favorable for oil and gas formation. These phases are characterized by the accumulation of a large mass of sedimentary rocks with dispersed organic matter, high heating of the subsoil, and a number of other indicators favorable for oil and gas formation. The main conclusions, according to (*Gavrilov, 1988*) arising from the proposed approaches in the field of oil and gas formation, are as follows:

1. The process of oil and gas formation is cyclical, repeating itself with varying degrees of intensity as the lithosphere evolves;
2. The determining factor of oil and gas formation is, first of all, the geodynamic regime of the subsoil, and the most favorable are subduction and riftogenic (*Gavrilov, 1988*).

The subduction-obduction geodynamic regime is typical for subduction zones located along the margins of the oceans, where peculiar associations usually arise from a deep-sea trench, an accretionary prism, an island arc, and a marine marginal basin, or from a deep-sea trench, an accretionary prism, and an active continental margin. In all cases, the maximum heating of the subsoil is typical of the rear part of the subduction zone. In the underthrust zones, peculiar natural stills appear, where, in a short geological time, the OM is transformed into drop-liquid oil. Thermal fluids (water heated up to 400 degrees and gases under enormous pressure) will tend to move from under the underthrust zone to an area of lower pressure. On their way, they will inevitably begin to squeeze out, dissolve and carry out drop-liquid oil (*Guliyev et al., 2020*). This powerful source rock micro-oil removal factor provides for efficient displacement and migration of dispersed micro-oil. Thermal waters rising along cracks with hydrocarbons (in free or dissolved state) will be unloaded within the lithospheric ledge and in the rear of the island-arc system with the formation of oil and gas deposits.

Moving away from the underthrust zones, the temperature and pressure of thermal waters decrease, and the filtration rate also slows down. Conditions favorable for the accumulation of hydrocarbons in the deposit are created.

The accumulation of oil and gas under the action of the subduction mechanism reaches its apogee during the period of the final closure of the ocean, when mountain-folded areas are formed in place of the ocean spaces, separated from the continental platforms by forward troughs.

The riftogenic geodynamic regime is inherent in intracontinental or continental marginal rift systems. Rifts and over-rift depressions are filled with a thick layer of sediments (4-7 km), enriched with organic matter. The high heat flow that comes from the hot mantle close to the base of the lithosphere (asthenospheric ledge) activates the processes of processing organic matter into droplet liquid oil. Superheated water-mineral flow coming from the bottom of the lithosphere and consisting of water, hydrogen, helium, carbon dioxide, methane and other components, flushes out liquid and gaseous OM and moves them into the reservoirs of the upper sections of the sedimentary cover (*Murzagaliev, 2011*).

If the processes of rifting are not accompanied by the opening of the ocean, but stop at the rift phase, then large depressions and syneclises usually occur above the rift structures. In the axial part of these large areas of subsidence, there are hot seams, a kind of "spiral", which intensely heats up the sediments and stimulates the conversion of OM into oil and gas. Regional zones of oil and gas accumulation of the rift type are formed within the continents.

Thus, rift geodynamic regimes can manifest themselves within continents and be intracontinental, but they can also affect passive continental margins and be, as it were, continental margins.

Expert assessments performed by researchers (*Kucheruk et al., 1985; Sorokhtin et al., 2002; Shein, 2007*) show that in the areas of action of the subduction-obduction geodynamic regime, up to 80 % of all identified reserves of hydrocarbon raw materials were generated, while under the influence of the rift regime, ~15 % of the reserves were formed, and only 5 % was passed to the share of the depression regime.

Thus, as a result of the above studies, the following conclusions can be drawn:

1. The geodynamic model of oil and gas formation in the lithosphere provides for a cyclical flow of the process with its periodic intensification during the most tectonically active epochs: rifting and closing of the oceans.

2. The necessary conditions for the formation of oil are: the presence of a sufficient volume of precipitation with diffuse organic matters (DOM) and a severe thermobaric regime of the subsoil.

3. The overheated water-mineral flow coming from the bottom of the earth's crust serves as the mechanism for the removal of droplet-liquid oil from the foci of formation into reservoir beds.

4. The formation of oil and gas deposits in reservoirs occurs according to the traditional scheme.

Such a geodynamic model of oil and gas formation, in our opinion, is sufficiently substantiated, confirmed by the world practice of prospecting and exploration for oil and gas, and can be taken as the basis for determining the degree of prospects of regions, depending on the number of stages of the geodynamic cycle that took place on the territory of these regions (*Alieva, 2016*).

Each stage of the evolution of the lithosphere corresponds to well-defined tectonic types of sedimentary basins, the formation of which is determined by the geotectonic (extension, compression, "passive" subsidence) and thermal regimes prevailing at this stage.

This, in turn, determines the geological parameters characteristic of this type of basins – the type of crust, the rate of subsidence and sedimentation, the lithofacies character and thickness of sedimentary fulfillment, geothermal gradients, nature of deformations and types of traps, conditions for the accumulation, burial and transformation of OM, types of oil and gas source rocks, reservoirs and seals, the scale of generation and migration routes of hydrocarbons, the location and nature of regional zones of oil and gas accumulation (*Mamedov, 2009*).

Most of the existing sedimentary oil and gas basins have gone through several stages of geodynamic development. Usually, during the transition from one stage to another, in place of the former sedimentary basin, a new one arises – of a different tectonic type, with its own structural features, thermobaric conditions, etc. Vertical overlap and/or lateral conjugation of sedimentary basins (or their parts) corresponding to successive stages of evolution lead to the formation of the resulting sedimentary basin with a much more complex geological structure. In the section of such basins, relics of various previous stages form independent structural stages. The basins of the most complex structure and long evolution turn out to be the most highly productive in terms of hydrocarbons (HC) (*Guliyev et al., 2009; Feyzullaev et al., 2016*). Each stage contributes to the total hydrocarbon potential of the resulting basin. Obviously, the last stage of evolution has a decisive influence on the structure and features of hydrocarbon distribution in any modern sedimentary basin. However, in the lower structural levels, corresponding to the basins (or parts thereof) of the previous stages, the oil and gas content typical for this type of sedimentary-rock basin can be preserved to a large extent. When the structural plan is restructured, to a greater or lesser extent, the ancient accumulations of hydrocarbons are reformed, moreover, the deposits of the upper structural stage receive significant portions of hydrocarbons from the lower (lower) ones both due to the destruction of the deposits available there, and as a result of additional generation of hydrocarbons in the lower parts of the section, which found themselves in new thermobaric conditions. Most of the giant – the largest oil and gas fields are confined to the basins of passive continental margins (the Tethys global belt of oil and gas accumulation), supra-rift depressions (the Laurasian global belt of oil and gas accumulation) (*Lebedko, 2013*). Smaller deposits are confined to the Gondwana and Pacific global belts of oil and gas accumulation, where basins of active continental paleomargins, orogens of plate collision, prevail.

Analysis of the distribution of hydrocarbon resources of the world, formed in different geodynamic settings, carried out by the US Geological Survey (*Ulmishek et al., 2004*), showed that the basins of passive continental paleomargins have the greatest resources. They contain 68 % of the world's oil resources and 49 % of gas. The second most important are the basins of rifts and supra-rift depressions, where 22 % of oil and 44 % of gas are concentrated. The basins of active continental margins and island arcs contain 4 % of oil and 3 % of gas resources, while the basins of plate collision orogens contain 6 % of oil and 4 % of gas.

The largest accumulations of hydrocarbons in the world are concentrated within long-term (more than 300 million years) passive margins, for example, Persian, Alaska, etc., transformed by the collision of plates in the Cretaceous-Cenozoic stage of development (*Kerimov et al., 2010*).

Thus, from the point of view of global lithospheric plate tectonics, high oil and gas potentials are associated primarily with continental margins, paleorift basins, zones of hidden foredeeps formed during the final stage of plate collision, as well as with thrust margins of folded mountain structures.

Isolation of previously unsolved parts of the general problem. Based on the foregoing, in order to predict the oil and gas potential of sedimentary basins, it is necessary first of all to study, along with the geotectonic regime, the geodynamic conditions of their formation, on the basis of which they should be appropriately typified and the territory be zoned. It is the approach that we have taken as the basis for studying the geological structure and prospects for the oil and gas potential of the Caspian Basin and adjacent regions.

It is well known that the Caspian Sea in its modern outlines, including the Caspian depression framing it in the north, is a submeridional heterogeneous megatrough or megabasin. This megatrough, referred by many researchers to the type of superimposed troughs, covers significantly different in structure and geological development, consequently, according to the geodynamic conditions of the formation of geostructural elements of classical platform and folded territories (*Tulegenova et al., 2016*).

In paleogeodynamic terms, the region of the Caspian megatrough is considered as a node of interaction, on the one hand, – the paleooceanic systems of the Urals and Tethys, and, on the other hand, the paleo-continental and microcontinental systems of Europe, Arabia and the Asia Minor-Iranian "wedge".

According to (*Murzagaliev, 1998*), from the standpoint of the modern plate tectonic model, the presence of East European, Scythian, West Turanian, Lesser Caucasian (Transcaucasian), South Caspian and Iranian lithospheric mesoplates is recognized within the region under consideration. Sutures of different ages are confined to their boundaries – fragments of the continental or suboceanic crust, which were affected by subduction and collision during the closing of the Tethys paleoocean. Since the late Miocene time, the East European Plate has been considered to be inactive. The Scythian and Lesser Caucasian plates move along an azimuth of 18° at a speed of 1.92 cm/year and simultaneously rotate counterclockwise by 2.03-10-7° (*Zonenshain et al., 1990*) West Turanian and the Iranian mesoplates move to the northwest along the collision seams at a speed of 1.7 cm/year, and the South Caspian plate is displaced along an azimuth of 319° at a speed of 0.4 cm/year. Relative to the East European Plate, it rotates at an angular velocity of 0.6 cm/year, 10-7° counterclockwise. Thus, the Caspian region found itself in the center of convergence of several plates with different kinematic parameters. All this caused the complexity of the geodynamic development and conjugation of geostructural elements of different types in this megatrough.

According to research (*Sokolov, 1985; Murzagaliev, 1998; Brazhnikov et al., 1987; Zonenshain et al., 1984; Ishutin, 1988; Maximov et al., 1987; Khalilov et al., 1991*), in the structure of the northern part of the Caspian subsidence area, a number of differently directed and different-aged rift systems were identified, which served as the basis for the development of various geodynamic models. According to the geodynamic model (*Brazhnikova et al., 1987*), in the Riphean-Vendian, after the breakup of Megagea, the microcontinents of the Ustyurt Plateau and the Karpinsky Swell began to separate from the East European continent, with which they previously formed a single whole. In the Cambrian, Ordovician, and Silurian, these microcontinents continued to separate from the mainland with the formation of the vast Paleo-Asian Ocean, which merged with the Paleo-Tethys Ocean 1, moreover, the territory of the Northern Caspian at that time was geographically located in the southern hemisphere, near the equator. In the Devonian, Carboniferous and Permian, the Paleo-Asian Ocean was compressed, the Ustyurt Plateau and the microcontinent of the Karpinsky Swell were pushed back towards the East European continent, however, not to their original, but to their current position. As a result of the pushing of the basaltic oceanic crust in the direction from north to south, from the side of the central part of the Caspian basin, the Devonian Biikzhal was formed – the North Astrakhan island arc in the south of the Caspian basin (Fig. 1), which actually, starting from the Devonian, divided the Caspian Basin into two sub-basins – the Central Caspian and the North Caspian. The deep-water trough in the North Caspian sub-basin was located at the site of the modern Tugarakchan trough and the Karakul-Zheltauz dislocation zone. Later, starting from the end of the Early Permian-Triassic, the North Caspian and Central Caspian sub-basins again become a single sedimentation basin. Significant influence on the development of the North Caspian Basin was also exerted by submeridional oriented ancient rift systems (Ural, Mezen-Caspian, etc.).

In the work (*Murzagaliev, 1998*), collisional, subduction, inversion, nappe-thrust, retrothrust and riftogenic structures were identified according to the most characteristic features of geophysical fields within the Caspian megadepression.

The South Emba paleorift, located within the North Caspian of the East European Precambrian platform, was formed in the Riphean-Vendian (Fig. 1). Morphologically limited by deep faults of the spall type. The roof of the Precambrian basement is lowered along the faults to a depth of 12–13 km. The early Hercynian stage of tectogenesis led to the opening of the rift and the accumulation of Devonian-Carboniferous deposits 7–10 km thick. In the Early Permian, as a result of the collision and collision of the East European and West Turanian mesoplates, the rift zone was formed into an inversion uplift. On the surface of Mohorovichich at a depth of 34–36 km, the North Caspian uplift is distinguished, which does not exclude the intrusion of a mantle diapir along weakened zones. The heat flux density values are 58 mW/m^2. The thickness of the earth's crust is reduced to 10–16 km.

In the evolutionary aspect, based on the accepted geodynamic model of the development of the North Caspian region in the Late Paleozoic (*Brazhnikov et al., 1987*), when a closed sub-basin existed here, it can be attributed according to the classification (*Kucheruk et al., 1983*) to subduction back-arc (or inter-arc) sedimentary basins, and since the Upper Permian-Triassic, when there was already a single Caspian basin, it should be classified as an intracontinental megabasin or a pericontinental-oceanic type of sedimentary basin. According to the classification (*Sokolov, 1985*), in the evolutionary and tectonic aspect, the Caspian depression, including its water area, in the final stage of its development, it most fully corresponds to the superimposed syneclise type of marginal platform basins. Since the basin floor contains traces of ancient rifts and rift-like structures, and its southern framing is represented by the Pripyat-North-Caspian suture zone, from geodynamic positions, it can be considered in accordance with the classification of Bally A.U. (*Kucheruk et al., 1983*) as a pericratonic basin on earlier rift systems, which were subsequently partially regenerated or rebuilt. (*Zonenshain et al., 1985*) believe that the Caspian Basin, in general, can be interpreted as a residual oceanic basin of pre-Devonian age, of the same type as the modern Gulf of Mexico. Its bed in the central part of the basin was swallowed up in deep-sea trenches and turned out to be buried under a layer of sediments.

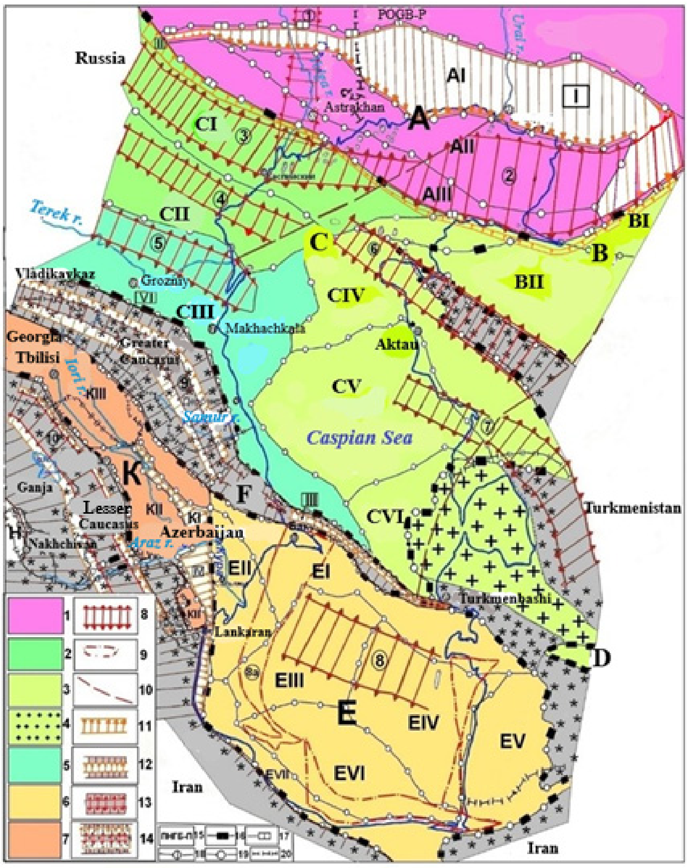

Fig. 1. Combined maps of geodynamic evolution, systemic oil and gas geological zoning of the Caspian megadepression and adjacent regions

Legend: 1 – Southern part of the East European Platform (basement age – Archean-Proterozoic; 2 – Southeastern part of the Scythian Plate (basement age – Paleozoic); 3 – Northwestern part of the Turan Plate (basement age – Paleozoic); 4 – Arch of the Turan plate; 5 – Advanced (piedmont) trough of the Scythian-Turan plate; 6 – South Caspian Plate (basement age – Upper Paleozoic – Lower Mesozoic); 7 – Lesser Caucasian (Transcaucasian) plate (basement age – Middle Paleozoic – Triassic); 8 – Paleorift (spreading) zones (numbers in circles) (1 – Mezen-Caspian; 2 – South Embian; 3 – ridge Karpinsky; 4 – Eastern-Manych; 5 – Tersko-Caspian; 6 – Central Mangyshlak; 7 – Tuarkyr-Karaaudinsk; 8-South Caspian); 9 – proposed Cenozoic-modern rift zone: 8a – South Caspian; 10 – Transform faults; 11 – Paleosubduction (island-arc) zones (Roman numerals in rectangles) (I – Biikzhal – North Astrakhan; II – Karpinsky ridge – North-Buzachinskaya; III – North Absheron; IV – Pre-Talysh – Mingachevir; V – Lesser Caucasian; VI – Greater Caucasus); 12 – zones past the geodynamic stages of subduction and collision; 13 – zones past the geodynamic stages of spreading and collision; 14 – zones past the geodynamic stages of spreading, subduction, collision and orogeny, with intense folding and metamorphism of the sedimentary cover; 15 – Pre-Caspian oil and gas basin-province (POGB-P); 16 – boundaries of oil and gas basins – provinces (NGB-P); 17 – boundaries of oil and gas bearing sub-provinces (OGSP); 18 – boundaries of oil and gas bearing independent regions (OGIR); 19 – boundaries of oil and gas bearing regions (OGR); 20 – state borders.

Systematic oil and gas geological zoning of the Caspian megadepression and adjacent regions (the largest parts of the zoning system are given): **A** – the southern marginal part of the Caspian megasyneclise, the North Caspian OGSP: AI – the eastern part of the buried Biikzhal-North Astrakhan island-arc system – the Emba OGR, AII – the Zavolzhsk-Tugarakchan depression region (Astrakhan-Primorsk OGR), AIII – the transitional cover-thrust area (Karakul-Zheltauz NGR); **B – Aral-Ustyurt syneclise (NGB-P):** BI – Mynsualmas gas-bearing region (GR), BII – Ustyurt oil and gas region (OGR); **C – Scythian-Turanian epihercynian plate and its advanced (piedmont) troughs (North Caucasian-Mangyshlakskaya NGB-P):** CI – Karpinsky ridge (South Kalmyk OGR), CII – East Pre-Caucasian tectonic region (East Pre-Caucasian OGR), CIII – Terek-Caspian advanced (piedmont) trough (Tersko-Caspian oil and gas basin), CIV – Mangyshlak OGR, CV – Central-Middle Caspian OGR, CVI – West- Karabogaz POGR; **D** – **Amudarya NGB-P; F – Axial zone SE of the subsidence of the meganticlinorium of the Greater Caucasus (independent Dibrar oil and gas region – IOGR); E – South Caspian megadepression (South Caspian OGB-P):** EI – northwestern side and side tectonic regions of the South Caspian depression – Gobystan-Absheron OGR, EII – Southwestern side and side tectonic areas of the South Caucasus (Lower-Kura-Enzeli OGR), EIII – South Caspian deep-sea basin (Central-South-Caspian POGR), EIV – Turkmen tectonic step (POGR of the Turkmen step), EV – West Turkmen OGR, EVI – Pre-Elburs trough (Pre-Elburs POGR), EVII – Mazandaran POGR; **K – Middle Kura-Kartli depression – South-East part of the Transcaucasian intermountain trough (Middle Kura-Kartli OGSP of the Transcaucasian OGB-P):** KI – Axial zone of the Pre-Talysh-Mingachaur buried island-arc system (cid-Talysh-Mingachaur unpromising region), KII – Yevlakh-Agdzhabedi trough (Yevlakh-Agdzhabedi OGR), KIII – Iori – Adzhinour trough (Iori-Adzhinour OGR); **H – Nakhichevan superimposed trough (Nakhichevan PNGSR)**

In the Late Devonian-Early Carboniferous, due to the expansion of transgression for most of the pericontinental margin, the carbonate type of sedimentation becomes predominant with the formation of shallow-marine layered carbonate, terrigenous-carbonate and basin formations confined to the inner regions of the North Caspian sub-basin.

The carbonate stage of Carboniferous sedimentation was most clearly manifested in the Late Visean-Early Bashkirian period, causing the formation of a carbonate shallow-water layered formation in a significant part of the margin of the North Caspian sub-basin. This stage is characterized by a rather clear expression of the carbonate shelf with the development of a reef subformation on its edge (*Khalilov et al., 1991).*

Within the southern part of the Northern Caspian, already on the Scythian plate, the initiation of the **Karpinsky ridge rift** is associated with the Riphean stage. According to the basement, the rift structure consists of blocks of different sizes, stepwise submerging up to 13–15 km. In the water area of the Northern Caspian, an intense positive anomaly is shifting to the north, which reflects the horizontal shift of the rift along the transform slip sutures. The intrusion of small massifs and dikes of alkaline ultramafic rocks was found in the Devonian deposits, which indicates the regeneration of the rift and extension of its bed along listric faults that served as magma conduits. The late Hercynian stage of tectogenesis is marked by the collision of the Scythian microcontinent with the passive margin of the Pre-Caspian continent. The further complication of geodynamic conditions led to the formation of zones of cover-thrust dislocations of the Karpinsky Ridge, under which the Paleozoic platform deposits of the Pre-Caspian Basin were buried.

Within the middle part of the Caspian depression at the turn of the late and early Mesozoic within the Scythian plate, weak extension continued, which did not reach the complete rupture of the earth's crust. Further evolution of rifting led to the formation of the East Manych and Terek-Caspian rifts (Fig. 1).

The rift zone is filled with terrigenous-carbonate and volcanogenic sediments of the Permian-Triassic, overlain with an angular unconformity by the Jurassic-Anthropogenic complex of the sedimentary cover.

The East Manych rift is about 150 km long and 60 km wide in the east. The foundation structure is expressed as a block structure with elements of thrust dislocations. The East Manych rift within the water area, apparently, is reduced, which is associated with the influence of transverse slip zones. In the rift area, the thickness of the earth's crust is about 32 km. The temperature on the Mohorovichic surface is 650°C, and the heat flux density is estimated at 55–60 mW/m^2.

The Terek-Caspian rift arose in the junction zone of the Scythian plate with the region of the Alpine folded structure of the Caucasus. The basement, lying at a depth of 12 km, is composed of dislocated and metamorphosed volcanic strata intruded by magmatic intrusions. Sedimentary complexes are filled with Jurassic-Anthropogenic deposits. In the Neogene-Quaternary, due to tangential compression in the Alpine belt, the Terek-Caspian rift experienced an inversion, which led to the formation of rootless folds of the Terek-Sunzhensky anticlinorium and the East Caucasian thrust belt. The eastern branch of the thrust belt is the Dagestan wedge, characterized by the development of thrusts and retrothrusts at different stratigraphic levels (*Makarova and Sukhanova, 2017*).

In the structure of the base of the earth's crust, the rift is reflected by a large mantle uplift revealed at a depth of about 45 km, and in the structure of the sedimentary cover, by elements of the inversion-slip type. The thickness of the earth's crust is 32–35 km. The temperature at the base of the crust is about 600 °C. The heat flux density is relatively low (35–50 mW/m^2), which is due to the underthrusting of the Greater Caucasus continental crust under the Scythian plate.

In the geodynamic aspect, in the west of the Turan Epipaleozoic Plate, the formation of the continental crust ended in the pre-Riphean time (*Milanovsky, 1987*). In the Riphean-Vendian, tectonomagmatic activation of the asthenosphere and upper mantle occurred with the manifestation of scattered rifting. According to modern mobilistic views, the Central Mangyshlak and Tuarkyr-Karaaudan rift systems were localized in the Early Paleozoic. The rift regime (Carboniferous-Permian) was associated with tectonic thinning and partial disintegration of the continental crust. The thickness of the granite layer within the rift zone is reduced to 9–10 km, while in the adjacent areas it is 15–18 km (*Dimakov, 1973*).

In the Late Permian and Early Triassic, the Earth's crust experienced slight extension, and flyschoid formations accumulated in rift zones. In the early Cimmerian epoch of tectogenesis, the microcontinents of Iran and Western Turan collided. The tangential compression force caused the formation of an inversion uplift in the zone of the Central Mangyshlak paleorift, which, having experienced collision and inversion, was transformed into an underdeveloped paleorift. This process completed the complete consolidation of the folded basement of the West Turan Plate, followed by the post-rift development regime.

The South Caspian rift in the area of Alpine folding was formed due to Mesozoic-Eocene divergence, Oligocene-Early Pliocene collision and Lower Pliocene-Anthropogenic isostasy of small plates. Mesozoic-Eocene extension, caused by the destruction of the crust due to the rise of the mantle diapir, caused thinning, rupture of the granite-metamorphic layer and intrusion of the substance of the basalt layer and mantle.

Mesozoic rifting is confirmed by the results of quantitative calculations of the depths of the upper edges of magnetically active bodies (*Murzagaliev, 1998*). In the Oligocene-Early Pliocene time of the collision of the Arabian ledge with the Lesser Caucasus plate, general compression begins. As a result of these processes in the Oligocene and Neogene there was a complete overlap of the South Caspian basin. Horizontal forces were transformed into vertical movements, as a result of which mountain structures were formed on the site of the Greater Caucasus and the South Caspian depression ceased to exist as an interarc basin and turned into an intermountain molasse trough (*Zonenshain et al., 1990; Milanovsky, 1983, 1987*).

In the Lower Pliocene-Anthropogenic time of isostasy, the expansion of the depression intensified. The region of the greatest thickness of sedimentary deposits (up to 25 km) coincides with the high position of the Mohorovichich surface. Of these, about 10–12 km falls on the Pliocene-Quaternary.

In the late Alpine stage, the development of the rift took place already against the background of submeridional compression, which led to the development of linear folds and reverse thrust formation at the boundary of interacting plates. This is the Apsheron-Pre-Balkhan tectonic zone with a series of local uplifts complicated by overthrusts.

The surface of Mohorovichich, framed by a rift, lies at a depth of 40–45 km, and in the center 30–32 km, outlining a large mantle uplift. The surface of the asthenosphere on the MTS materials is expressed as a highly conductive layer, the depth of which under the rift is 40–50 km, and along the periphery it plunges to 100–120 km. The heat flux density is relatively increased – 60–70 mW/m^2.

According to (*Glumov et al., 2004*), from the point of view of modern geodynamics, the South Caspian rift system is possibly associated with the West Caspian system, forming together with it a "multi-beam" (in plan) complex of structures of the secondary (latent) rifting occurring in the late Cenozoic at the level of the consolidated crust below the sedimentary cover. The development of this process here is evidenced by the zones of deep subsidence of the basement, which in some basins lies at depths of 20–24 km or more, significant thicknesses (5–8 km) of Neogene-Quaternary deposits, the presence of "hot" spots along these zones, increased rates of modern subsidence of the marine bottom and, in some places, adjacent land areas.

The secondary nature of the process is determined by the fact that it occurs against the background of the prevailing transverse compression and orogeny of the Alpine region. The emergence of sliding structures in this case is due not so much to deep subcrustal processes as to a complex wedging effect on the earth's crust of the South Caspian from the Iranian blocks of Deshte-Kevir and Lut and vertical compression, and, consequently, horizontal stretching, of the earth's crust of the era region between a thick sedimentary cover from above and elevated to a depth of 28–25 km by the upper mantle – from below.

On the other hand, the South Caspian system itself, apparently, is a segment of an older Mesozoic-Eocene sublatitudinal intercontinental rift belt, which in the west also included the rift zones of Transcaucasia, the southern and eastern parts of the Black Sea (*Murzagaliev, 1997*).

Based on the foregoing, the united "South-West-Caspian" system, in fact, should be considered as an inherited – superimposed formation, which includes in its structure both the latest sub-meridional expansions and partially regenerated fragments of sub-latitudinal rifts.

Thus, in terms of their geological and geophysical nature, the considered rifts are the results of intracontinental rifting.

The rift stage in the Caspian region proceeded asynchronously. The stages of evolution migrated in time and space: from the Riphean-Vendian on the East European platform to the early Mesozoic on the Scythian plate.

In the process of geodynamic evolution of the region, two large subduction zones were formed: the North – Absheron and the Karpinsky Ridge – North Buzachi. The subduction of the South Caspian Plate beneath the Scythian-Turanian Plate was studied and confirmed by (*Khalilov et al., 1987*) based on complex interpretation of DSS data and earthquake hypocenter depths projected onto the profile line.

According to (*Akhmedbeyli et al., 2002; Bayramov et al., 1998; Ismail-zade, 2005, 2017; Kangerli, 1999*) for the adjacent territory of the Republic of Azerbaijan located in the southwestern part of the region under study, the geodynamic history of development can only be reconstructed from the Late Paleozoic.

The absence of Precambrian-Lower Paleozoic deposits of the epicontinental shelf in the geological section in this territory indicates that it entered the Caucasian-Caspian shield of the Gondwana megacontinent in the Early Paleozoic. Throughout the entire Hercynian stage, the zones of the South Caucasus and the South Azerbaijan segment of the Central Iranian microplate were geostructures of the passive continental margin of Gondwana with independent development regimes, separated by an emerging rift zone, which later became the Lesser Caucasian branch of the Mesotethys Ocean.

At the end of the Hercynian cycle of tectogenesis (Carboniferous-Early Triassic), the South Azerbaijan segment represented the Atlantic-type passive continental margin of Gondwana, where terrigenous-carbonate strata, sterile in relation to magmatism, accumulated.

At the Alpine stage of the formation of the territory under consideration, according to the data (*Moshashvili, 1982*), three stages are distinguished: oceanic, transitional and continental (neotectonic).

Oceanic stage (Leyas-Aalen). The initial stage of Alpine tectogenesis (the boundary of the Triassic and Jurassic) was marked by intense extension.

During the Lias-Aalen, as a result of the pulling apart of the North and South Caucasian microplates, an extensive sedimentary basin of the marginal sea type with an axial rift basin with a suboceanic crust was formed in the place of the Greater Caucasus, where outpourings of calc-alkaline basalt-andesite-dacite-rhyolitic magmas, series and the introduction of small intrusions of gabbro-diorite composition occurred.

Transitional stage (Late Aalen-Oligocene). The transitional stage in the Caucasus is divided into two epochs: the pre-collision epoch of the origin and development of island arcs, which lasted until the middle Cretaceous, and the collisional epoch of the closure of ocean basins and the collision of continental plates.

Along the southern boundary of the South Caucasian microplate, shearing occurred along the junction of the continental and oceanic crust, and a mode of convergent interaction of this plate with the oceanic lithosphere subducting under it was formed, which persisted for 90 Ma until the Early Senonian. According to (*Moshashvili, 1982*), the Saatly-Kurdamir island-arc system of uplifts was formed within the middle part of the Kura depression in the Early Jurassic – Senonian.

The Bayos-Bathian period of compression is characterized by a significant restructuring of the structural plan. The central and southern parts of the South Caucasian microplate, covered in the Baiosian-Bathonian period by a shallow sea, became the scene of powerful calc-alkaline island-arc volcanism of basalt-rhyolitic (Bajocian) and basalt-andesite-dacite-rhyolitic (Bathonian) series. The Lesser Caucasian oceanic basin continued to expand during this period.

The paleotectonic setting in the eastern part of the South Caucasian microplate (region of the South Caspian) during this period was characterized by the presence in its central part of a large uplift – a denudation area, bordered in the north and south by deep-sea troughs. The northern and southern shallow waters were separated by bands of barrier reefs from the deep-water basin, which was reborn into a flysch sedimentation basin with the intrusion of small gabbro and plagiogranite intrusions.

Reef limestones also developed along the southern edge of the South Caucasian microplate in the Late Jurassic, and subduction calc-alkaline volcanism continued in a weak form (similar in composition to basalt-andesite-dacitic volcanism in the central part of the microplate), the maximum of which occurred in the Kimmeridgian time.

The subduction process was accompanied in the Early Cretaceous by andesite-basalt magmatism in the front and the intrusion of numerous granitoid intrusions of gabbro-tonalite and gabbro-granite series in the rear of the Jurassic volcanic arc of the Lesser Caucasus under conditions of carbonate sedimentation.

The next structural restructuring – the Austrian phase of tectogenesis falls on the boundary of the Early-Late Cretaceous, when the first signs of general compression that appeared marked the beginning of the collision epoch.

Island-arc volcanism continued on the territory of the South Caucasian microplate in the Albian-Cenomanian and Early Nenonian times.

In the rear of the northeastern volcanic belt (Talysh), at the end of the Cretaceous-beginning of the Paleogene, the formation of the marginal basin of the South Caspian continued.

As a result of late Eocene-Oligocene diastrophism (Pyrenean phase) with inversion of geodynamic conditions, the main structures of the Lesser Caucasus were created.

The transition from the Cretaceous to the Paleogene is marked by the shallowing of the Greater Caucasus basin, and in the subsequent segment of the transitional stage of development, weak and moderate downward movements occurred.

Continental stage (late Miocene-Quaternary). Since the Late Miocene, the region enters a new stage of development – neotectonic, when modern geological structures and relief are formed, megastructures of the Greater and Lesser Caucasus, the Kura and Caspian depressions are isolated.

In the Lesser Caucasus, mountain building was accompanied by active terrestrial volcanism and the formation of volcano-plutonic complexes in the Miocene-Early Pliocene and Late Pliocene-Quaternary.

Simultaneously with the formation of the orogens of the Greater and Lesser Caucasus and Talysh, the depression zones, the Kura and South Caspian, subsided.

Conclusions. Based on all the above data on the geodynamic evolution of the earth's crust within the Caspian megadepression and the adjacent territory of Azerbaijan, a combined map of the geodynamic evolution of the above territory was compiled, which shows paleoriftogenic zones, subduction zones, collisions and orogeny, as well as large links of the optimal system of oil and gas geological zoning developed by the authors of this work.

The obtained results of the above studies make it possible to recommend the obligatory use of the analysis of geodynamic evolutions of the earth's crust as an important criterion in assessing the prospects for the oil and gas potential of large complex regions.

References

Ahmedbeyli, F.S., Ismail-zade, A.D., Kengerli, T.N. (2002). Geodynamics of the Eastern Caucasus in the Alpine tectonic-magmatic cycle (Azerbaijan). *Proceedings of the Institute of Geology of the National Academy of Sciences of Azerbaijan*, 30, 36–48. [in Russian]

Alieva, S.A. (2016). Features of the geodynamic evolution of the Caspian megadepression and adjacent territories in connection with the assessment of the prospects for oil and gas. In: The fundamental basis of innovative technologies for prospecting, exploration and development of oil and gas fields and priority areas for the development of the resource base of the Russian fuel and energy complex, pp. 5–9. [in Russian]

Averbukh, B.M., Alieva, S.A. (2006). Industrial oil and gas potential of the North Caspian shelf. *Geology of oil and gas*, (1), 18–24. [in Russian]

Averbukh, B.M., Alieva, S.A. (2013). Systemic oil and gas geological zoning of the Caspian megadepression and adjacent territories. In Bakirov eds. pp. 13–14. [in Russian]

Averbukh, B.M., Babaev, R.Ya. (1980). Prospects for prospecting for deposits of the lithological-stratigraphic type in the junction zone of the Kurdamiro-Saatly buried ledge and the Nizhnekurinsky depression. *Azerbaijan Oil Industry*, 1, 23–28. [in Russian]

Bayramov, A.A., Baba-zade, V M., Akhundov, R.A. (1998). Geodynamic features of the placement of mineral deposits in the Azerbaijan Republic and the adjacent water areas of the Caspian Sea. *Vestnik Bakin. un-ta, a series of natural sciences*, 1, 86–95. [in Russian]

Brazhnikov, O.G., Mikhalkova, V.N. (1987). Geodynamics and oil and gas potential of the Caspian basin. Oil and gas potential of the Caspian depression and adjacent areas. Moscow: Nauka, 141–147. [in Russian]

Feizullaev, A.A., Kadirov, F.A., Kadirov, A.G. (2016). Tectonic-geophysical model of the South Caspian in connection with oil and gas potential. *Physics of the Earth*, 6, 129–138. [in Russian]

Gavrilov, V.P. (1988). Geodynamic model of oil and gas formation in the lithosphere. *Geology of oil and gas*, 10, 1–8. [in Russian].

Glumov, I.F., Malovitsky, Ya.P., Novikov, A.A., Senin, B.V. (2004). Regional geology and oil and gas potential of the Caspian Sea. [in Russian]

Guliev, I.S., Alieva, S.A., Kerimov, V.Yu., Mustaev, R.N. (2020). Hydrocarbon systems and prospects for prospecting for oil and gas accumulations in the North and Middle Caspian. *Mining Journal*, 8, 62–67. [in Russian]

Guliev, I.S., Fedorov, D.L., Kulakov, S.I. (2009). Oil and gas potential of the Caspian region. "Nafta-Press". [in Russian]

Ishutin, V.V. (1988). Mezen-Caspian rift system and its structural position in the eastern part of the Russian plate. *Geotectonics,* 5, 34–46. [in Russian]

Ismail-zade, A.D. (2005). Geology of Azerbaijan. Vol. IV. Tectonics. [in Russian]

Ismail-Zadeh, A.D. (2017). A new look at the formation of the South Caspian oil and gas basin in the aspect: mantle diapirism-transformation of endogenous hydrocarbon fluid. *Quality management in the oil and gas industry*, 1, 54–58. [in Russian]

Kangerli, T.N. (1999). Features of the geodynamic development of the Greater Caucasus in the Alpine tectonic-magmatic cycle (on the example of Azerbaijan). *Abstracts of the International Conf. Geodynamics of the Black Sea-Caspian segment of the Alpine fold belt and prospects for prospecting for minerals*, Baku: Nafta-Press, 98–99. [in Russian]

Kerimov, I.A. (2021). Gravity anomalies, fault tectonics and seismicity of the Terek-Caspian trough. *Geology and Geophysics of the South of Russia*, 11(4), 30–42. [in Russian]

Kerimov, I.A., Gaisumov, M.Ya. (2014). Modern geodynamics and seismicity of the Terek-Caspian trough. *Geology and geophysics of the South of Russia*, 3, 71–84. [in Russian]

Kerimov, V.Yu., Rachinsky, M.Z. (2016). Geofluid dynamic concept of hydrocarbon accumulation in natural reservoirs. *Reports of the Academy of Sciences*, 2(471), 187-190. Federal State Budgetary Institution "Russian Academy of Sciences". [in Russian]

Khalilov, E.A., Averbukh, B.M., Mamedova, V.A., Huseynov, G.M. (1991). Geodynamic and paleogeographic conditions for the formation of regional and gas-bearing formations of the Paleozoic of the Northern Caspian. Geological and geochemical studies in the search, exploration and development of hydrocarbon deposits. Baku: *Thematic collection of scientific works of AzIU.* [in Russian]

Khaustov, V.V. (2011). Features of the fluid-dynamic system of the South Caspian depression. *Proceedings of the Southwestern State University*, 1, 150a–158. [in Russian]

Kucheruk, E.V., Alieva, E.R. (1983). Evolutionary classification of sedimentary basins from the standpoint of plate tectonics is the basis for assessing their oil and gas potential. *The collection of VIEMS: "Geological methods of prospecting and exploration of oil and gas fields"*, Moscow, 4. [in Russian]

Kucheruk, E.V., Alieva, E.R. (1983). The current state of the classification of sedimentary oil and gas basins. Overview information. Oil and gas geology and geophysics. Moscow: VNIIOENG, 88. [in Russian]

Kucheruk, E.V., Ushakov, S.A. (1985). Plate tectonics and oil and gas potential. Itogi nauki i tekhniki. Physics of the Earth. Vol. 8. [in Russian]

Makarova, N.V., Sukhanova, T.V. (2017). Actual problems of studying the latest platform structures (on the example of the East European Platform and the adjacent part of the Scythian Plate). *Bulletin of Moscow University. Series 4. Geology*, 3, 17–26. [in Russian]

Maksimov, S.P., Goncharenko, B.D., Dickenstein, G.Kh. (1987) Regime of tectonic development and oil and gas potential (on the example of the Pripyat-North-Caspian lineament). *Geology of oil and gas*, 12. [in Russian]

Mamedov, P.Z. (2009). Tectonotypes of the paleobasins of the Caucasus-Caspian region and the main stages of the evolutionary development of the South Caspian megabasin. ANAN, Baku, 134–147. [in Russian]

Milanovsky, E. E. (1987). Rifting in the history of the Earth: Rifting in mobile belts. Bosom. [in Russian]

Milanovsky, E.E. (1983). Rifting in the history of the Earth: Rifting on ancient platforms. Bosom. [in Russian]

Moshashvili, A.B. (1982). Evolution of the Earth's crust in the Kura depression and its connection with the Paleo-Tethys problem. Problems of geodynamics of the Caucasus. Moscow: Nedra, 64–71. [in Russian]

Murzagaliev, D.M. (1998). Geodynamics of the Caspian region and its reflection in geophysical fields. *Geology of oil and gas*, 2, 10–15. [in Russian]

Murzagaliev, D.M. (2011). Seismological and geodynamic conditions for the development of oil and gas fields on the shelf of the Northern Caspian. *Geology, Geography and Global Energy*, 4, 32–38. [in Russian]

Narimanov, N.R. (2003). Geodynamic aspects of the formation of the sedimentary cover of the South Caspian Basin. *Geology of oil and gas*, 6, 26–31. [in Russian]

Shein, V.S. (2007). Geodynamic analysis of oil and gas bearing territories and water areas in connection with the search for oil and gas fields. *Geology of Oil and Gas*, 2, 70–80. [in Russian]

Sokolov, B.A. (1985). Evolutionary-dynamic criteria for assessing the oil and gas potential of the subsoil. Bosom. [in Russian]

Sorokhtin, O.G. (1984). The theory of lithospheric plate tectonics is a modern geological theory. M.: o-in "Knowledge" of the RSFSR. [in Russian]

Sorokhtin, O.G., Ushakov, S.A. (2002). Earth development. [in Russian]
Tulegenova, G., Seitov, N.S. (2016). Tectonic zoning and geodynamic conditions for the formation of structures in the North Caspian oil and gas region. Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. *Geology and Engineering Science Series*, 2, 5–16. [in Russian]
Zonenshain, L.P., Korinevsky, V.G., Kazmin, V.G., Sorokhtin, O.G., Koroteev, V.A., Maslov, V.A., ... & Kabanova, L.I. (1984). Structure and development of the Southern Urals from the point of view of lithospheric plate tectonics. In: History of the development of the Ural paleoocean, pp. 8–56. [in Russian]
Zonenshain, L.P., Kuzmin, M.I., Natapov, L.M. (1985). Tectonics of lithospheric plates in the territory of the USSR. Vol. II. [in Russian]
Zonenshin, L.P. et al. (1990). Tectonics of lithospheric plates in the territory of the USSR. Book 1. Subsoil. [in Russian]

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ГЕОДИНАМІЧНА ЕВОЛЮЦІЯ КАСПІЙСЬКОЇ МЕГАЗАПАДИНИ І СУМІЖНИХ ТЕРИТОРІЙ

Завданням цього дослідження є встановлення зв'язків між особливостями геодинамічної еволюції складнопобудованої, гетерогенної за своєю геологічною будовою, Каспійської мегазападини та суміжних з нею регіонів – з можливостями оцінки перспектив нафтогазоносності всієї цієї території. З цією метою було проаналізовано дані опублікованих робіт з геодинамічної еволюції вищевказаної території та на основі цього аналізу складено зведену карту геодинамічної еволюції Каспійської мегазападини та суміжних регіонів, поєднану з оптимальним системним нафтогазогеологічним районуванням цієї території, раніше розробленим авторами цієї роботи. Проведений аналіз ресурсів нафти і газу по окремих великих ланках оптимальної системи районування з особливостями їхньої геодинамічної еволюції показав, що на дослідженій території в основному існує пряма залежність кількості та щільності вуглеводневих ресурсів від кількості стадій геодинамічної еволюції земної кори, що пройшли тут, а також наявності або відсутності зон палеоспредингу (рифтів) та зон палеосубдукції (острівних дуг).

Ключові слова: Каспійська мегазападина, Азербайджан, геодинаміка, складно побудовані регіони, оптимальне системне нафтогазогеологічне районування, ресурси ПВ, перспективи нафтогазоносності, органічна речовина, розсіяна органічна речовина.