ГЕОЛОГІЯ НАФТИ І ГАЗУ

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GEODYNAMIC AND PALEOTECTONIC ANALYSIS OF THE SOUTH CASPIAN MEGADEPRESSION IN CONNECTION WITH OIL AND GAS PROSPECTS (USING THE EXAMPLE OF THE YEVLAKH-AGJABEDI DEPRESSION)

(Представлено членом редакційної колегії д-ром геол. наук, проф. Володимиром МИХАЙЛОВИМ)

Background. ***When assessing the prospects for oil and gas potential, the most important task is to determine the genetic affiliation of the sedimentary basin, i. e. type of geodynamic regime. In this regard, this article devoted to the geodynamic evolution of the Caspian Basin is relevant. The work analyzed data from published works on the geodynamic evolution of the above-mentioned territory.***

From the standpoint of global plate tectonics, high oil and gas potential is associated primarily with continental margins, paleorift basins, zones of intermontane and foredeeps formed during the final stage of plate collision, as well as with thrust margins of folded mountain structures.

The determining factor in oil and gas formation is, first of all, the geodynamic regime of the subsoil, and therefore, when assessing the prospects for oil and gas content, the primary task is to determine the genetic affiliation of the sedimentary basin, i. e. type of geodynamic regime. When determining the genotype of a sedimentary basin, an extremely important parameter is the type of consolidated crust, which is associated not only with the amplitude of tectonic subsidence and, consequently, the rate of sedimentation, the thickness of the sedimentary cover, but also the magnitude of the heat flow, which determines the conditions of oil and gas formation.

Results. ***As a result of the analysis of the main criteria of oil and gas potential, we associate the greatest prospects with the NE side part of the Yevlakh-Agjabedi depression region and its north-eastern section of the SE centricolinal closure, where the articulation of the said depression with the slopes of the Geokchay-Mingachevir, Saatly-Kurdamir and Bilasuvar-Karadonly Mesozoic protrusions occurs. The probable zone of oil and gas formation, which served as a source of hydrocarbon fluids for the regional oil accumulation zone under consideration, was the central part of the Yevlakh-Agjabedi trough, where, during most of the Mesozoic-Cenozoic history, there was a steady subsidence and accumulation of a thick layer of Eocene deposits, from where oil migrated into lithological-stratigraphic traps, confined to the zone of unconformable adjacency of Eocene terrigenous-carbonate reservoirs to the eroded surface of Upper Cretaceous effusive formations.***

Conclusions. ***The formation of lithological oil deposits in zones of increased fracturing of the regolith surface of the Upper Cretaceous effusive rocks – in the crest of the uplift – occurred as a result of lateral migration and partial flow of oil from the Eocene reservoirs of the south-west wing and south-east pericline – along weathering zones and cracks.***

Keywords: ***South Caspian Plate, lithospheric plate, geodynamic regime, East European Plate, sedimentary basin, hydrocarbon potential, Yevlakh-Agjabedi region, Muradkhanli oil and gas accumulation zone, non-structural traps, reservoirs, seals.***

Background

The formation and development of sedimentary basins is an integral part of the overall global evolution of the lithosphere. Only within the framework of the global evolution of the lithosphere can one understand the conditions for the emergence and the nature of further transformations of a sedimentary basin at various stages of geological history, the result of which is a modern oil and gas sedimentary basin. Each stage of the evolution of the lithosphere corresponds to very specific tectonic types of sedimentary basins, the formation of which is determined by the prevailing geotectonic (extension, compression, "passive" subsidence) and thermal regimes at this stage. This, in turn, determines the geological parameters characteristic of this type of basin – type of crust, rates of subsidence and sedimentation, lithological-facies character and thickness of sedimentary infill, geothermal gradients, nature of deformations and types of traps, conditions of accumulation, burial and transformation of organic matter (OM), types of oil and gas source rocks, reservoirs and seals, scale of generation and migration routes of hydrocarbons, location and nature of regional oil and gas accumulation zones.

Most existing sedimentary oil and gas basins have gone through several stages of development. Usually, during the transition from one stage to another, a new one appears in place of the previous sedimentary basin – of a different tectonic type, with its own structural features, thermobaric conditions, etc. Vertical superposition and (or) lateral conjugation of sedimentary basins (or parts thereof), corresponding to successive stages of evolution, lead to the formation of the resulting sedimentary basin with a much more complex geological structure. In the context of such basins, relics of various previous stages form independent structural floors. In addition, they can participate in the structure of the foundation of the basin or in its framing.

Basins with the most complex structure and long evolution turn out to be the most highly productive in terms of hydrocarbons.

Each stage contributes to the total hydrocarbon potential of the resulting basin. It is obvious that the last stage of evolution has a decisive influence on the structure and features of the placement of hydrocarbons in any modern sedimentary basin. However, in the lower structural levels corresponding to the basins (or parts thereof) of previous stages, the oil and gas conditions characteristic of this type of sedimentary rock basin can be largely preserved.

The basis for the geodynamic interpretation of sedimentary basins can be the mobilist concept of lithospheric plate tectonics. Based on this concept, (Kucheruk, & Alieva, 1983; Shikhlinskii, Kheirov, & Mustafayev, 1990; Shykhlinskiy, Kocharli, & Gadzhiev,

1990) proposed a general scheme for the formation of the main types of sedimentary basins in a natural connection with certain stages of the evolution of the lithosphere.

In the proposed classification of sedimentary basins by tectonotypes from the position of mobilism, the Caspian Basin is classified as a group of internal seas that formed after the closure of marginal seas and the collision of lithospheric plates of the continent-arc type. For internal (formerly marginal) seas with their centriclinal intermontane depressions, the entire diversity of tectonic types of sedimentary basins can be represented as a single evolutionary series. It is based on the geotectonic cycle of the evolution of the lithosphere, which begins with the split of the continent, the opening of a marginal sea with oceanic crust, and the formation of its continental and island-arc margins and ending with plate collision and orogenesis in the process of compression, convergence and collision of plates and the formation of an intermountain basin with a residual deep-water basin.

Results

For a detailed study of the deep structure and evolution of the Caspian basin and a correct assessment of the oil and gas potential of its sedimentary strata, identifying favorable zones for the formation of traps (structural and non-structural) for hydrocarbons, it is necessary to find out not only its modern structure, but also its entire geological prehistory, i. e. identify the geodynamic regime and stages of formation of various paleotypes of basins with their characteristic sedimentary complexes, oil and gas accumulation zones and traps.

The Caspian basin, which finds itself at the center of the convergence of several plates with different kinematic parameters, is a heterogeneous structure of a very complex deep structure, where the junction of continental structures of different ages occurs: East European Precambrian platform, Scythian and Turanian epi-Paleozoic plates and Alpine folded structures in the south.

Three large geoblocks are distinguished within the contours of the Caspian Sea: the North Caspian, the Middle Caspian (a small fragment of the North Ustyurt geoblock is also considered in its composition) and the South Caspian. From the standpoint of the modern plate tectonic model, the presence of East European, Scythian, West Turanian, Lesser Caucasus, South Caspian and Iranian lithospheric mesoplates is recognized (Fig. 1, 2).

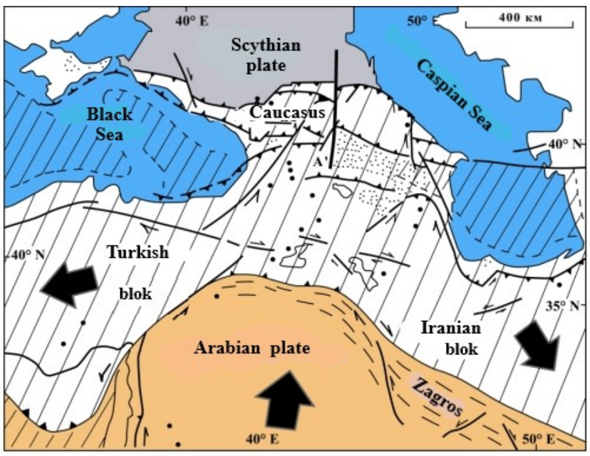

Fig. 1. Scheme of tectonics of plate movement in the Black Sea-Caspian region and Transcaucasia (according to Sobornov, 1995)

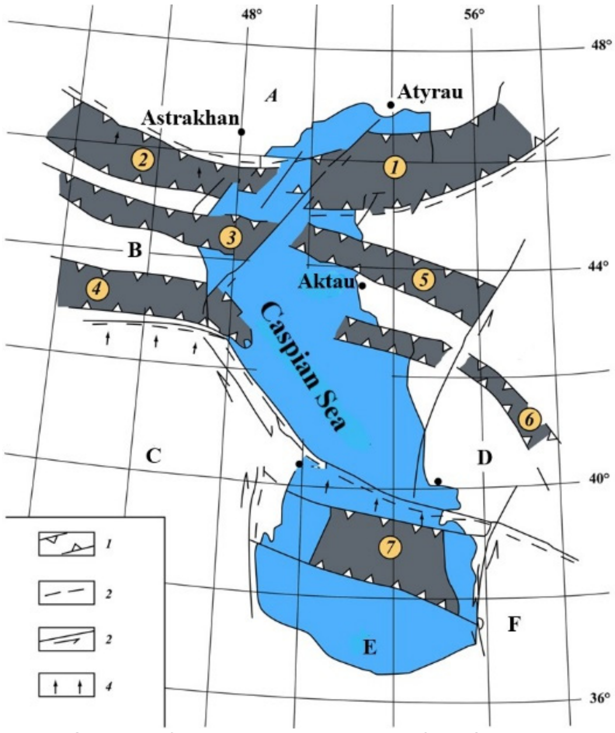

Fig. 2. Scheme of geodynamic structures of the Caspian region:
a – paleorifts (numbers in circles):
1 – South Emba (East European Platform); 2 – Karpinsky ridge;
3 – East Manychsky; 4 – Terek-Caspian (Scythian plate);
5 – Central Mangyshlak; 6 – Tuarkyr-Karaaudan (Turanian plate);
7 – South Caspian (Alpine folded region); 2 – mesoplate boundaries–collision seams of platforms of different ages;
3 – sliding seams, shifts; 4 – subduction zones; mesoplates:
A – East European, B – Scythian, C – Lesser Caucasus,
D – Western Turanian, E – South Caspian, F – Iranian

These plates are very different in their structure, are in motion, and are not characterized by such a complex pattern of distribution of velocities and vectors of modern horizontal movements of individual blocks. Structures of different ages are confined to their boundaries – fragments of continental or suboceanic crust, which were influenced by subduction and collision during the closure of the Tethys paleoocean (Fig. 1, 3).

Since the late Miocene, the East European Plate has been considered inactive. The Scythian and Lesser Caucasus plates move along an azimuth of 18° at a speed of 1.92 cm/year and simultaneously rotate counterclockwise by $(2.03–10^{-7})°$. The West Turanian and Iranian mesoplates move to the northwest along collision sutures at a rate of 1.7 cm/year, and the South Caspian plate moves along an azimuth of 319° at a rate of 0.4 cm/year. Relative to the East European Plate, it rotates with an angular velocity of $(0.6·10^{-7})°$ counterclockwise. Thus, the Caspian region found itself at the center of the convergence of several plates with different kinematic parameters. All this led to the complexity of the stage of geodynamic development and the coupling of different types of geostructural elements.

The South Caspian Basin (SCB), which includes the Kura, South Caspian and West Turkmen depressions, stretching in the sublatitudinal direction, in the north it is limited by the anticlinoria of the Greater Caucasus and Greater Balkhan, in the west – by the Dzirul massif, in the east – by the spurs of the Kopetdag, in the south – by the northern slopes of the Lesser Caucasus, Talysh and Elburz (Fig. 4).

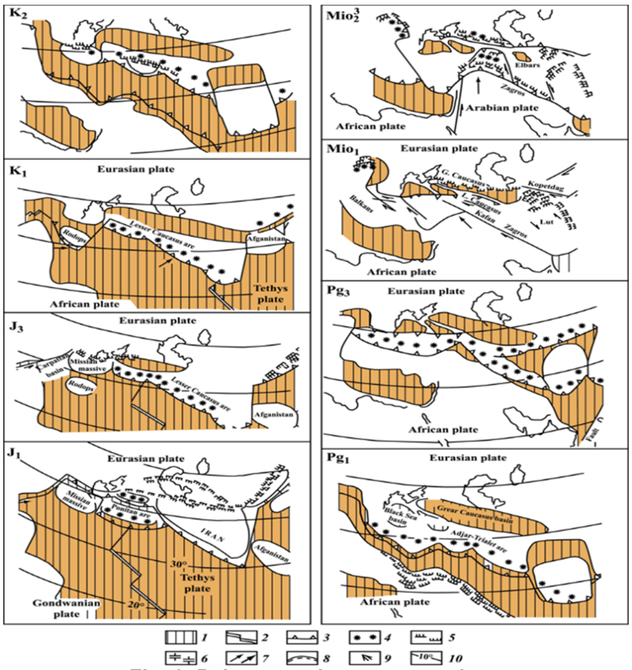

Fig. 3. Paleotectonic reconstructions of the Tethys mobile zone (Zonenshein, Kuzmin, & Kononov, 1987):
1 – oceanic crust; 2 – spreading axes;
3 – subduction zones (borders of plate convergence);
4 – volcanic arcs; 5 – folding and integumentation;
6 – continental rifts; 7 – direction of relative movement of slabs and microplates; 8 – contours of continents and microcontinents;
9 – underwater alluvial fans; 10 – paleolatitudes

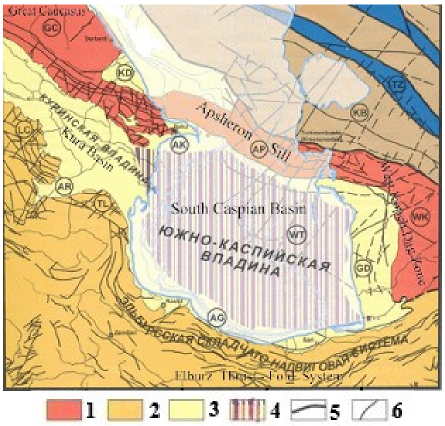

Fig. 4. Tectonic map of the South Caspian Basin (Khain, & Bogdanov, 2003)
Legends: The most important structural elements of the Caspian region: 1 – Greater Caucasus and Kopetdag;
2 – Lesser Caucasus, Talysh, Elbrus; 3 – Forward troughs and depressions; 4 – Depressions with oceanic crust;
5 – Discontinuous faults corresponding to the boundaries of large structures; 6 – Other important faults.
The most important structures (letters in circles):
GC – Greater Caucasus folded system;
KD – Kusaro-Divichi trough; AP – Apsheron-Pribalkhan zone;
WK – West Kopetdag zone; LC – Lesser Caucasus folded system;
AR – Lower Araks trough; TL – Talysh zone;
AG – Elburz-Gorgan foredeep; WT – West Turkmen trough;
GD – Gogran Dag-Okarem zone

It differs from the enormous thickness of the sedimentary cover – 25–30 km, against 12–17 km in other deep-sea basins of the Alpine-Himalayan mobile belt. The SCB is characterized by a reduction in the areas of shelf accumulation and a decrease in the overall size of the basin in the Cenozoic (Fig. 4, 5). The basin is declining especially rapidly in the Pliocene-Pleistocene, the reason for which is its location within a tectonic compression belt that experienced extreme crustal shortening in the late Cenozoic.

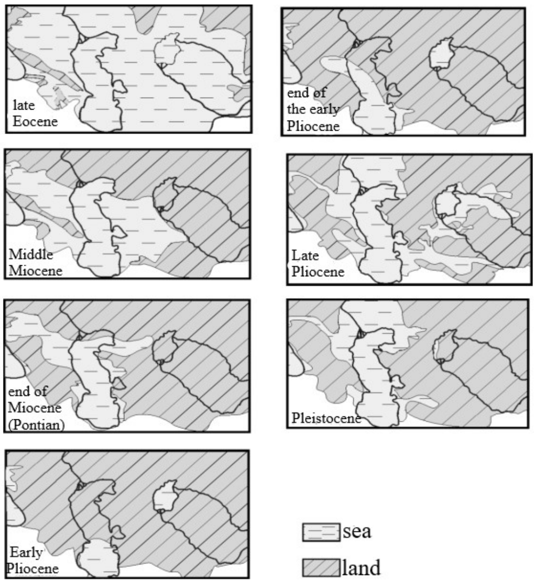

Fig. 5. Paleogeography of the Eastern Paratethys in the Cenozoic (according to Nevesskaya et al.,1984, with additions from the authors)

Discussion and conclusions

According to the ideas (Adamia, Zakariadze, & Lordkipanidze, 1974; Bazhenov, & Shipunov, 1991; Gamkrelidze, 1988; Khain, & Sokolov, 1984; Knipper, Satian, & Bragin, 1997; Mamedov, 2006; Nevesskaya et al., 1984, 2003; Rustamov, 2005; Zonenshain, & Pichon, 1986; Zonenshain, 1990) in the geological past, on the site of the Caucasian-South Caspian segment of the Alpine-Himalayan belt, there was a complex of structures and geological bodies characteristic of the active margin of continents, consisting of the Lesser Caucasus branch of the Mesotethys ocean (relics of which are ophiolites), a volcanic island arc, a back-arc (marginal) Greater Caucasus Sea and passive elements on the edge of the Eurasian continental margin. These structures formed in the oceanic space of Mesotethys, where the Afro-Arabian and Eurasian platforms interacted with the microcontinents located between them (Anatolian, Iranian, South Caucasian, Nakhchivan, Maker, etc.). The tectonic evolution of this segment of the Alpine belt in the Mesozoic is characterized by the opening of the marginal Greater Caucasus Sea and the formation of the South Caucasus volcanic island arc, which many researchers associate with the subduction of the Mesotethys oceanic crust (Middle Jurassic – Early Cretaceous), its complete absorption in the Caucasian segment. The drift of the Afro-Arabian Platform to the north led to the closure of the Lesser Caucasus branch of the Mesotethys. The process of ocean closure began in the Senonian and was completed at the end of the Cretaceous (Zonenshain, 1990).

By the end of the Eocene in the Caucasus region, the entire crust of the Mesotethys ocean was completely absorbed, and there was a collision of the Anatolian and Iranian microcontinents with the Transcaucasian microcontinent located north of them and their pressing towards Eurasia.

As a result, compression structures of the Lesser and Greater Caucasus were formed, as well as the Eastern Paratethys basin, isolated from the World Ocean, with oceanic crust and stagnant conditions, in which black non-carbonate and weak-carbonate clay sediments accumulated in the Oligocene-Miocene (Fig. 3).

As a result of the evolution of the lithosphere in the region, a unique South Caspian Basin (SCB) was formed, characterized by a thin consolidated crust (6–8 km) and a large thickness of the sedimentary cover (25–30 km) (Kerimov et al., 2014). The rate of subsidence in the Pliocene in the northern part of the SCB is 20–30 times higher than at the rift stage of opening, and 2 orders of magnitude higher than in the Cretaceous and Paleogene periods. The reason for the significantly higher Pliocene sedimentation rates and loads observed in the SCB is the very large volume of sediment introduced in a short period of time. The Pliocene–Quaternary time (5.3 million years) here is represented by stable subsidence, high rates and rates of sedimentation, as well as the activity of the Paleo-Volga, Paleo-Kura, Paleo-Uzboy, Paleo-Amu Darya (Guliev, Kerimov, & Mustaev, 2016), associated with the introduction of a huge volume of sedimentary fill (Fig. 6).

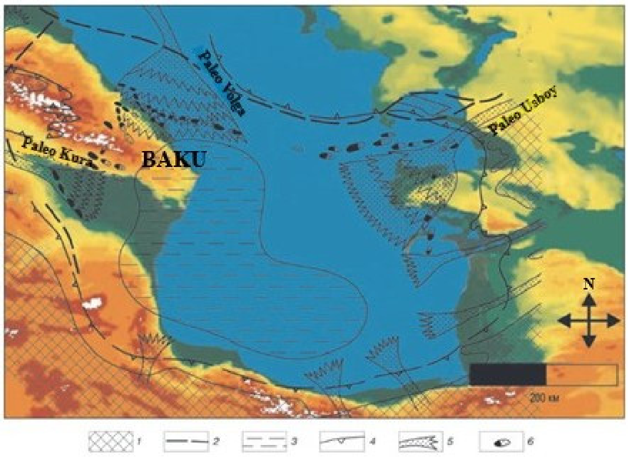

Fig. 6. Paleogeographical scheme of the South Caspian depression in the Pliocene (Kerimov et al.,2014):
1 – meganticlinoria and folded areas; 2 – main faults;
3 – pontic basin by the end of the century; 4 – boundary of the South Caspian basin towards the end of the Lower Pliocene;
5 – paleodeltas; 6 – oil and gas fields

At this time, the growth of mountain structures in the frame of the megadepression is accompanied by rapid subsidence of the crust within the Southern Caspian Sea, its shallowing and reduction in the area of the sedimentation basin. The thickness of the sediments accumulated during this period reaches about 9–10 km, of which the Lower Pliocene – Productive Strata (PS) – accounts for 6–7 km. With a duration of the PS century of 2–2.5 million years, the average rate of sedimentation here is about 3–3.5 km/million years, and at certain stages it becomes hurricane-like, with a speed of 6–7 km/million years. Isochron maps constructed for the PS indicate that in these intervals sedimentation occurred in a subsidence basin that did not experience active deformation during subsidence. The eastern (Turkmen) part of the basin subsided at a lower rate, and sediment accumulation was less powerful. The increased thickness of sediments in the western and northern parts of the basin indicates that the source of sedimentation was the predecessor of the Kura in the western part and the paleo-Volga in the north. Thus, in contrast to the peripheral areas of the sea basin, which experienced strong tectonic deformations and folding, the South Caspian depression, squeezed on all sides, remained relatively little deformed.

The Pliocene age for the beginning of the stage of rapid subsidence and deformation of the earth's crust of the Southern Caspian Sea corresponds to the time of the opening of the Red Sea, which led to a rapid and sharp movement to the north of the Arabian Platform, acceleration of plate convergence, extreme reduction of the SCS and mountain framing structures, and intensification of folding processes in its sedimentary cover.

Analysis of materials from ultra-deep seismometry in the South Sea (Alizadeh et al., 2017), as well as seismometry and gravimetry (Allen, & Weihed, 2002) showed that the subsidence of the South Caspian in the northern direction occurs according to the subduction model.

However, there is another point of view on the rapid subsidence of the consolidated crust of the SCS, based on the plumotectonic concept that is being developed (Ismail-Zade, 2006; Pogorelova, & Abdulla-zada, 2023; Rustamov, 2005). According to M. I. Rustamov, the main events in the plumotectonic processes of the SCB are mantle absorption and crustal resurgence, the emergence of waveguides along the zones of deep faults at the crust-mantle boundary and crustal level, and the failure of the bottom of the basin. Sedimentation in the Cenozoic in the South Caspian basin occurs in a regional collisional geodynamic setting, accompanied by successive thinning of the consolidated crust. The resurgent crust of the South Caspian basin, the author believes, corresponds only in geophysical parameters to a basalt layer, and it should not be accepted as a relic of the spreading oceanic crust of the geological past. The crust of the SCB was revived at the regional collisional geodynamic stage in the Cenozoic as a result of mantle diapirism, decompression and heating of the upper mantle, accompanied by intense high-temperature fluid flows, similar in modern intraplate rifts – Baikal, Krasnomorsky, etc. (Rustamov, 2005).

The area of the present research is the Yevlakh-Agjabedi region of subsidence and increased sedimentation (Fig. 7), which constitutes the Yevlakh-Agjabedi oil and gas region, located in the southeastern part of Western Azerbaijan, includes two oil and gas regions (the Mil oil and gas region, which includes the Muradkhanli oil and gas accumulation zone, and the Lesser Caucasus oil and gas region with the Naftalan oil accumulation zone included in it), as well as the Jalilabad promising oil and gas region.

This area of subsidence has the shape of an irregular oval, extends in the NW-SE direction, covering significant parts of the Mil and Shirvan steppes, as well as the foothill regions of Talysh. The most intense area of subsidence of the zone is located in the area between the Terterchay and Khachinchay rivers, where the thickness of the sedimentary cover is more than 14 km.

The indicated sedimentation area is a highly promising territory for oil and gas formation and oil and gas accumulation in Upper Cretaceous, Paleogene and Miocene deposits, since within its boundaries there were features of geological structure and development that determined favorable combinations of the main conditions for oil and gas formation and oil and gas accumulation. This depression area, throughout the entire Mesozoic-Cenozoic cycle of sedimentation, was a paleo-depression, characterized by significant dimensions (on the order of hundreds of kilometers along the perimeter) and stable subsidence (the subsidence of Paleogene deposits in the axial parts of this large depression was up to 8–9 km). The accumulation of

Paleogene-Miocene sediments occurred mainly in a subaqueous environment with an anaerobic geochemical situation; here, geological and geophysical work has revealed structural and non-anticlinal traps in the range from Upper Cretaceous formations to Miocene deposits, with which a number of oil and gas accumulations are associated here. Below we will consider the prospects for the oil and gas potential of each oil and gas region included in this area.

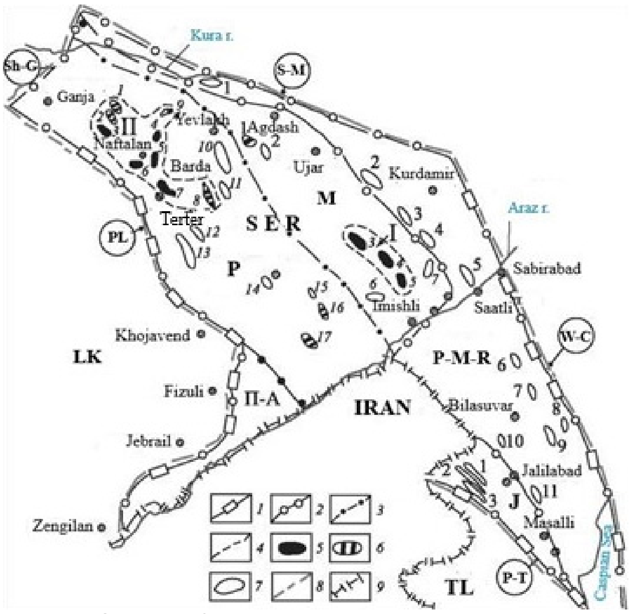

Fig. 7. Scheme of tectonic and oil-gas-geological zoning of the Yevlakh-Agjabedi oil and gas region (OGR) and the Pre-Talysh-Mingechaur low-prospect region Middle Kura-Kartli oil and gas subprovince (NGSP) of the Transcaucasian oil and gas provinces (NGP)

Borders: 1 – southwestern and southeastern borders of the Middle Kura-Kartli NGSP; 2 – borders of the Yevlakh-Agjabedi NGR and the Pre-Talysh-Mingachevir unpromising region; 3 – boundaries of tectonic (oil and gas-bearing) regions; 4 – boundaries of oil and gas accumulation zones. Hydrocarbon accumulation sites: 5 – oil; 6 – areas with industrial inflows of oil and gas; 7 – anticlinal folds of the Mesozoic-Paleogene; 8 – major tectonic faults (faults): Z-K – West Caspian; S–M – Saatly-Mingachevir; SH–G – Shamkhor-Geokchay; P–M – Pre-Lesser Caucasus; P–T – Pre-Talysh. 9 – state borders of Azerbaijan. MK – meganticlinorium of the Lesser Caucasus; TL – Talysh mountain system.

Tectonic and oil and gas geological zoning: JAO – south-eastern region of the deflection of the Middle Kura-Kartli depression (NGSP) – Yevlakh-Agjabedi oil and gas bearing region. M – Silsky tectonic (oil and gas bearing) region. I – Muradkhanly oil and gas accumulation zone. Accumulation locations: 3 – Zardob; 4 – Muradkhanly; 5 – Jafarli. Anticlinal uplifts: 1 – Amirarkh-Western; 2 – Amirarkh; 6 – Shirinkum; 7 – Milskaya. P – Pre-Lesser Caucasus tectonic (oil and gas bearing) region. II – Naftalan oil accumulation zone. Accumulation sites and areas with industrial oil inflows: 1 – Dalmamedli; 2 – Borsunly; 3 – Kazanbulag; 4 – Gedakboz; 5 – Naftalan; 6 – Ajidere; 7 – Terter; 8 – Shirvanly; 9 – Duzdag. Anticlinal uplifts: 10 – Airidja; 11 – Barda; 12 – Tazakend; 13 – Gullyudzha; 14 – Agjabedi; 15 – Aggel; 16 – Sovetlyar; 17 – Zhdanovsk. D – Jalilabad tectonic (prospective oil and gas bearing) region.

Anticlinal uplifts: 1 – Tumarkhanly; 2 – Germeli; 3 – Boykhanly. P–A – Priaras tectonic region with unclear oil and gas potential. P–M–O – Pre-Talysh-Mingachevir tectonic (unpromising in terms of oil and gas) region. Elevations: 1 – Karadzha; 2 – Karadzhally; 3 – Sor–Sor; 4 – Dzharly; 5 – Saatly; 6 – Khalafli; 7 – Middle Mugan; 8 – Shorsulu; 9 – Kyrmyzykend; 10 – Bilasuvar; 11 – Uzuntepe

As already noted, the Mil oil and gas region is located within the north-eastern edge of the Yevlakh-Agjabedi trough, in the zone of its junction with the Saatly-Mingachevir branch of the Pre-Talysh-Mingachevir zone of uplifts. A number of deposits have been identified here in Upper Cretaceous, Eocene, Maikop and Chokrak rocks, which are part of the Muradkhanli oil and gas accumulation zone. The oil and gas potential of this region is mainly based on the works (Averbukh, 1993; Averbukh, Shilov, & Nadirov, 1994; Gadirov, Gadirov, & Gamidova, 2016; Guliyev, 1997; Kerimov, & Averbukh, 1979; Kerimov, & Averbukh, 1982; Rachinsky, & Kerimov, 2015).

In 1971, within the NE edge of the Yevlakh-Agjabedi trough of the Srednekura depression, the Muradkhanli oil field was discovered, confined to a volcano-tectonic buried uplift of Cretaceous age, in which the oil-bearing rocks were found to be effusive-pyroclastic rocks of the Upper Cretaceous (Fig. 8).

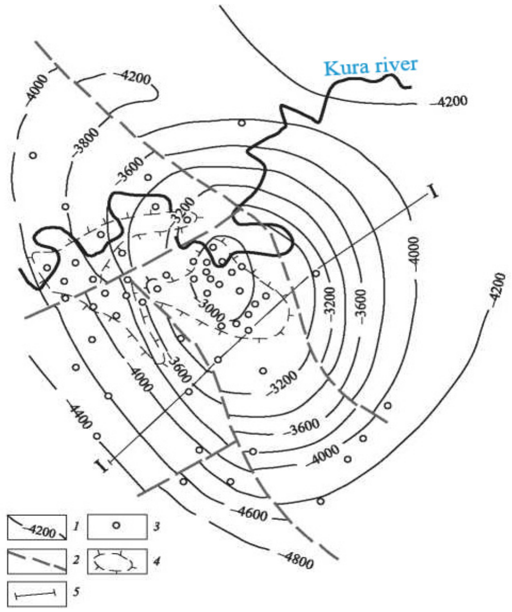

Fig. 8. Muradkhanly area. Structural map of the surface of effusive-pyroclastic formations of the Upper Cretaceous

Legend: 1 – isolines of the surface of effusive-pyroclastic formations of the Upper Cretaceous; 2 – faults; 3 – wells that exposed effusive-pyroclastic rocks of the Upper Cretaceous; 4 – boundaries of oil and gas accumulation zones in the weathering crusts of effusive formations of the Upper Cretaceous; 5 – line of the Shirinkum-Muradkhanly profile section (Alieva et al., 2017)

In subsequent years (1973–1976), oil deposits were also discovered in the complex of Paleogene-Miocene rocks overlying the effusive formations – in the Eocene, Maikop, and Chokrak deposits (Mykhailov, & Zagnitko, 2017; Yetirmishli, Mammadli, & Kazimova, 2013; Yusubov, Alizadeh, & Rajabli, 2019; Yusubov, & Guliev, 2022).

Similar deposits in effusive (volcanic) rocks are known only in the Shaim oil and gas accumulation zone of the Krasnolensk arch in Western Siberia, within the Oymashinsky accumulation in Western Turkmenistan, and also: 1) in east-central Texas (USA), where a group of oil accumulations is known along the Luling-Mexia fault zone (the largest of which is Lytton Springs), within which oil deposits are confined to fractured serpentinite metavolcanic rocks of Upper Cretaceous age; 2) the oil accumulation sites of the island of Cuba, where the oil deposits are associated with Cretaceous serpentinites, in Febro (Mexico), some accumulation sites in Ecuador, and also Aujila in Libya, where the oil is found in igneous or crystalline rocks that have been subjected to erosion and weathering (Reilinger et al., 2006; Sosson et al., 2016; Tibaldi et al., 2018; 2019).

In all these localities, the fracture porosity of volcanogenic-pyroclastic rocks is caused by processes of internal adaptation inherent in the transition of lava and pyroclastic formations into modern metavolcanic rock, as well as by processes of weathering, denudation and erosion: their oil saturation is secondary and occurs, in all likelihood, due to migration from neighboring overlying or underlying regional oil-bearing sedimentary formations.

The above-mentioned deposits, according to the classification of stratigraphic, lithological and combined deposits (Guliev, Kerimov, & Osipov, 2011; Hudson et al., 2008) belong to the complex type of combined structural-lithological-stratigraphic deposits, to a group of deposits with sharply changing reservoir properties of volcanic or crystalline formations, unconformably covered by impermeable rocks.

In the Muradkhanly area, oil deposits in effusive-pyroclastic formations of the Upper Cretaceous are confined to complex traps formed in zones of weathered and altered effusive-pyroclastic rocks of the Upper Cretaceous as a result of processes of disintegration, leaching, hydrolysis, halmyrolysis and cataclasis and also in the deluvium (delapsia) of these rocks, with their unconformable overlap by younger clay formations of the Upper Eocene and Maikop. Such complex traps and the deposits associated with them, as already noted above, by their confinement to buried uplifts, lithological limitation of the reservoir by area and unconformable overlap by fluid seals, are classified as structural-lithological-stratigraphic (combined). The above-mentioned deposits are classified as the so-called "vein" type, which contradicts the actual data of lithological and petrographic studies of rocks of volcanic formations in the zones of their oil saturation (Mykhailov, 2018).

Within the central tectonic block, to which the arched part of the Muradkhanli volcano-tectonic uplift in the Upper Cretaceous is confined, the lowest elevation at which industrial inflows were obtained is minus 3315 m and the height of the discovered deposit in these formations within the central block is about 397 m. An approximate outline of the identified oil content is shown on the structural map along the surface of effusive-pyroclastic formations (see Fig. 8). The discovered deposit on the crest of the uplift in the central block has dimensions of 3.2×2 km.

Analyzing the depth of the exposed section of effusive-pyroclastic formations of chalk in productive wells, we can conclude that the oil saturation of effusive-pyroclastic rocks on the crest of the fold is associated with their upper, roof part. In the overwhelming majority of wells, oil inflows were obtained from a section interval of 5–50 m from the roof of effusive-pyroclastic formations. Only in well No.3 was oil inflow obtained from an interval located at depths of 75 to 100 m from the roof of the effusive-pyroclastic rocks. In well No.27, it was not possible to precisely identify the oil-bearing interval, since the oil inflow with a flow rate of 1 m^3/day was obtained from an interval located from 3 to 200 m from the roof of the effusive-pyroclastic rocks.

In the western block, tectonically lowered below the central block, represented by the central part of the relatively steeply dipping southwestern wing of the uplift, the identified deposit is located in the northeastern part of this block and has the form of a strip with dimensions of 2.7×1 km. The approximate height of the discovered deposit in the western block is 150 m. The initial flow rates of the productive wells of this block vary greatly. The highest initial oil flow rate (270 m^3/day) was obtained from well No.211, drilled in the southwestern part of the deposit. The oil saturation intervals of the productive wells are also quite different: from 0 to 128 m from the roof of the effusives.

In the northwestern block, which tectonic corresponds to the northwestern pericline of the western wing of the uplift, the identified deposit is located in the southeastern part of the block, adjoins a tectonic fault, has an irregular shape in plan and dimensions of about 5×2.7 km. The height of the deposit discovered within the northwestern block is approximately 1100 m. The initial flow rates of productive wells in the northwestern block, as well as in other previously considered blocks, are extremely ambiguous (from 2–4 to 300 m^3/day). In all wells of this block, the oil-saturated interval from the roof of the effusive-pyroclastic rocks does not extend to a depth of more than 100 m.

In the eastern block, tectonically corresponding to the gently sloping northeastern wing of the fold, in all four wells, when sampling both the effusive-pyroclastic formations and the Upper Cretaceous carbonate deposits lying above them, no oil or water inflows were obtained; the wells turned out to be dry (Fig. 8).

Oil reservoirs, within the limits of the identified oil deposits in the Upper Cretaceous effusive formations within the Muradkhanli uplift, are fractured and cavernous effusive-pyroclastic rocks of the porphyrite type and their tuffs, as well as their brecciated varieties.

The distribution of oil in effusive-pyroclastic formations is associated with pores, caverns, cracks and intergranular space. In addition, oil is found in the form of accumulations, spots of various shapes, veins and point (effusive) occurrence in the rock. The filling of voids with oil is to some extent related to the structure of the host rocks, with the greatest accumulation usually confined to areas with a more granular structure.

Zonal distribution of oil-bearing capacity within the effusive-pyroclastic formations of the Upper Cretaceous Muradkhanli volcano-tectonic uplift, the highly variable reservoir properties of these formations, as well as the limited depth from the surface and changing area of the effective thickness of these rocks are largely associated with the features of the history of the formation of these formations.

Within the NE edge of the Yevlakh-Agjabedi trough, where the Muradkhanli area is located, from the beginning of the Upper Cretaceous the deep Mingachevir-Lenkoran fault began to develop intensively, along which an intensive subsidence of the NE edge of the Yevlakh-Agjabedi trough occurred with simultaneous intensive manifestation of volcanism. As a result, a more than 2000-m thick layer of effusive-pyroclastic formations was formed here.

Volcanism in this region developed according to the island arc type, with the accumulation of erupted material in the first stage in an underwater environment, and by the end of the volcanic cycle (the beginning of the Senonian). It is possible that above-water eruptions also took place here – on large volcanic islands located in the Muradkhanly and Zardob region, which were simultaneously also subject to denudation processes.

In the Senonian, the territory of the NE edge of the Yevlakh-Agjabedi trough was a sedimentation basin of carbonate and terrigenous-carbonate deposits. However, the arched parts of the volcano-tectonic uplifts in the Muradkhanly and Zardob areas either remained unaffected by the Senonian transgression or were covered by thin sediments, washed away during the subsequent regression that began at the beginning of the Paleogene (Fig. 9).

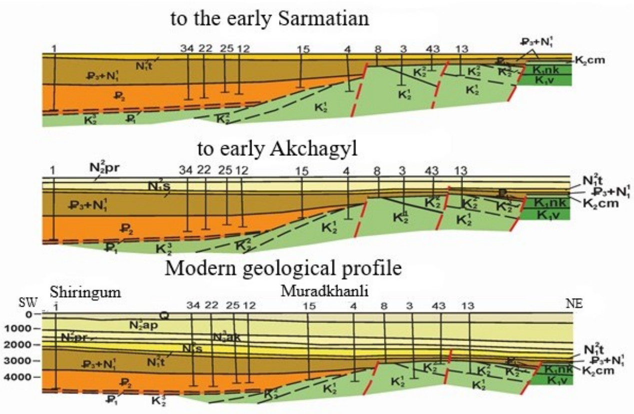

Fig. 9. Paleostructural profile sections along the Shirinkum-Muradkhanly line

During this long regression, which lasted for about 20–25 million years, right up to the top of the Eocene, and on the crest of the uplifts – even up to the top of the Maikop, the effusive-pyroclastic formations of the Upper Cretaceous were subjected to intensive processes of weathering, erosion and denudation.

These processes proceeded especially intensively near the fault zones that developed in the effusive-pyroclastic formations of the Upper Cretaceous as a result of orogenic movements at the beginning of the Maikopian, as well as in the domed and near-domed parts of the uplifts that were subject to weathering processes for the longest time.

Another promising direction within the oil and gas region under consideration is the search for oil and gas deposits in the carbonate deposits of the upper part of the Upper Cretaceous (Upper Santonian-Danian rocks). These deposits are distributed within the more submerged wing zones of the above-mentioned uplifts, where there may be stratigraphic hydrocarbon deposits in fractured reservoirs associated with these deposits.

Within the Paleogene deposits of the Mil oil and gas region, the greatest oil and gas potential is associated with the Eocene deposits.

Within the oil and gas region under consideration, the following are identified as the main promising oil and gas-bearing horizons of the Eocene, in which commercial oil content has already been identified in a number of areas of the Muradkhanli oil and gas accumulation zone: carbonate (terrigenous-carbonate) unit, covering the entire volume of the middle Eocene (fracture reservoir), and sandy-siltstone unit (fracture-pore reservoir, a pack of frequently alternating layers of sandstones, siltstones, and sometimes marls with layers of clays), stratigraphically corresponding to the lower parts of the Upper Eocene deposits (analogs of the III Kazanbulag horizon or the supramarl pack – the lower parts of the middle foraminiferal layers) (Averbukh,1993).

The Eocene deposits under consideration within the north-eastern (Saatly-Mingachevir) subzone of the Yevlakh-Agjabedi trough (Mil oil and gas region) (Fig. 7) have now been exposed and studied by drilling in a number of areas (Muradkhanly, Mil, Zardob, Shirinkum, Amirarkh). Large oil deposits of the lithological-stratigraphic type have been identified in these deposits – in the Muradkhanly area – in the terrigenous-carbonate (marl) pack of the middle Eocene and in the sandy-silty supramarl pack of the lower Upper Eocene. The identified deposits are confined to horizons (terrigenous-carbonate deposits of the Middle Eocene and sandy-tuff-silt rocks of the supramarl pack of the lower Upper Eocene (Aslanov, Khuduzade, & Aslanzade, 2020; Ganbarov, & Ibrahimli, 2012) stratigraphically and lithologically wedging out upward along the rise of the layers, caused the formation of lithological-stratigraphic traps. The reservoir type of the deposits is massive-layered.

Thus, as can be seen from the above, within the north-eastern edge of the Yevlakh-Agjabedi trough, the oil content of Eocene formations in various traps, but mainly non-anticline ones, has a regional character – along the entire strip of regional wedging out of these deposits (Ganbarov, & Ibrahimli, 2012).

The indicated fractured and pore reservoir units are the main promising oil and gas-bearing horizons of the Eocene within the entire subzone under consideration.

The assessment of the oil and gas potential of this subzone is based on the following featurs of its geological structure and development: the specified subzone of oil accumulation in geological terms is a strip of junction of the NE edge of the Yevlakh-Agjabedi trough of the Middle Kura-Kartli depression and the south-western slopes of the Geokchai-Mingachevir, Kurdamir-Saatly and Bilasuvar-Karadonly buried ledges of the second order, which are part of the large Talysh-Vandam transverse uplift, dividing the Middle Kura and Lower Kura depressions. All these projections during most of the Mesozoic-Cenozoic time experienced a tendency to uplift and acted as areas of uplift and erosion, exerting a significant influence on the distribution of facies and thicknesses within the Yevlakh-Agjabedi trough of the Middle Kura depression.

The Yevlakh-Agjabedi trough, in contrast to the described protrusions, experienced a tendency towards stable subsidence and was an area of intensive sedimentation. The boundary zone between these structural elements alternately experienced subsidence and uplift during the Mesozoic-Cenozoic history. The alternating tectonic stresses that existed for a long time in this zone led to the formation of a network of long-developing deep faults and to the periodic manifestation of volcanic activity (mainly in the Mesozoic period). In the Paleogene, these features of geological development led, on the one hand, to the accumulation of terrigenous-carbonate reservoirs and thick clayey covers, and on the other hand, to the formation of extensive zones of regional unconformities and wedging out, which together led to the formation of lithological-stratigraphic traps in this oil and gas accumulation zone (Ganbarov, & Ibrahimli, 2012).

The probable zone of oil and gas formation, which served as a source of hydrocarbon fluids for the regional oil accumulation zone under consideration, was the central part of the Yevlakh-Agjabedi trough, where, during most of the Mesozoic-Cenozoic history, there was a steady subsidence and accumulation of a thick layer of Eocene deposits, from where oil migrated into lithological-stratigraphic traps, confined to the zone of unconformable adjacency of Eocene terrigenous-carbonate reservoirs to the eroded surface of Upper Cretaceous effusive formations.

The formation of lithological oil deposits in zones of increased fracturing of the regolith surface of the Upper Cretaceous effusive rocks – in the crest of the uplift – occurred as a result of lateral migration and partial flow of oil from the Eocene reservoirs of the south-west wing and south-east pericline – along weathering zones and cracks.

The identified industrial oil content of the middle and upper Eocene deposits in one of the areas of this regional oil accumulation zone (Muradkhanly), similar geological structure of the Shirinkum, Milskaya, Zardobskaya and Amirarkhskaya areas and oil and gas shows recorded during the drilling and testing of a number of wells, leave no doubt that both to the northwest and to the southeast of the Muradkhanli area, oil and gas reserves of the lithological-stratigraphic type can be identified in the indicated strip of regional wedging and stratigraphic unconformity, confined to the terrigenous-carbonate pack of the middle Eocene (fracture-pore collector) and to the sandy-silty layers of the lower parts of the upper Eocene (pore collectors).

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ГЕОДИНАМІЧНИЙ ТА ПАЛЕОТЕКТОНІЧНИЙ АНАЛІЗ ПІВДЕННОКАСПІЙСЬКОЇ МЕГАДЕПРЕСІЇ У ЗВ'ЯЗКУ З ПЕРСПЕКТИВАМИ НАФТИ І ГАЗУ (НА ПРИКЛАДІ ЄВЛАХ-АГДЖАБЕДИНСЬКОЇ ЗАПАДИНИ)

Вступ. ***При оцінці перспектив нафтогазового потенціалу найважливішим завданням є визначення генетичної належності осадового басейну, тобто типу геодинамічного режиму. У зв'язку із цим актуальною є стаття, присвячена геодинамічній еволюції Каспійського басейну. У роботі проаналізовано дані опублікованих робіт щодо геодинамічної еволюції вищезгаданої території. З погляду глобальної тектоніки плит, високий нафтогазоносний потенціал пов'язаний передусім із континентальними окраїнами, палеорифтовими улоговинами, зонами міжгірських та передових прогинів, що утворилися на завершальному етапі зіткнення плит, а також з насувними краями складчастих гірських структур. Визначальним фактором у нафтогазоутворенні є насамперед геодинамічний режим надр. При визначенні генотипу осадового басейну надзвичайно важливим параметром є тип континентальної земної кори, який пов'язаний не лише з амплітудою тектонічного просідання і, як наслідок, швидкістю осадконакопичення, потужністю осадового чохла, але й з величиною теплового потоку, що визначає умови утворення нафти і газу.***

Результати. ***В результаті аналізу основних критеріїв нафтогазового потенціалу найбільші перспективи ми пов'язуємо з північно-східною частиною області Євлах-Агджабединської западини та її північно-східною ділянкою південно-східного центрикінального замикання, де відбувається зчленування зазначеної западини зі схилами мезозойських виступів Геокчай-Мінгечаур, Саатли-Кюрдамір та Білясувар-Карадонли. Ймовірною зоною нафтогазоутворення, яка слугувала джерелом вуглеводневих флюїдів для розглянутої регіональної зони нафтонакопичення, була центральна частина Євлах-Агджабединської западини, де протягом більшої частини мезозойсько-кайнозойської історії відбувалося стійке просідання та накопичення потужного шару еоценових відкладень, звідки нафта мігрувала в літолого-стратиграфічні пастки, приурочені до зони незгодного примикання еоценових теригенно-карбонатних колекторів до розмитої поверхні верхньокрейдових ефузивних утворень.***

В и с н о в к и . ***Формування літологічних родовищ нафти в зонах підвищеної тріщинуватості поверхні реголіту верхньокрейдових ефузивних порід – у гребені підняття – відбулося в результаті латеральної міграції та часткового перетікання нафти з еоценових колекторів південно-західного крила та південно-східної периклінали – вздовж зон вивітрювання та тріщин.***

К л ю ч о в і   с л о в а : ***Південнокаспійська плита, літосферна плита, геодинамічний режим, Східноєвропейська плита, осадовий басейн, вуглеводневий потенціал, Євлах-Агджабединський регіон, зона нафтогазонакопичення Мурадханлі, неструктурні пастки, колектори, ущільнення.***

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