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ANTI-CAUCASIAN FOLDING OF THE KURA-SOUTH CASPIAN HOLLOW (BY THE EXAMPLE OF SOUTH CASPIAN BASIN AND CIS-LESSER CAUCASIAN TROUGH)

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

The South Caspian Basin (SCB) is the deepest submerged sedimentary basin in the World and occupies the entire southern deep-water part of the Caspian Sea and the Kura and West Turkmenian lowlands adjacent to it from the west and east. The SCB has the thinnest (6...8 km) consolidated oceanic-type crust and the thickest sedimentary cover (25...30 km). The thickness of the Pliocene-Quaternary deposits is 10...12 km. The thickness of the main oil and gas complex – Productive-Red-Colored Strata of the Lower Pliocene is 7 ... 8 km. More than 6 km of volcanic-sedimentary deposits accumulated within the Lesser Caucasian trough at the Mesozoic stage of development. However, in the western part of the trough the translucent pre-Jurassic basement which has a northeastern orientation formed a similar orientation of the overlying deposits. All of the above mentioned events took place under conditions of compression in the north of SCB which were realized at the level of the consolidated crust by subduction, and at the level of the sedimentary cover by structure forming processes. Primary migration passes into the lateral from the submerged zones to the uplifted ones. Deep faults that have formed transverse folding can also serve as migration routes. The submerged predominantly gas-bearing depositional zone of the Productive Strata is represented by folding of both Caucasian and anti-Caucasian strike. Despite the fact that the Kura-South-Caspian depression at the present stage covers the territory from the Dziruly massif in the west to the West Turkmenian depression in the east inclusive as a single negative structural element, in the Mesozoic time as follows from the above it represented two independent areas of subsidence and sediments accumulation in the Transcaucasian microcontinent (western part) and the Greater Caucasian-South Caspian rift basin (eastern part). Therefore, the anti-Caucasian folding of the Kura-South Caspian depression has a different genesis and naturally a different oil and gas potential.

***Keywords:** oil and gas bearing, oil and gas potential, folding, Transcaucasian microcontinent.*

Challenging problem. The South Caspian Hollow (SCH) is the most deeply submerged sedimentary basin in the World and occupies the entire southern deep-water part of the Caspian Sea and the Kura and West Turkmenian lowlands adjacent to it from the west and east.

According to most researchers, it is a relic of the Greater Caucasian-South-Caspian marginal back-arc sea, which opened up in the Middle Jurassic (Bajocian-Bathian)-Upper Cretaceous, and differs from deep-water basins in the inland and marginal seas of the World in a number of parameters and indicators (Fig. 1) *(Kadirov, Gadirov, 2014; Mamedov, 2008; Yudin, 2008*).

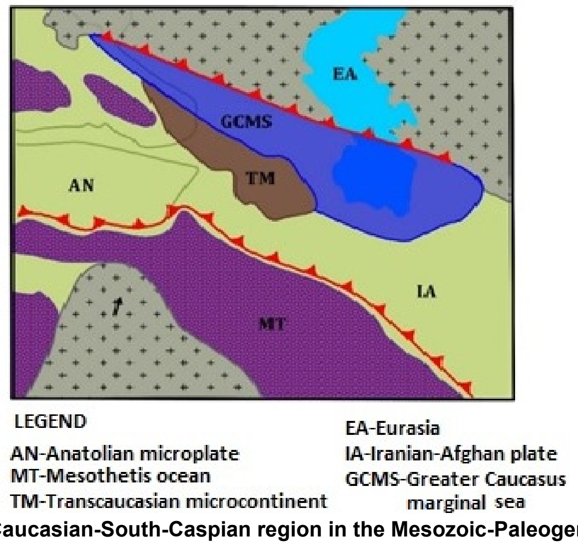

Fig. 1. Geodynamics of the Caucasian-South-Caspian region in the Mesozoic-Paleogene time (by *Mamedov, 2008*)

The South Caspian basin has the thinnest (6...8 km) consolidated oceanic-type crust and the thickest sedimentary cover (25...30 km). The thickness of the Pliocene-Quaternary deposits is 10...12 km. The thickness of the main oil and gas complex – the Productive-Red-Colored Strata – the Lower Pliocene is 7...8 km) *(Gahramanov, 2017; Alizade et al., 2018; Geology of Azerbaijan, 2007).*

Research analysis. Since all sedimentary-rock basins of the world have hydrocarbon reserves, researchers are faced with the task of identifying hydrocarbon accumulations in traditional and unconventional traps. For this, in our case, paleotectonic and structural analysis of the development of the Kura-South Caspian basin is used in order to identify the above-mentioned objects.

SCB was formed in the Arabian-Eurasian collision zone and bordered by the mountain systems of the Greater Caucasus, Kopetdag, Talysh, and Albours *(Khalilov,1985; Alizade et al., 2018).*

Pre-Lesser Caucasian trough is also located in this collision zone, with the only difference that at the Mesozoic stage of development it was an integral part (shallow sea) of the Paleozoic Transcaucasian microplate an ensialic basement (Fig. 2, 3) *(Golonka, 2007, Pogorelova, Serikova, 2010).*

In the Late Triassic, the main oceanic basin Tethys opened up, as the opening of which the Iranian-Afghan microcontinent began to move from south to north, towards Eurasia. The geometry of this continent contributed to the pushing of the Kura (Transcaucasian microcontinent) and South Caspian (Greater Caucasian marginal sea) depressions towards the Eurasian Plate (Fig. 4). At the point of colliding of the plates, a subduction zone (Absheron sill) and collisions (orogen of the Greater Caucasus) were formed *(Abdullaev et al., 2015).*

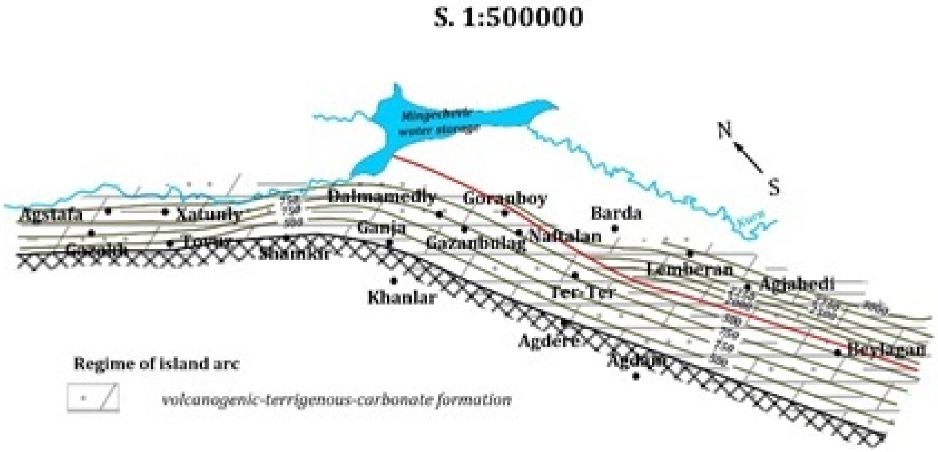

Fig. 2. Paleotectonic map of the Late Jurassic stage of the Cis-Lesser Caucasian trough (composed by *Pogorelova, 1991*)

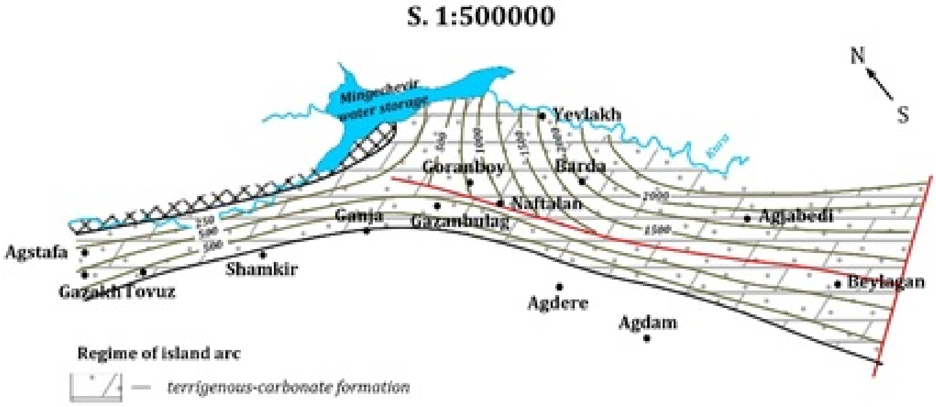

Fig. 3. Paleotectonic map of the Early Cretaceous stage of the Cis-Lesser Caucasian trough (composed by *Pogorelova, 1991*)

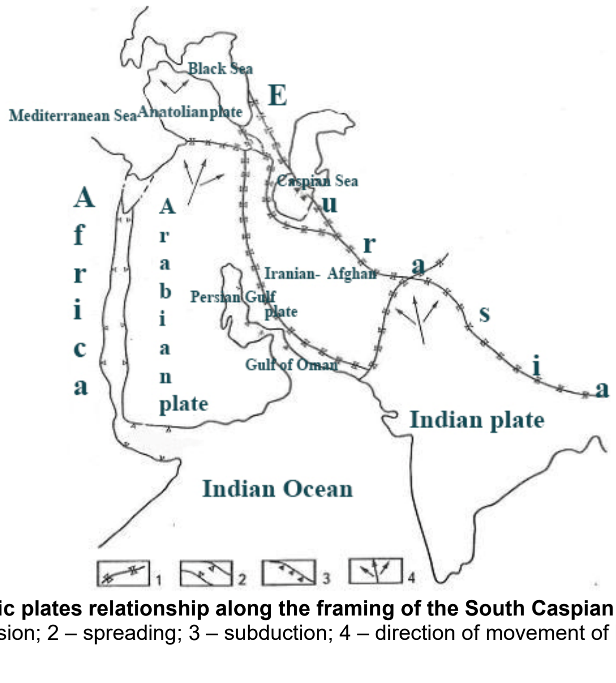

Fig. 4. Scheme of lithospheric plates relationship along the framing of the South Caspian Hollow (by *Narimanov, 2008*)
Borders: 1 – collision; 2 – spreading; 3 – subduction; 4 – direction of movement of lithospheric plates

Objective of the research. The purpose of the research is to determine the lithofacies composition of specific stratigraphic units in a geodynamic model to identify and predict hydrocarbon accumulations in the deep buried sediments. Stratigraphic surfaces, not refined by well results, were determined by the propagation of velocities of seismic waves (*Pogorelova, 2021*).

This concerns, first of all, the Meso-Cenozoic deposits of the Lesser Caucasian trough, since accumulations of oil and gas were found within it both in the Mesozoic deposits (Gullyuja) and in the Paleogene-Miocene (Gazanbulag, Naftalan). Today the main work on the search and production of hydrocarbons is aimed at the deposits of the lower Pliocene (productive strata) on the shelf of the South Caspian.

The Cis-Lesser Caucasus trough separated from the South and North by deep faults began to emerge as an independent structure on the southern side of the Kura depression starting from the Bathonian time (therefore the sedimentary deposits of the trough include not only molasse formations but also the deposits preceding them), and the Greater Caucasian-South-Caspian back-arc marginal sea like a rift was opened in the Bajocian-Bathonian and Upper Cretacious time on the active margin of the Mesotethys *(Mamedov, 2008; Pogorelova, 2010)*.

Research methodology. To solve the problem, on the basis of geophysics, petrophysics, lithostratigraphy, volcanology, paleotectonic, structural maps and isopach were compiled; based on paleomagnetic data, a geodynamic analysis of the formation and development of the Lesser Caucasus trough was carried out *(Hudson et al., 2008; Gamkrelidze et al., 1981; Ophiolites of the Lesser Caucasus, 1985)*.

A large amount of material on the Black Sea-Caspian megabasin was compared, and in order to identify not only the places of hydrocarbon accumulations, but also their generation, the geochemical component of the Meso-Cenozoic deposits was also considered. For this purpose, materials of mud volcanoes, widespread in the region, were used *(Guliyev, Tagiyev, 2001; Mikhailov, 2017; Aliyev, 2008)*.

Laying out the main material. Over 6 km of volcanic-sedimentary deposits accumulated within the Lesser Caucasus trough at the Mesozoic stage of development; however, in the western part of the trough, a translucent pre-Jurassic basement, which has a northeastern strike, formed a similar orientation of the overlying deposits. (Fig. 5).

Since the opening the riftogenic Greater Caucasus-South Caspian basin, i.e. from the end of the Early Jurassic-Upper Cretaceous to the end of the Mesozoic, 4...6 km of sediments accumulated in the depression with the greatest thickness in the area of the Absheron threshold (8...10 km).

By the end of the Oligocene-Early Miocene time, the sedimentary stratum in the South Caspian depression (already separated into a closed marine basin) was 14...16 km. This means that the Paleocene-Eocene period accounts for an average of 10 km of deposits *(Alizade et al., 2018).*

In the Cis-Lesser Caucasus trough, in its western part, the monoclinal subsidence of the Paleocene-Eocene deposits towards the Kura depression is complicated by a number of structural promentories of the anti-Caucasian strike, fixed in the area of the Tovuz-Gazakh, Gyragkesaman, Khatunly areas, and clearly shows that the modern structural plan, where these protrusions are clearly visible along the top of the Eocene, was formed during the deposition of these formations, and is not associated with a younger restructuring. This circumstance is undoubtedly connected, as mentioned above, with the reduced thickness of the Mesozoic, the approach to the surface in the Paleocene-Eocene period of the pre-Jurassic basement and, as a result, with the translucence of the pre-Jurassic submeridional plan, correcting the formation of a younger, sublatitudinal Caucasian plan (Fig. 6).

By the beginning of the Oligocene-Miocene (Maikopian) stage of development, the region was covered by a short-term uplift associated with the entry of the Lesser Caucasus into the orogenic stage of development. Then a transgression occurred again and a significant area of the Eocene land was covered by the Maikopian Sea, although the contours of the sea were very indented, representing an alternation of promontories and bays.

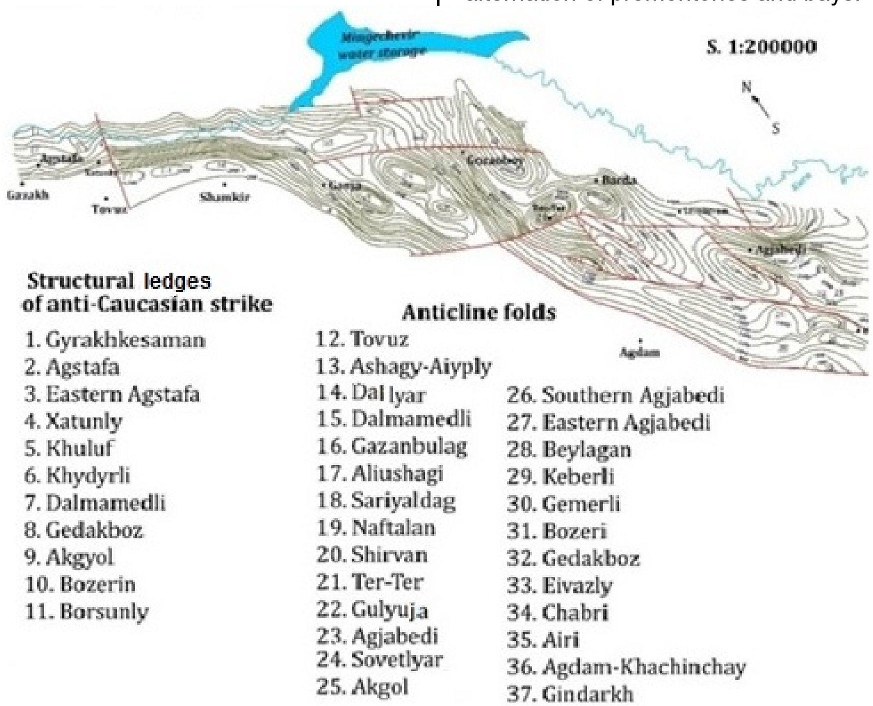

Fig. 5. Structural map by the surface of the Mesosoic of the Cis-Lesser Caucasian trough (composed by *Pogorelova, 1991*)

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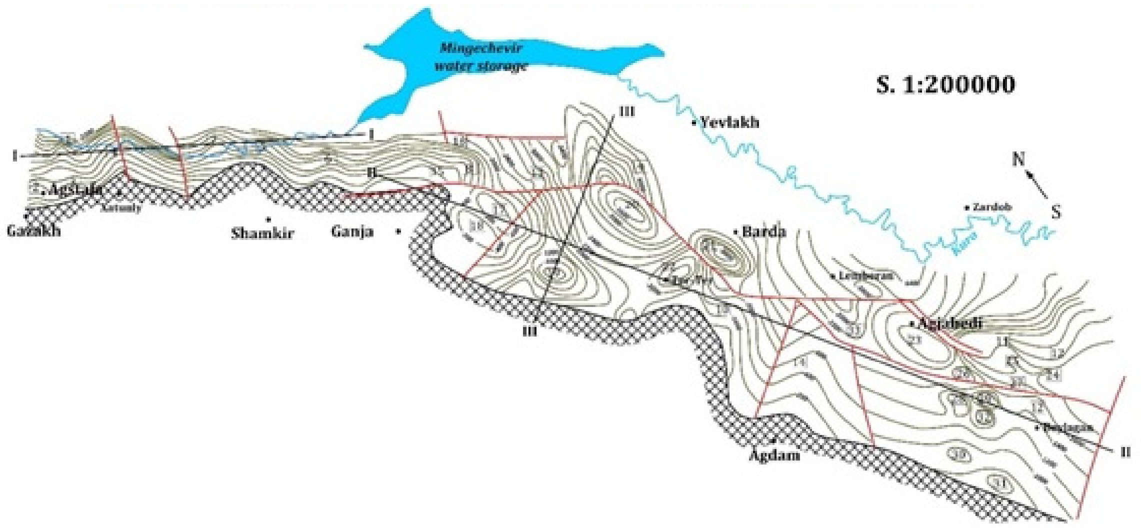

Fig. 6. Structural map by the surface of the Eocene of the Cis-Lesser Caucasian trough (composed by *Pogorelova, 1991*)

Like the surface of the Eocene, the surface of Maikopian outlines a number of structural promontories of the anti-Caucasian strike, located in the western part of the Cis-Lesser Caucasian trough, plunging in a northerly direction. The inherited development of structures was supplemented by the influence of a normal fault that appeared here and the inherited development of the transverse Revazlyu-Uchgyul deep fault (near the towns Khatunly and Tovuz (Fig. 7).

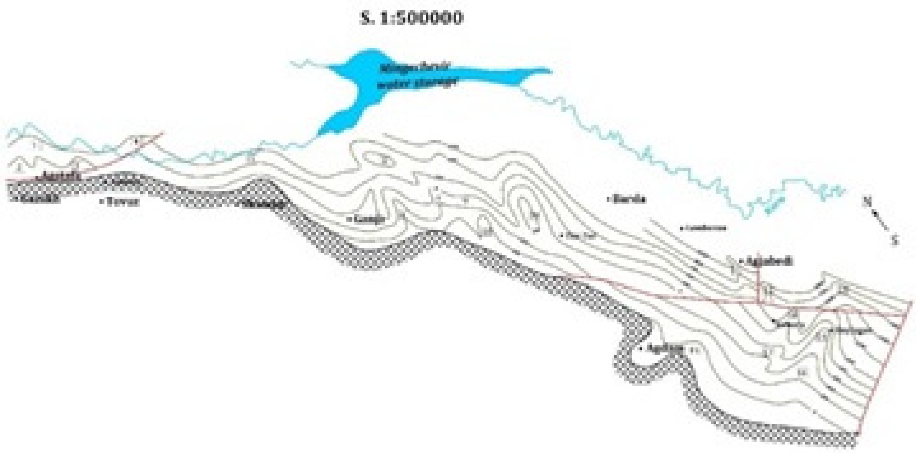

Fig. 7. Structural map by the surface of the Maicopian of the Cis-Lesser Caucasian trough (composed by *Pogorelova, 1991*)

The South Caspian depression in the Miocene-Pliocene-Quaternary time accumulated a sedimentary layer more than 15 km thick, where the Lower Pliocene Productive-Red-colored sedimentary sequence 6...7 km thick is of the greatest interest.

All of the above mentioned events occurred under conditions of compression in the north of the South Caspian basin, which were realized at the level of the consolidated crust by subduction, and at the level of the sedimentary cover – by structure-forming processes *(Mamedov, 2008).*

Concerning the Cis-Lesser Caucasian trough, it is not necessary to speak about the existence of such a trough in the Miocene, since it was a far onboard part of the Yevlakh-Agjabedi trough (its far southwestern trough), borderline with the rising block of the Lesser Caucasus *(Pogorelova, 2010).*

At the Pliocene-Quaternary stage, the trough turned into an inclined alluvial-deltaic plain. Although Pliocene deposits have accumulated here from 0 to 500...1000 m, the smallest number of structural elements is confined to them. These are, again, monoclinally dipping towards the Kura basin, complicated by transversely oriented structural noses (Fig. 8).

There is no doubt that Mesozoic tectonics put its mark on the general geotectonic appearance of the Pliocene-Quaternary at the South Caspian as well. However, there is no reason to speak about the complete identity of the structural plans of the Pliocene and Mesozoic, and even the Miocene. Moreover, based on the results of studies on the Absheron Peninsula and in Gobustan, where there is a sharp discrepancy in the orientation of the structures of the Pliocene and the underlying interval, it can be assumed that the Quarter-Pliocene structural stage within the Absheron-Pribalkhan zone of the uplifts of the South Caspian has superimposed character (the Mesozoic trough corresponds to the Absheron-Pribalkhan zone of uplifts) *(Guliyev et al., 2011).* Moreover, the highest degree of tectonic activity was recorded here in the late Pliocene time, i.e., after the accumulation of a thick sandy-clay weakly dislocated Lower Pliocene cover *(Mekhtiev at al.,1984; Yudin, 2008).*

Two transverse deep faults pass through the central part of the South Caspian basin – Sefidrud-Karabogaz and Central Caspian. To the west of them is the Shakh-Azizbekov deep fault of submeridional strike. All sublongitudinal faults are crossed by a series of sublatitudinal faults almost parallel to each other. This zone of ancient transverse faults, located south of the Sangachal-Ogurjali sublatitudinal zone, corresponds to the zone of transverse folding of the Oligocene-Anthropogenic sediment complex (Fig. 9, 10).

According to the results of detailed gravimetric studies, an extended (about 150 km) Alov-Ataturk zone of maxima was revealed here, possibly due to Mesozoic folding, complicated by local anomalies of meridional strike, indicating the inherited development of Mesozoic and Pliocene structures here *(Babaev, Gadzhiev, 2006).* The far northeastern continuation of the Mesozoic zone of the Alov-Ataturk uplifts can be traced within the South Karabogaz zone in the form of gravity maxima and transverse strike faults.

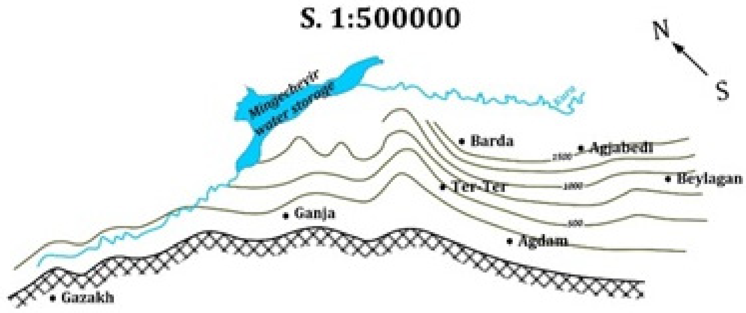

Fig. 8. Isopach map of Neogene deposits of the Cis-Lesser Caucasian trough (composed by *Pogorelova, 1991*)

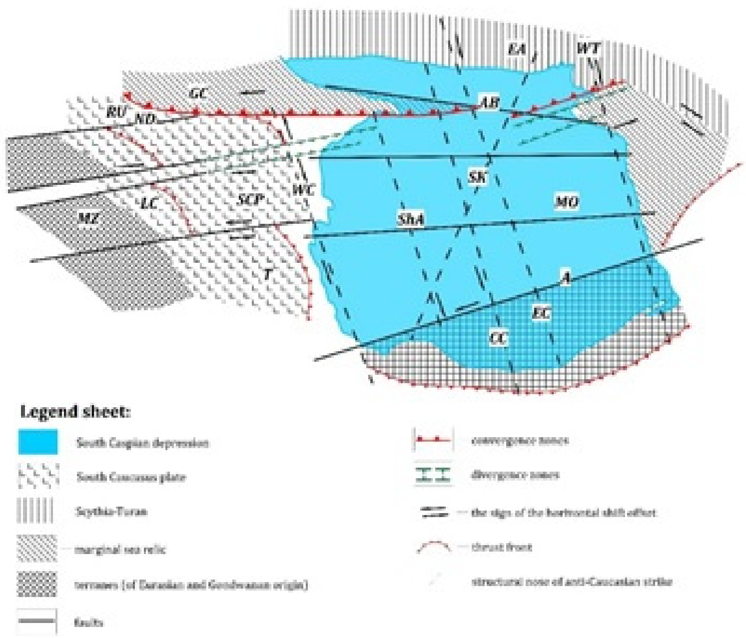

Fig. 9. Scheme of the South Caspian depression boundaries (according to *Murtuzayev, 2008* with additions):
1 – South Caspian depression; 2 – South Caucasian plate; 3 – Scythia-Turan; 4 – relic of the marginal sea; 5 – terrains (of Eurasian and Gondwanan origin); 6 – faults; 7 – convergence zones; 8 – divergence zones; 9 – the sign of the horizontal displacement along the shift; 10 – thrust front; 11 – structural noses of anti-Caucasian strike; 12 – objects names. Faults: A – Atrek, WT – West Turkmenian, SK – Sefidrud-Karabogaz, AP – Absheron-Pre-Balkhanian, SO – Sangachal-Ogurjali, MO – Mil-Okarem, EC – East Caspian, CC – Central Caspian, ShA – Shah-Azizbekov, WC – West Caspian, RU – Revazlyu-Uchgyul, ND – Nizhneagdan-Demirchilyar, GC – Greater Caucasus, LC – Lesser Caucasus, T – Talysh, EA – Eurasia, SCP – South Caucasus plate, MZ – Miskhan-Zangezur terrane, NA – North Albors terrane

In general, the Alov-Ataturk zone for the most part separates the deep-water basin of the South Caspian from the Turkmen shelf. In the deep-water part of the South Caspian, this zone of uplifts played a dominant role in the distribution of lithofacies of the Lower Pliocene deposits, the formation of the structures of the Turkmen terrace and the marine part of the Lower Kura region. The Alov-Ataturk zone of uplifts is also a unifying link between the Absheron-Pre-Balkhanian anticline zone in the north and the "massif" located in the Pre-Albours zone (Fig. 10).

The zone of cross folding is confined to the deep-water part of the basin, and the Oligocene-Anthropogenic sediment complex itself is submerged to depths of up to 8000 m, and in synclines – up to 10000 m. According to the thermal catalytic theory, such depths correspond to the main phase of gas formation *(Dadashev et al., 2010).*

Primary migration passes into the lateral from the submerged zones to the uplifted ones. Deep faults that have formed transverse folding can also serve as migration routes. The submerged, predominantly gas-bearing, depositional zone of the Productive Strata is represented by folding of both the Caucasian and anti-Caucasian strike.

The largest gas condensate field Shah Deniz with a preliminary estimate of proven geological reserves of more than 1.2 trillion m^3 of gas and 300 million tons of condensate was put into development in 2007. In the large promising structures adjacent to the Shah Deniz field, Absheron, Nakhchivan, Zafar-Mashal, as well as the chain of cross anticlines Gulustan-Ataturk, Gara Garayev – I. Huseynov, Avesta – J. Mamedguluzada the content of condensate in the gas phase at depths of more than 6000...6500 m. The source of gas generation can be Paleogene-Miocene and Mesozoic deposits *(Alizade et al., 2018; Fedorov, 2007).*

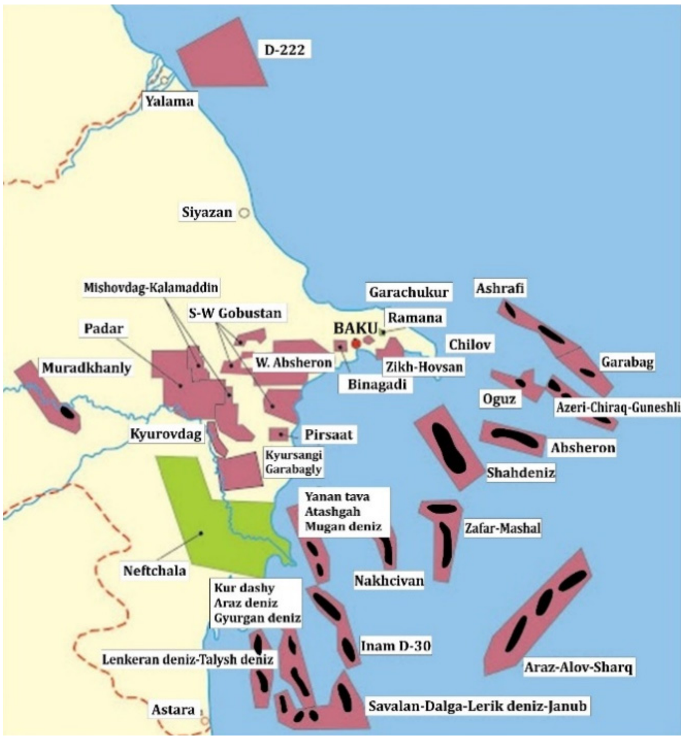

Fig. 10. Anti-Caucasian folding of the South Caspian depression (by *Yusifzade et al., 2013*)

Conclusions. As for the cross folding of the Cis-Lesser Caucasian trough, here the oil and gas potential is associated with Cretaceous-Paleogene deposits, which are hypsometrically located much higher than those of the South Caspian depression, and therefore, mainly, the accumulations here are oil and gas bearing. Purely gaseous manifestations were noted only in the Gulluja area, which, as a transverse structure, manifests itself only on the Eocene surface (it fades in the overlying layers) (Fig. 6). This is most likely due to the shallow occurrence of Eocene deposits (up to a depth of 2000 m) and in the process of lateral migration, the Gulluja structural ledge turned out to be the last obstacle in the way of the secondary gas mixture, which filled the Gulluja trap.

Despite the fact that the Kura-South-Caspian depression at the present stage covers the territory from the Dziruly massif in the west to the West Turkmenian depression inclusive in the east as a single negative structural element, in the Mesozoic time, as follows from the above, it represented two independent areas of subsidence and accumulation of sediments within the Transcaucasian microcontinent (western part) and the Greater Caucasian-South Caspian rift basin (eastern part). Therefore, the anti-Caucasian folding of the Kura-South-Caspian depression has a diverse genesis and, naturally, a different oil and gas potential.

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АНТИКАВКАЗСЬКА СКЛАДЧАТІСТЬ КУРИНСЬКО-ПІВДЕННОКАСПІЙСЬКОЇ ЗАПАДИНИ (НА ПРИКЛАДІ ПІВДЕННОКАСПІЙСЬКОГО БАСЕЙНУ І ПЕРЕДМАЛОКАВКАЗСЬКОГО ПРОГИНУ)

Південнокаспійська западина (ПКЗ) є найглибшим осадовим басейном у світі і займає всю південну глибоководну частину Каспійського моря і прилеглі до нього із заходу та сходу Куринську та Західнотуркменську низовини. ПКЗ має найтоншу (6...8 км) консолідовану кору океанічного типу та найпотужніший осадовий чохол (25...30 км). Потужність пліоцен-четвертинних відкладень становить 10...12 км. Потужність основного нафтогазоносного комплексу – продуктивних червонокольорових товщ нижнього пліоцену становить 7...8 км. У межах Малокавказького прогину на мезозойському етапі розвитку накопичилося понад 6 км вулканогенно-осадових відкладень. Однак у західній частині прогину простежується доюрський фундамент, що має північно-східне орієнтування і формує аналогічне орієнтування вищезалягаючих відкладів. Ці явища відбувалися в умовах стиснення на півночі ПКЗ і реалізувалися на рівні консолідованої кори субдукційними, а на рівні осадового чохла – структуротвірними процесами. Первинна міграція переходить у бічну – із занурених зон у підняті. Глибинні розломи, що сформували поперечну складчастість, також можуть служити шляхами міграції. Занурена переважно газоносна зона осадконакопичення продуктивної товщі представлена складчастістю як кавказького, так і антикавказького простягання. Незважаючи на те, що Куринсько-Південнокаспійська западина на сучасному етапі охоплює територію від Дзирульського масиву на заході до Західнотуркменської западини на сході включно, як єдиний негативний структурний елемент, у мезозойський час, як випливає з вищевикладеного, вона являла собою дві самостійні області осадконакопичення в Закавказькому мікроконтиненті (західна частина) та Великому Кавказько-Південнокаспійському рифтогенному басейні (східна частина). Тому антикавказька складчастість Куринсько-Південнокаспійської западини має інший генезис і, природно, іншу нафтогазоносність.
Ключові слова: нафтогазоносність, складчастість, Закавказький мікроконтинент.