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The role of the "land-sea" transition zone in the formation of oil and gas deposits in the Azerbaijani sector of the southern caspian

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Abstract

Analysis of drilling data suggests that the activity of the buried volcano began at the end of the Middle Pliocene or the beginning of the Upper Pliocene and ended in the Middle Absheron. The activity of the Khara-Zira mud volcano most likely started at the end of the Productive Layer era and is currently ongoing. The Bulla-Sea uplift is an enclosed fold structure. Based on the VII horizon of the Productive Layer in the Garadag region, the Bulla-Sea uplift is primarily a large brachyanticlinal fold that is symmetric in the transverse section and asymmetric in the longitudinal section.

Keywords: Caspian Sea, Baku Archipelag, South Caspian Basin, depth increases, Analysis of drilling, extrapolation etc.

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Introduction

In the monograph "Deep Structure and Oil and Gas Prospects of the Caspian Sea Basin," published in 2006 by D.X. Babayev and A.N. Hajiyev, the region's three geotectonic stages – Alpine geosyncline and Epihersin platform folding, as well as the southern part of the Russian platform – were analyzed from the perspective of oil and gas potential, based primarily on complex geophysical data analysis.

Separate issues regarding the deep tectonics of the South Caspian Basin, including the tectonic structure of the Baku Archipelago, have been investigated in geophysical studies by Y.P. Malovitskin, N.V. Fyodorov, I.S. Hasanov, R.M. Hajiyev, K.A. Ismailov, A.N. Hajiyev, D.X. Babayev, B.S. Aslanov, and others.

The fault that encompasses the graben from the northeast and southwest extends in a southeast direction towards the Khara-Zira Island uplift. The surface expression of these faults on the sea floor, where new faults crossing Khara-Zira Island are formed, is in the southeast direction of the Duvanny sea fold's periclinal.

Discussion

As depth increases, this fault merges with the main longitudinal fault, creating a potential for a unified fault zone. Only the surface of the sea floor encompassing the graben from the southwest is characterized by faults with steep dips of the Productive layer (up to 60-70° and 85°) and Pleistocene

(20-22°) rocks. This fault changes direction between the Duvanny sea and Khara-Zira Island folds, intensifying the merging of the Khara-Zira Island and Bulla-Sea folds and extending further southeast.

The uplift of the southwest block along this fault and its exposure to intensive erosion is evidenced by the presence of an erosion breccia in contact with Pleistocene sediments of the Productive layer in the area of the number 10 structural-exploration well.

In the modern structural appearance, this block is covered by Quaternary sediments. Considering data from aerial photogrammetry, V.V.Sharkov relates the sharp disappearance of the Abseron limestone series in the southwestern wing of the southeast periclinal from the northwest of Duvanny Island to the subsidence of the southeast block as a result of a transverse fault.

The Duvanny-Sea structure has been subjected to relatively strong tectonic stress due to buried folds and has expanded more intensively compared to the adjacent Kanizadag and Khara-Zira anticlinal zones.

The Khara-Zira Island structure, located 25 km southeast of the Sangachal Cape, forms the last uplift of the Sangachal-Sea-Duvannı-Sea-Khara-Zira Island fold. Khara-Zira Island consists of a brachyanticlinal fold in a northwest-southeast direction based on the upper layers of the Productive layer and the Aghcagil stage. The dimensions of the fold are 6×2 km at the 1100 m isohypse.

The structure of the fold is asymmetric in both longitudinal and transverse sections. The angle of dip of the layers on the southwest wing is 13-35°, while on the northeast wing it is 12-20°. The southeast periclinal dips at 7-8°, whereas the northwest periclinal dips at 8-10°. In the arch part of the uplift, the roof of the Productive layer lies at a depth of 950-1000 m. In the arch-flank area, however, the structure along the disjunctives complicates the fold's structure, and the hipsometric depth of these rocks in the northeast wing approaches closer to the surface.

The central block of the fold is surrounded by faults on both sides and has subsided as a graben.

In the northwest part of the area, the displacement amplitude below the PL sediments is 550 m on the northeast fault and 230 m on the southwest fault. The faults diminish in the southeast direction. As noted earlier, the saddle between the Duvanny-Sea and Khara-Zira island folds is complicated by two large transverse faults, causing the sharp subsidence of the Khara-Zira island structure. The 1000 m amplitude northwest transverse fault complicates the southeast periclinal of the Duvanny-Sea fold, while the southeast transverse fault complicates the northwest periclinal of the Khara-Zira uplift, resulting in the saddle's subsidence of approximately 450 m.

A third transverse fault is noted on the northeast wing of the fold in wells 8 and 22. This fault has caused the southeast area to subside by 100 m.

The known rupture is believed to be due to strong gas showings coming to the surface at the bottom of the sea (A.M.Suleymanov, 2014). In the deep subsidence of the southwest wing of the fold, another large disjunctive fault has been identified at the junction of the Khara-Zira Island and Bulla-sea structures. Along this fault, the southwest block has risen by 200-300 m relative to the opposite side, as confirmed by data from wells 18 and 20 drilled on Khara-Zira Island.

In addition to the described tectonic faults, the structure of Khara-Zira Island is complicated by a mud volcano.

Analysis of drilling data suggests that the activity of the buried volcano began at the end of the Middle Pliocene or the beginning of the Upper Pliocene and ended in the Middle Absheron.

The activity of the Khara-Zira mud volcano most likely started at the end of the Productive Layer era and is currently ongoing.

The Bulla-Sea uplift is an enclosed fold structure. Based on the VII horizon of the Productive Layer in the Garadag region, the Bulla-Sea uplift is primarily a large brachyanticlinal fold that is symmetric in the transverse section and asymmetric in the longitudinal section. The structure has a length of 27 km and a width of 9 km, with the height of the fold reaching 1400 m on the northeast wing.

The fold exhibits an asymmetric structure, with the dip angle on the northeast wing decreasing from 22° to 15° towards the arch section, while on the southwest wing it varies between 22° and 11°. The northwest periclinal and partly the northeast wing of the fold is connected to the southwest wing of the Khara-Zira Island uplift through a narrow synclinal. The southwest wing of the Bulla-Sea structure transitions into the Kichikdag-Andreyev sinklinorium. The area near the arch and the adjacent southwest wing of the fold is complicated by two longitudinal faults extending in a northwest-southeast direction.

The northeast wing of the structure has been studied based on deep drilling well data. The results from drilling and seismic exploration have revealed that the fold is complicated by transverse faults.

The Umid field, situated southeast of the Bulla-Sea structure, is independent and does not fall within any known anticlinal zones. This fold zone extends 40 km in a nearly vertical direction within the Kichikdag-Andreyev depression boundaries. It is separated from the Bulla-Sea fold and the Pirsahhet-Sabail zones by synclinal depressions.

According to recent interpretations of seismogeological data, the Umid fold's appearance shows a bending that creates three small local structures with undulations. The first structure is a relatively large northwest fold, surrounded by two isohypses (2000-2300 m), and measures 6700×900×150 m. As depth increases, the fold slightly enlarges.

The next central undulation merges through a shallow saddle. The central fold, surrounded by a 2300 m isohypse, measures 3000×300×100 m. This height indicates that the fold of the Productive Layer in the Garadag region has been significantly stretched from the arch section southeastwards by 2200 m.

The edge southeast fold is separated from the central uplift by an inclined saddle. It measures 6500×800×250 m at the 2400 m isoline.

All three described local uplifts are aligned along the same axis. The southwest wing (20-25°) is steeper compared to the northeast wing (16-19°). Along the fold axis, along the southwest part of the arch, the Umid "jar" extends as a fault-like longitudinal fault related to the mud volcano.

The mud volcano is located at the arch-flank of the Central-Umid fold and is clearly expressed as a "jar" with a 20 m isobath in the seabed relief.

At the location of the volcano, the sea depth is 6 m. The subsidence process at the seabed in the southeast direction has been relatively intense.

The Babak uplift is situated in the depression zone southeast of the Bulla-Sea deposit. The Babak fold is described as a long anticlinal fold extending in a northwest-southeast direction. It measures 36×8 km according to the 3000 m isohypse (upper part of the Productive Layer). The southwest wing of the fold is steeper compared to the northeast wing.

The Babak zone is in the open sea, 58 km from the coast, in the center of the Baku Archipelago, at the boundary of the shelf and continental slope (in depths ranging from 60 to 550 m). A bent structural promontory, 20 km wide, is noted in this area. This morphological element, oriented northwest-southeast, corresponds to the Babak jar anticlinal fold according to the Pliocene sediments.

As is well known, the current oil potential extracted from the Caspian Sea constitutes only a small part of the actual reserves of the basin. A significant discrepancy between the actual values and theoretical calculations can be revealed if a proper evaluation of the oil and gas potential of the Caspian oil-gas province, including the "land-sea" transition zone, is conducted.

The western coast of the Caspian Sea, covering the southwestern part of the Middle Caspian and the northwestern part of the South Caspian, falls within the contact zone of the Eurasian and Gondwana platforms. This area is characterized by various geodynamic development regimes associated with the formation of large oil and gas deposits, as illustrated in (Fig. 1).

In general, the Caspian basin is characterized by three regions:

Northern Caspian-The southeastern edge of the Eurasian platform, characterized by the Upper Paleozoic sedimentary complex, where the Kashagan-Tengiz oil and Astrakhan gas condensate deposits have formed.

Middle Caspian-The western fringe of the Eurasian platform, with the Lower Triassic, Lower-Middle Jurassic, and Lower Cretaceous Mesozoic, as well as Oligocene-Miocene Cenozoic oil-gas complex deposits forming large gas condensate and oil fields.

Southern Caspian-The thin-layered Baikal basement, covered by Mesozoic and Cenozoic sediments, is the northern edge of the sub-oceanic Gondwana platform, according to some researchers (Y.V.Xain, A.A.Aliz-Zadeh, E.B Shikhalibeyli, etc.).

The main oil deposits in the Azerbaijani sector include the Neft Dashlari, Gunashli, Chirag, Azeri, and Kapaz fields in the Pliocene-Aghcagil and Pleistocene-Abseron layers of the Productive Layer (PL). Below the PL, the Shah Deniz gas condensate deposit and Paleogene-Mesozoic oil-rich complexes are found in the Lower Kura Valley (transition zone). Some researchers (A.L.Yanshin et al., 1977; I.A.Qaraqash et al., 1999) have noted that these oil fields were formed on a sub-oceanic crust with a thickness of 10-12 km, and in some places, without a granite layer. The geodynamic development regime, the formation period of structural sector zones, and the diversity of lithofacies features have not only not negatively affected the formation of giant and large oil-gas deposits on the Baikal basement but have even created favorable conditions for their formation.

The lateral heterogeneity of the Caspian basin, especially the correlation of oil-gas formation periods with tectonic-magmatic phases, has become apparent in recent years (A.C. Ismayilzadeh, 2011). The following dependency has been established:

Northern Caspian – Paleozoic oil-gas formation during the Hercynian phase.

Middle Caspian – Mesozoic oil-gas formation during the Kimmeridgian phase.

Southern Caspian – Cenozoic oil-gas formation during the Alpine phase.

Tectonic-magmatic activation, volcanic-plutonic accumulation formations, and the lateral and vertical migration of oil and gas deposits have been observed, indicating a sequential process of "migration-accumulation-storage" as described by A.C. Ismayilzade (2011). The process can be outlined as follows:

In the Azerbaijani sector of the Caspian Sea: Oil and gas complexes are identified from the Upper Cretaceous to the Pleistocene, encompassing the Siyazan Monocline, the Northern Absheron Depression, and the Absheron Archipelago regions within the marginal ocean sea or marginal ocean depression.

In the Baku Archipelago, Gobustan, and the western Lower Kura Depression: This area transitions to the continental margin of the Lower Kura region.

In the Suboceanic or Oceanic Zone: The South Caspian Depression is characterized by suboceanic or oceanic conditions.

In these zones, based on various evolution structures and real-time observations, maximal concentrations of oil and gas are found in the Absheron-Balakhany area within the Productive Series (PS) layers. Notably, major oil fields are concentrated here. Additionally, the giant Shah Deniz gas-condensate field is located northeast of the Baku Archipelago.

Overall, the composition and characteristics of oil in productive areas of Azerbaijan, including the “land-sea” transition zone along the western coast of the Caspian Sea, suggest that the variability in generation and migration processes is closely related to regional tectonic-magnetic activity and the depth of deposit formation. For instance, in the marginal ocean sea or depression of the Caspian-Guba zone, oil complexes such as the Chokrak-Maykop or Paleogene-Upper Cretaceous sediments are dominated by alkanes and aromatic compounds.

In the shelf zone, as the depth increases, the degree of methane formation rises significantly, and the oil capacity (e.g., Cheyldag, Rahim) transitions from naphthenic to methane (e.g., Dashgil, Kenizdag). The oil traps in the Baku Archipelago, located at greater depths, exhibit high levels of methane formation (Fig.2 and 3).

The role of endogenous processes related to the deep geological structure is undeniable in the formation of the fluid-dynamic system of the study area.

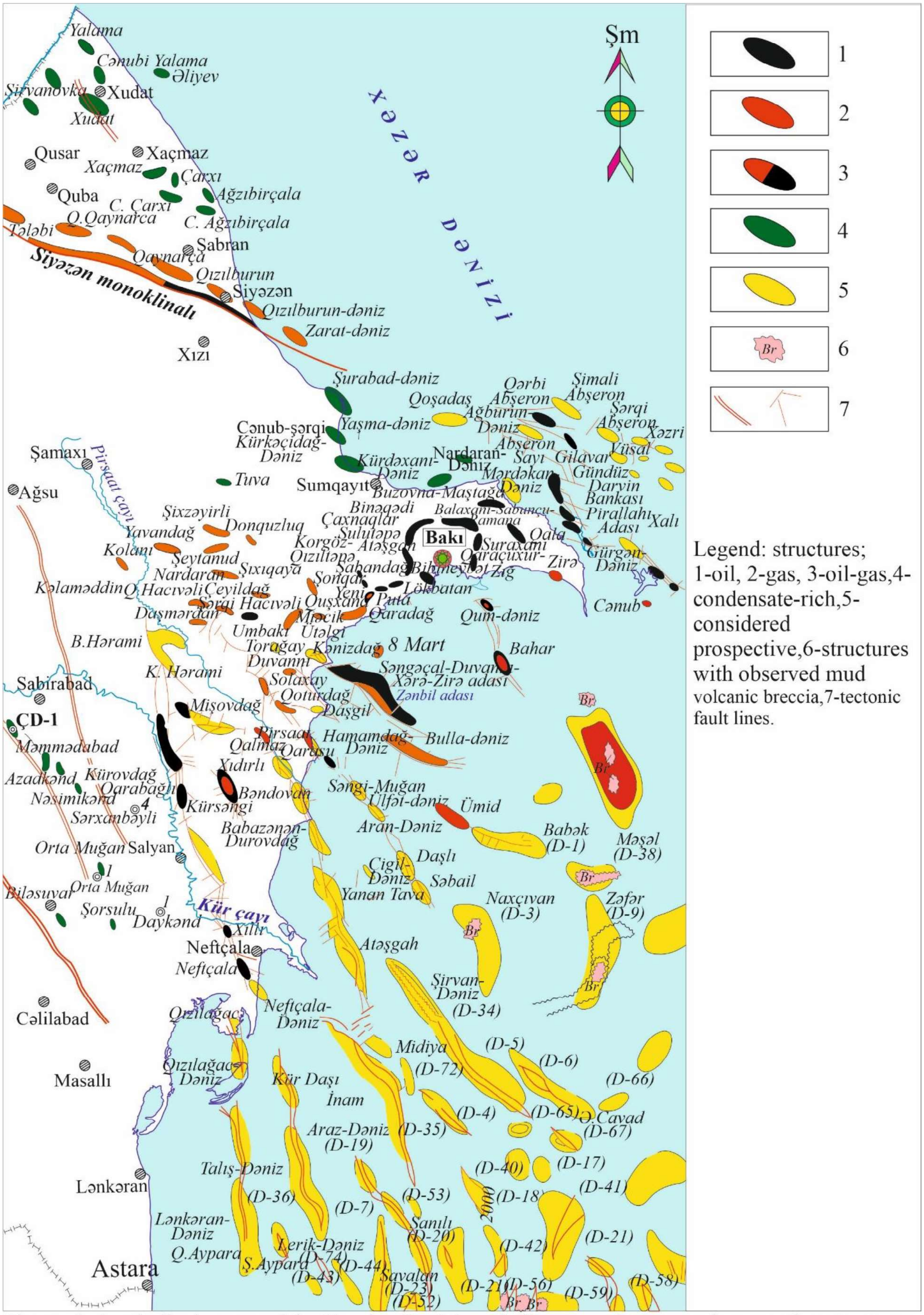

Figure. 1. Azerbaijani sector of the Caspian Sea.Map of oil-gas-condensate andprospective structures

The Caspian Basin, particularly the western coast of the South Caspian within the “land-sea” transition zone, is believed to belong to an ancient riftogenic province. This suggests that the traps concentrated in the western part of the basin, which are governed by products migrating from deep layers, are influenced by tectonic-magmatic activation (A.C.Ismayilzade, 2011). Neotectonic movements also play a role in this regulation, as recognized by researchers (A.I.Timurzoyev, 2006).

In the South Caspian's western shelf zone (“land-sea” transition zone), a 6-8 km thick continental crust with a decreasing thickness of 2-3 km towards the sea has been identified (F.G.Dadashov, 2006). This zone is characterized by intense mud volcanism, with the size of these volcanoes increasing towards the sea (e.g., Elm, Buz, Abix volcanoes). Additionally, the structural features of mud volcanoes, such as the covering layer above and the screening complex layer below, suggest that these volcanic formations could serve as sources for accumulation.

It is also known that the South Caspian Depression is characterized by a suboceanic or metamorphic "basalt" layer (Fig. 1). This layer's sedimentary complex is likely to be the "source rock" for oil and gas, and newly formed traps may be nourished by this source. It is highly probable that during tectonic-magmatic active phases, lateral and vertical migration of hydrocarbons (HCs) from these traps occurs, supplying surface structures with HC products. Additionally, serpentinization of suboceanic or metamorphic "basalt" layers may also supply surface structures with HC products.

In the Lower Pliocene, at a depth of 6-7 km in the "Fasila" suite of the Productive Series (PS), the giant gas-condensate Shah Deniz field is characterized by a methane-dominant composition with high temperatures typical of 10-12 km depth. This feature is likely related to the tectonic-magmatic activity specific to the Baku Archipelago region, indicating that the HCs are primarily in a migration state. The absence of formation phases or very short periods of HC generation suggests that the Shah Deniz field is a completely independent structure where HC products can only migrate from deep layers.

Regardless of the composition, whether granite or basalt, the tectonic block structure of the basement in the South Caspian Basin creates conditions without a screening layer for the formation of giant oil-gas-condensate fields. Additionally, the mentioned block-folding, oriented along the Alp-Himalayan tectonic belt, is associated with the alignment of the region's giant oil fields within this zone.

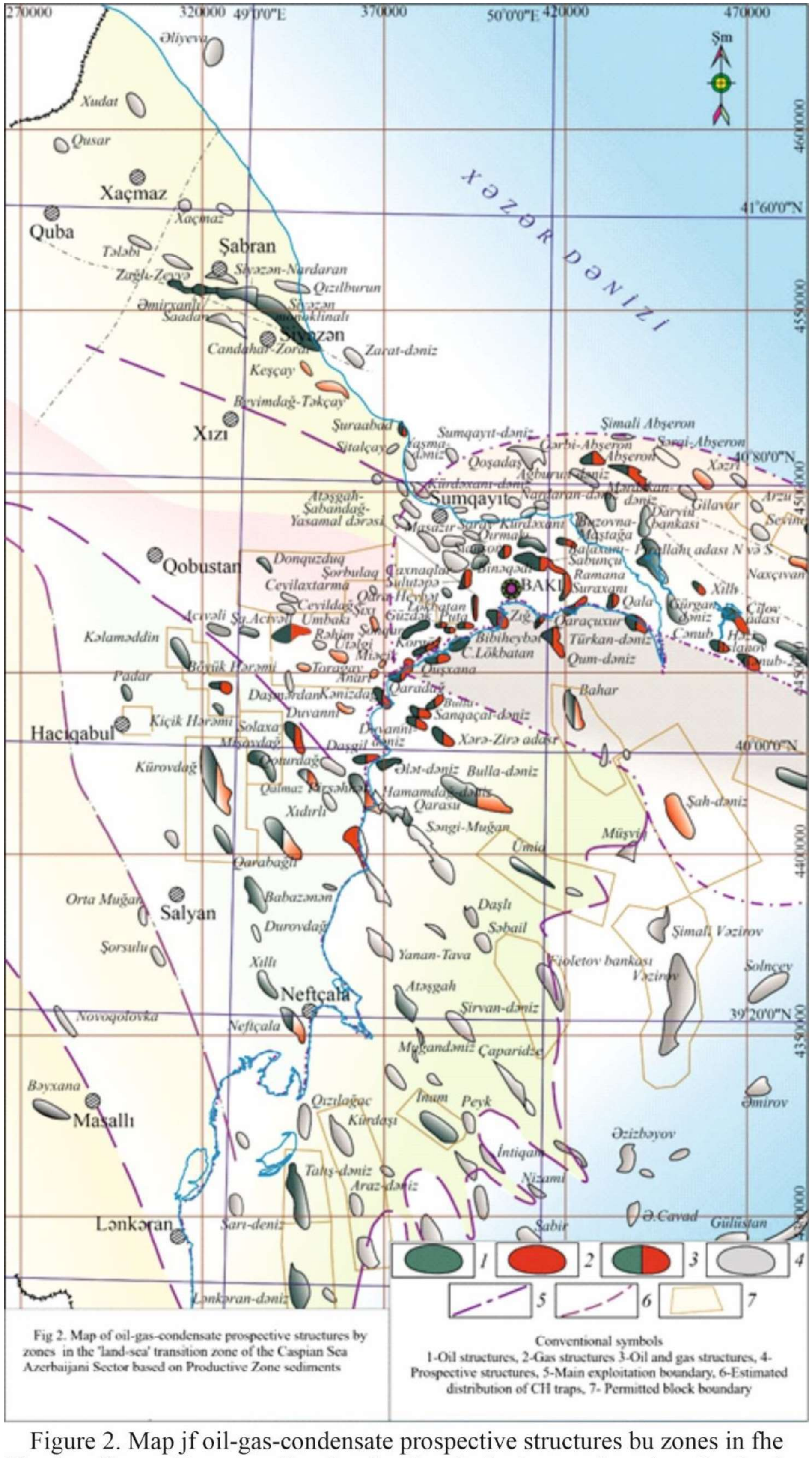

Figure 2. Map jf oil-gas-condensate prospective structures bu zones in fhe "land-sea" transition zone Caspian Sea Azerbaijani sector besed on Productive Zone sediments

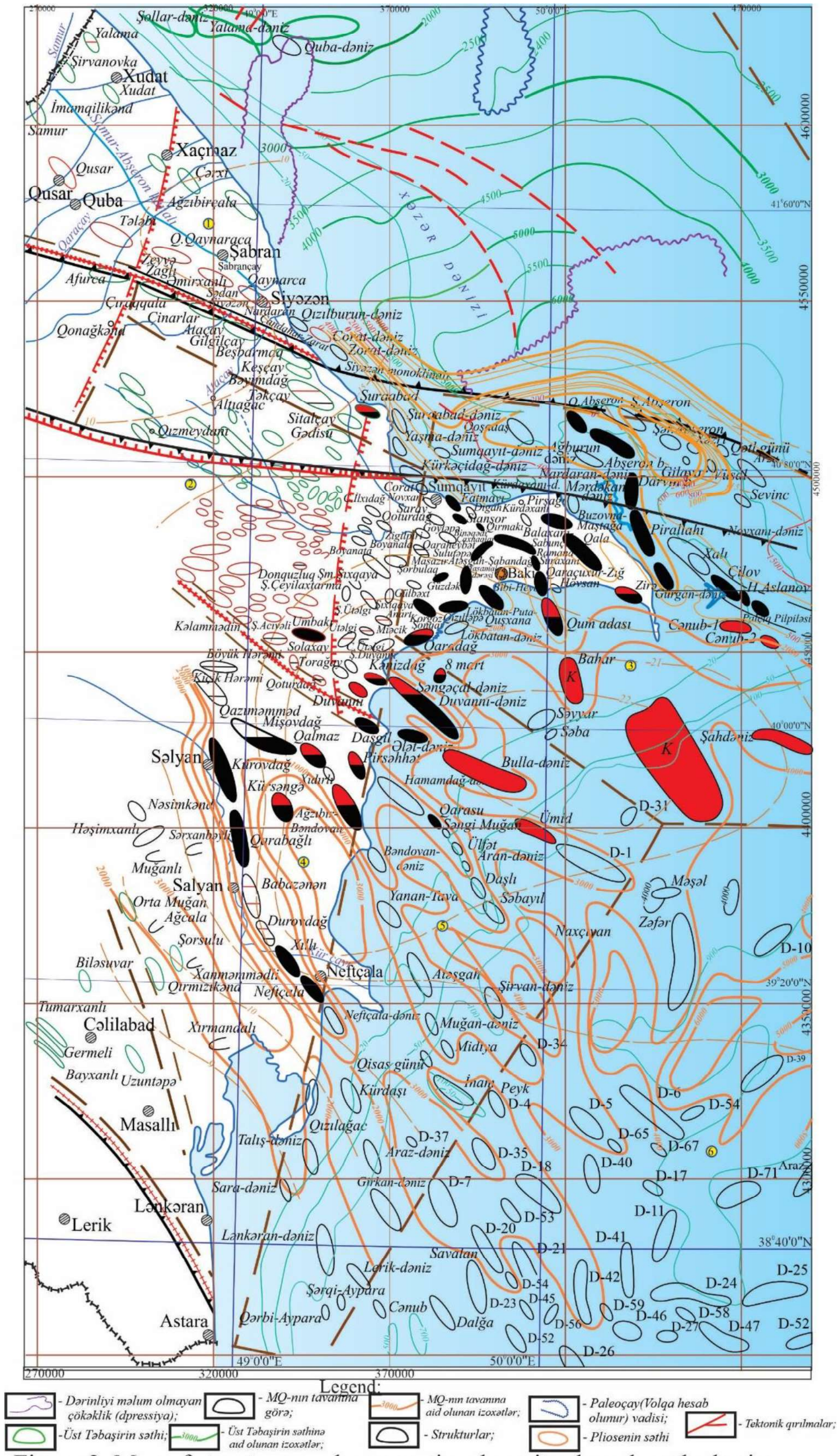

Figure 3. Map of structures and prospective deposites based on the horizon of the Productive Series and Upper Mezozoic sedimentes in the "land sea" transition zone along the western coast of the Caspian Sea.

Regarding the western coastal "land-sea" transition zone, it should be noted that the thick continental crust of the Baku Archipelago, Eastern Gobustan, and Lower Kura areas plays a screening role in the migration path of HCs. Therefore, it is quite convincing that HC migration and generation in the Paleogene-Lower Miocene and Middle-Late Miocene periods occurred solely due to tectonic faulting. This presents a significant obstacle to the formation of giant fields.

Conclusions

Thus, by summarizing what was briefly explained above, the following conclusions can be reached:

1. Considering that the South Caspian Sea basin, including the western coastal "land-sea" transition zone, belongs to the ancient riftogenic Barents-Iran Gulf oil-gas belt in a submeridional direction, it can be inferred that the formation and development of HC fields are correlated with tectonic-magmatic activation phases.

2. Given that the basement of the South Caspian Sea basin, including the western coastal "land-sea" transition zone, is characterized by consolidated layers, it is likely that oil-gas-condensate fields formed and developed in the Maykop and Diatom-aged sedimentary complexes.

In the western coastal "land-sea" transition zone around the Baku Archipelago, industrially significant oil structures are presumed to result from tangential movements along the collision (subduction) boundaries of lithospheric plate contact zones, with HC migration from deep layers facilitated by tectonic faults.

Conflict of Interest

The authors declare that they have no conflict of interest in relation to this research.

References

1. Babaev, D.Kh., and Gadzhiev A.N. Deep structure and prospects for oil and gas potential of the Caspian Sea basin, Baku, “Nafta-Press”, 2006. 305 p.

2. Geology of Azerbaijan. Tectonics, Publishing House “Nafta-Press”. Baku, 2005. Vol. IV

3. Geology of the USSR. Volume XLVII. Azerbaijan SSR. “Minerals”,Moscow, “Nedra”, 1976, 404 p.

4. Glumov, I.F., Malovitsky, Ya.P., Novikov A.A., and Senin B.V. Regional geology and oil and gas potential of the Caspian Sea., Moscow, Nedra-Business Center LLC, 2004, 342 p.