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Meso-Cenozoic Hydrocarbon Potential in the Azerbaijan Sector of the Southern Caspian Sea

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Abstract— This paper presents Meso-Cenozoic hydrocarbon potential in the Azerbaijan sector of the southern Caspian Sea.

***Index Terms*— meso-cenozoic, South Caspian, productive series, hydrocarbon, folding, land-sea.**

1. Introduction

As is known, the oil potential extracted from the Caspian Sea so far constitutes only a small fraction of the region's actual reserves. If the petroleum and gas potential of the geological structures in the Caspian oil and gas province is accurately assessed including the "land-sea" transition zone, it becomes evident that there is a significant discrepancy between actual evaluations and theoretical calculations.

The western coastal area of the Caspian Sea—the southwestern Middle Caspian and northwestern South Caspian—encompassing the Azerbaijani sector, is part of the contact zone between the Eurasian and Gondwana platforms. This zone is characterized by a diverse geodynamic development regime that is conducive to the formation of massive oil and gas fields, as illustrated in Fig. 1, 2.

In general, the Caspian Basin is characterized by three distinct regions:

1) *Northern Caspian:* Located on the southeastern edge of the Eurasian platform with a pre-Baikal basement and Upper Paleozoic sedimentary complex, hosting oil fields such as Kashagan-Tengiz and gas-condensate fields like Astrakhan.
2) *Middle Caspian:* Representing the western margin of the Eurasian platform or the northwestern edge of the Turan plate, this region features a Hercynian basement with oil and gas complexes from the Lower Triassic, Lower-Middle Jurassic, Lower Cretaceous Mesozoic, and Oligocene-Miocene Cenozoic eras, forming large gas-condensate and oil fields.
3) *Southern Caspian:* With a thin-layered Baikal basement and a sub-oceanic crust covered by Mesozoic and Cenozoic sediments, this region is linked to the northern edge of the Gondwana platform, according to researchers such as Y.V. Khain, A.A. Alizade, and E.B. Shikhalibeyli.

Key oil fields in the Azerbaijani sector include Neft Dashlari, Gunashli, Chirag, Azeri, and Kepez, which are located in the Pliocene-Aghjagil and Pleistocene-Absheron stages of the Productive Series (PS). Beneath the PS lies the Shah Deniz gas-condensate field, as well as oil-saturated complexes from the Paleogene-Mesozoic era, found in the Lower Kura Valley (transition zone). Some researchers (e.g., A.L. Yanshin, 1977; I.A. Karakash, 1999) have suggested that these oil fields are formed over a sub-oceanic crust up to 10–12 km thick, sometimes lacking a granite layer.

The diversity in geodynamic development regimes, structural sector zones, lithofacies features, and formation periods has not only had no negative impact on the formation of giant oil and gas fields over the Baikal basement but has actually created favorable conditions for their development.

The Caspian Basin's lateral heterogeneity, particularly the correlation of hydrocarbon generation periods with tectonic-magmatic stages, has recently been elucidated (A.C. Ismayilzade, 2011). The following dependency has been identified:

- *Northern Caspian:* Paleozoic hydrocarbon generation during the Hercynian phase.
- *Middle Caspian:* Mesozoic hydrocarbon generation during the Kimmerian phase.
- *Southern Caspian:* Cenozoic hydrocarbon generation during the Alpine phase.

Tectonic-magmatic activation, the formation of volcanic-plutonic assemblages, and the lateral and vertical migration of hydrocarbons have accompanied the sequential processes of hydrocarbon formation, which follow a "migration-accumulation-concentration" sequence, as described by A.C. Ismayilzade (2011).

The Azerbaijani sector of the Caspian Sea encompasses hydrocarbon complexes from the Upper Cretaceous to the Anthropocene, situated across three geodynamic zones:

1) The marginal oceanic basin, including the Siyazan monocline, the North Absheron depression, and the Absheron archipelago regions.
2) The Lower Kura regions, transitioning into the continental slope of the Kura depression.

The sub-oceanic or oceanic zone of the South Caspian depression.

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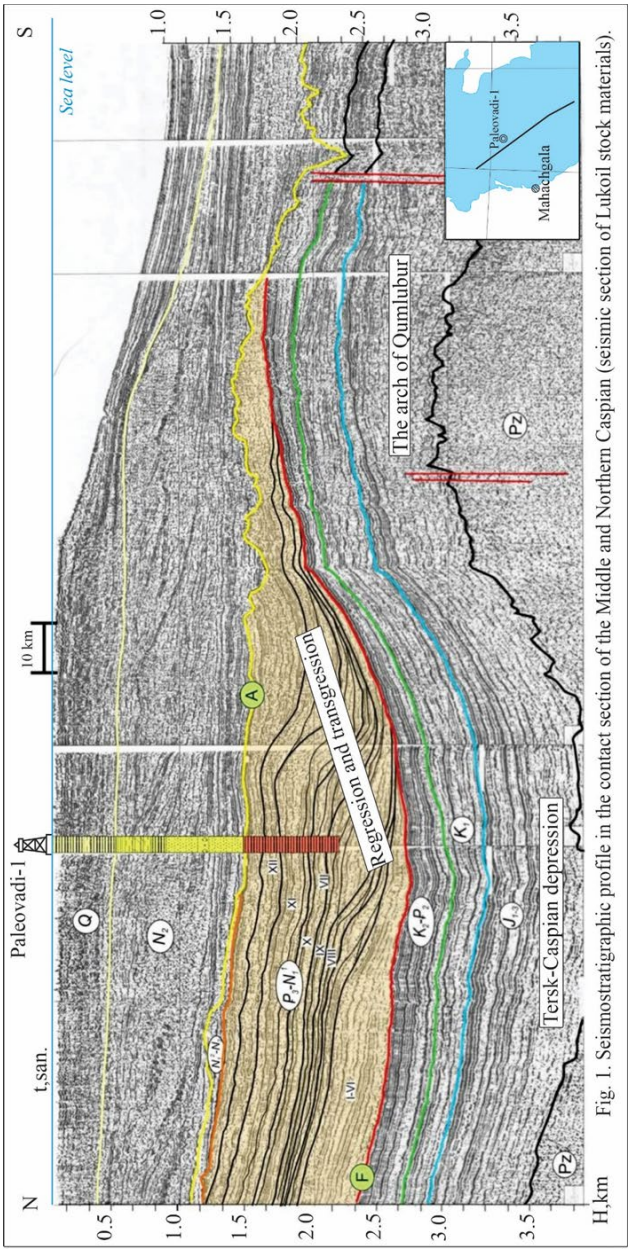

Fig. 1. Seismostratigraphic profile in the contact section of the Middle and Northern Caspian (seismic section of Lukoil stock materials).

Fig. 1.

Maximum oil and gas concentrations are located in the Absheron-Balkhan threshold's Productive Series layers, where large oil fields are found. In the northeast of the Baku archipelago, the giant Shah Deniz gas-condensate field is situated.

The composition and characteristics of oil in Azerbaijan's oil and gas regions (OGR), particularly in the "land-sea" transition zone along the western coast of the Caspian, suggest that the accumulation processes are directly related to tectonic-magmatic activity and formation depth.

In the Caspian-Quba region, characterized by an oceanic sea or depression, within the Siyazan monocline, which is considered an oil-gas complex, alkanes and aromatic compounds dominate the oil fraction in the Chokrak-Maykop or Paleogene-Upper Cretaceous sediments.

In the shelf zone, as the hypsometric depth increases, the degree of methanization notably rises, and the oil-bearing capacity (Cheildag, Rahim) transitions from naphthenes to methane (Dashgil, Kenizdag).

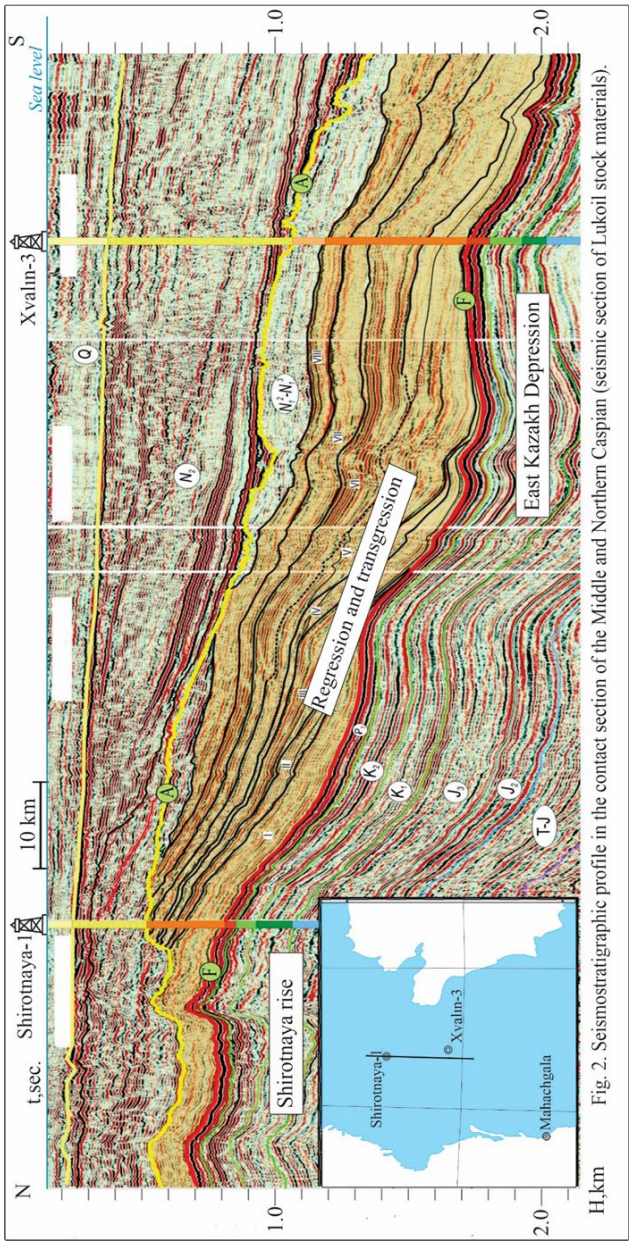

Fig. 2. Seismostratigraphic profile in the contact section of the Middle and Northern Caspian (seismic section of Lukoil stock materials).

Fig. 2.

The oil traps of the Baku Archipelago are located under conditions of great depth, and the methanization within the hydrocarbons is high.

The role of endogenous processes related to the deep geological structure in the formation of the fluid-dynamic system of the research area is an indisputable factor.

It is suggested that the Caspian Basin, especially the "land-sea" transition zone along the western coast of the South Caspian, belongs to the ancient riftogenic province (Xain V.Y., 1998), which is part of the oil and gas-bearing Barents-Iran Gulf belt. This implies that the traps concentrated in the western part of the basin's structures, and the hydrocarbon products migrating from deep layers, are regulated during tectonic-

magmatic activation (A.C. Ismailzade, 2011). The role of neotectonic movements in this regulation process is also acknowledged by researchers (A.I. Timurzoev, 2006).

In the western shelf zone of the South Caspian ("land-sea" transition zone), a continental layer with a thickness of 6-8 km, which decreases to 2-3 km towards the sea, has been identified in the Lower Kura valley (F.Q. Dadashov, 2006). According to studies, this zone is characterized by intense mud volcanism, and the size of these volcanoes increases towards the depths of the sea (Elm, Buz, Abikh volcanoes).

Moreover, the structural features of mud volcanoes, such as the cover on top and the potential to play the role of a sealing complex layer beneath, along with the collector properties of the Eocene-Miocene sediments, suggest that mud volcanoes may be an accumulation source.

It is also known that the South Caspian depression is characterized by a suboceanic or metamorphic "basalt" layer (Fig. 1). It can be assumed that this sedimentary complex may be the "oil-source" and the newly formed traps may be nourished by this "source". During tectonic-magmatic active phases, it is highly probable that lateral and vertical migration from these traps would occur, providing the overlying structures with hydrocarbon products. Additionally, the serpentinization of the suboceanic or metamorphic "basalt" layers could also supply the overlying structures with hydrocarbons.

Below the Pliocene, at a depth of 6-7 km – in the "Fasila" set of the PS – the giant gas-condensate "Shah Deniz" field, which has high-temperature characteristics at 10-12 km depth, is dominated by methane in its hydrocarbon composition. This feature likely corresponds to the hydrocarbon release state in the Baku archipelago region, related to tectonic-magmatic activation. The absence or very short phases of hydrocarbon generation suggests that the gas-condensate "Shah Deniz" field is an entirely independent structure, and hydrocarbons can only migrate from deep layers into this trap.

Regardless of composition, whether granite or basalt layers, the tectonic fault-block structure of the basement in the South Caspian Basin creates conditions for the absence of a sealing layer in the formation of giant oil-gas-condensate fields. Furthermore, the fact that this fault-blocking structure extends in the direction of the Alp-Himalayan active zone corresponds with the alignment of the region's giant oil fields along this zone.

When addressing the western coastal "land-sea" transition zone, it is essential to note that the thick continental layer in the Baku Archipelago, Eastern Gobustan, and the Lower Kura regions, acting as a barrier to hydrocarbon migration, plays a screening role. Therefore, during the Paleogene-Lower Miocene and Middle-Late Miocene periods, hydrocarbon generation and migration likely occurred solely through tectonic fractures. This presented a significant obstacle to the formation of giant hydrocarbon fields.

2. Summary of Results

1) Considering that the South Caspian Basin, including the western coastal "land-sea" transition zone, is part of the submeridional ancient riftogenic Barents-Iranian Gulf oil and gas belt, it can be hypothesized that the formation and development of hydrocarbon deposits correlate with phases of tectonic-magmatic activation.
2) Given the consolidated foundation of the South Caspian Basin, including the western coastal "land-sea" transition zone, it is assumed that oil and gas-condensate deposits formed within the Maykop and Diatom sedimentary complexes.

In the western coastal "land-sea" transition zone around the Baku Archipelago, it is believed that industrially significant oil structures formed at the collision (subduction) boundaries of lithospheric plates through tangential movements of two types, with hydrocarbons migrating from deep layers along tectonic fractures (see Fig. 2).

As is well known, the formation and development of oil and gas fields in the Central Caspian, including the "land-sea" transition zone, are associated with the Hercynian phase of the Caucasian orogeny. From a geodynamic perspective, this region is a transitional platform area from a continental-oceanic basin, corresponding to a marginal marine environment, and encompasses the North Absheron trough, which is an integral part of the southern Turan epi-Hercynian plate and the Qusar-Devechi marginal trough. According to data from well № 1 in Agzibirchala, the structure of this zone reveals that Paleozoic substrates typical of the Turan plate (195–242 million years) lie above Triassic-Jurassic andesites (168–188 million years). The southern boundary of the area is the Absheron-Balkhan threshold. Known deposits within the Turan plate indicate that oil-gas-bearing complexes belong to Early Mesozoic (Jurassic-Aalenian, Bajocian, Bathonian, Kimmeridgian, Tithonian) and Early Cretaceous (Neocomian) sediments. The hydrocarbons in these regions differ in their physical-chemical properties compared to other areas, with Miocene oil resembling Tithonian oil (V. Gelman, V. Paduchik, V. Chernov, B. Solntsev, 2002). It is believed that hydrocarbons migrated extensively in heavily dislocated structures under specific fluid pressures, with the Miocene complex in the "land-sea" transition zone serving as a screen. The structural heterogeneity of the Upper Alpine structural layer is related to the tectonics of the pre-Alpine foundation of the Central Caspian.

3. General Observations

Overall, the Caspian Sea basin, characterized as a continental oil and gas formation basin and a heterogeneous depression, intersects various geostructural elements, including the Alpine geosynclinal fold system and the epi-Hercynian platform (Turan plate) (see Fig. 2 and 3). Despite numerous scientific studies dedicated to the Caspian Sea, especially the "land-sea" transition zone, many issues regarding the geological structure and development history of the region remain unresolved.

This particularly affects to the inherited relationship of sedimentary structures in the western coastal "land-sea" transition zone, especially in the Central Caspian. Additionally, until recently (1980s–1990s), accurate data on the upper layers of sedimentary strata were unavailable, leading to uncertainty in interpreting the geological development and structural-

tectonic characteristics of the Central Caspian and its western coastal "land-sea" transition zone.

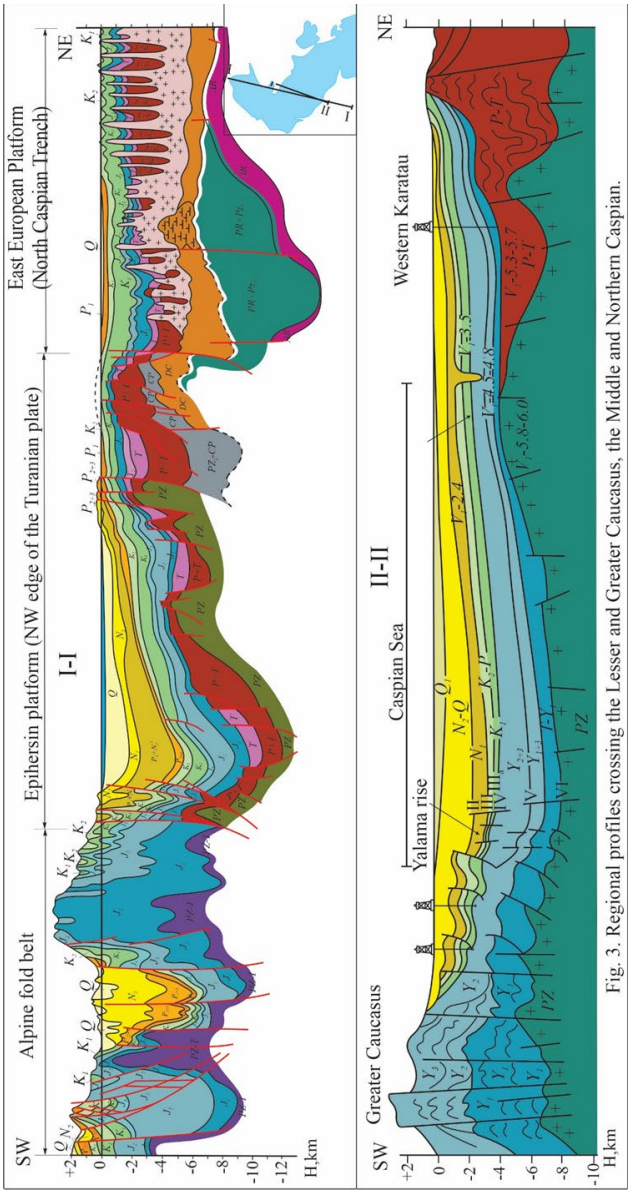

Fig. 3. Regional profiles crossing the Lesser and Greater Caucasus, the Middle and Northern Caspian.

Fig. 3.

Seismic exploration using gravity-magnetic and UD methods conducted by organizations like the "Xəzərdənizneftqazgeofizkəşfiyyat" center (F.G. Rahimkhanov, D.X. Babayev, 1980–1990) partially clarified the deep and surface structural-tectonic features of the Caspian Sea. However, due to the steep coastline, coastal areas remain insufficiently studied.

In addition, it has been determined that the Middle Caspian is heterogeneous in composition and origin, while the western coast of the Middle Caspian region is characterized by a complex meso-Cenozoic folding. The study area is located within the Tersk-Caspian marginal depression and the Absheron-Pirallahi fictitious depression, where the foundation is the Turan plate with the Epihersin platform, transitioning from an uncertain geosynclinal folding to a platform structure. These various and complex tectonic elements not only provide a platform structure to the western coastal "land-sea" transition zone but also further prove the heterogeneity of the zone due to its evolutionary development. It enhances the likelihood of the zone being a prospective area for oil and gas deposits based on tectonic criteria, as indicated in regional profiles (Fig. 2).

Based on tectonic criteria, the prospective nature of this zone for oil and gas accumulation is further confirmed by the results of high-precision complex geophysical research conducted by the "Lukoil" company in the Central Caspian Sea in 2012 (Fig.3). The cross-sections mentioned are taken from the foundation materials published by "Lukoil" in literature sources. Geographically, the profiles are located at the boundary between the Central and Northern Caspian regions and cover the western coastal "land-sea" transition zone in the research area. They also reflect the Tersk-Caspian basin, the Kumluburun arch (Fig. 3), as well as the Shirotnaya uplift and the western margins of the Eastern Kazakh depression.

These cross-sections provide new insights into the role of Meso-Cenozoic folding in the formation of oil and gas fields while reinforcing the hypothesis that the region's deep structure and tectonic criteria positively influenced the formation of hydrocarbon traps and reservoirs.

In summary, oil and gas basins formed during the Mesozoic era have retained their original geometric shapes into the Cenozoic era. However, during the Paleogene-Miocene period, the basin underwent significant impacts from endogenous and exogenous processes, with regression and transgression features, as well as the role of paleo-rivers in sediment deposition, clearly expressed in cross-sections (Fig. 3).

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