

AN INTEGRATED ANALYSIS OF HYPOTHESES ON THE FORMATION AND DISTRIBUTION OF HYDROCARBON POTENTIAL IN THE SOUTH CASPIAN BASIN

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Abstract

This article presents an integrated analysis of existing hypotheses on the formation and distribution of the hydrocarbon potential of the South Caspian Basin. The basin is characterized by high tectonic complexity, extreme thickness of the sedimentary cover, active geodynamic processes, and significant oil and gas reserves. Despite a long history of research and active development of the region, the mechanisms of basin formation and patterns of hydrocarbon distribution remain controversial and ambiguous. Various hypotheses for the basin's origin are considered, including models of rift development, back-arc and residual ocean basins, as well as scenarios of collisional and post-collisional geodynamics. Each of them assumes specific mechanisms of sedimentary cover formation, thermal regime, generation, migration, and accumulation of hydrocarbons, which directly affects the assessment of their potential and spatial distribution. Particular attention is paid to the multifactorial nature of the processes determining the oil and gas potential of the region, caused by the interaction of tectonics, lithological and stratigraphic features, geochemical factors, thermobaric conditions, and fluid dynamics. The analysis aims to systematize and critically evaluate the hypotheses of the formation of the South Caspian Basin with the identification of key factors controlling the distribution of hydrocarbon resources.

Keywords: *South Caspian Basin, hydrocarbon potential, oil and gas potential, integrated analysis, geodynamics, formation hypotheses, spatial distribution of hydrocarbons, multivariate analysis, sedimentary cover, gas export*

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INTRODUCTION

The South Caspian Basin is one of the most unique and complex tectonic and petroleum-geological regions in the world, characterized by an extremely thick sedimentary cover, high sedimentation rates, active geodynamic processes, and significant hydrocarbon potential. Despite a long history of exploration and intensive development, questions about the basin's formation and the patterns of its petroleum potential distribution remain controversial and largely ambiguous.

The scientific literature has proposed a wide range of hypotheses explaining the origin of the South Caspian Basin, including rift models, back-arc basins, and residual ocean basins, as well as scenarios based on collisional and post-collisional geodynamics. Each of these hypotheses suggests different mechanisms for sedimentary cover formation, thermal regime, and hydrocarbon generation, migration, and accumulation, which directly impacts the assessment of hydrocarbon potential and its spatial distribution. The multifactorial nature of the processes determining the petroleum potential of the South Caspian Basin is due to the interaction of tectonic, lithological-stratigraphic, geochemical, thermobaric, and fluid-dynamic factors. The lack of a unified approach to their comprehensive assessment leads to discrepancies in the interpretation of the basin's geological structure and the prediction of the petroleum potential of individual structures and zones.

In this regard, a multifactorial analysis of existing hypotheses on the formation of the South Caspian Basin is urgently needed, taking into account their influence on the generation and distribution of hydrocarbon potential. The aim of this study is to systematize and analytically evaluate the main hypotheses on the basin's formation, taking into account the combined geological and geodynamic factors determining the region's petroleum potential, as well as to identify the key controlling mechanisms for the distribution of hydrocarbon resources [1, 3, 5, 6, 8, 10, 13].

Materials and discussion

The South Caspian Depression is a unique geological structure, comparable in productivity and distinguished by powerful hydrocarbon systems similar to those of the Persian and Mexican Gulfs. The first geological exploration and planning work in the South Caspian megadepression and adjacent areas was carried out by G.V.Abikh, N.I.Golubyatnikov, P.G.Volarovich, I.M.Gubkin, N.I.Usheikin and other researchers. In subsequent years, the following researchers worked to study the geological and tectonic structure and oil and gas prospects of the region: S.A. Kovalevsky, V.A.Sulin, B.G.Babazade, V.A.Gorin, M.F.Mirchink, A.G.Aliyev, A.A.Yakubov, V.S.Malik-Pashayev, V.Yu.Khain, I.I.Potapov, Sh.F.Mekhdiev, A.N.Researchers including Shikhalibeyli, A.N.Alikhanov, A.A.Alizade, G.A.Ismailov, S.Kh.Salayev, F.Kh.Dadashov, N.Yu.Khalilov, F.M.Bagirzade, A.V.Mamedov, F.S.Akhmadbayli, H.B.Yusifzade, K.M.Kerimov, I.S.Hasanov, Yu.Kh.Ganbarov, P.Z.Mamedov, A.A. Narimanov, A.K.Akhmadov, A.M.Akhmadov, A.N.Huseynov, and others participated in large-scale projects. In recent years, Azerbaijan's oil industry has developed rapidly, and significant strategic successes have been achieved. The Caspian Sea's high oil and gas prospects are due to its high hydrocarbon potential, even at great depths [3, 6, 10].

Thus, to improve the efficiency of geological exploration, it is necessary to develop and implement high-quality scientific research methods and approaches, and to restore and utilize effective methods. The relevance of work based on these ideas is obvious. Many scientific papers contain differing views on the age and formation of the South Caspian depression. Analysis and systematization of these papers indicate an insufficient geological substantiation.

In the geological literature, the deepwater part of the South Caspian, where the sedimentary cover is thick, is not recognized as a tectonic unit of the southern part of the Greater Caspian Basin. This area is often referred to as the South Caspian depression. However, this name reflects not only the

geological nature of the deepwater bend but also the newer structure of the same name at the base of the Pliocene-anthropogenic layer. In this case, the older rift-related bend is not distinguished, but is characterized as an area with a completely different tectonic and geodynamic nature and deepwater structure. The evolution of the deep-water Central Ridge is a key factor in the development of the Greater Caspian basin. It should be noted that some scientific studies subdivide the South Caspian depression into separate tectonic structures along the base of Pliocene-Quaternary sediments [1, 5, 8].

In the southern Caspian Sea, the granite layer is not part of the crustal structure, and a thick, weakly deformed sedimentary cover lies on the basaltic layer or oceanic crust. The thickness of this layer is considered by many researchers to be in the range of 15-20 km, with a P-wave velocity of 6.6-7.0 km/s. In the deep-sea depression of the South Caspian Trough, the sedimentary rock thickness is noted to be more than 20-22 km, and in the Apsheron-Chelekan section, it is more than 26-28 km. The latter boundary corresponds to the lower section of Pliocene-Quaternary deposits. The remaining 10-11 km of sedimentary rock thickness, spanning the entire period up to the Lower Pliocene, are usually attributed to the Jurassic-Cretaceous and Paleogene-Miocene sedimentation periods. Here, sedimentation begins with Upper Cenomanian carbonate deposits in a rift-related bend, while the molasse sedimentation cycle begins with an epicontinental regime throughout the South Caspian Basin. It should be noted that the latter has a heterogeneous tectonic structure based on sedimentation, age, and geotectonic development of the substrate. The deep-water central depression of the South Caspian, along with the Absheron-Chelekan and West Turkmenistan bends, constitutes one of the depression's structural units. The formation and complication of the South Caspian Depression occurred during different geological periods, conditioned by different geodynamic conditions.

Researchers explain the formation of the Black Sea and Caspian depressions with two controversial theories of oceanic crust formation. The first theory was put forward based on the results of deep seismic sounding after seismic studies (Rustamov, 2005). Ideas about young depressions that formed at the end of the Miocene and even in the Pliocene-IV period (Muratov, Neprochnov, 1967; Muratov, 1972) were later associated with the new idea of the formation of consolidated crust of inland seas (Yanshin et al., 1980). Yanshin and others explained the youth of the depressions by the expansion and elongation of the upper SiAl layer of the earth's crust. They assumed deep sedimentation of the former continental basement and explained their formation mainly by eclogitization of rocks associated with intense bending. In their opinion, the main reason for the formation of the granite layer of the crust is the subsidence of the basin floor. This idea is similar to the theory of V.V. Belousova (1962) on the formation of oceanic and oceanic crust from the original continental crust [1, 2, 13].

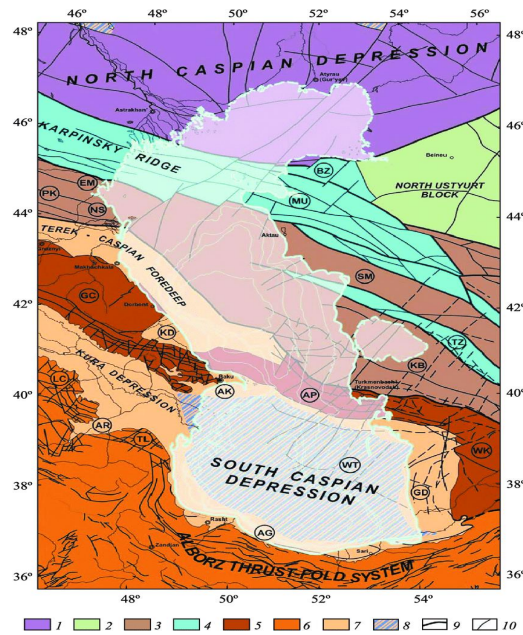


Fig. 1. Main structural elements of the Caspian Sea region: basement of platform areas (1-4) [10]: 1-Early Precambrian; 2-Baikalian; 3-Hercynian; 4-Early Cimmerian; 5, 6-Alpine fold-thrust systems: 5-Greater Caucasus and Kopet Dagh, 6-Lesser Caucasus, Talesh, Alborz; 7-foredeeps and depressions; 8-depressions with oceanic-type crust; 9-tectonic lineaments corresponding to boundaries of large structures; 10-other important lineaments. Main structures (letters in circles): AK-Apsheron-Kobystan Periclinal Trough, BZ-Buzachi Arch, MU-Mangyshlak -Central Ustyurt, SM-South Mangyshlak-Ustyurt system of troughs, TZ-Tuarkyr Zone, KB-Middle Caspian Karabogaz Antecline, EM-East Manych Trough, PK-Kuma system of uplifts, NS-Nogai Scarp, GC-Greater Caucasus Fold System, KD-Kusary-Divichi Trough, AP-Apsheron Balkhan Zone, WK-West Kopet Dagh Zone, LC-Lesser Caucasus Fold System, AR-Lower Araks Trough, TL Talesh Zone, AG-Alborz-Gorgan Foredeep, WT-West Turkmen Trough, GD-Gograndagh-Okarem Zone.

There are also completely opposing views on the formation of the depression, which describe it as a relict layer of the ancient Paleozoic or Early Mesozoic Tethys Ocean (Kornev et al., 1962; Sorsky, 1966; Rakhimov, 1966; Milanovsky, 1968; and others). This result is explained by the great thickness of the sedimentary rocks, which indicates a highly intensive bending process. It is sufficient to note that the fact that the thickness of the Middle Pliocene-IV deposits in the depression is 8-12 km proves the incorrectness of this approach, and therefore it can be said that the above does not correspond to geological reality.

The concept of the primordial oceanic nature of the deep-sea depressions of the Caspian and Black Seas is based on the theory of plate tectonics and the paleotectonic reconstruction of the region (Zonenshain and Le Pichon, 1987). The authors share the same position: the formation of these depressions in the back-arc region of the Lesser Caucasus—the Pontic island arc—is considered the result of rifting and spreading. However, a fundamental difference is noted in their paleotectonic reconstruction, which views the deep-sea folds as remnants of oceanic crust in the marginal basin. This reconstruction is based on the different ages of complex formation and sedimentation of the oceanic crust and the zone in the South Caspian, as well as its distribution and location.

L.P. Zonenshain and K. Le Pichon's reconstructions are based on the idea of a connection between Talysh and Adzhar-Trialet. Furthermore, their proposed geodynamic reconstruction of the region is inconsistent with the geological structure and geotectonic development of the Caucasus, Alborz, and Talysh. At the beginning of the Middle Jurassic, the Greater Caucasus Basin formed with oceanic crust.

It developed in the Late Jurassic and, during spreading, merged not toward the Kopetdag, but toward the rear of the South Caspian Basin. However, the oceanic crust, called the South Caspian marginal sea, merges with the Adzhar-Trialet Basin through the Kursk Depression. They believe this marginal sea reached its maximum size in the Eocene, as evidenced by intense subduction volcanism in the Adzhar-Trialet and South Caspian belts of that period.

A completely different position is taken by Shikhalibeyli et al. (Shikhalibeyli, 1980, 1983) due to the absence of a granite layer at the base of the South Caspian Depression. They believe this region formed as a result of prolonged uplift of the intermediate Gondwana massif under conditions of abrupt tectonic processes during the Early Cimmerian and Hercynian geological periods. This process was accompanied by erosion of the granite layer, and trough-like subsidence occurred along the periphery of the massif. This subsidence of the region was observed with the participation of volcanic products. In some places, the crust was metamorphosed along giant faults and reworked into basaltic layers in the form of inclusions of material compacted within the crust as mantle diapirs. According to Shikhalibeyli et al., it is entirely possible that the area of consolidated crust over the vast territory of the South Caspian Depression consists solely of Jurassic volcanic deposits in its upper portion.

Although researchers hold differing views on the formation of the South Caspian Depression, noting the significant scientific and practical importance of this issue, the primary objective is to determine the age of the upper consolidated crust and the stratigraphic level of the lower sedimentary layer in each geodynamic type of bending of the South Caspian seafloor. The consolidated crust beneath the sedimentary layer formed as a result of multistage changes in the continental crust. It developed during the formation of bends of various geodynamic types in the South Caspian region, up to the collision stage. Regional collision is associated with the manifestation of intense burial of the South Caspian Depression seafloor on a larger scale and subcrustal "erosion" of the crust during the geodynamic stage. On the other hand, these conditions and processes are determined by compacted deep mantle diapirism and the flow of powerful thermal masses in the South Caspian lithosphere. During the initial stage and corresponding to this stage, crustal changes in the Central Fold are associated with the development of subduction-rift structures, namely, the arcuate bend of the transverse segment in the southern Caspian Basin and the intraplate rift of the meridional segment in the central part of the southern Caspian Basin. They border the southern Caspian Sea at the bottom of the molasse basin. A thick Cretaceous volcanic layer and numerous subvolcanic thrust bodies in their axial zone form the roof of the consolidated crust beneath the sedimentary layer of the Upper Cenomanian, Paleogene, and Neogene as a result of metamorphism during the late collisional stage. In contrast, the formation of thinned or suboceanic crust in the northern part of the South Caspian occurred earlier, associated with the development of carbonate-terrigenous flysch of Late Jurassic-Cretaceous age. In later stages, these processes were accompanied by a southward shift of the axial zone and the divergence of the newly formed fold along the South Gobustan-Absheron-Chelekan line along the continuation of the South Absheron ridge.

In this regard, the different ages and geodynamic types of the bends separating at the bottom of the South Caspian Depression are controlled by free deep fault zones. These, in turn, serve as pathways for the transformation of deep flows of hot masses [2, 9, 13].

The study of petroleum systems has been more precise in the South Caspian depression, which is explained by the absence of such systems in the Middle and North Caspian. As noted by Abiha (1863), although oil formation is associated with the remains of ancient organisms, long-term transformation of these substances is necessary. Mendeleev (1869) proposed the carbide hypothesis for oil formation. Since the mid-20th century, most specialists in petroleum geology have accepted the idea of the

organic origin of oil, and Sh.F.Mekhdiev (1969) dismissed the idea of the inorganic origin of oil as historical data. Gubkin (1937) created the history of petroleum geology and put forward a new biogenic concept, showing that the beginning and end of subduction processes in the evolution of the Paleotethys are a fundamental fact in the formation of these deposits.

As early as the late 1970s, a group of scientists adopted the idea of an inorganic origin for oil. The connection between oil and gas formation and the Benioff zone was first proposed by Getberg. This idea was adopted by Thomson, Sorokhin, Ushakov, Fedinsky, Lazarenko, and other scientists, whose quantitative and qualitative indicators were analyzed. According to their theory, oil formation occurs in zones where plates move toward each other at temperatures of 100-400°C. The resulting high pressure causes oil to migrate to the upper layers. This idea is one of the possible explanations for the organic origin of hydrocarbons and is based on the subduction of pelagic sediments in convergent zones of lithospheric plates. According to M.I. Rustamov (2005) believes that the transformation of organic matter located at great depths under high-temperature conditions (400°C and above), the formation of hydrocarbons, and their vertical migration should be considered as factors in the new concept of the origin of oil and the formation of mud volcanoes. According to Sh.F.Mekhdiev (1985), oil and gas-bearing formations are also centers of degassing on the Earth. This idea refutes previous ideas about the deep-biogenic origin of oil. These centers are located at different depths in the lithosphere; as a result of the flow of thermal masses, centers of hydrocarbon, oil, and gas generation are formed.

According to some researchers (Mekhdiev, Khalilov, Mamedov, Nikishin, and others), the subduction process is directed northward on the southern slope of the Greater Caucasus, while others (W.Gealey, Jacobson, Rodkin) believe that subduction processes continue in modern times, but are directed southward. However, a southerly subduction direction is not supported by seismic tomographic sections with varying thicknesses of consolidated crust [11, 12, 13].

Two main mechanisms for the formation of oil and gas are proposed: rifting and subduction-obduction. The formation of oil and gas fields is typical for subduction zones located along the edges of oceans and for zones of continental collision during the closure of ocean basins. The length of active zones is approximately 40,000 km, and the average thickness of the oceanic sedimentary layer is 500 m. Approximately 3 billion tons of sedimentary material are deposited annually under island arcs and active continental margins at an average rate of 7 cm. Assuming that the average organic matter content in ocean sediments is 0.5%, and the hydrocarbons released from them are 30%, then approximately 5 million tons of hydrocarbons are formed annually in subduction zones. Under the accepted conditions, hydrocarbon reserves are expected to form in the amount of $2.5-3 \times 10^{15}$ tons throughout the Phanerozoic (the last 500–600 million years).

The abundance of faults in the active zone and the location of hydrocarbon reserves on these faults are largely distributed in time and space. Thermal destruction of pelagic sediments in burial zones plays a significant role in methane formation, with some methane escaping into the atmosphere.

Under the influence of the subduction-obduction mechanism, oil and gas accumulation peaks during the final period of ocean closure. Two main mechanisms leading to hydrocarbon formation in plate convergence zones are distinguished. The first is the burial of an oceanic plate beneath continents or island arcs (subduction), and the second is the formation of an island arc or continent over the passive margin of another continent (obduction). The second mechanism is superior to the first in terms of oil and gas production. This explains the high oil and gas content at platform margins, along with folded systems. In a geological sense, these are the frontal bends and lateral slopes of platforms.

The rift-based model of oil and gas formation assumes the accumulation of a thick sedimentary layer (10-12 km) in continental settings, followed by intercontinental seas. Stagnant sedimentation creates conditions for the formation of clayey rocks. High heat flow activates the conversion of organic products into droplet-shaped oil. A significant advantage of the rift-based and subduction-obduction models of oil and gas formation is that they determine the mutual exchange of fluids between the surface and deep layers. This creates favorable conditions for hydrothermal methane synthesis in the lower layers of the Earth's crust [4, 7, 14].

Table 1.

Factors affecting the hydrocarbon potential of the south caspian basin

No	Factor	Type of Influence	Impact on Hydrocarbon Potential
1	Tectonics	Deformation, rifting, collisions	Determines structural traps and migration pathways
2	Litho-stratigraphic characteristics	Thickness and composition of sediments	Controls hydrocarbon generation and accumulation
3	Geochemical parameters	Organic matter content, maturity	Affects the quantity and quality of hydrocarbons
4	Thermobaric conditions	Temperature and pressure	Defines zones of hydrocarbon generation and degassing
5	Fluid dynamics	Groundwater and gas flows	Controls migration and spatial distribution of resources

If there is an explanation of the formation of the South-Caspian Depression on a geodynamic basis, then the search for hydrocarbons here is favorable and should be based on the model of its formation and development (taking into account the oceanic basin, the relationship of the hydrocarbon complex with individual structural elements). The South-Caspian depression plays an important role in oil and gas formation as a rift basin (15% of hydrocarbons belong to it); On the other hand, the South-Caspian depression is explained by its belonging to plate convergence zones. Thus, its northern part is buried under the Scythian-Turanian plate (80% of hydrocarbons belong to this zone). Subduction processes of various directions in the Southern Caspian are associated with the evolution of the flysch depression in the Cretaceous period. On the other hand, seismotomography data confirm the activation of plume tectonic processes along deep faults. Deep faults are recorded along the Absheron threshold and the center of the South Caspian depression and are divided into age categories according to different geodynamic and tectonic faults. In the period of collision in the South-Caspian Depression, interrelated deep processes of different intensity are restored, diapirism is formed in the mantle and the movement of fluid thermal masses occurs.

In the period after the late Cimmerian tectonogenesis, the rate of subduction of the Greater Caucasian Basin decreased to the north, and flysch transformation occurred. Due to this, the Katekh-Vandam zone and its eastern continuation, buried in the Caspian Sea, from the Albian to the lower Senonian stage turned into a riftogenic subalkaline basaltic mechanistic zone. The spread of volcanism in this area occurs in the southern direction in accordance with the speed of subduction in the conditions of

the activity of deep transverse meridional and longitudinal faults directed to the east. This process covers the Hercynian period and corresponds to intraplate subduction-surface riftogenesis in the Southern Caspian. This period is also accompanied by the formation of the Pontic-Malo-Caucasus-Albor island arc belt. The island arc zone, which includes transitional massifs and their northern edges, enters a stable mode of geodynamic and geotectonic development at the end of the Late Cretaceous period. At this time, carbonate accumulation occurs in shallow waters. Terrigenous depressions in this area are subject to folding in each of them, forming antiform and syncline structures and diapirs. Since the stretching direction of these structures is different, this is a very important evidence of the absence of subduction in the South-Caspian depression, as well as in the Kursk depression. For this reason, the thick sedimentary rocks of the South-Caspian depression are differentiated according to the folding direction in accordance with the tectonic plan. The folds were formed in a sedimentary layer of Toar age more than 14 km thick.

Thus, during the formation of thick terrigenous complexes in the Cenozoic, intense sedimentation was accompanied by completely different geodynamic processes. The analogy of molasse deposits in deep-sea depressions is inconsistent with the collisional stage of the Caspian Sea's evolution. Thus, the formation of oil and gas fields in the Southern Caspian is not supported by the subduction theory (M.I. Rustamov, 2005).

There are other explanations for the formation of oil and gas fields within the theory of plate tectonics. Therefore, there is no need to dwell on radical concepts that link the source of hydrocarbons to the mantle and the formation of oil solely to inorganic origins [2, 11, 12, 13].

Table 2.
Summary of basin formation hypotheses and their impact on hydrocarbon potential

№	Hypothesis	Main Mechanism	Influence on Sedimentary Cover	Influence on Hydrocarbon Distribution	References
1	Rift model	Crustal extension, rifting	Formation of thick sedimentary sequences in rift depressions	Concentration of hydrocarbons in gravity-closed zones	Eppelbaum et al., 2020
2	Back-arc model	Subduction and back-arc basin development	Localized sedimentary depressions	Hydrocarbon distribution along arc structures	Kaveh-Firouz et al., 2023
3	Residual oceanic basin	Remnants of oceanic crust	Sedimentary cover with heterogeneous thickness	Hydrocarbon accumulations in subsiding troughs	Feyzullayev et al., 2021
4	Collisional / post-collisional model	Compression, folding	Deformation and disruption of sedimentary cover	Accumulation of hydrocarbons in structural traps	Abdullayev et al., 2024

In the geodynamic approach to solving this problem, the formation of oil and gas fields is explained by classical theory. Gubkin's term "source horizon" has been replaced in modern theories by the term "oil

and gas basin." Therefore, a number of lithological-stratigraphic formations, independent oil and gas systems, are distinguished within the sedimentary cover of each oil and gas province.

It should be noted that, in light of the above, the concept of an oil and gas system, as used in the Caspian Basin example, is used without regard to geodynamic factors. Thus, basin evolution, geological history, sedimentation stages, and deep-seated geological and geophysical parameters are not considered.

Comprehensive geological and geophysical studies aimed at reconstructing the basin's geodynamic evolution in the Paleozoic, Mesozoic, and Cenozoic have not been conducted in this region. For this reason, theoretical aspects of the geodynamics of rift zones and inland seas have not been considered. The geodynamic background explains the mechanisms of oil and gas field formation when forecasting the oil and gas potential of the Caspian region.

The oil and gas complexes that formed in the Paleotethys, Neotethys, and Mesotethys are associated with various lithological stratigraphic complexes, and on this basis, new oil and gas systems can be identified. A system (Rustamov 2005) is defined as a specific plate tectonic structure located along deep faults, exhibiting various geodynamic types and ages. The multistage evolution of these systems is expressed in the formation of basins, accompanied by subsidence of sedimentary rocks. The activity of these systems occurs under conditions of active thermal masses. Under high thermobarodynamic conditions, various deep crustal and mantle processes interact with the geodynamic evolution of the region and share common genetic and structural-spatial relationships [2, 8, 13].

Table 3.

Thermo-baro-dynamic conditions and hydrocarbon generation zones

No	Zone	Depth, km	Temperature, °C	Pressure, MPa	Type of Generation	Main Fields
1	Upper Sedimentary Cover	0–5	50–120	5–15	Gas and light oil	ACG
2	Middle Sedimentary Cover	5–10	120–180	15–30	Main oil generation	Shah Deniz
3	Lower Sedimentary Cover	10–15	180–250	30–45	Gas condensate	Local deep traps

On the other hand, geodynamic analysis of the Caspian oil and gas regions shows that oil and gas systems with high potential are formed as a result of the activation of deep basement faults. This activation occurs even in platform regions and is accompanied by the formation of large-scale basins above the fault. It is in such regions that the spontaneous conversion of organic matter into oil under natural thermal conditions is impossible. The following oil and gas systems associated with deep faults are identified in the South Caspian oil and gas region: the Absheron depression, the Central-South Caspian depression system, and the Caspian depression located along the Gyurgan-Messer deep fault.

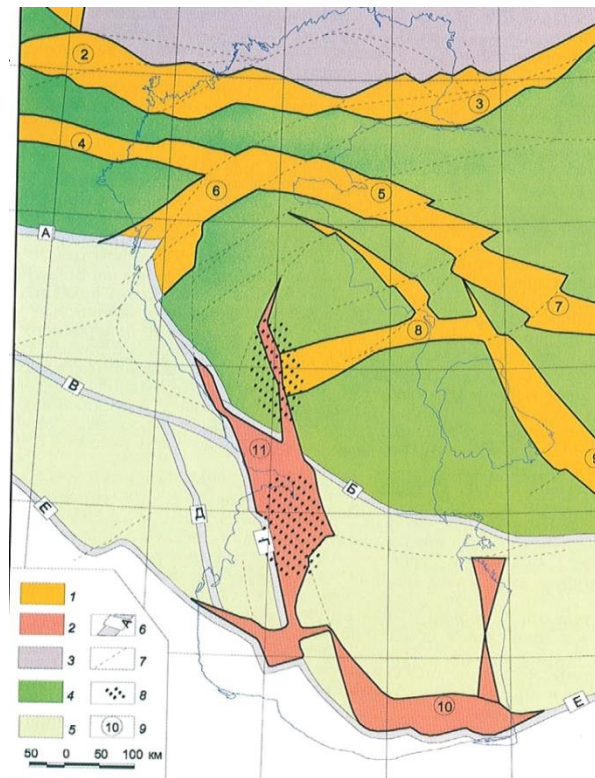


Fig. 2. Scheme of riftogenic systems of the Caspian region (D.M. Murzagaliev, 2025): 1-riftogenic systems; 2-hypothetical zones of latent Cenozoic rifting; other tectonic systems: 3-East European Platform; 4-Scythian-Turanian Platform; 5-Alpine orogenic-folded belt; 6-deep suture zones and indices: (A-North Caucasus; B-Turkmenistan; C-Greater Caucasus, Central; D-Western Caspian; E-Kura; F-Iran); 7-tectonic lineaments; 8-hot spots; 9-indices of riftogenic systems.

Riftogenic systems (numbers in circle): 1- Aralsor; 2- Karpinsky Ridge; 3- South Embensk; 4- East Manych; 5- Central Mangyshlak; 6-Agrakhansk; 7- Central Ust-Yura; 8- Kara-Audansk; 9- Tuarkirsk; 10. South Caspian Sea; 11. Western Caspian Sea.

CONCLUSION

The results of the integrated analysis show that the formation and distribution of the South Caspian Basin's hydrocarbon potential are closely linked to Azerbaijan's current strategic energy resource development. First, attracting major investments from international oil and gas corporations and foreign businesses not only facilitates accelerated entry into the global energy market but also stimulates the implementation of advanced production and exploration technologies, which directly impacts the identification of new hydrocarbon accumulation zones.

Second, the creation of an integrated export pipeline system ensures the reliable and efficient delivery of oil and gas to international markets. The gas sector is particularly important, as Azerbaijan exports natural gas to more than ten countries. This underscores the South Caspian Basin's significant role as a strategic source of hydrocarbons and the importance of accurately forecasting hydrocarbon concentration zones for export planning.

Third, the accumulation of oil and gas revenues ensures the country's sustainable economic development. Such resource management creates long-term conditions for the rational development of hydrocarbon potential, including the assessment and distribution of gas and oil reserves across the basin. Finally, the implementation of modern technologies contributes to the increased efficiency of exploration and production processes, the reduction of operational risks, and the optimization of geological and technical solutions. This, in turn, improves the accuracy of integrated analysis of hypotheses regarding the formation of hydrocarbon potential and enables more accurate modeling of resource distribution in the basin.

Thus, the strategic directions for exploiting Azerbaijan's oil and gas resources and the geological processes underlying the formation of the South Caspian Basin are mutually reinforcing: efficient exploitation and export of hydrocarbons stimulates new geological research, while integrated analysis of hydrocarbon distribution supports strategic planning in the energy sector.

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