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Contents

Formation conditions of the deep structure and hydrocarbon potential of the South Caspian oil-gas province and the Persian Gulf

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Abstract
The distribution of huge hydrocarbon (HC) deposits on Earth is mainly observed in the junction zones of large tectonic elements. Similar regions are the Persian Gulf basins, Alaska, Venezuela, South Caspian province, etc. From the point of view of the global tectonics theory, oil formation occurs in the subduction zone of the lithospheric plates as a result of sublimation and thermolysis of substances carried into the ocean together with oceanic sediments. For the first time, without any evaluation, this idea was expressed by H. Hedberg in 1970. Later, this possible mechanism of oil formation at the level of general quantitative calculations was continued by O. G. Sorokhtin, S. A. Ushakov, V. V. Fedinsky, A. A. Abidov, A. V. Bally, V. P. Gavrilov, L. I. Lobkovski, V. E. Khain and others.
The Persian Gulf and the South Caspian Sea are areas where huge hydrocarbon deposits are collected. Hydrocarbon deposits are located where foreland seas overlap the former Gondwana margins: Mesopotamian fore depression (MFD) in the Persian Gulf, Pirallahi-Kelkor in the South Caspian. In addition, it is found in the northern peripheries of the active seismic zones of the Persian Gulf and the South Caspian: The Zagros fold system in the Persian Gulf and the Absheron-Balkhan uplift zone in the South Caspian.
These strips are also the richest oil and gas regions. Is this a coincidence or is it related to the geological evolution of the region? What is the nature of these unique deposits? Where did the oil come from, when, where and how did it move to its current layers? The article is devoted to answering such questions based on the analysis of existing geological and geophysical material.
Keywords: Persian Gulf, South Caspian, province, geodynamics, seismic geodynamics, physiographic model, Alpine-Himalayan seismic belt, segment, Arabian plate, Cambrian basement.

Keywords:.
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1. Introduction.

Based on the analysis and comparison of limited literature published on different websites at different times and by different authors, a "genetic link" (formation from the same source) has been established in the hydrocarbon composition of the South Caspian Persian Gulf. 2,3,18].
When people talk about the "black gold" of the world, the Persian Gulf comes to mind, which has about 70 billion tons of oil and 20 trillion recoverable hydrocarbon reserves. Calculations by researchers [9÷11] show that according to the model of organic oil and gas formation, the Persian Gulf reserves could produce no more than 7.5 billion tons of oil, which is less than 5% of geological oil. This factor indicates the absence of a single oil source of the Persian Gulf and South Caspian oil fields and the abiogenic nature of the oil reserves of the studied provinces.

The oil and gas provinces of the South Caspian megadepression and the Persian Gulf are elements of a single seismic geodynamic block clearly delineated by the modern seismic geodynamic map (Fig. 1, A and regional physiographic models Fig. 1, B). Geological and geophysical materials taken mainly from websites: tectonic, topographic-geodesy, physical, structural maps of different horizons, physiographic and seismic geodynamic models of different years, deep geological and geophysical sections, earthquake catalogs, etc. it supports the joint exploration of the South Caspian and the Persian Gulf.

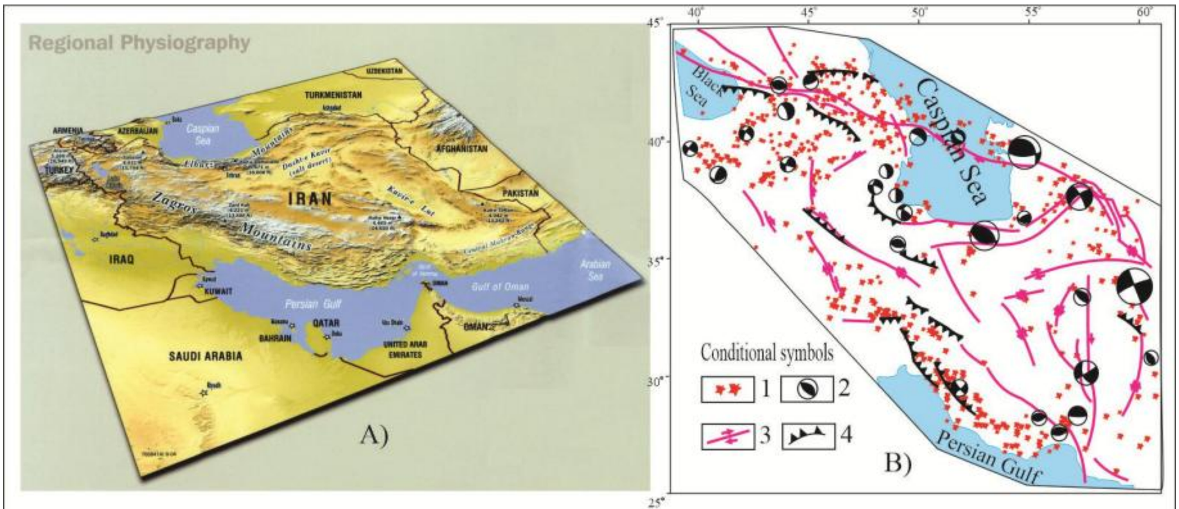

Figure 1. Physical-geographic geodynamic 3D model of the study area (A) and location map of deep-focus earthquake epicenters (B)

Fig. 1. A) Modern seismic geodynamics of the studied region; B) detailed digital (electronic) map (3D relief model). Conventional signs: 1 – earthquake epicenters, 2 – earthquake histograms (compression area is shown in black, extension is shown in white), 3 – transform faults, 4 – thrust sections. Image taken from http://old.ifz.ru/tecton and http://www.nationalsecurity.ru, modifications made by B.S. Aslanov.

2. The role of geodynamics in the formation of modern tectonics.

Located between the large Eurasian and Arabian lithospheric plates, the studied region is limited to a seismically active zone. The zone belongs to the Caucasian segment of the Alpine-Himalayan seismic belt (AHSB) and is characterized by a sharp contrast and intensity of magmatic processes, unusually high tectonic and geodynamic activity, mobility, migration, a wide network of multidirectional faults, minerals, including hydrocarbons.

The formation of the AHSB is related to the collision of the Arabian and Central Iranian plates. The segment covering Central Iran, Zagros, Makran and South Caspian is located east of the northern edge of the Arabian plate [4÷6]. The probable continuation of the northern branch of Neotethys is the Central Iranian microcontinent. It is characterized by Precambrian metamorphic basement and Vendian-Triassic platform cover. In the east, the meridional elongated Lut block stands out. According to the works [2÷15], the geodynamic evolution of this region is directly related to the north-eastern displacement of the Arabian plate, which began in the Mesozoic and continued throughout the Oligocene to the early Miocene. As a result, the Iranian plateau and the Elbrus mountains were formed, and at the same time, central Iran was separated from the Caspian Paleoben. Deformed blocks in the area between the South Caspian and the Black Sea (Fig. 2, A and

B) as well as adjacent low-order tectonic elements within the Persian Gulf and South Caspian basin are also the result of this displacement. Shifting movements continue to this day to one degree or another. These maps clearly show blocks of different scales, deep faults and landslides, and the role they play in supporting the neotectonic environment. The main stages of the development of the main tectonic elements of the region were determined in the Mesozoic history under the conditions of the horizontal movement of the Eurasian and Afro-Arabian continental plates, during which the Tethys paleocean water area gradually decreased until it completely disappeared.

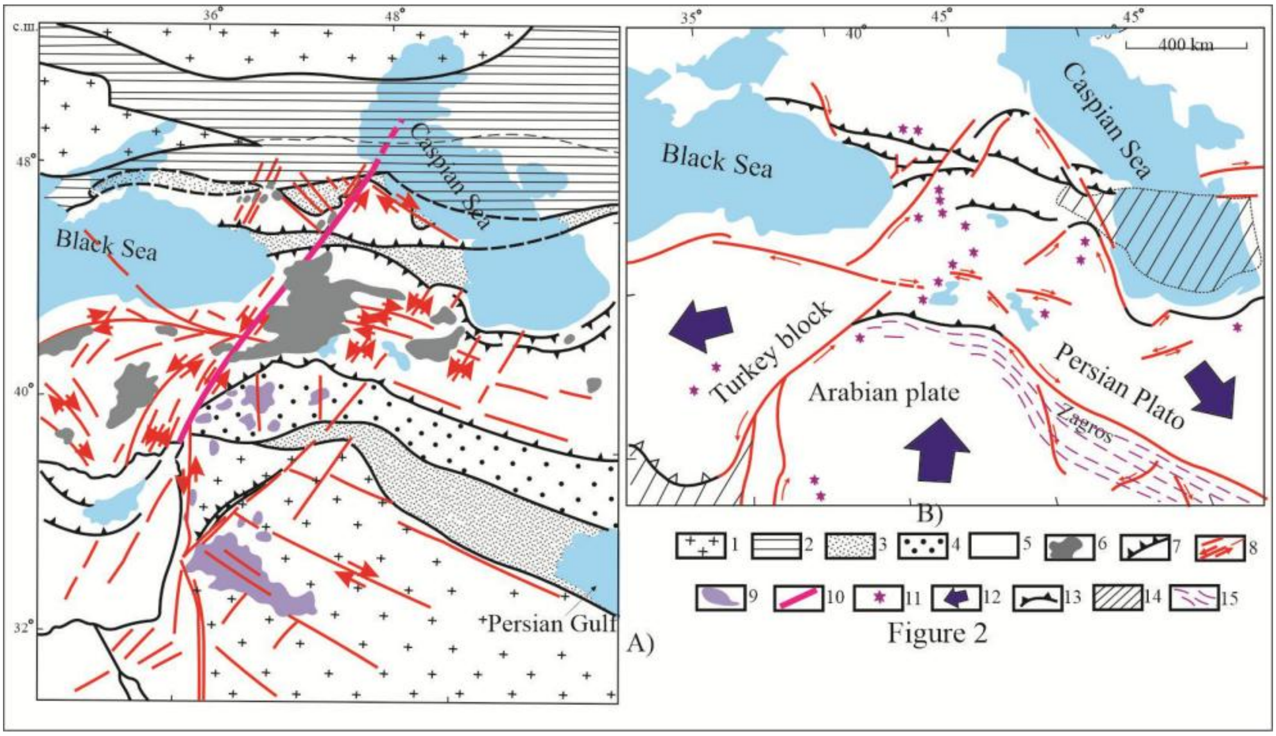

Fig. 2. A) Modern structural-geodynamic scheme (according to N.V. Koronovsky [7]) and B) fundamental tectonic features of the studied region (L.S. Smith-Roche [2]). Conventional signs: 1 – Precambrian plates, 2 – Epipaleozoic plates, 3 – advanced and intermountain plates, 4 – Submerged part of the Arabian plate, 5 – Main directions of relative movement of the Earth's crust (geoblocks, Alpine fold structures: a- proposed by the author of this article, b- proposed by the author of the works [7]), 6 – area of distribution of collision volcanism (Late Miocene-Anthropocene), 7 – impact force of geoblocks and main (main) directions, 8 – landslide faults and other faults (arrows relative shows movement), 9 – basaltic volcanism of the Arabian plate (mainly Quaternary), 10 – Agrahan-Tbilisi-Levantine left-lateral slip zone, 11 – collision zone volcanoes, 12 – oceanic crust, 13 – Zagros fold zone. The scheme was corrected by B.S. Aslanov.

Based on the general regularities of tectonic and magmatic evolution, it was determined that passive continental margin (PCM) conditions exist in this region in the Mesothetis. This region is the region where the PCM shelf is under the continental crust. The storage of most of the hydrocarbon resources in the PCM has been repeatedly noted by geologists A.I. Konyukhov, L.E. Levin, B.E. Khain, B.A. Sokolov, R.G. Garetsky, S.A. Ushakov and others. According to the data, 7/8 of all identified oil and gas reserves are linked to the PKM; only 1/8 of these reserves fall on the active continental margins (ACM). The ACM is formed where the oceanic crust sinks under the continent.

The complete closure of the Mesozoic Tethys Ocean occurs in the Cenozoic era, and subduction processes continue to this day in varying degrees in a number of places, for example, in the northern part of the South Caspian Sea (the Pre-Caucasus-Turkmen transform fault, as well as in the north of the Persian Gulf (the Zagros Mountains)). The periphery of the Tethys paleocean is regionally rich in oil and gas [16÷18]. The oil and gas provinces of the South Caspian and the Persian Gulf are located within its borders. The northeastern edge of the African-Arabian plate collided with the Iranian plate during the Cenozoic. The intense subsidence of this area of the Earth's crust is the result of the compression of the island arc systems of the southwestern periphery of the Tethys Ocean to the edge of the platform. The largest hydrocarbon reserves are concentrated in the layers existing on the edges of the continents during the closing of the oceans, primarily in the Jurassic and Cretaceous sediments, as well as in the oil and gas zones of the Persian Gulf during the Paleozoic (Permian).

Oil and gas basin of the Persian Gulf (OGBPG).

One of the unique regions of such a junction is the sedimentary basin of the Persian Gulf. 54% of all hydrocarbon reserves of the planet are concentrated here, and there are also more than twenty huge deposits, each of which has a reserve of 1 billion tons of oil and 1 trillion cubic meters of gas. The oil and gas basin of the Persian Gulf is located on the northern periphery of the Arabian-Nubian shield, in the junction zone with the folded mountainous Alpine belt. It is bounded to the north and northeast by the Zagros and Eastern Taurus structures, to the south and southwest by the South Arabian epirift uplift known as the Hadramaut Plateau, and to the west by the Aleppo uplift and folds. The eastern boundary of the basin is the obduction ophiolite complex of Oman structurally, the Persian Gulf basin is divided into a platform part corresponding to the northeastern slopes and foreland areas of the Arabian-Nubian shield (Fig. 3); Pre-Tharus dislocation zone, Mesopotamia and South Oman depressions. In the northern and eastern peripheral regions of the Arabian Craton, the thickness of the sediment cover varies from 1-2 to 4.5-7 km. In the Mesopotamian fore depression, the thickness of sedimentary rocks increases sharply, reaching 15 km in flooded areas. At the Oligocene and Miocene border, the closure of the Tethys Ocean took place, which was accompanied by the uplift of mountain fold belts (Zagros, Elburz and Caucasus mountains), and the formation of large and small foothills and inter-algae depressions. The tectonic events that led to the closure of the Tethys Ocean created a favorable structural background for the generation and accumulation of hydrocarbons, especially at several margins of the former passive Gondwana. Strong tectonic dislocations and the accumulation of sediment masses in large areas accelerated the processes of oil and gas formation in the sediments that once formed on the continental slopes and their foothills in the peripheral regions of the Tethys Ocean. Flows of liquid and gaseous hydrocarbons migrated from areas affected by folding and metamorphism to ancient shelves, where they filled traps and reservoirs formed in earlier stages. However, only the hydrocarbon deposits formed on the southern edge of the disappeared ocean have remained to this day (Persian Gulf and South Caspian). The Persian Gulf, with a basin depth of no more than 100 m, occupies the vast plain of the Tigris and Euphrates rivers adjacent to it from the northwest, as well as the coastal plains bordered by the gulf. The total area of the basin is 5063 thousand km^2, of which 4853 thousand km^2 is on land and only 213 thousand km^2 is in water. OGBPG is one of the five richest basins in the world (along with the Western Siberian, Western Canadian, Orinoco and North Caspian basins). It is unique in terms of primary recoverable hydrocarbon reserves (current reserves are more than 150 billion tons of standard fuel, 92-107 billion tons of oil, 50 trillion m^3 of gas;

primary hydrocarbon reserves are more than 180 billion tons, including oil - more than 130 billion tons, gas - 52 billion m^3). Estimates of Saudi Arabia's current oil and condensate reserves reach 36-42 billion tons. The oil reserves of Kuwait, Iran and Iraq are unique. In Iran, and in recent years in Qatar, large gas reserves have been discovered both on the coast and in the Gulf. A boundary (platform layer) type basin was formed at the junction of the ancient Arabian continental margin with the AHSB. The basin has a platform southwest and orogenic northeast frame and is sharply asymmetric. It covers the Mesopotamian fore depression and the gently sloping part of the Arabian plate - the pericraton, separated from the edge of the Arabian shield by a zone devoid of hydrocarbon deposits.

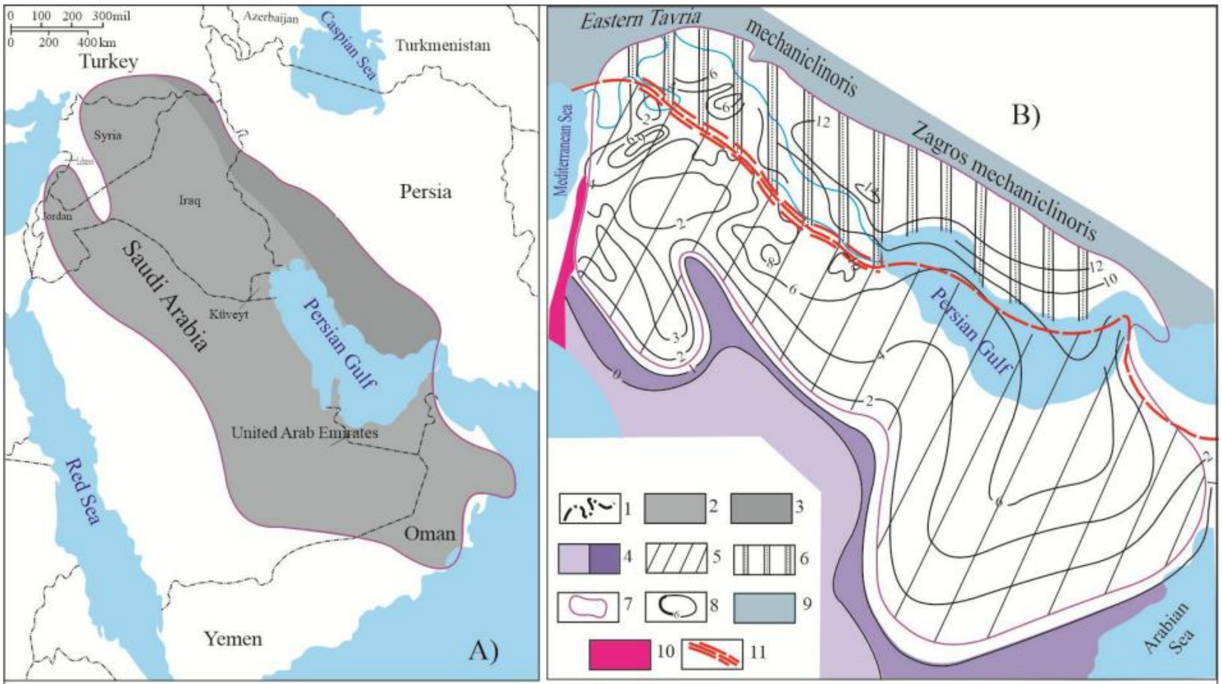

Figure 3

Fig. 3. A) Overview map of the sediment cover of the Persian Gulf; B) isopach map. Conventional signs: 1 – interstate boundary lines, 2 – saturated oil and gas area, 3 – rich oil and gas area, 4 – Nubian-Arabian shield under a thin sedimentary cover, 5 – Arabian plate, 6 – Predzagorsky regional depression, 7 – Persia boundary of the Gulf basin, 8 – isopachs of sediment cover, 9 – meganticlinoriums of Eastern Taros and Zagros, 10 – Eurasian sea rift, 11 – faults separating geotectonic areas within the Persian Gulf basin. The figure modified by B.S. Aslanov, retrieved from http://www.ipages.ru, http://www.nationalsecurity.ru.

Since the beginning of the 40s of the last century, OGBPG has taken a leading position among the oil-producing regions of the world. It is a province with a unique concentration of oil and gas (Fig. 3, A). It includes the Arabian Peninsula and Bahrain, Jordan, Iraq, southwestern Iran, Qatar, Kuwait, UAE, Oman, Saudi Arabia, most of Syria, and southeastern Turkey.

The province is bounded by a large asymmetric heterogeneous depression formed during long-term subsidence at the junction of the African-Arabian platform with the AHSB (Fig. 3, B). The main tectonic elements are the Arabian plate and the Mesopotamian fore depression, which form the platform and fold parts of the basin, respectively. The basis is Archaeo- Proterozoic. The maximum thickness of the sedimentary cover is 10-12 km in the deepest part of the basin, and the minimum thickness is 2-2.5 km along its periphery (areas adjacent to the Arabian-Nubian shield) represented by sediments from the Vendian to the Quaternary.

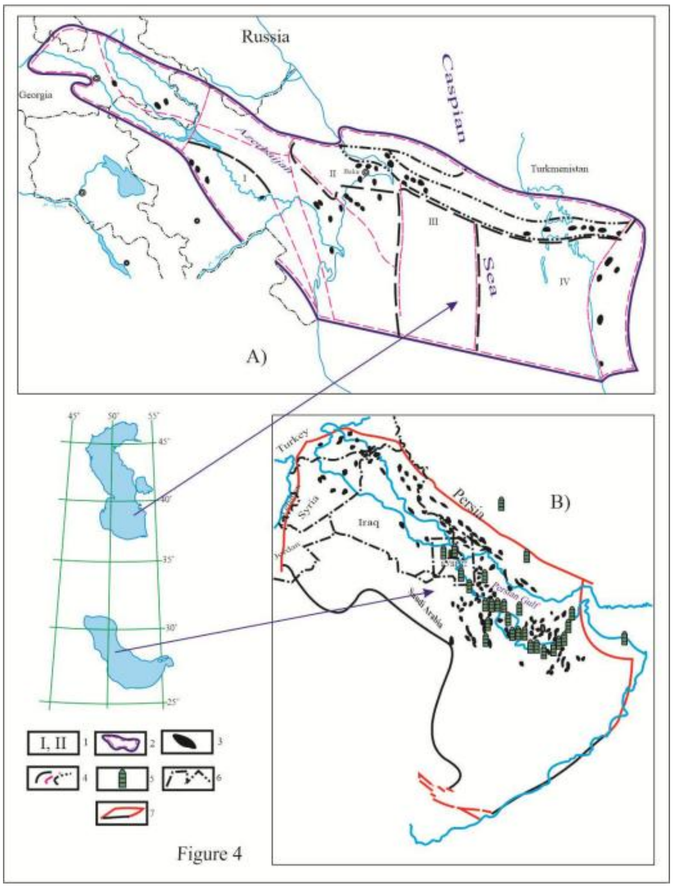

Fig. 4. Oil and gas provinces: A) South Caspian; B) Persian Gulf. Conventional signs: 1 – oil and gas fields within the South Caspian province: I – Gobustan-Kur, II – Absheron-Balkhan, III – Central-South Caspian, IV – Western Turkmen; 2 - the border of the South Caspian oil and gas region, 3 - oil and gas structures, 4 - the border of oil and gas regions, 5 - large oil refineries, 6 - interstate border lines, 7 - the border of the Persian Gulf oil and gas basin. The figure edited by B.S. Aslanov, taken from http://www.biblioclub.ru (Persian Gulf) and http://www.mining-enc.ru (South Caspian Oil and Gas Province).

In the geological structure of OGBPG, the Paleozoic section is mainly sandy-clay. Permian, Mesozoic, Paleogene and Lower Miocene deposits are mainly represented by carbonate rocks. Neogene-Quaternary sediments are dominated by terrigenous type, among which the Middle Miocene salt layers with a thickness of up to 1 km are distinguished. The main oil and gas complexes are Permian, Upper Jurassic, Lower Cretaceous, Upper Cretaceous and Oligocene-Lower Miocene. Mesozoic deposits make up 3/4 of the proven oil reserves, the main gas reserves are concentrated in Permian and Cenozoic rocks. Most of the deposits are concentrated in the eastern sediments of the Arabian plate (Basra-Kuwait basin, Gaza structural terrace, Rub-al-Gali basin) and the Mesopotamian fore depression. Hydrocarbon accumulations in the Mesopotamian fore depression are mainly confined to the Oligocene-Lower Miocene (Asmari formation) and Upper Cretaceous limestones at a depth of 0.2-2.7 km. The main proven hydrocarbon reserves in the basin are located at a depth of 1-3 km. The maximum oil and gas reserves are in the 2-3 km interval, and the maximum gas reserves are in the 3-5 km depth. Structure-type deposits are mainly multi-layered. Sediments in the Mesopotamian fore depression are confined by high-amplitude anticlinal folds running from northwest to southeast along the Zagros fold system (Fig. 4, B). A significant part of oil and gas fields is limited by salt diapirism structures. The density of oil is 820-990 kg/m3, medium density oil (855-860 kg/m3) prevails. More than 1,500 trillion cubic feet of gas reserves have been discovered in Permo-Triassic carbonates sealed by thick Triassic anhydrites in the Zagros fold system (southwest Iran), southern Persian Gulf (Iran, Qatar and Abu Dhabi) and Saudi Arabia. Oil production began in the Middle Jurassic in extensive depositional areas, with the main formation phase occurring locally in the early Middle Cretaceous. Large volumes of oil and gas have accumulated in several major regional arches and salt structures belonging to the Zagros fold system. Some of the gas was lost during folding because some anticlines collapsed. Other parts of the gas have passed into the undamaged anticlinal traps along with the light oil.

South Caspian Oil and Gas Province (SCOGP).

The region includes Azerbaijan, Eastern Georgia and Western Turkmenistan. The location and orientation of the oil structures is similar to that of the Persian Gulf (Fig. 4, A and B). Its area is more than 200 thousand km^2. It includes the Ghabirri-Acinohur, Yevlakh-Aghjabedi, Gobustan-Absheron, Lower Kura depression, the South Caspian oil and gas regions and the oil and gas regions of Western Turkmenistan. The most popular deposits are: Samgori-Patardzeul, Naftalan, Muradkhanli, Kirovdagh, Neftchala, Sabunchu-Balakhani, Ramani, Bibi-Heybat, Binagadi, Neft Dashlari, Shahdeniz, Azeri, Chirag, Umid, Nebitdag, Gorgandag, Okarem, etc. The first oil fields (Balakhani-Sabunchu-Ramany, Çelakan) were discovered in the middle of the 19th century. Systematic exploration of oil and gas began in the 20s of the 20th century. Tectonically, the SCOGP was formed as a result of regional subsidence associated with the main geostructural elements of the Zagros Mountains, the Dasht-Lut block, and the Turanian plate with similar geodynamic regimes, and is divided into a series of depressional structures: The Kura intermountain depression, consisting of the Upper, Middle and Lower Kura depressions, the South Caspian depression, which includes the South Absheron, Pahlavi-Gorgan and Elbrus depressions, and the West Turkmen, Balkhan-Kyzylgum depressions in the east. From the north, this system of depressions is adjacent to Shamakhi-Gobustan and Absheron depressions, which are other components of the megadepression (Fig. 4, A). The northern and northeastern border of the SCOGP is represented by the megathiclinorium of the Greater Caucasus and its underwater extension, the Absheron-Pribalkhan anticlinal uplift zone, and the south is the megathiclinorium of the Lesser Caucasus. In the east, the megadepression is adjacent to the Dziryulski outcrop of the crystalline basement. In different parts of SCOGP, the crystal foundation tends to collapse step by step. It is located at a depth of 4-6 km in the western part, 16 km in the Middle Kura Basin, up to 20 km in the Lower Kura depression, and more than 25 km in the South Caspian Basin. A gradual subsidence of the pre-Alpine substrate also occurs in the transverse direction from the Greater and Lesser Caucasus to the central part of the SCOGP. Among the special depressions are the buried uplifts of the pre-alpine bedrock and the deep faults that limit them. There is no doubt that the Lower Pliocene deposits in the South Caspian are productive layers, but the formation and migration of oil is still a matter of debate among researchers. The main petroleum complex of the South Caspian oil and gas province, which includes almost all proven oil and gas reserves, is the Pliocene "Productive" layer (PL) and its counterpart "red" layer (RL) in Western Turkmenistan.

The PL is represented by the alternation of sandy reservoirs and clayey caps with a total thickness of 1.2 to 4 km, and the RL is represented by a monotonous alternation of sandy-silty and clayey rocks with a thickness of 0.8-3 km. In the western part of the province, in the subsidence part of the Lesser Caucasus (Ganja oil and gas region) and in eastern Georgia, there is no MF, hydrocarbon deposits were discovered in the Maykop range deposits of the Oligocene-Lower Miocene and in the Upper Cretaceous rocks. The main areas of oil and gas production are limited to the Absheron-Balkhan oil and gas region of Azerbaijan and Western Turkmenistan. PL reservoirs in Absheron Peninsula deposits are represented by well-sorted quartz sands with high porosity and permeability values. Up to 40 oil and gas fields have been identified on the border. The deposits are bounded by brachyanticlinals, intensively dissected by numerous faults of varying amplitudes, compounded by mud volcanism.

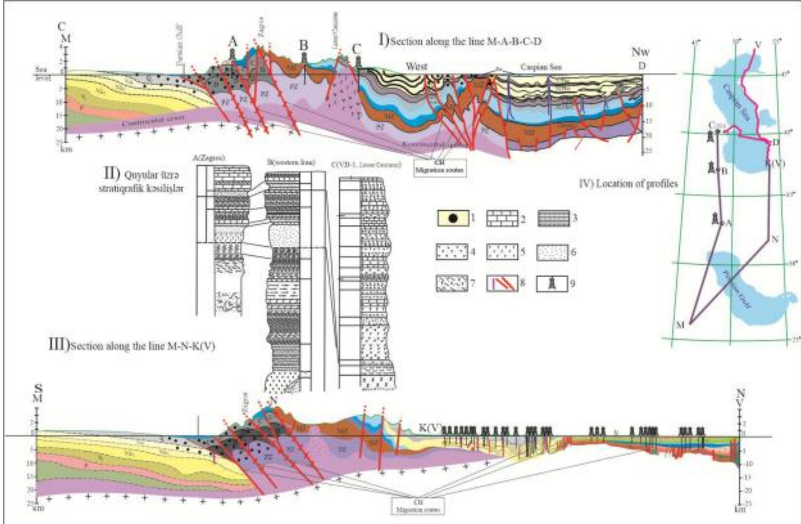

Figure 5

Fig. 5. Results of interpretation of geological and geophysical material in the study area: I) and III) geological sections; II) Comparison of stratigraphic sections from wells located on both sides of the Main Zagros (A and B) and in the Lesser Caucasus (C, SG-1); IV) location of profiles. Conventional signs: 1 – oil field (condensate or gas), 2 – limestones, 3 – clays, 4, 5 – volcanic rocks, 6 – coarse sands, 7 – fragments of intrusive rocks, 8 – deep faults and volcanoes, 9 – wells . The figure was compiled by B.S. Aslanov.

The composition of gas condensate is dominated by light hydrocarbons, the amount of paraffin, tar and asphaltenes is insignificant. The density of the condensate is 729-813 kg/m^3, which means that the oil here is lighter than in the Persian Gulf. The Western Turkmen depression is the eastern part of SCOGP. It is filled with very thick Mesozoic and Cenozoic sediments. Only within the Western Turkmen basin, the thickness of the Neogene reaches 5-6 km. The oil and gas fields of the Western Turkmen Basin are associated with the sandy-clay layers of the Pliocene. Based on the theory of lithospheric plates, by comprehensively analyzing the geodynamic transformations, geological evolution, tectonic structure of the main lithospheric plates of SCOGP and OGBPG (geoblocks of the Alpine fold belt), comparing the oil and gas bearing structures, and as a result of the interpretation of existing geological and geophysical materials, we made profile sections in two directions reflecting their structures, which have determined the geological structure of the research region. (Fig. 5, I and III). These sections clearly show both the deep and surface tectonic setting of both provinces. At this time, a structural-tectonic discrepancy is clearly observed. It should be noted that for the Caspian region, we used existing sections collected from multiple wells. (Fig. 5, IV, red color). The surface geological structure of the Persian Gulf (oil and gas formations) is complicated by the Zagros Mountains, and the South Caspian Sea by the Absheron-Balkhan uplift zone

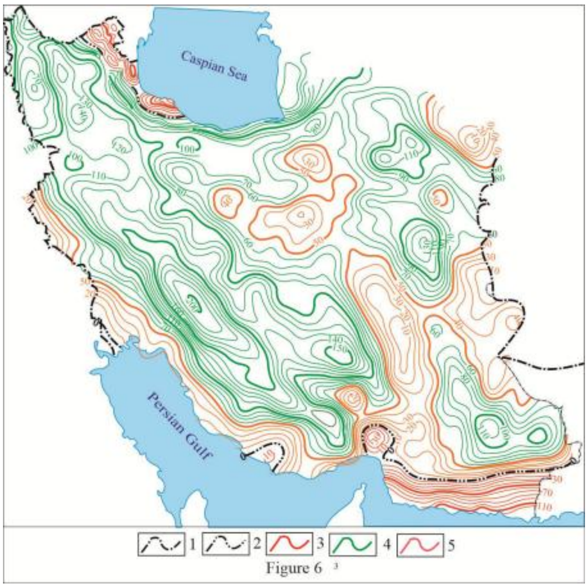

Fig. 6. Structural map of the Moho boundary (thickness of the Earth's crust). The map was compiled based on seismological data [11]. Conventional signs: 1 – isohypses along the ceiling of the Moho boundary, 2 – interstate boundary.

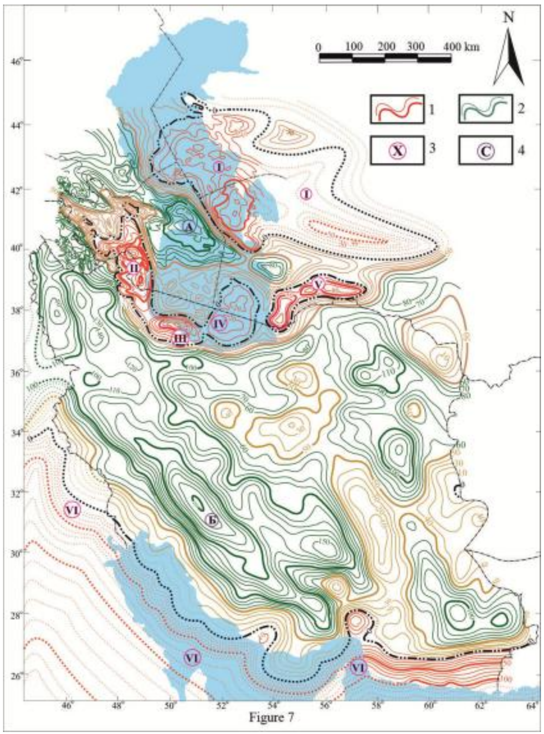

Fig. 7. Gravimetric map [14] (σ=2 300 kg/m^3 on Bouguet anomaly of Iran) Conventional signs: 1 – boundary, 2 – zero isolates; Gravity field isolates: 3 – positive, 4 – negative and 5 – up to 50 mGal. The figure was edited by B.S. Aslanov.

This complexity was formed on the basis of compression and extension processes that continue to this day [9÷11]. In other words, the Absheron-Balkhan region, characterized as the development zone of the Paleogene-Miocene fold, is tectonically complicated by the Alpine syncline, the Epihersin platform. The Zagros fold zone is complicated by a complex of Paleozoic, Mesozoic and Cenozoic sediments formed as a result of the collision of the Arabian and Eurasian plates at the end of the Mesozoic and the beginning of the Cenozoic. In addition, the Absheron threshold and the Zagros mountain move over deep depressions. Absheron is in the Pirallahi-Kalkor depression (PKD), and the Zagros mountain is in Mesopotamia. In addition, the Zagros Mountains are characterized with a ridge, which is 1300 km long, 250 km wide and 4.5 km high. This ridge, extending up to 350 km, consists of a thick (up to 8-10 km) sedimentary cover. By folding the passive edge of the Arabian plate, it gradually changes its movement from northwest to northeast. At the same time, the similar structures of the Persian Gulf and South Caspian oil fields are also clearly expressed. This once again shows that these oil provinces were formed in a single Paleo-Tethys basin, but were divided into Persian Gulf and South Caspian provinces in the process of evolution. On the schematic structural map (Fig. 6) along the surface of the Moho boundary, compiled from the seismological data of the last 50 years (the catalog of earthquakes that occurred in the studied region), two depressions located almost perpendicular to each other are distinguished: 400 km long and 56 km deep in the Zagros Mountains and northeast of the Iranian Plateau, and about 200 km long and 48 km deep within the Dasht-Lut block. Figure [15]. Between them, in the central part of Iran, at a depth of 40 km, there is a plain known as the "Iranian Plateau". Further north, in the South Caspian Sea, upwelling with an amplitude of 6 km is determined at a depth of 36 km. The depression in the northeastern Zagros Mountains and the Iranian Plateau is probably a component of the MFD and the depression within the Dasht-Lut block may represent a new tectonic unit in deep layers. (The Dasht-Lut block has an inversion structure). The geological structure of the South Caspian Sea in the deep layers is presented as a superimposed depression limited by the transitional tectonic regime (from the orogenic Alpine geosyncline and the Epihersian platform).

In order to analyze the obtained understanding of the geological structure of the studied region, the gravimetric map of Iran taken from [15] and added by us (Fig. 7) was analyzed. This map is based on a similar map within the oil and gas provinces of the South Caspian (Fig. 8). According to the gravimetric map of Iran, a gravity low with an intensity of up to 300 mGal extends along the Zagros Mountains. The geological interpretation of this minimum suggests that it is related to a deep tectonic structure. Because its parameters, that is, its size and intensity, cannot be explained by the folded structure of the Zagros and the structure of the Iranian plateau. In addition, the minimum in plan corresponds to the northeastern part of the MFD.

According to V. Zabanbark [19], the MFD is in the outer part of the Arabian platform, adjacent to the Zagros structure, the northeast side is protruding, and the southwest side is flat and has an asymmetric structure. The most intensive formation of tectonic structures is recorded in the parts that stretch parallel to the Zagros fold structure and develop relatively narrow folds. The depression itself was formed in the last stage of the Alpine folding. The dominant shear dislocations in the Zagros have caused disharmonic compression of the sedimentary layers. In the MFD, hydrocarbons are accumulated in Upper Cretaceous, Lower Cretaceous, Upper Jurassic, Middle Jurassic, and

Upper Permian rock formations. Mesopotamia is the largest depression in the considered region, covering a distance of 2.5 thousand km from northwest to southeast. The width of the depression varies from 180 to 400 km, and the total thickness of the sediment cover in the most tilted (axial) part reaches 14-15 km. In the late Precambrian and Paleozoic periods, the ancient continental masses existing in the territory of Iran were an integral part of the Arabian continental platform. Their separation in the Permian or Triassic indicates a belt of Zagros ophiolites bounded by the main Zagros fold line. PKD can be attributed to a similar geotectonic transformation. The MFD was formed at the border of the Arabian Platform with the Iranian Plateau. The PKD is bounded by the Epichersian Platform to the northeast and the Alpine fold to the southwest. But paradoxically, the dimensions of these bends are not comparable. It turned out that both depressions overlapped in older sedimentary basins. This is due to the fact that two tectonic stages are distinguished in the geodynamic evolution of the Persian Gulf and South Caspian basins: Initially, the region developed as part of the continental margin of Gondwana until it collided with the Eurasian continent. As a result of this collision, the Zagros zone and later the MFD, which once overlapped with the deep sea structure, were formed. In parallel, a similar evolution took place on the northern edge of the seismodynamic block, resulting in the formation of the PKD.

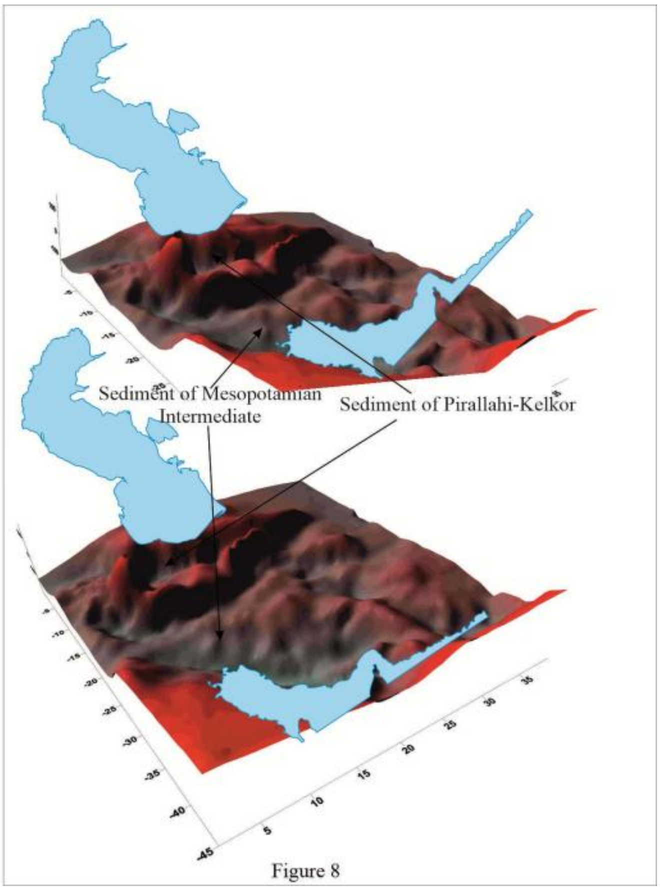

Fig. 8. Gravimetric map of the studied region (σ=2 300 kg/m^3 according to Bouguet anomaly). Conventional signs: 1- positive and 2- negative isolates of the gravity field, 3- gravity maxima: I - Middle Caspian-Turan, II - Mughan-Karabakh, III - Safiudrudsky, IV - South Caspian and V - North Kopetdag; 4 – gravity minima: A – Northern Absheron and B – Northern Zagros. The figure was compiled by B.S. Aslanov

We assume that this also explains the deep structure of OGBPG and SCOGP.

Comparing the gravimetric map (Fig. 6) and the structure map of the Moho surface, we assume that the deepest part of the MFD is located further north than previously thought, i.e. beneath the Zagros

Mountains. Just like in PKD. Thus, the deepest part is located in the northeast under the Absheron-Balkhan threshold.

This idea is well illustrated by the 3D model of the gravimetric map (Fig. 8) that we made using the SURFER program. Here you can clearly see how OGBPG and SCOGP are located: The tectonic structure of both provinces appears to be inversion, i.e. they are located in deep "basins". However, the formation of hydrocarbon potential is probably related to completely different geotectonic conditions, especially tectonic units. In our opinion, the hydrocarbons of the Persian Gulf are formed in the MFD, this process is influenced by the dynamics of three tectonic units: Arabian Plate, Dasht-Lut Block and Iranian Plateau. The hemechanism occurs as follows: when the Arabian plate moves in the northeast direction, the southeastern edge touches the Dasht-Lut block, and the block turns counterclockwise and compresses the Iranian plateau. As a result of these compressive forces, favorable conditions for the formation of hydrocarbons are created in the deep interior of the MFD. Subsequently, again due to these compressional forces, the hydrocarbons formed migrate along existing deep fractures into the oil and gas bearing structures of the Persian Gulf.

In the South Caspian, this process has a slightly different character. We assume that hydrocarbons in the South Caspian Sea are formed in the PKD depression as a result of the influence of geodynamic forces of three tectonic units: Iranian plateau, Dasht-Lut block and Turanian plate. The geomechanical process here is also related to the Arabian plate mechanism, that is, when the Arabian plate moves in the northeast direction, the southeast edge touches the Dashta-Lut structure, and the block passes through the Kopetdag mountain layer and touches the Turan plate, and the plate turns counterclockwise and compresses the South Caspian geosyncline. Since the deep structure of the South Caspian Sea is represented by an arcuate uplift along the Moho boundary, the center of compressive forces falls on the PKD. As a result, the deep underground of the PKD creates favorable conditions for the formation of hydrocarbons. Later formed hydrocarbons migrate along existing deep fractures into the oil and gas bearing structures of the South Caspian region. The movement of geodynamic blocks in the study area was studied and analyzed in [4], which is consistent with the geomechanism described above.

3. Conclusion

Thus, based on existing geological and geophysical data, earthquake catalogs, comparative analysis of hydrocarbon composition and evolutionary processes of geotectonic formation, we briefly analyze the structural-tectonic structure, seismogeodynamic characteristics, and come to the following conclusion:

1. The hydrocarbon potential of the OGBPG and SCOGP is connected with the rift system of the Tethys Ocean and is formed in the PCM. The migration and generation routes in the study area are as follows:

– in the South Caspian oil and gas region, in the pre-Caucasian-Turkmen fault and inside the Persian Gulf;

– In the deep fractures of the Zagros support system;

2. Oil and gas provinces of the Persian Gulf and South Caspian have existed as PCM during most of their evolution (late Paleozoic to Miocene), but the northern part (South Caspian Sea) has been more active than the south (Persian Gulf);

3. After the collision of two opposing edges of the Tethys, they turned into modern basins typical of the fusion zones of ancient cratons with younger mountain-fold structures;

4. Most of the accumulation of hydrocarbons in these provinces is the result of degassing that occurred during the second stage of basin evolution, when the folds (MFD and AKP) overlapped at the edges of the former Gondwana;
5. From the point of view of the global tectonics theory, the formation of oil occurred as a result of sublimation and thermolysis of substances carried along with ocean sediments to the subduction zone of lithospheric plates;
6. The difference of the geological and tectonic structure of the named provinces is related to the seismic geodynamic evolution.

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Prediction of porosity in mountain rocks

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Abstract: Porosity is one of the most important parameters when studying groundwater. The porosity parameter is used to estimate storage and travel times in aquifers and aquifers. Studies use seepage theory to determine the thickness and variation of rocks. The percentage of voids in a substance is called its porosity. To calculate porosity, it is needed to divide the volume of voids by the material's total volume to get the percentage.

Keywords: porosity, mountain rocks, displacement modulus, leakage theory, seepage theory.
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1. Introduction

Over the past few years, progress in predicting the elastic properties of porous materials over the entire porosity range has been closely related to the power law empirical relationship of Phani and Niyogi.