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Modern seismogeodynamics of Absheron oil and gas region

S.E. Kazimova, G.E. Guseinzade, P.J. Mammadova

National Academy of Sciences of Azerbaijan, Republican Seismic Survey Center,
123 Guseyn Javid Str., Baku AZ1001, Azerbaijan,
e-mail: sabina.k@mail.ru

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Abstract: Relevance. In many regions of the world, the concentration of oil and gas and large hydrocarbon deposits is observed in the nodal zones of active faults, as well as in neotectonic block structures. A change in the stressed state of mountain structures can cause activation of seismic geodynamic processes accompanied by tectonic disturbances. In addition, it should be noted that the main danger of seismic impacts on the territory of the Absheron Peninsula comes from the Caspian Sea, the seismic activity of which is increasing every year. **The aim** of these studies is to study modern geodynamic and seismic activity within the Absheron oil and gas region. **Methods.** Maps of earthquake epicenters for the period 2003–2023 were built on the ArcGIS10.5 program and analyzed. Based on the catalog data and maps of seismic activity were constructed for two periods. Based on the method of inversion of waveforms and the first arrivals of a longitudinal wave, the earthquake source mechanisms were constructed, maps of the compression and tension axes, as well as maps of the distribution of the Lode–Nadai stress state coefficient were constructed. **Results.** The analysis of seismicity showed that within the Absheron oil and gas region there are two active seismic zones. The first zone is located in the northern part of the peninsula, and the second is below Absheron on the southern side. Most earthquake hypocenters are located within the basalt layer and upper mantle. The northern focal zone is located at a depth of 0–25 km and has a width of 35 km. The northern zone is associated with the rupture system of the Absheron–Pribalkhan deep fault. In 2003–2012 seismic activity in the northern part of Absheron varies from Act = 0.8 to 1.3, and in 2013–2023. – from 0.45 to 0.65 with a background level of 0.1. On the distribution maps of the Lode–Nadai stress state coefficient, it is clear that the zone of the Absheron Peninsula is mainly characterized by compression stresses.

Keywords: earthquake source mechanism, map of epicenters, depth distribution of earthquakes along the profile, orientation of compression and tension axes, seismic activity, oil and gas fields.

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ГЕОФИЗИКА

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Оригинальная статья

Современная сейсмогеодинамика Апшеронского нефтегазоносного региона

С.Э. Казымова, Г.Э. Гусейнзаде, П.Дж.Маммадова

Национальная Академия Наук Азербайджана,
Республиканский Центр Сейсмологической Службы,
Республика Азербайджан, AZ1001, г. Баку, ул. Гусейн Джавида 123,
e-mail: sabina.k@mail.ru

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Резюме: Актуальность работы. Во многих регионах мира концентрация нефтегазовых и крупных месторождений углеводородов наблюдается в зонах пересечения активных разломов, а также в неотектонических блочных структурах. Изменение напряженного состояния глубинных структур может стать причиной активизации сейсмогеодинамических процессов, сопровождающихся тектоническими нарушениями. Кроме того нужно отметить, что основная опасность сейсмических воздействий для территории Апшеронского полуострова исходит со стороны акватории Каспийского моря, на дне которого из года в год возрастает сейсмическая активность. **Целью** данных исследований является изучить современную геодинамическую и сейсмическую активность в пределах Апшеронского нефтегазоносного района. **Методика.** Были проанализированы карты эпицентров землетрясений за период 2003–2023 гг., построенные в программе ArcGIS10.5. По данным каталога были построены карты сейсмической активности за два периода. На основе метода инверсии волновых форм и первых вступлений продольной волны были построены механизмы очагов землетрясений, карты осей сжатия и растяжения, а также карты распределения коэффициента напряженного состояния Лоде–Надаи. **Результаты.** Анализ сейсмичности показал, что в пределах Апшеронского нефтегазоносного района существуют две активные сейсмические зоны. Первая зона расположена в северной части полуострова, а вторая – ниже Апшерона с южной стороны. Большая часть гипоцентров землетрясений расположена в пределах базальтового слоя и верхней мантии. Северная очаговая зона расположена на глубине 0–25 км, с шириной 35 км. В 2003–2012 гг. сейсмическая активность в северной части Апшерона варьируется от $A_{кт}$=0,8 до 1,3, а в 2013–2023 гг. – от 0,45 до 0,65 при фоновом уровне 0,1. На картах распределения коэффициента напряженного состояния Лоде-Надаи, видно, что зона Апшеронского п-ва в основном характеризуется напряжениями сжатия.

Ключевые слова: механизмы очагов землетрясений, карта эпицентров, глубинное распределение землетрясений по профилю, ориентация осей сжатия и растяжения, сейсмическая активность, нефтегазовые месторождения.

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Introduction

The formation and evolution of the stress–strain state, geophysical processes and seismicity of the Earth's crust are determined by its structure, natural dynamics and the totality of impacts on the geological environment. The heterogeneity of the structure of the Earth's crust leads to a non–uniform distribution of stresses and to their concentration at the points of contact between blocks. Slow deformations of the Earth's crust, caused by natural and man–made causes, lead to movements along tectonic faults. As a result, stress is reduced and seismic energy is released. Finding out the specific reasons for their occurrence presupposes knowledge of the features of the geological structure of the territory in terms of its historical formation [Nesterenko et al., 2018; Nesterenko et al., 2019].

For many decades, leading petroleum geologists and many other researchers have been studying the oil and gas potential of the Mesozoic deposits of Azerbaijan. The patterns of formation and location of oil and gas accumulation zones in the Mesozoic deposits of the republic were studied as the basis for assessing the prospects for oil and gas potential and developing directions for prospecting and exploration work. The search for oil and gas deposits in the Mesozoic deposits of Azerbaijan began mainly in the post–war years [Gurbanov, 2019].

Like many old oil and gas producing provinces in the world, Azerbaijan has largely exhausted the possibilities of discovering easily accessible oil and gas fields at shallow depths in anticlinal traps, as well as at shallow sea depths. In Azerbaijan, despite the wide stratigraphic range of oil and gas content, its two floors are mainly distinguished: the upper – Pliocene and lower – Mesozoic, separated by a thick clayey strata of the Paleogene–Miocene, in the section of which in some cases small accumulations of oil are found. As a result of the analysis and interpretation of geological–geophysical and petrophysical materials, it was established that oil and gas–bearing reservoirs are mainly fractured volcanic–sedimentary and carbonate rocks of the Cretaceous sediments [Gurbanov, 2019].

As a result of intensive exploitation of gas and oil fields due to a decrease in reservoir pressure, natural geophysical and, accordingly, geodynamic equilibria in the geological environment containing them and adjacent groundwater systems are significantly disturbed. This leads to the formation of dangerous geodynamic processes and a manifold increase in the number and intensity of seismic events in oil and gas production areas [Yushkov et al., 2013]. The Absheron–Balkhan threshold, in the Azerbaijani sector of the Caspian Sea, is a connecting link between the Middle and Southern Caspian Sea, where giant oil fields are concentrated, and to the southwest in the Baku archipelago – the giant gas condensate field Shah Deniz. The intensity of tremors on the Absheron Peninsula from the Baku earthquake sources reaches VII points, from the Mashtagin earthquakes – up to VIII points. The intensity of earthquakes, the epicenters of which are located in the North Absheron water area, reached VIII points, and in almost the entire rest of the peninsula – VII points [Karagezova, 2015].

In this regard, we analyzed the geological structure and geodynamics of the upper part of the Earth's crust in the Absheron oil and gas region, refined its geodynamic model and analyzed the stress–strain state, which largely determines the response of the geological environment to technogenic impacts.

Geological structure of the district

The Absheron oil–gas region is tectonically a continuation of the southeastern dip of the Great Caucasus megaanticlinorium. The land area of the region consists of the Absheron peninsula extending in the latitude direction and covers an area of 2059 km^2. The region includes the Absheron peninsula, the Absheron archipelago located east of it, and the islands of the Baku bay belonging to it. The territory of the Absheron oil and gas region is located in the northwestern part of the South–Caspian basin, and its geological structure consists of Upper Cretaceous to Anthropogenic sediments. Lower Cretaceous sediments were studied up to 700 m thick in exploration wells dug in Khazri (well 4), Gilavar (well 2) and Arzu (well 2) areas of the northern tectonic zone of the

Absheron archipelago [Aliyev, 2003]. Faults and mud volcanoes play an important role in the complexity of the structure of the Absheron region. Both transverse and longitudinal fractures are noticeable in this structure. The Meso–Cenozoic complex (8.5–9 km) of terrigenous carbonate sediments is involved in the geological section of the Absheron oil and gas field. Of these, there are more than 30 oil–gas horizons with a thickness of 10–80 km in the section of the Middle Pliocene (alternation of sand, sandstone and clay). The tectonic units of the Western Absheron anticlinorium, the Western Absheron anticlinorium, the Western Absheron synclinorium, the Central Absheron anticlinorium, the Eastern Absheron synclinorium and the anticlinorium of the Absheron archipelago are separated in the area. There are 7 anticlinal zones with more than 50 free folds. 26 of these mixtures are processed. All anticlinal zones are complicated by tectonic disturbances and mud volcanoes. The future of the field is mainly related to Oligocene–Miocene and possibly Upper Cretaceous sediments [Yusifov, 2018].

Absheron oil and gas field

There are many oil fields, gas condensate oil fields, and condensate fields in the Absheron oil and gas field. Millions tons of oil, gas and condensate are produced from these fields every year. A different picture of oil and gas formation and oil and gas accumulation is established for the Absheron–Balkhan threshold with a near–latitudinal strike (more than 300 km), which is a protrusion of the continental crust of the Eurasian plate (the Epi–Hercynian Turanian plate is located to the north), covered by a platform Mesozoic–Eocene–Pliocene cover [Vorobyov, 1999]. In the northwestern part of the threshold (Neft Dashlary), Eocene deposits are established directly under the layers of the productive strata, overlying Cretaceous rocks with a significant break and unconformity [Agayev, 2004]. A thick complex of Pliocene sediments, reaching 6–7 km in the South Caspian basin, sharply thins along the Absheron–Balkhan threshold, to the north, where in some places it lies directly on the sediments of the Mesozoic complex. The change of complexes along the threshold is accompanied by the replacement of oil fields with gas and gas condensate fields. Oil fields along the Absheron–Balkhan threshold – Neft Dashlary, Gunashli, Chirag, Azeri, Kapaz – are confined to arches of anticlinal sedimentary coverings in the productive strata, which are hydrocarbon traps [Kazimova, 2020]. The zone of the Absheron–Balkhan threshold in the north is limited by the North Absheron trough, with a maximum thickness of the Pliocene sedimentary up to 7 km, and in the south, during the transition in the South Caspian basin, by the Caucasus–Kopet Dag fault–slip fault, which apparently was a consequence of what took place in the early Pliocene failure of the South Caspian depression [Ismail-zade, 2013; Mamedov, 2008].

Formed in the post–Pliocene period, the giant gas condensate field Shah Deniz in the productive strata at a depth of 6.5–7.0 km corresponds in composition and physicochemical parameters to hydrocarbons – high–temperature methane, characteristic of depths of 10–12 km. The lack of proper combinations of phase transformation conditions – excessively high pressure and relatively low temperature, as well as a relatively short development period did not contribute to their transformation into the liquid phase. All this allows us to consider the Shah Deniz gas condensate field as an independent gas condensate stage of the hydrocarbon manifestation in the Caspian basin, which has no direct connection with earlier oil fields in the region. According to the author in the article [Ismail-zade, 2013; Mamedov, 2009], the main source of gigantic oil inflows into the Absheron–Balkhan threshold could be the oil and gas complexes of the Middle Caspian Sea, in which the Epi–Hercynian plate with a platform Mesozoic–Cenozoic cover is capable of creating the conditions of a screening layer capable of accumulating hydrocarbons with their subsequent transformation within the cover in the phase of liquid hydrocarbons.

Research methods

The earthquake source mechanism is one of the most important parameters characterizing a seismic event. In modern seismology, it is associated with sudden movement of rocks, accompanied by the emission of seismic waves along a surface of weakened strength, and simultaneously reflects the spatial orientation of the axes of the main stresses, possible planes of ruptures and movements in the earthquake source. Since earthquakes have not been recorded on the territory of the Absheron Peninsula, we analyzed the sources of Caspian earthquakes [Etirmishli, 2019].

Earthquake source mechanism were established in the "Dynamics of earthquake source" department of RSXM based on the signs of P waves of 52 digital stations of earthquakes with ml≥3.0 in "Fa_major" and MomentTenzor software [Dreger, 2002; Etirmishli, 2019]. During the years 2003–2023, an analysis of 54 earthquakes with magnitude ml≥3.0, depth h=2–69 km in the Absheron territory was carried out, and the source mechanisms were established (Fig. 1).

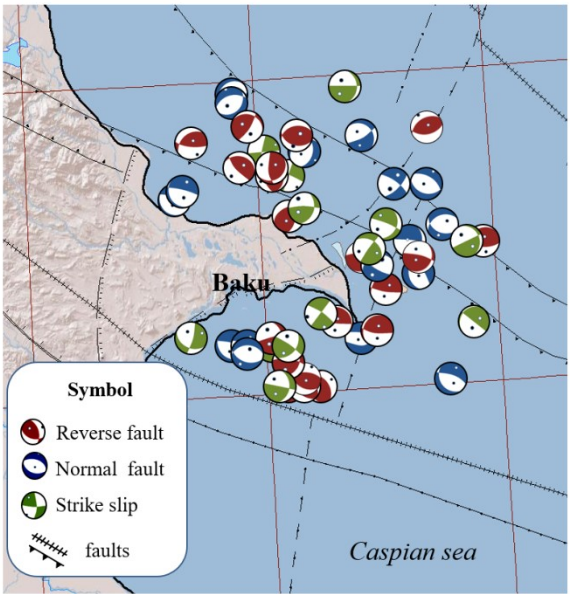

Fig. 1. The map of earthquake source mechanism with ml≥3.0 for the period 2003–2023

As can be seen from the map, the Absheron region is dominated by, normal faults and horizontal displacement.

Ten earthquakes with a magnitude ml≥4.0 were recorded in Absheron territory in 2003–2017. Three of these earthquakes are horizontal strike–slip, four are reverse fault and three earthquakes with normal fault type movements and they coincide with Shakhov–Azizbayov, Krasnopolyansky–Zengi–Sangachal–Ogurchi, Makhachkala–Krasnovodsk, Central–Caspian, Siyazan faults. This sources they are located in the depth interval 7–69 km.

On October 24, 2003, at 20:47:24, an earthquake (ml=4.2) felt 43 km northeast of Absheron was recorded. Several aftershocks were recorded after the earthquake. It should be noted that the earthquake that occurred in the Absheron area extends along the Siyazan deep fault. As can be seen from the table, the direction of the compression axis P is directed to the horizon (PL=4), and the direction of the tension stress axis T is directed to the plane close to the horizon (PL=7). A sharp drop was determined for the nodal plane (DP=87–82). It is shown that the value of displacement at the source is (SLIP=–8–(178)). Based on the above, as a result of the stress states, it was determined that the earthquake has normal fault type. On February 6, 2017 at 13:46:39, an earthquake (ml=4.4) felt 60 km southeast of Absheron was recorded. Several aftershocks were recorded after the earthquake. As can be seen from the table, the direction of the compression axis P is directed to the horizon (PL=7), and the direction of the tension stress axis T is directed to the plane close to the horizon (PL=9). A sharp drop was determined for the nodal plane (DP=88–79). It is shown that the value of displacement at the source is (SLIP=–169–(2)). Based on the above, as a result of the stress states, it was determined that the earthquake was of displacement–rupture–fall type.

Thus, having analyzed the data on the source mechanisms of all earthquakes, it was established that for the territory of the Central Caspian Basin, small values of the angles of the tension axes are characterized by large angles of the compression axes, which indicates the predominance of normal–slip movements there (Table 1). Given the choice (according to geological data) of preferred fault planes, both right– and left–lateral strike–slip faults occur [Kazimov et al., 2016]. The earthquakes occurred under conditions of compressive and tensile stresses that were close in magnitude (shear type of movement). The fault type of movement mainly prevails in the central part of the study region. Reverse faults are also found on the territory of the Northern Caspian [Etirmishli et al., 2019]. Comparative analysis of the earthquake source mechanism that occurred in 2003–2023. showed that, in general, the tendency for the predominance of fault–slip movements within the study region remains unchanged. In order to study how the orientation of the main axes of compression and extension changes with depth, we constructed a distribution diagram of the orientation of the main axes of compression and extension of the Caspian region in the depth intervals of 20–30 km, 30–40 km, 40–55 km, 55–70 km. As can be seen in Fig. 4, with depth, the tendency for the SW–NE orientation of the tension axes and the NW–SE orientation of the compression axes becomes more and more clearly evident.

Table 1

Earthquake source mechanism that felt in Absheron territory in 2003–2023 ml≥4.0

№	Date	Time	Coordinates		Principal stress axes						Nodal planes						ml	H, km
			φ°N	λ°E	T		N		P		NP1			NP2				
					PL	AZM	PL	AZM	PL	AZM	STK	DP	SLIP	STK	DP	SLIP		
1	20030725	23:59:28	40.00	50.25	66	210	16	339	17	74	332	64	72	187	31	122	4.2	41
2	20031004	09:10:58	40.19	49.84	27	35	6	302	62	200	300	72	–97	141	19	–70	4.3	35
3	20031024	20:47:24	40.68	50.15	4	243	82	360	7	153	198	87	–8	288	82	–178	4.2	43
4	20090604	14:20:03	40.40	50.64	16	57	23	320	61	180	309	65	–115	178	35	–47	4.2	44
5	20100603	04:53:30	40.47	50.42	56	207	20	82	25	342	269	73	111	35	27	39	4.2	57
6	20111115	19:33:54	40.05	50.13	60	124	28	285	7	20	267	58	56	138	44	132	4	55
7	20130607	08:33:00	40.52	50.81	17	195	15	290	66	60	118	64	–72	262	30	–121	4.1	69
8	20130909	04:35:47	40.68	49.98	62	66	9	319	27	225	142	72	99	295	20	64	4	7
9	20161027	10:12:52	40.46	50.83	41	170	20	60	41	311	60	90	–110	330	20	0	4.1	55
10	20170206	13:46:39	40.30	50.23	7	170	79	45	9	262	36	88	–169	306	79	–2	4.4	60

Seismicity of Caspian sea water area.

The Caspian Sea occupies a special place in the seismic life of Azerbaijan. Strong (M_{LH}≥6.0) earthquakes that occurred here in 1910, 1935, 1963, 1986, 1989 repeatedly shook the bottom of the Caspian Sea, the city of Baku and other coastal areas with high intensity V–VIII points.

The first information about an earthquake in the Caspian water area coincides with 957. The earthquake registered in 957 was felt in the Caspian coastal regions with intensity VII point. There was destruction in the Caspian coastal regions. The main parameters of the earthquake: φ=42.10; λ=49.00; magnitude M=5.5 (± 1.0); the depth of the hearth was h=7–60. This earthquake in the Caspian Sea is believed to be two earthquakes. After the earthquake, the sea retreated from the coast by 150 m. So far, the strongest earthquake in the Caspian Sea was recorded on January 2, 1842 at 22:00 (±1 hour). The earthquake was felt with intensity VIII point. The main parameters of the earthquake: φ=40.50; λ=50.0; magnitude M=4.3 (± 0.5); the depth of the source was h=3 (2–5). 700 houses were destroyed in Mashtaga, and 5 were seriously injured. After the Mashtaga earthquake, aftershocks continued until January 12.

The last strong earthquake (M=6.2) in the Azerbaijani part of the Caspian Sea occurred on November 25, 2000, 50–60 km south of Absheron, and shook the bottom of the Caspian Sea with intensity VIII point. This earthquake also occurred in Baku and a number of coastal areas with intensity VI–VII points. In Baku, 34 houses were partially destroyed, 7350 houses were damaged [Ismayilova, 2021]. The magnitude of the first shock was M=5.2. According to the instrumental data, the main parameters of the earthquake: φ =40.15; λ = 50.15; depth of the source h=25 km. At 1.5 intervals, the second impulse occurred. The magnitude of the second shock was M=6.2. The main parameters of this earthquake: coordinates of the source – φ=40.05; λ=50.35; the depth of the source varies between h=40–45 km.

In 2003–2023, 75 earthquakes of ml≥3.0 were registered in Absheron territory and a map of epicenters was created. Earthquakes are located at a depth of 2–70 km. (Figure 2.)

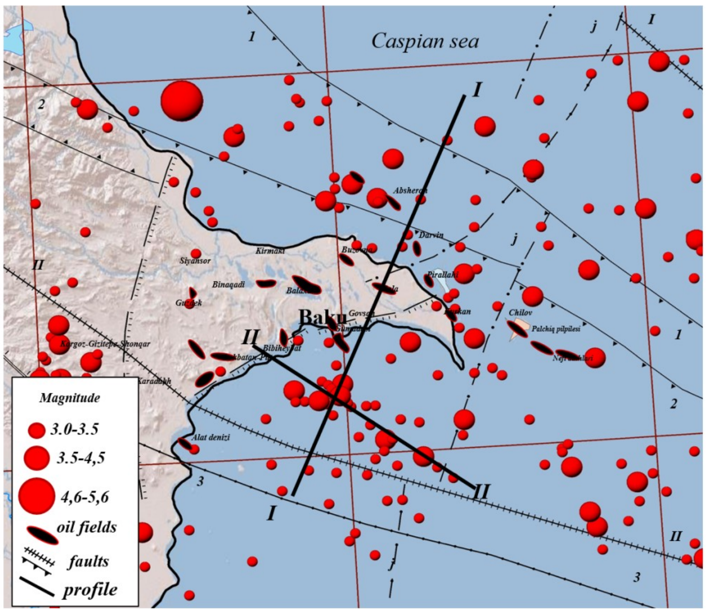

Fig. 2. Absheron oil and gas field during 2003–2023 map of epicenters of earthquakes on faults
Faults: I – Agrakhan–Krasnovodsk; II – Krasnopolyansk–Zangi – Sangachal–Ogurchi; 1 – Makhachkala–Krasnovodsk; 2 – Siazan; 3 – Ajichay–Alat; j – Shakhov–Azizbeyov (The fault map was compiled by: Musayev Sh. [Gasanov, 2006; Gurbanov, 2019; Khain, 2005])

The map of earthquake epicenters that occurred in the Absheron oil and gas field has been created. There are several oil fields in this area. A large amount of oil is produced in these fields during the year. We can give an example of Oily Rocks (Neft Dashlari), Palchyg pilpiles, Chilov, Bibiheybat, Buzovna, Balakhani–Sabunchu–Raman, etc., which are important deposits of the Absheron oil and gas field [Gurbanov, 2019].

Oily Rocks is the world's first oil platform. Oily Rocks is an urban–type settlement and is included in the territory of Baku's Pirallahi district. Located 42 km southeast of the Absheron peninsula, this settlement was built a few meters above sea level on stilts on metal poles attached to the bottom of the sea. Mud Pilpilesi field is located in the Absheron archipelago of the Caspian Sea, 110 km east of Baku and 50 km southeast of Artyom Island. In the area where the deposit is located, the depth of the sea varies from 10 m to 25 m. The deposit belongs to the brachyanticnal fold, complicated by a large number of transverse and longitudinal fractures [Abdullayeva, 2016]. The bed is 9 km long and 3 km wide according to the ceiling of the Kirmaki layer set. The Chilov field is located in the southeastern part of the Absheron archipelago in the Caspian Sea, 62 km from Baku, 20 km from Pirallahi Island, in the northeast direction. The bed is connected to the island of the same name, which is 7 km long and 5 km wide. Chilov Island, which is 6 km long, is the second largest island in the Absheron archipelago. The island stretches from the northeast to the southwest and is in the form of a thin long strip that gradually narrows [Agayev, 2006; Gadji–Kasumov, 2012]. The depth of the sea is up to 10 meters near the island, and it varies in the range of 5–25 meters along the structure. The Chilov structure belongs tectonically to the Khali–Neft Stones anticlinal belt.

In recent years, the level of seismic activity in certain areas of the Caspian Sea has changed. The amount of seismic energy released in the Central Caspian Sea has increased several times. Along with strong seismic events, a large number of weak earthquakes occur in the study area, which make it possible to study the seismicity of this region in connection with its deep structure [Abdullayeva et al., 2016].

Note that the formation, migration and accumulation of hydrocarbons in the Caspian region occur in the sedimentary cover. Although various geological and geophysical studies have been carried out so far, no geological exploration work has been carried out in the region, taking into account the seismic geodynamic conditions of oil and gas and their patterns. To do this, in order to clarify the nature of seismic geodynamic and dynamic changes in the region, we analyzed the distribution of earthquake source mechanism over area and depth, which determines the geodynamic energy status of the sedimentary cover.

The seismological sequence of earthquakes with ml≥1 km in the Absheron oil and gas field has been established (Fig. 3). The number of earthquakes with magnitude ml≥1.0 was 319, and the depth was distributed in the range of 1–70 km. 4 earthquakes with magnitude ml≥4.0 were recorded [Kazimova et al., 2020; Magomedov, 2021; Kazimov, 2021; Yetirmishli, Kazimov, 2022]. These earthquakes are distributed at a depth of 6–62 km.

A map of the earthquake's epicenters showed that within its boundaries there are two active seismic zones with a 100–year return period for magnitude 8 earthquakes. The first zone is located in the northern part of the peninsula, and the second one covers Absheron from the south. Most earthquakes occurred within these two seismically active zones.

As can be seen in the profile, two focal zones are distinguished to the north of Absheron and to the south (Fig. 3). The northern focal zone is located at a depth of 0–25 km and a width of 35 km. The northern zone is associated with the system of ruptures of the Main

Caucasus and the Absheron–Pribalkhan deep fault, which passes through the northern coastline of the Absheron Peninsula and the territory of the Caspian Sea to the west of Turkmenistan. The destructive Mashtaga earthquake of 1842 occurred precisely in this zone [Ismayilova, 2021]. In addition, less strong earthquakes with a magnitude below 6.0 are confined to it (1983, 1989). In addition, a series of sources are observed at depths of 40–50 and 50–60 km. The southern seismogenic zone is concentrated at a depth of 20–62 km, with a width of 25 km.

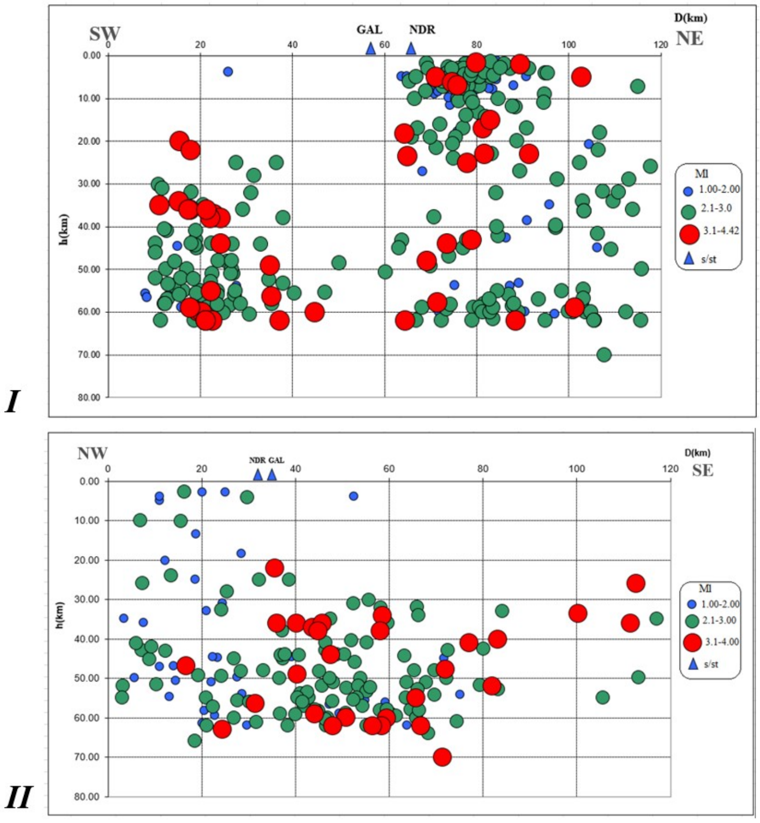

Fig. 3. Seismological cross–section of earthquakes with ml≥1.0 of the Absheron zone on the I–I and II-II profiles in 2003–2023

Earthquakes in the seismological section of the II–II profile are mainly distributed at a depth of 3–70 km. Earthquakes with magnitude ml≥4.0 were accumulated at a depth of 30–62 km. This zone coincides with the eastern continuation of the Vandam zone. The epicenter of the Caspian earthquakes were located in it (35 km south of Baku, November 25, 2000 with magnitudes 5.8 and 6.3). The last Caspian earthquake on November 25, 2000, with a foreshock (magnitude 5.8, focal depth 50.4 km) and with a main strong shock (magnitude 6.3, focal depth 33 km) had a strong impact on the entire Absheron Peninsula and, of course, on Baku (35 people died, 1292 buildings were destroyed and damaged). The source of the November 25 earthquake had a large magnitude and was located close to the study area.

The scheme of compression–tension axes was established based on the data of earthquake source mechanism with ml≥3.0 in the Absheron zone during the years 2003–2023 (Figure 4).

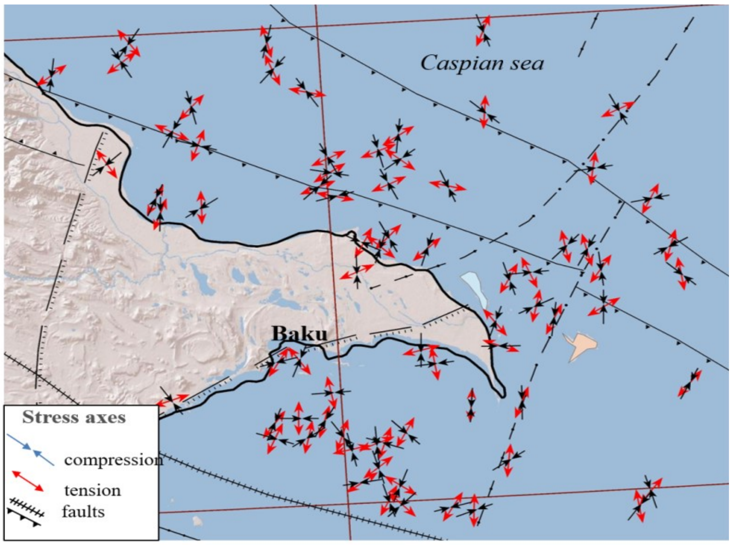

Fig. 4. The scheme of compression–tension axes of earthquake source mechanism ml≥3.0 in the Absheron region during 2003–2023

On the map, blue indicates compression arrows, red indicates tensile stress. The direction of the compression axis of earthquakes is observed in the Absheron zone in the NE–NW orientation, while the direction of the stress axes is in the NE–SW direction (Fig. 4).

As a result of the orientation of the compression and tension axes, a distribution map of the Lode–Nadayi coefficient was constructed. On the map, the blue color shows the tensile stress, the red color shows the compressive stress. As can be seen from the map, the stress in the Absheron zone is mainly characterized by compression stress. The level of the stress in the years 2003–2007 is 0.1–0.3, in the years 2008–2012 0.1–0.4, in the years 2013–2017 0.2–0.6, and in the years 2018–2023 in the range of 0.3–0.8 higher (Fig. 5).

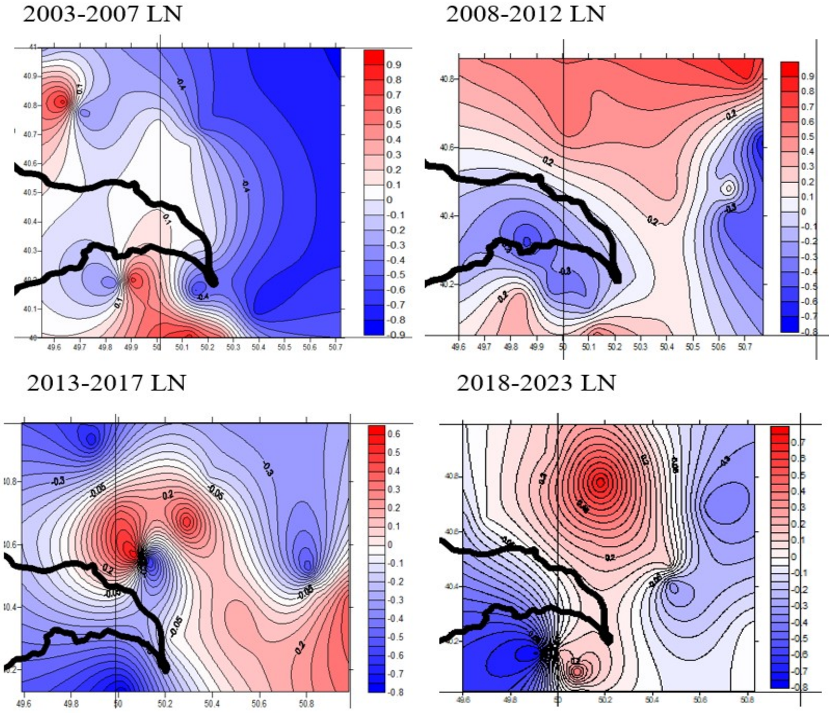

Fig. 5. Distribution map of the Lode–Nadayi coefficient as a result of the orientation of compression and tension axes of earthquake source mechanism ml≥3.0 in the Absheron territory during 2003–2023.

As a result of the research carried out in the Absheron area in 2003–2013, a map of seismic activity was created based on the catalog and map of epicenters. During the years 2003–2023, changes are observed in the northern, southern and eastern parts of the Absheron territory. As can be seen from the map, the activity in the southern part is 1.2–2, compared to the background level of 0.1 in 2003–2012, and in the range of 0.75–1.1 in 2013–2023, compared to the background level of 0.05.

During the years 2003–2012, the activity in the northern part of the Absheron area varies from 0.8 to 1.3, and from 2013 to 2023, it varies from 0.45 to 0.65, compared to the background level of 0.1. In the years 2003–2012, the activity in the northeastern part of the Absheron area varies between 0.4–0.7, compared to the background level of 0.1, and in the years 2013–2023, it varies in the range of 0.25–0.4, compared to the background level of 0.05.

Results of the study

Thus, the analysis of seismicity showed that within the Absheron oil and gas region there are two active seismic zones, with a 100–year return period for earthquakes of magnitude 8. The first zone is located in the northern part of the Absheron peninsula, and the second one covers from the south. Most earthquakes occurred within these two seismically active zones. The largest part of the hypocenters is observed in the consolidated layer and upper mantle and was formed as a result of active tectonic movements at the junction of the two largest structures of the Earth's crust (Turanian and Kopetdag ridges). The northern focal zone is located at a depth of 0–25 km and has a width of 35 km. The northern zone is associated with the system of ruptures of the Main Caucasus and the Absheron–Pribalkhan deep fault, which passes through the northern coastline of the Absheron Peninsula and the territory of the Caspian Sea to the west of Turkmenistan. The southern seismogenic zone is concentrated at a depth of 20–62 km, with a width of 25 km. This zone coincides with the eastern continuation of the Vandam zone. The epicenters of the Caspian earthquakes were located in it (35 km south of Baku, November 25, 2000 with magnitudes 5.8 and 6.3).

In order to study zones of stress and deformation of the Earth's crust, the parameters of the earthquake source mechanism, the conditions for their formation, and the stress zones of the Earth's crust were analyzed. Displacement values at the source indicate that strike–slip and normal fault movements predominate. But in the area of the Central Caspian Sea and oil fields, movements such as reverse faults and reverse faults are formed. Analysis of the compression and extension axes shows that the compression axes of earthquakes are oriented in the SW–NE direction, while the extension axes are predominantly oriented in the NW–SE direction. The stress state in the study area changes over the years and is characterized mainly by tensile stresses.

Geological interpretation of materials from earthquake sources shows that in this uplift zone, corresponding to the intercontinental accretion zone. This activation occurs as a result of the subduction of the South Caucasian microplate under the Middle Caspian segment of the Scythian–Turanian epihertzian platform, i.e. pseudosubduction.

Conclusions

Oil and gas intensification in regions characterized by large oil and gas fields leads to changes in the natural (geological) environment, including changes in hydro–gas–geodynamic and geodynamic processes in large areas of ten kilometers or more (10,000 km^2) in the Earth's crust, and causes environmental problems. Those changes can be considered as one of the factors affecting the development of nature in the region and lowering the quality of life of the population.

As a result, the rate of occurrence of natural and man–made processes in oil and gas regions increases, and the seismic activity causes an unexpected event with a wide range of dangers. The solution of this problem is one of the important factors of conducting seismological research in a complex manner, it is possible to study the processes occurring at depth under the influence of hydrocarbons, including the state of technological processes. Thus, the study and analysis of these processes provides an opportunity to answer many questions. It will be possible to increase economic activity in the region by forecasting oil and gas production of Absheron region and increasing the efficiency of oil and gas production, ensuring their safety through pipelines.

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