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SEISMOPROGNOSIS OBSERVATIONS IN THE TERRITORY OF AZERBAIJAN

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Republican Seismic Survey Center of
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SEISMOPROGNOSIS OBSERVATIONS IN THE TERRITORY OF AZERBAIJAN

CONTEMPORARY GEODYNAMICS OF THE EASTERN MEDITERRANEAN

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Introduction

As you know, the Eastern Mediterranean and the Caucasus region are located among the Eurasian, African and Arabian plates, characterized by complex tectonic activity such as volcanic eruptions, orogeny and earthquakes. [15, 16] Eastern Anatolia, the Caucasus and Bitlis-Zagros are zones of active continental collision due to modern tectonic conditions. The Eastern Mediterranean is one of the important regions for understanding fundamental tectonic processes such as continental riftogenesis, subduction and accretion, and post collision. [11] The edges of the colliding continents under conditions of compression break into a large number of micro plates. For this reason, the collision zones, unlike all other types of interplate boundaries, do not represent narrow linear zones (as, for example, zones of spreading, subduction or transform faults), but always have "blurred" outlines in plan, and their width reaches hundreds and thousands kilometers. Note that the movement along the faults coincides with the direction from the movement of Arabia and Eurasia. The result of this geometry is that the continent throughout the active region [17] continues to influence the elevation of the Caucasus.

The Global Positioning System (GPS) has provided a new opportunity for direct observation of modern movements and deformations of the Earth's crust, as well as seismic-ionospheric disturbances [6, 8, 9, 12-14, 23, 24]. Previous GPS studies have helped to quantify regional deformation in the plate interaction zone [1, 18-22]. Regional studies of plate movement use fault orientation, local observations, and constraints on relative plate movement.

The results of GPS measurements obtained in recent years [1, 2, 3, 5, 7], including in the territory of Azerbaijan, once again convincingly indicated the importance of the horizontal component of tectonic movements in the development of the Earth's crust and the entire lithosphere. With the help of global satellite geodesy, it became possible not only to obtain high-quality information about modern geodynamics, but also to quickly monitor all its spatial and temporal changes, which is especially important for the purposes of adequate seismic zoning and long-term prognosis of strong earthquakes.

Intensity of seismicity in the Eastern Mediterranean

The tectonic activity of the Mediterranean was completely determined by the processes of closure of the relict basins of the Tethys Ocean with the residual crust of the oceanic type, taking place against the general background of the convergence of the African and Eurasian plates. Due to the roughness of the contour of the northern edge of the African Plate, subduction did not begin in different arcs simultaneously: in the Middle Miocene in the Calabrian, in the Oligocene in the Hellenic, and at the beginning of the early Miocene in the Cyprus. For the same reason, as well as due to the different width of the band of absorbed residual oceanic crust and different convergence rates along the border of the Eurasian and African plates, the subduction zones of the Eastern Mediterranean closed at different times, but in general, the process of continental collision developed from east to west: from the Middle Miocene to east (Bitlis) to the second half of the Pliocene (Cyprus/Cyrenaica) in the west [5].

The Eastern Mediterranean region has experienced many devastating earthquakes throughout its history. The earthquake observed around the Aegean Sea, covering most of Greece and Western Anatolia, was the most remarkable geodynamic event in the Eastern Mediterranean region (Fig. 1). The tectonic evolution of the Eastern Mediterranean region is dominated by the effects of subduction along the Hellenic (Aegean) arc and continental collision in eastern Turkey (Anatolia) and the Caucasus. The northern subordination of the African plate, Western Turkey and the Aegean region is a continuation of the continental crust [5]. In terms of historical seismicity, strong earthquakes have occurred with a magnitude greater than Mw=6 in the Eastern Mediterranean and the Caucasus. The Anatolian plate is of interest for more than two decades of GPS studies, mainly focusing on the seismically and tectonically active region of the Sea of Marmara, Western Anatolia, Central Anatolia, and the North Anatolian fault system with determination of the rate of deformation and slip [20, 21].

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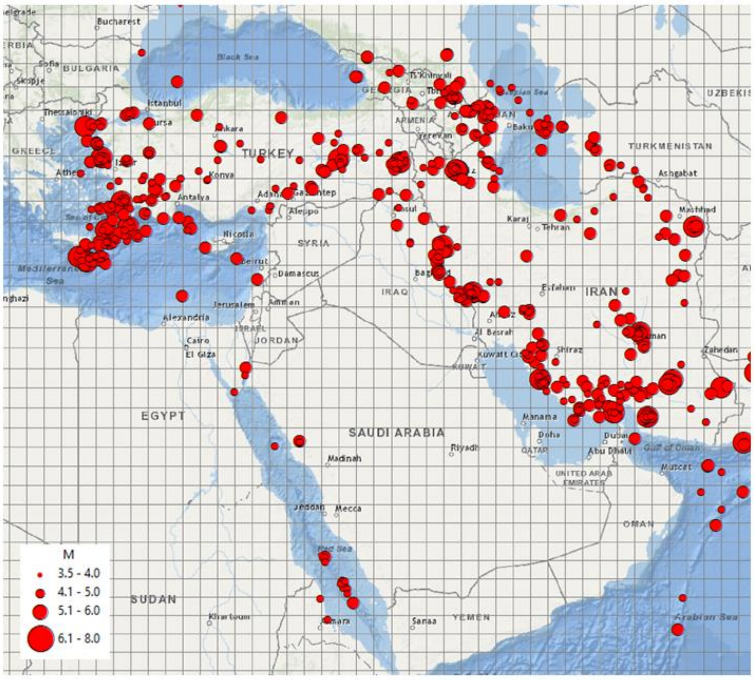

Figure 1. Map of the epicenters of earthquakes with ml>3.5 that occurred within the Mediterranean region for the period from 2005-2020

In seismogenic terms, interblock zones are structures within which, as a result of the gradient of tectonic stresses arising during deformation processes, a significant amount of seismic energy is released. The relatively shallow penetration of these zones into the lithosphere is confirmed by the location of hypocenters in the overwhelming majority of cases at a depth of 20-40 km, much less often up to 80-240 km. In interblock zones, it is easy to see a certain analogue of transit zones established between large plates, which serve as one of the expressions of the fractal structure of the continental lithosphere [5, 10].

Turkey is one of the most earthquake-prone countries in the world. According to scientists, Turkey is located on a small wedge-shaped Anatolian plate. The Anatolian plate is a continental tectonic plate, which is almost entirely located on the territory of Turkey (Fig. 2). The earthquake catalogue was taken from EMSC.

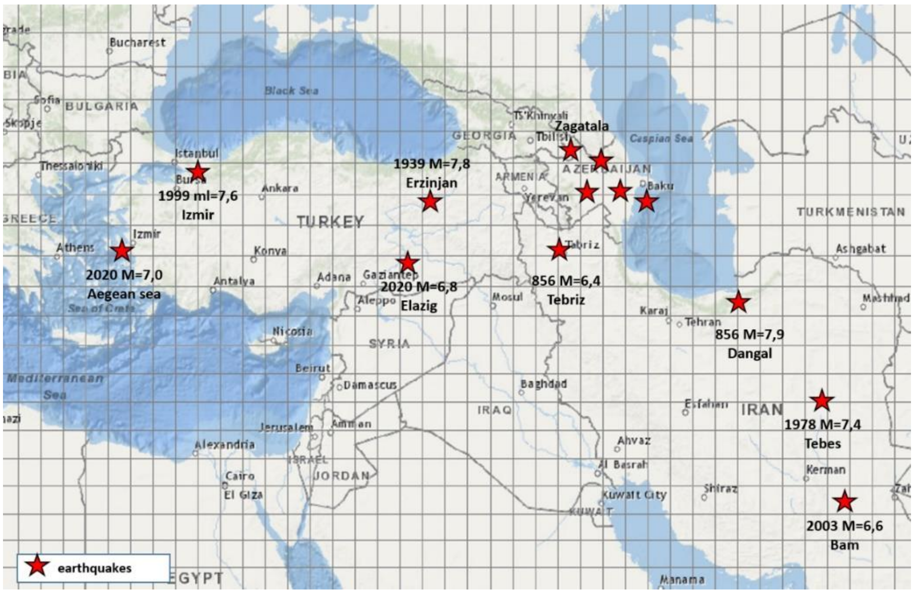

Figure 2. Map of the epicenters of strong historical earthquakes with ml>5.0 that occurred within the Mediterranean region for the period from 856-2020

Has an area of 0.014 18 steradians (0.57 thousand km^2). Usually is considered as a part of the Eurasian Plate. The eastern edge is bordered by the Arabian plate, the left-sided transform East Anatolian fault. In the south and southwest, it has a convergent border with the African Plate, which manifests itself in the features of compression of the oceanic crust under the Mediterranean Sea, as well as within the continental crust of Anatolia and in subduction zones along the Greek and Cypriot arcs. The western edge has a divergent border with the plate of the Aegean Sea [5]. The northern edge along the border with the Eurasian plate forms the North Anatolian fault zone 500 miles long. At its western end is the volcanic underwater North Aegean fault, following through the middle of the Aegean Sea. The fault zone further follows under Greece and further under the Ionian and Adriatic seas. As a result of active interaction and movement along these major faults, hundreds of earthquakes of various strengths occur in this region. The Anatolian plate is moving to the west (2–2.5 cm/year), because it is pressed by the Eurasian plate from the north, the African plate and the Arabian plate from the south (Fig. 3).

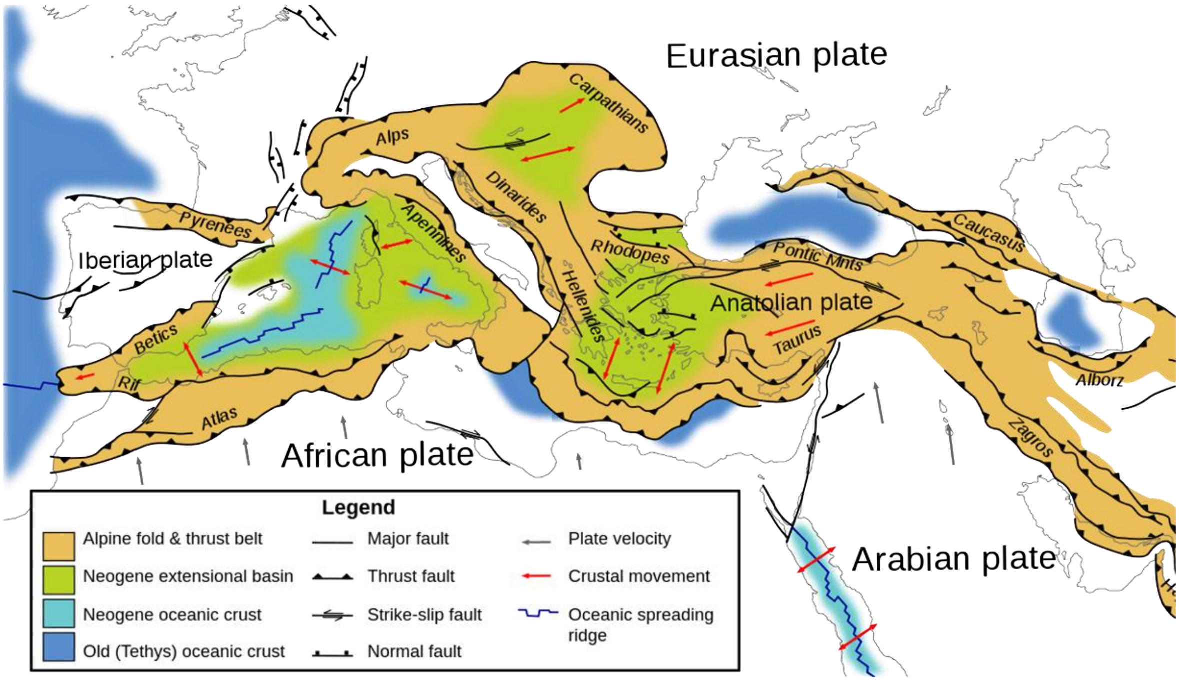

Figure 3. Alpine-Himalayan fold belt

Many major earthquakes in Turkey occur on one of two faults adjacent to the Anatolian plate to the north and east. In 1939-1999 violent tremors went west along the northern rift, causing scientists to fear that Istanbul would eventually be destroyed. In 1999, an earthquake with a magnitude of 7.9 happened in the vicinity of Izmir (only 70 km from Istanbul), killing about 17 thousand people. At the moment, in Turkey, seismically unstable regions are the Black Sea coast and the Eastern part of Turkey, where the border of the junctions of the Arabian and Turan-Scythian lithospheric plates is located. The most earthquake-prone point of this fault is outside the territory of Turkey, namely in the eastern part of the North Caucasus, where the greatest number of earthquakes of great strength occurs. Cities are a mixture of rich and poor infrastructure, putting a huge proportion of the population at risk. In 1999, a 7.4 magnitude earthquake struck the city of Izmit, just 97 km from Istanbul. Around 18,000 people died in the region. In 1997, seismologists predicted that the same earthquake could be repeated in the region until 2026 with a 12 percent chance.

The strongest earthquake that hit Turkey in the 20th century took place in Erzindjan in December 1939. It destroyed most of the city and killed more than 30,000 people. One of the most destructive earthquakes in Turkey occurred near Istanbul on August 17, 1999. The earthquake with epicenter in 11 km from the city of Izmir and 80 km from Istanbul killed 19,000 people and damaged numerous historical monuments and structures. An earthquake with a magnitude of 7.4 almost completely destroyed the industrial center of the country.

Van earthquake On October 23, 2011, a 7.2 magnitude earthquake struck at a distance of 38 km northeast of the city of Van in Turkey. The number of victims of the devastating earthquake in Van exceeded 260 people, about 1300 were injured. The earthquake was also recorded in Armenia, Georgia and Iran. The tremors in Armenia ranged from 3-5 points.

A devastating earthquake in the eastern Turkish province of Elazig with a magnitude of 6.7 occurred on January 24, 2020 at 20 hours 55 minutes local time. The source of oscillations (hypocenter) lay at a depth of 11.9 km near the city of Seavridge. The earthquake was felt in the neighboring provinces of Diyarbakir, Malatya, Adiyaman and Samsun. Its duration was about 40 seconds. The magnitude of the aftershocks ranged from 5.4 to 3.3. The intensity of the earthquake was 8 points.

On October 31, 2020, Izmir shuddered from another earthquake: in the morning at about 08:30 local time, there was a strong aftershock with a magnitude of 5.0. But most residents spent the entire night on the streets, fearing a repetition of a strong shock of almost 7 points on October 30, which could bring down the buildings affected by the first earthquake. According to AFAD, at least 389 aftershocks were recorded, 33 of them having a power of more than 4 points, which lasted until the morning.

Central Iranian block

The Central Iranian block has a Late Precambrian metamorphic basement and a Vendian-Triassic platform cover. The Central Iranian microplate lies in the same zone as the Anatolian-Taurus "platform" of Turkey. In the east, the Lut block of Central Iran is bounded by the zone of development of the Upper Cretaceous-Lower Eocene ophiolites and their accompanying flysch, expanding to the south. Its southwestern framing forms the Urmia-Bazman (Dokhtar) volcano-plutonic belt of Late Cretaceous-Cenozoic age with subalkaline volcanics from basalts to rhyolites [6]. The formation of the belt is associated with the collision of the Arabian and Central Iranian plates. The magma belt itself is confined to the border of Central Iran and the mobile belt of the same northwestern strike, which arose on the site of the southern branch of the Neotethis, stretching here from the Taurus system of Anatolia. In Iran, this belt consists of two zones - the Sanandadj-Sirdjan metamorphic zone and the Zagros fold zone [6].

The Sanandadj-Sirdjan zone is characterized by a complex and not yet fully understood structure. It is composed of the Paleozoic with the participation of volcanics, metamorphosed in the Hercynian or Early Cimmerian epochs, as well as the Mesozoic, and is bounded in the southwest by the Main Zagros thrust, which separates this zone from the Zagros zone. The thrust is directed to the southwest and consists of a number of scales, in which Mesozoic ophiolites protrude in places [6].

Iran is also one of the most seismically active countries in the world, a place where several large faults intersect, which cover at least 90% of the country's territory. As a result, earthquakes in Iran are frequent and quite destructive. Since 1900, there have been at least 126,000 deaths in the Iranian earthquake.

In Iran, earthquakes are concentrated mainly along the fold-thrust belt of the Zagros, extending from northwest to southeast, - the result of the collision of the Arabian and Eurasian plates. This zone is associated with the activity of two main faults - a right lateral strike-slip - the Main Modern Fault (MRF) and its continuation in the southeast - the Main Zagros Thrust (MZT). The mechanisms of earthquake sources in the form of uplift and uplift shifts are mainly observed here. In northern Iran, near the Elburz Mountains, there are numerous strike-slip faults located south of the Caspian Sea. [6]

The 856 Damgan earthquake is the deadliest earthquake in Iranian history, killing more than 200,000 people. On September 16, 1978, there was a strong earthquake in Tebes, which killed 25,000 people. Earthquake in Bam on December 22, 2003, one of the last strong earthquakes occurred on August 11, 2012 in Tabriz (Fig. 2).

Analysis of satellite navigation system (GPS) data

The edges of the colliding continents under conditions of compression and agglomeration break into a large number of microplates. For this reason, the collision zones, unlike all other types of interplate boundaries, do not represent narrow linear zones (as, for example, zones of spreading, subduction or transform faults), but always have "blurred" outlines in plan, and their width reaches hundreds and thousands kilometers. The accretion and collision conditions on the modern Earth are manifested within the Alpine-Himalayan fold belt, which stretches for many thousands of kilometers from the Atlantic to the Pacific Ocean (Fig.3). [5] The Eurasian, Indian, Arabian and African lithospheric plates are currently in contact along this convergent boundary.

Using the data of the GPS stations of the RSSC ANAS, UNAVCO, Turkey and Iran, a map of vectors of azimuthal movements and a diagram of the velocities of horizontal movements of blocks of the studied region were compiled (Fig. 4,5). It should be noted that in the territory of Azerbaijan since 2013, within the framework of the RSSC, a new monitoring system has been installed, consisting of 24 GPS stations from “Trimble” company (USA) [4].

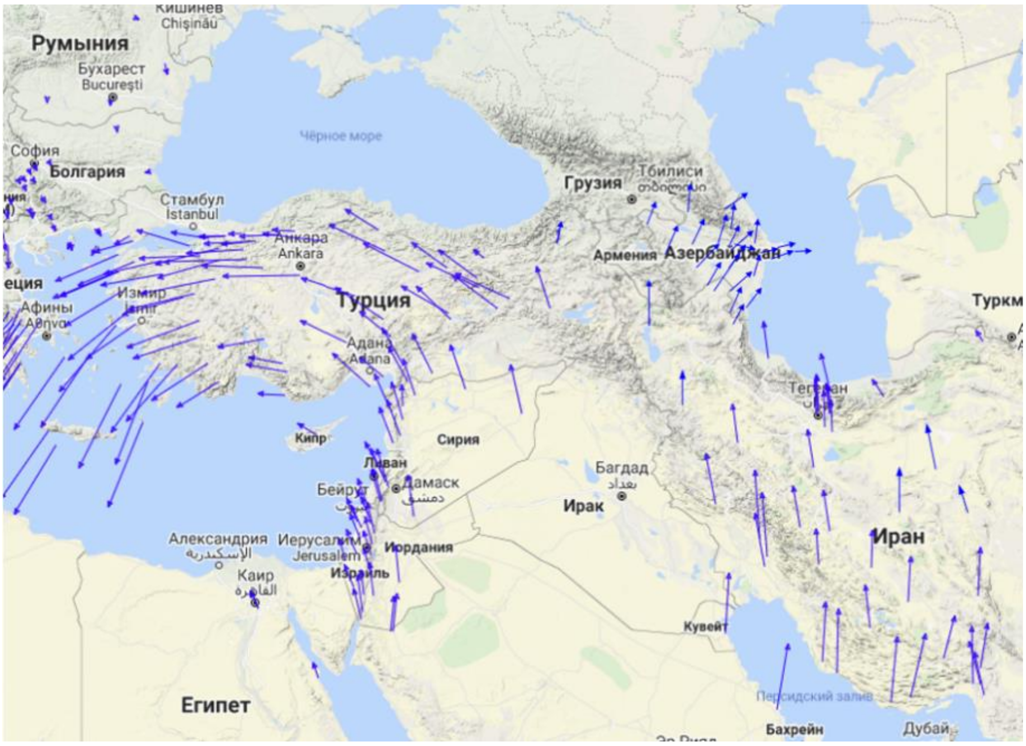

Figure 4. Azimuthal map of vectors of GPS stations of the Mediterranean region according to the RSSC ANAS data, UNAVCO, Turkey and Iran

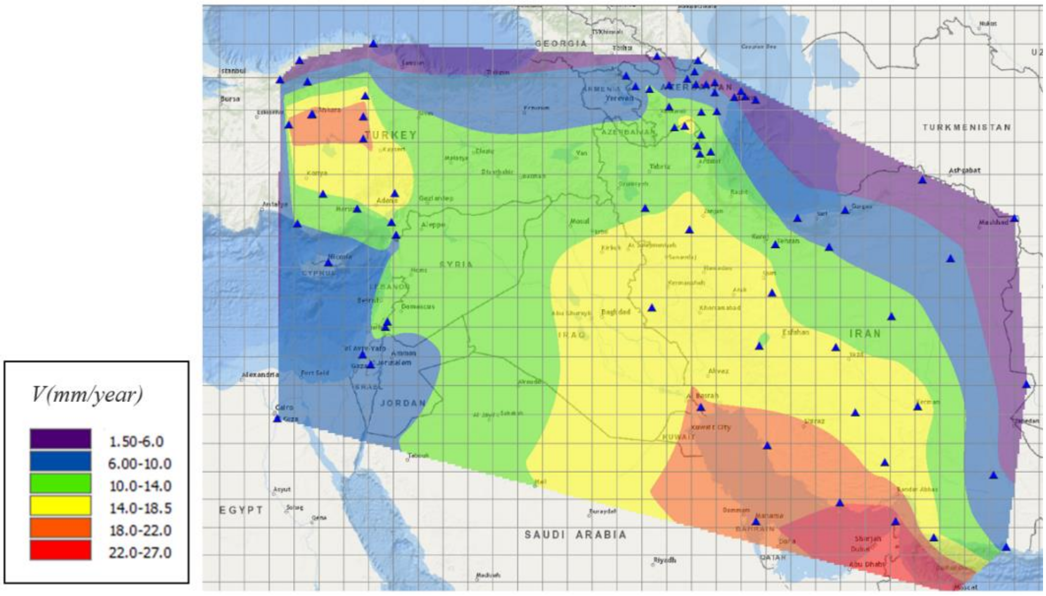

Figure 5. Distribution of the velocities of horizontal movements in the Mediterranean region according to GPS stations for the period 2006-2020

Analysis of the velocity field of GPS stations showed the heterogeneity of deformation processes in the region of the Eastern Mediterranean and the Caucasus. The considered results show the movement of the Arabian plate relative to the Eurasian one. Considering the velocities of movement of the Anatolian and Eurasian plates, and the Arabian and Anatolian plates, it was found that the shear rate along the North Anatolian fault was 20 mm/year, along the East Anatolian - 14 mm/year. This indicates the convergence of the Anatolian and Eurasian plates through the system of right shift faults in eastern Turkey and the Thrust system in the Caucasus. The total reduction in the distance between the Lesser and Greater Caucasus is 10 mm/year.

According to the results of the study of GPS networks by French and Egyptian researchers (Nocquet et al., 2006), during the opening of rifts, the displacement of blocks in the ITRF (International Terrestrial Reference Frame) system along the eastern and northeastern vectors with speeds of 4-6 mm/year prevails. One of the possible reasons for this may be the higher velocities of movement to the northeast of the Somali and Arabian plates (35-44 mm/year) compared to the eastern part of the African plate (25-32 mm/year). The North African-Apulian transit zone separates the western part of the North Eurasian and African plates (Gatinsky et al., 2007a). [5] The Apulian, Central Mediterranean and Rabat blocks included in it are displaced in absolute coordinates (ITRF system) to the east and northeast at rates of 25-40 mm/year. The first two of them rotate counterclockwise relative to the Eurasian N-plate taken for a stationary one, which is discussed in detail in (Nocquet and Calais, 2003). The movements of the main plates on both sides of the North African-Apulian transit zone are different: the African one is displaced by 40-45° NE, and the North Eurasian by 50-55°. Blocks in the eastern part of the Alpine-Iranian transit zone at the borders of the North Eurasian, African and Arabian plates have even greater kinematic independence. The Aegean block moves along an azimuth of 133-165° SE at velocities of 11-30 mm/year. Their maximum values are observed in the south, which is consistent with the extension in the Aegean Sea within the rear trough of the Hellenic island arc. The Rhodope-Sinop block (6) located to the north is displaced in absolute coordinates to the east at a rate of up to 41 mm/year along the largest North Anatolian right lateral shift fault, which serves as the boundary between it and the Anatolian block located to the south [5]. This shift extends for more than 1400 km from the Karliov point, where the triple junction of the Arabian plate, the Lesser Caucasian and Anatolian blocks occurs, to the Sea of Marmara, in the area of which the fault zone splits into several branches. In general, the kinematics of the Eastern Mediterranean is determined by counterclockwise rotation with respect to the Eurasian N-plate of the Arabian plate and most blocks south of the North Anatolian fault [5, 21]. The increased movement velocities and tension within the Aegean block are associated with the roll-back of the slab in the Hellenic Trench. In some works, it is assumed that such a roll-back occurs under the influence of the more intense velocities of movement of the Arabian plate and subduction in Makran beneath Eurasia in comparison with the velocity of subduction under the Hellenic arc [20]. Thus, the modern relative movements of the blocks of the Eastern Mediterranean are controlled by at least two processes: their "squeezing" to the west from the collision zone of the North Eurasian and Arabian lithospheric plates and the displacement to the south of the southern edge of the Aegean block above the retreating Hellenic trench.

According to modern data from GPS measurements, the Western Zagros with a velocity of ~10±2 mm/year in the direction of 12±8° north-north-west, the central Zagros - 14-18 mm/year, and the Eastern Zagros with approximately twice the velocity (~20±2 mm/year) in the direction of 7±5° north-north-east. The difference in crushing rates is most likely associated with a significant portion of shear deformation along the Main Rift Fault MRF in the Northwest Zagros.

The velocity field of GPS observations within the Caucasus region clearly illustrates the movement of the Earth's crust surface in the N-NE direction in the territory of Azerbaijan and adjacent regions of the Lesser Caucasus relative to Eurasia. The most pronounced feature of the velocity field is a decrease in velocity at observation points located perpendicular to the Main Caucasian Thrust (i.e., at stations PQLG, XNGG, ZKTG, ATGG, IMLG, and GBLG). GPS-observation points located along the GKN show a decrease in velocity in the westerly direction. N-NE movement of the Earth's surface is interpreted as one of the reasons for the accumulation of stresses on this thrust. In addition, there is a tendency for horizontal movement within the Kura depression and the Lesser Caucasus, where the velocity increases from west to east along the strike of the mountain range.

Conclusion

Analysis of the velocity field of GPS stations showed the heterogeneity of deformation processes in the region of the Eastern Mediterranean and the Caucasus. The considered results show the movement of the Arabian plate relative to the Eurasian one. Considering the velocities of movement of the Anatolian and Eurasian plates, and the Arabian and Anatolian plates, it was found that the shear rate along the North Anatolian fault was 20 mm/year, along the East Anatolian - 14 mm/year. This indicates the convergence of the Anatolian and Eurasian plates through the system of right shift faults in eastern Turkey and the Thrust system in the Caucasus. The total reduction in the distance between the Lesser and Greater Caucasus is 10 mm/year.

In the Central Iranian block and the Caucasian block, movement was noted clockwise with a rotation in azimuth from 350 to 90 degrees. The tectonics of Iran is dominated by the collision of the Arabian and Eurasian plates. The velocity of movement of the plates was estimated at 22 mm/year. During these movements, the Zagros crust is shortened by about 9±2 mm/year in the north-south direction.

According to modern data from GPS measurements, the Western Zagros with a speed of ~10±2 mm/year in the direction of 12±8° north-north-west, the central Zagros - 14-18 mm/year, and the Eastern Zagros with approximately twice the speed (~20±2 mm/year) in the direction of 7±5° north-north-east. The difference in crushing rates is most likely associated with a significant portion of shear deformation along the Main Rift Fault MRF in the Northwest Zagros.

In addition, in the strike cross of the Greater and Lesser Caucasus, a noticeable decrease in the velocities of horizontal movements is observed at an epicentral distance of 65 km, which indicates that the Lesser Caucasus is thrusting into the Kura depression at an average rate of 10-12 mm/year and a gradual underthrust of the Kura depression under the Greater Caucasus.

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PROBABILISTIC ASSESSMENT OF THE SEISMIC HAZARD LEVEL OF THE "TAKHTAKORPU" RESERVOIR LOCATION

T.Y.Mammadli [1], R.B.Muradov [1]

Takhtakorpu reservoir is located on the northern part of the eastern slope of the Greater Caucasus. Although this area is not characterized by high seismic activity, relatively weak seismic shocks are observed regularly in this area. A map of the earthquakes epicenters with magnitude ≥3.0 recorded in Azerbaijan and adjacent areas during 1980-2018 years [1] shows that although there are a small number of weak seismic shocks in the study area (Fig. 1). It should be noted that the registration of a large number of weak seismic shocks in Azerbaijan is mainly due to the activities of digital seismic stations produced by the US company Kinemetrics, which has a very wide frequency-dynamic range in the country since 2003.

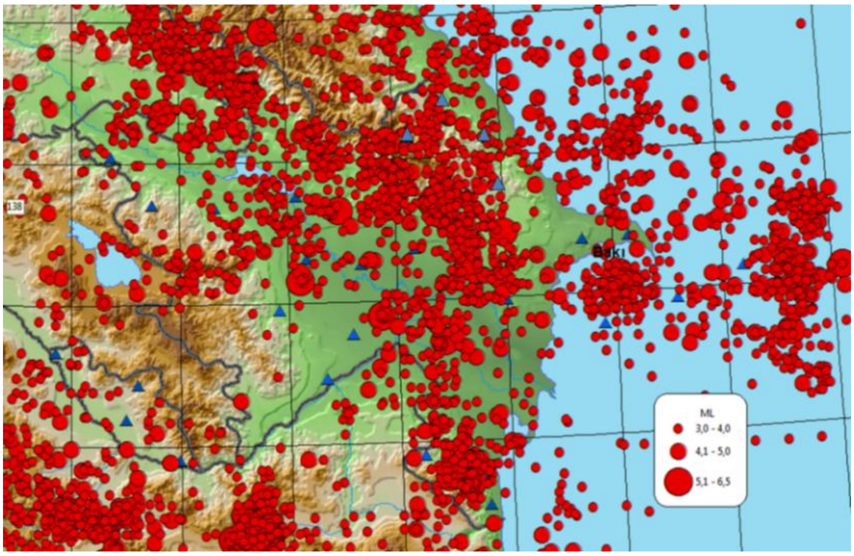


Figure 1. The map of earthquakes epicenters with magnitude >3 recorded in Azerbaijan and adjacent areas during 1980-2019 years.

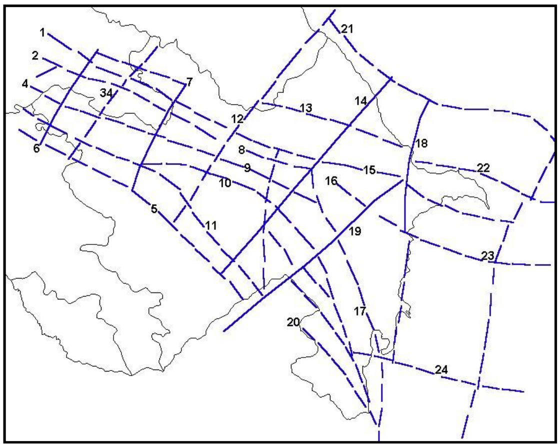


Figure 2. The map of the depth faults of the territory of Azerbaijan (K.M.Karimov and A.Sh.Shikhalibeyli, 1992).

Symbols: Faults: 1 - Vandam; 2 - Gagro-Chava; 4 - South-Adjar-Trialet; 5 –Front Lesser Caucasus; 6 - Qazakh-Signakh; 7 - Gandja-Alazan; 8 - North-Adjinohur; 9 - Goychay; 10 - Mingachevir-Saatli; 11 - Kura; 12 - Arpa-Samur; 13 - Siyazan; 14 - Gizilbogaz-Davachi; 15 - Germian; 16 - Adjichay-Alyat; 17 - West Caspian; 18 - Yashma; 19 - Lower -Araz; 20 - Talish; 21 - Central Caspian; 22 - Absheron-Balakhayani; 23 - Sangachal-Ogurchu; 24 – Mil.

[1] *Republican Seismic Survey Center of Azerbaijan National Academy of Sciences*

At the same time, this area is affected by strong earthquakes shocks occurred in pan-Caucasian and anti-Caucasian active depth faults passing through the territory of Shamakhi-Ismayilli region near the reservoir and slightly to the north as well as in the Central-Caspian fault zones in the Caspian Sea (fig.2).

Directly no strong and destructive earthquakes have been recorded so far in the study area (Fig. 3). Strong earthquakes occurred mainly in the north, west and south of the Shabran district (reservoir) [3,4]. Undoubtedly, these earthquakes that are strong enough were felt with high intensity in the Shabran district.

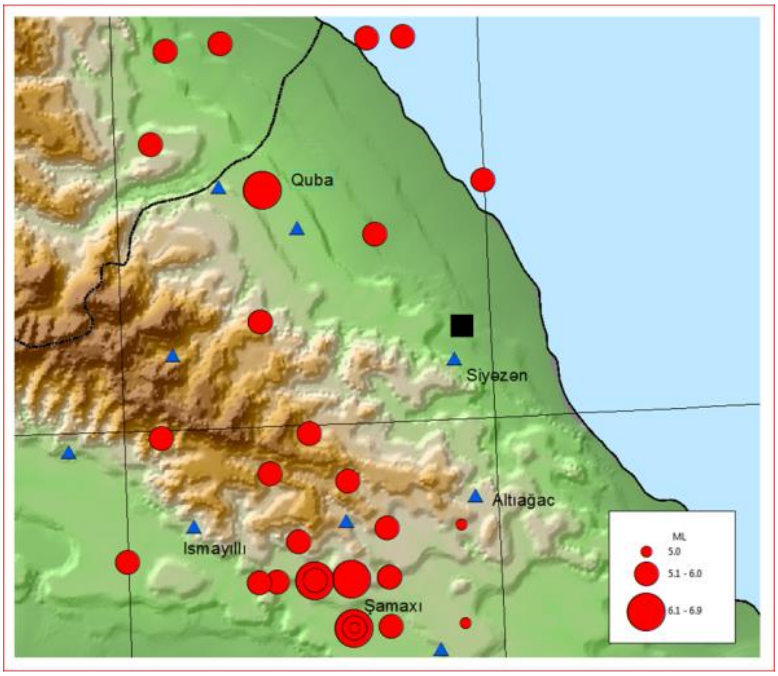


Figure 3. The map of the epicenters of strong earthquakes occurred in the north-east part of Azerbaijan during 427-2019 years.

Analysis of isoseist schemes of strong earthquakes in the territory of Azerbaijan shows that, so far, no earthquake with a magnitude higher than 6 on the MSK-64 scale has been recorded in the "Takhtakorpu" reservoir of Shabran district. Seismic shocks with this intensity were mainly spread by earthquakes in the Shamakhi district. It should be noted that only in 1963, a strong (M=6.2) earthquake in the Caspian Sea was felt in the narrow area along the coast of Shabran district with a magnitude of 7 points.

In order to determine the characteristics of the depth distribution of earthquakes in the study area,seismological sections were compiled on the I-I profile of the W-E direction and II-II profile of the SW-NE (Fig.4 and 5).

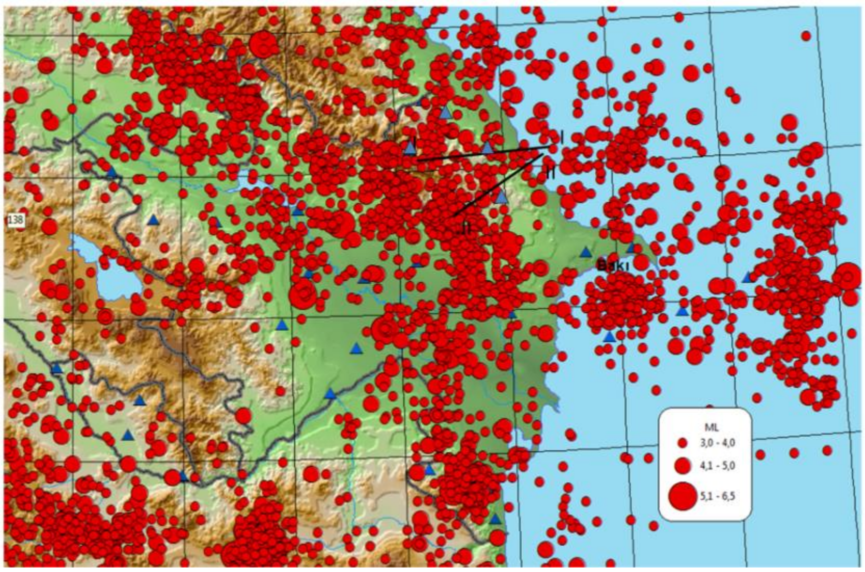
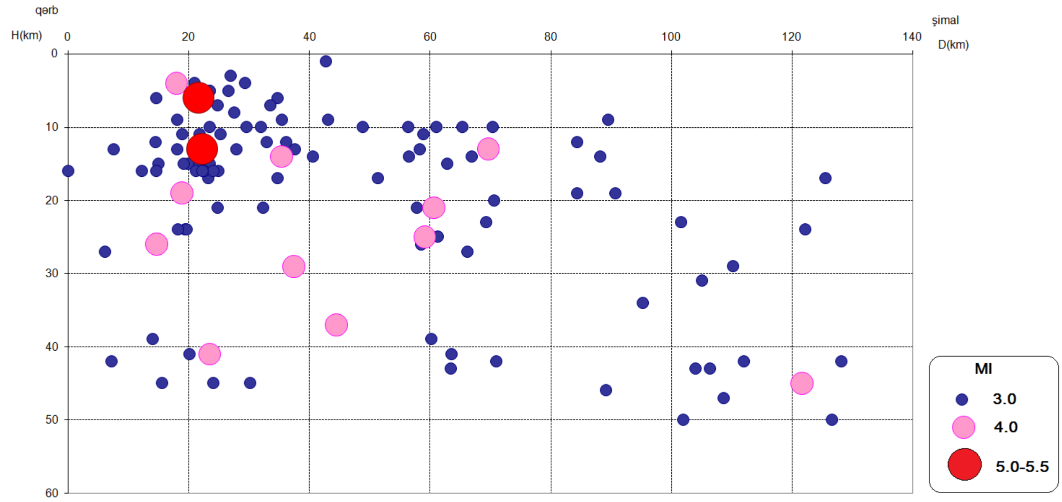
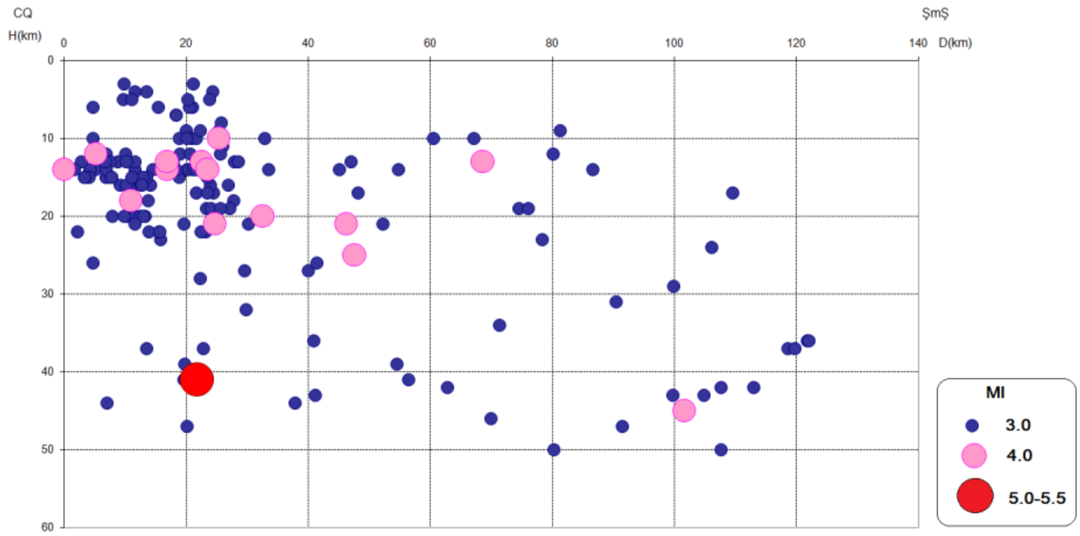


Figure 4. The location map of I-I and II-II profiles.



I-I profile



II-II profile

Figure 5. The seismological sections on profiles.

As can be seen from the seismological sections map, the seismic shocks are mainly concentrated in the western and south-western part of the sections corresponding to the Shamakhi-Ismayilli zone. Although these hypocenters extend from a depth of 3 km to 20-25 km, the depth of some shocks reaches 40-45 km. Strong (M≥5,0) earthquakes, as in other parts of the Greater Caucasus, occur at depths close to the surface of the crystalline base (10-15 km).

The area where the Takhtakorpu reservoir is located is characterized by 8-point seismic hazard on the MSK-64 scale on the seismic zoning map of Azerbaijan. Seismic zoning map of the territory of the republic (mapping of the area according to the level of seismic hazard) has been compiled several times. The last map is the "Temporary seismic zoning map of the Republic of Azerbaijan" compiled in 1991 (Fig. 6) [5].

Probable seismic hazards in this area are calculated by deterministic and probabilistic methods by determining the source zones in areas of high seismic activity.

Calculation of seismic hazard by probabilistic methods is carried out in the following stages:

1. The epicenter and its characteristics are determined. Depending on the geological nature of the source, it can be considered as a field, line or point.
2. Seismic parameters (repetition) and probability models are evaluated for each seismic source. The model is usually based on the Gutenberg-Richter dependence.
3. The extinction model of ground vibrations is selected on the basis of the extinction coefficient, which reflects the change of ground vibrations depending on the magnitude of the earthquake and the distance from the source.
4. The seismic hazard is assessed taking into account the influence of the above three factors.

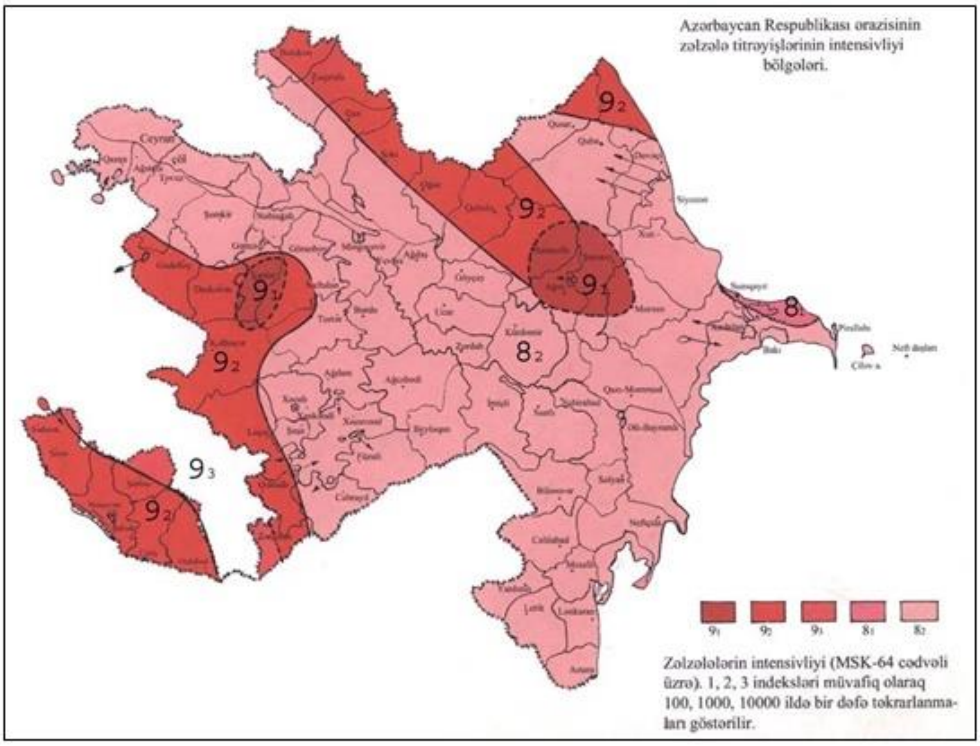


Figure 6. The temporary seismic zoning map-scheme of the territory of Azerbaijan (1991).

Earthquake sources are defined as fault zones that extend to the Earth's surface and have a certain depth. It is believed that earthquakes are evenly distributed in these fault zones, and there is a possibility of an earthquake at any point within the fault zones. Soil movement in the study area is modeled on the basis of earthquakes of known magnitude and extinction coefficients on known ground conditions. Our studies used the formulas Boore and Atkinson (Boore, Atkinson (2008)), Campell and Bozorgnia (Campell, Bozorgnia (2008)) [6,7]. Calculations were made on rocks with transverse wave velocities of 760 m/s and the seismic effect of the ground equal to the value of acceleration.

Based on the above research sequence, initially the active depth faults in the territory of Azerbaijan were selected (Fig.7).

Then a model of seismic source zones (SSZ) was compiled (Fig.8).

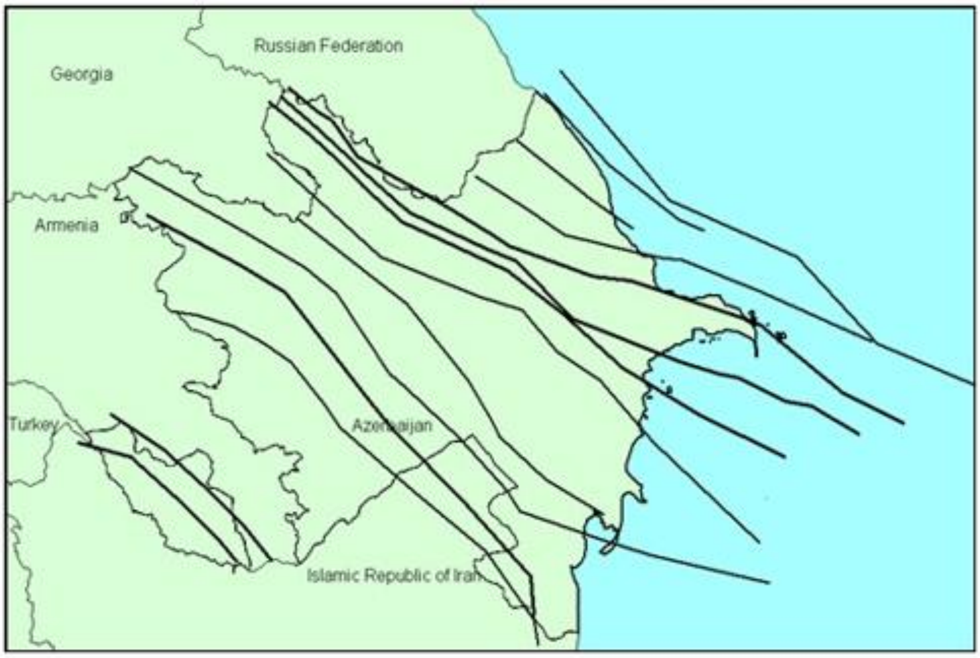


Figure 7. The map of the active tectonic faults in the territory of Azerbaijan.

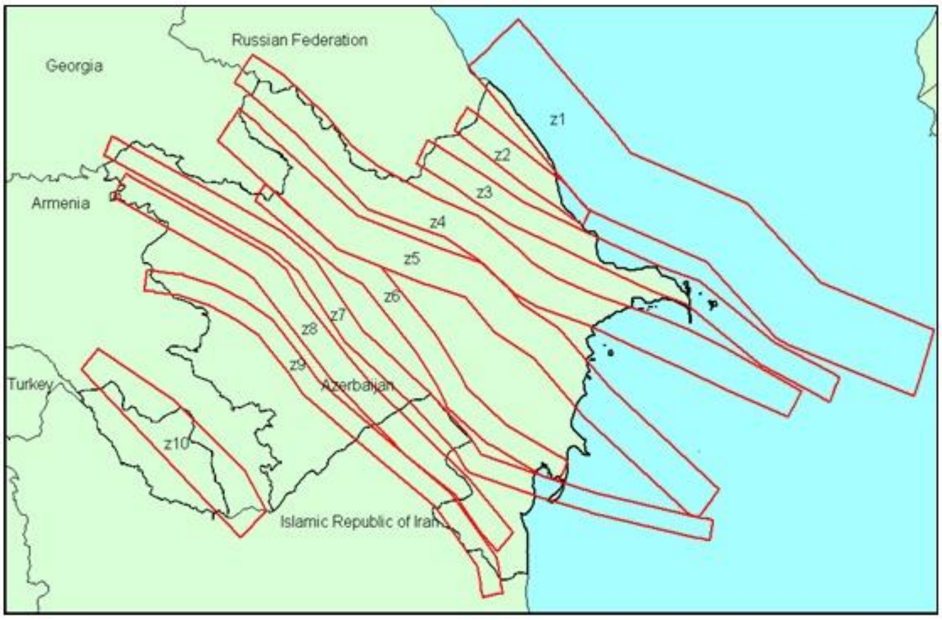


Figure 8. The model of seismic source zones (SSZ) in the territory of Azerbaijan

As can be seen from Figures 7 and 8, possible strong earthquakes in the Shabran district, where the study zone is located, may occur within zone 3. Therefore, in the next stage, earthquakes with magnitude of ≥4.0 in the area within zone 3 were selected and the values of activity parameters a and b were calculated for that source zone. The seismic characteristics of this zone (SSZ) are shown below:

SSZ	Mmax	Mmin	Depth		coefficient b	Activity on Mmin
			hmin	*hmax*		
Zone 3	5,7	4.0	3	60	-0.765	0.709

The seismic hazard in the study area was assessed using the EZ-FRISK software package and maps were compiled using the Mapinfo program.

Seismic hazard maps have been prepared as correspond to the intervals of 475 and 2475 years of peak ground acceleration (PGA) (with a probability of more than 10% for 50 years and with a probability of more than 2% for 50 years), pseudo-emergency (SA) for 0.2, 1.2, 2.0, 4.0 seconds. (Fig.9.- Fig.18.).

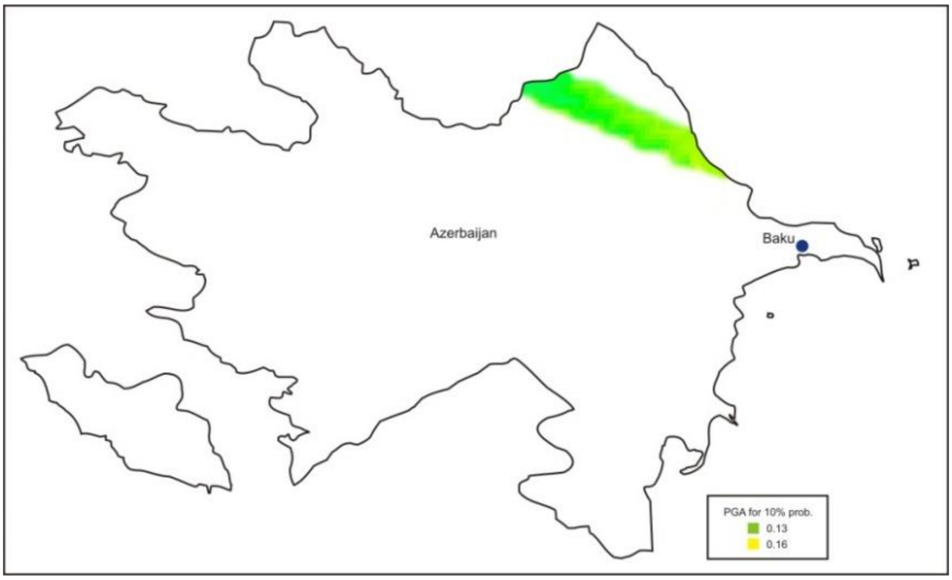


Figure 9. Peak Ground Acceleration (PGA) values over a 475-year recurrence interval (10% probability over 50 years).

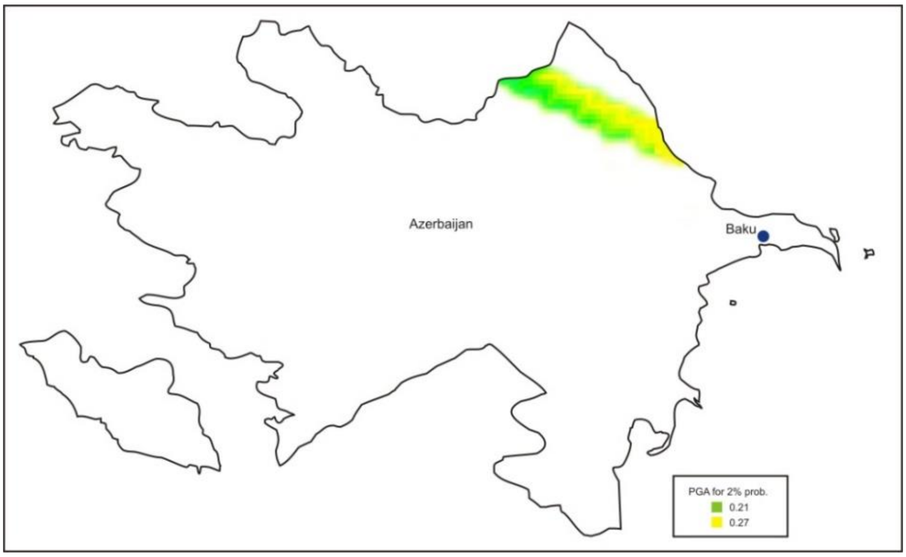


Figure 10. Peak Ground Acceleration (PGA) values for a 2475-year recurrence interval (with a probability of 2% over 50 years).

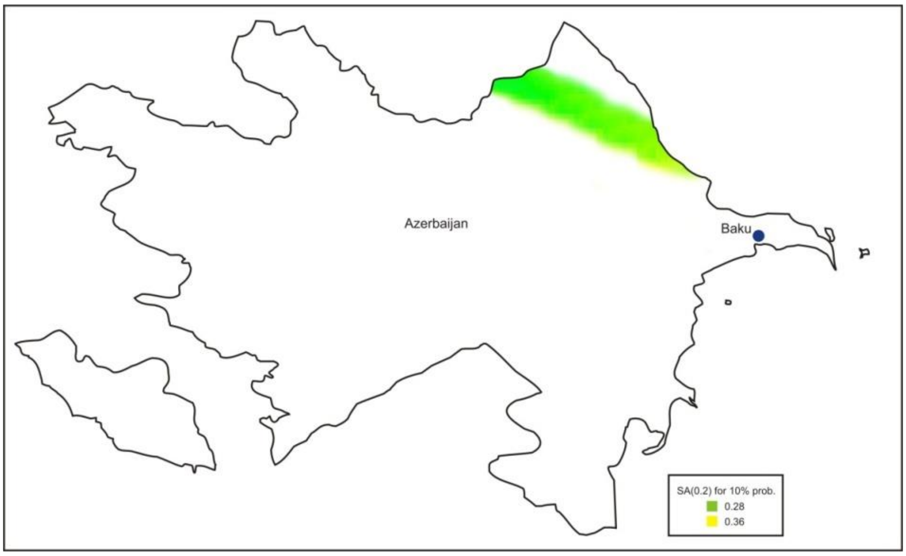


Figure 11. SA (0.2s) values of spectral acceleration over a period of 475 years (probability 10% over 50 years).

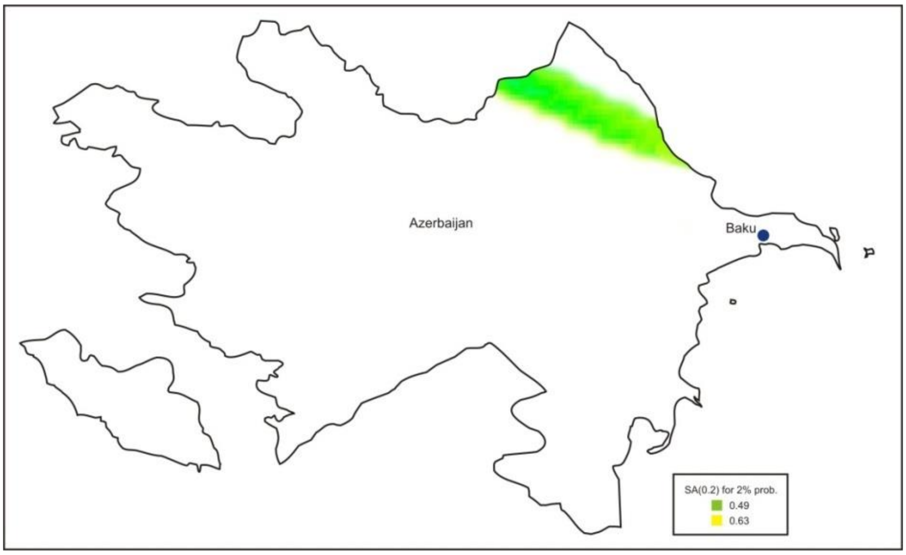


Figure 12. SA (0.2s) values of spectral acceleration at 2475 years interval (probability 2% over 50 years).

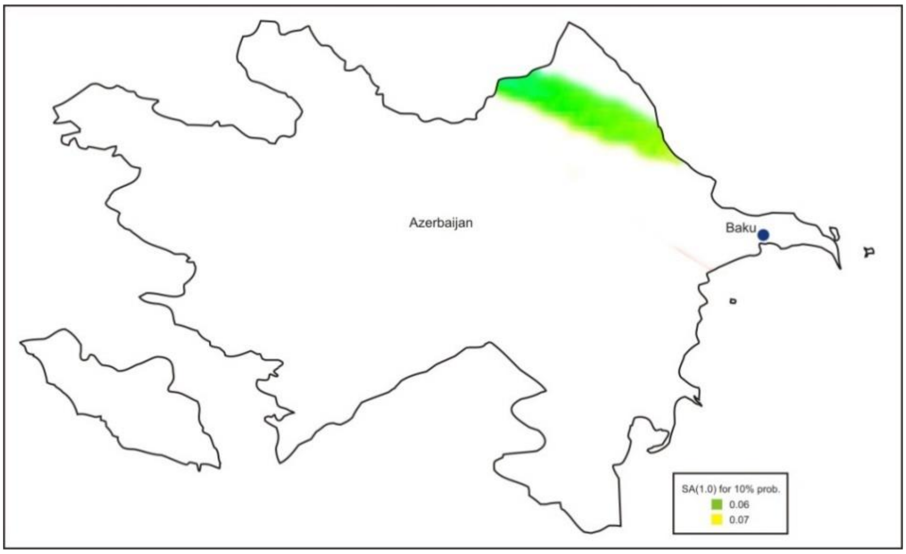


Figure 13. SA (1s) values of spectral acceleration over a period of 475 years (probability 10% over 50 years).

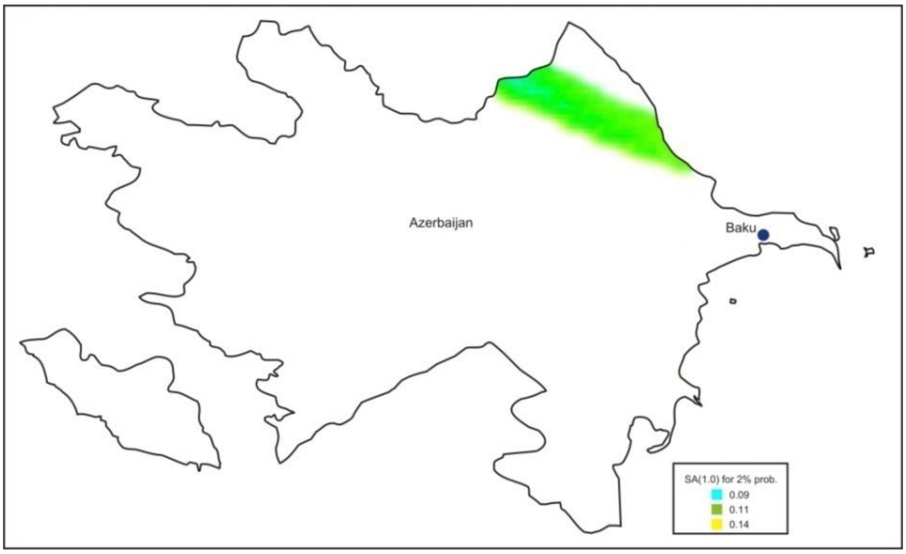


Figure 14. SA (1s) values of spectral acceleration at 2475 years interval (probability 2% over 50 years).

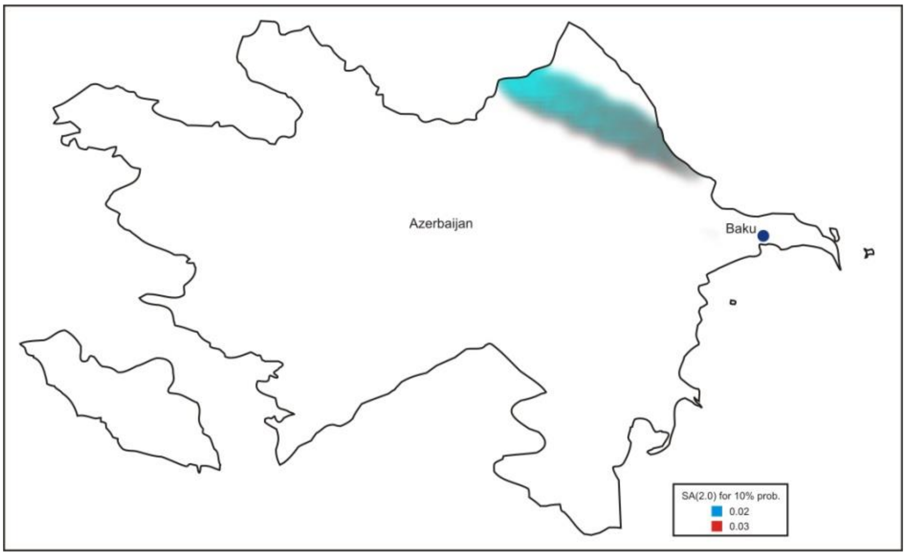


Figure 15. SA (2s) values of spectral acceleration over a period of 475 years (probability 10% over 50 years).

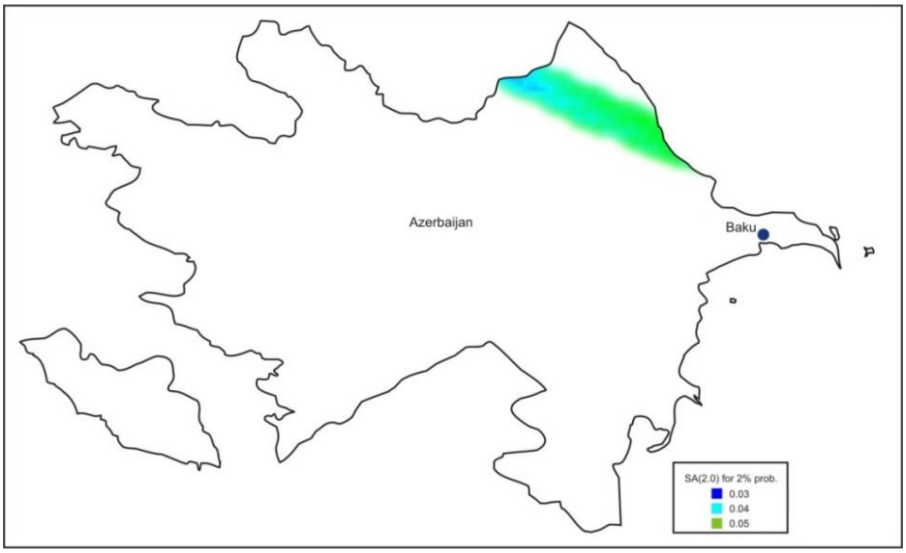


Figure 16. SA (2s) values of spectral acceleration at 2475 years interval (probability 2% over 50 years).

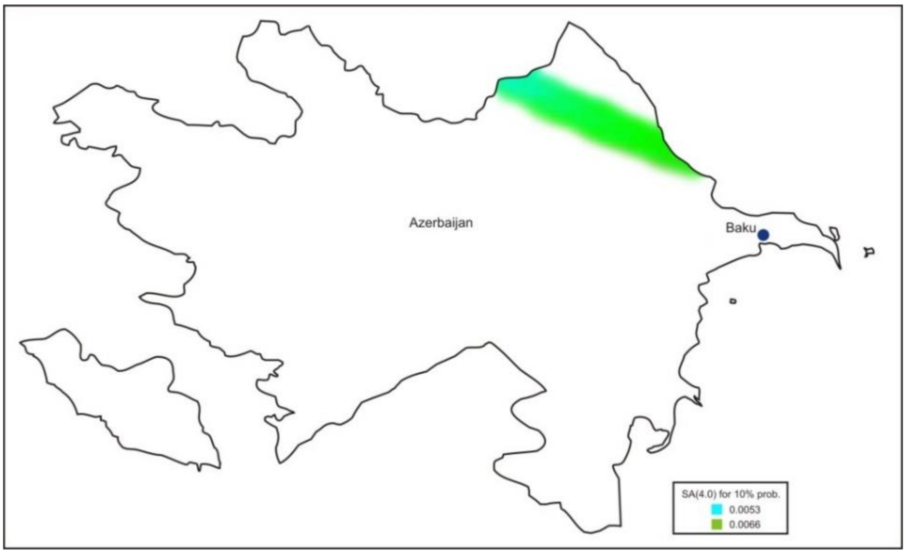


Figure 17. SA (4s) values of spectral acceleration over a period of 475 years (probability 10% over 50 years).

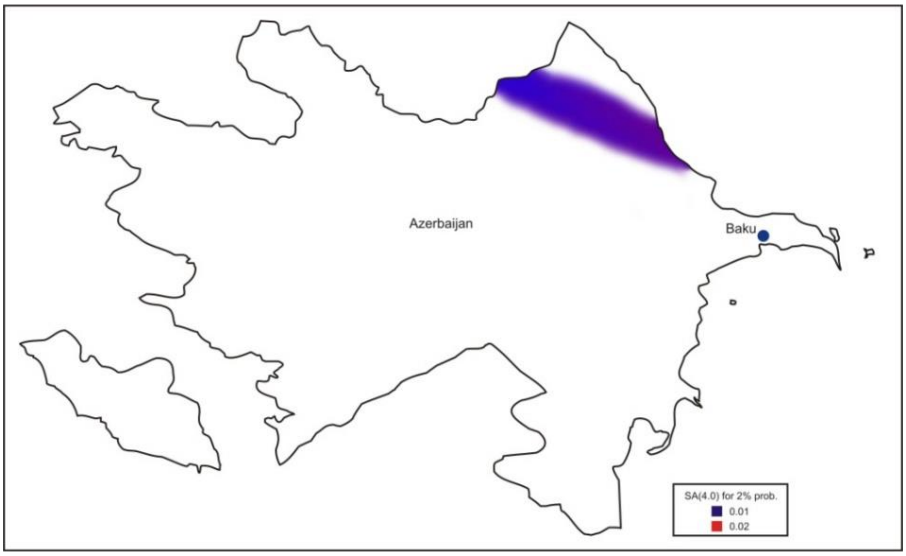


Figure 18. SA (4s) values of spectral acceleration at 2475 years interval (probability 2% over 50 years).

Thus, as a result of the research, the level of seismic hazard in the area where the reservoir is located is estimated by the probability method as follows: The value of the peak ground acceleration in the area for 10 years with a probability of 10% is 0.16g (I0 = VII points on the MSK-64 scale), the value of the peak ground acceleration with a probability of 2% for 50 years is 0.27g (I0 = VIII points on the MSK-64 scale)). The value of the peak ground acceleration corresponding to a period of 0.2 s of spectral acceleration with a probability of 10% for 50 years is 0.36 g, and the value of the peak ground acceleration corresponding to a period of 0.2s of spectral acceleration with a probability of 2% over 50 years is 0.63 g.

The value of the maximum acceleration for a period of 1s of the spectral acceleration with a probability of 10% for 50 years is 0.07 g, and the value of the maximum acceleration for a period of 2s with a probability of 2% for 50 years is 0.14g.

The value of the maximum acceleration corresponding to the 2s period of the spectral acceleration with a probability of 10% for 50 years is 0.03 g, and the value of the maximum acceleration corresponding to the 2s period of the spectral acceleration with a probability of 2% over 50 years is 0.05g.

The value of the maximum acceleration corresponding to the 4s period of the spectral acceleration with a probability of 10% for 50 years is 0.0066g, and the value of the maximum acceleration corresponding to the 4s period of the spectral acceleration with a probability of 2% over 50 years is 0.02 g.

The value of the maximum acceleration corresponding to the 4s period of the spectral acceleration for a recurrence period of 475 years is 0.0066g, and the value of the maximum acceleration corresponding to the 4s period of the spectral acceleration for the 2475-year recurrence period is 0.02 g.

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Acknowledgments

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CLARIFICATION OF ENGINEERING-GEOLOGICAL AND ENGINEERING-SEISMOLOGICAL CONDITIONS OF CONSTRUCTION SITES IN THE TERRITORY OF ABSHERON REGION AND SUMGAYIT CITY

L.T.Fattahova[1], F.Z.Mehdizade [1], I.N.Djalilova[1]

Introduction

Earthquakes are the most dangerous of natural disasters, often causing major disasters, large-scale economic losses and human casualties.

The earthquakes occur in the zones of active depth faults in the Earth's crust and seismic waves propagating from the source expose the surrounding areas to vibrations with one or another intensity. The intensity level of the vibrations depends on the magnitude (magnitude M) of the earthquake, the depth of the source (H) and the distance (Δ) to the study area. Determining the level of intensity is one of the necessary conditions in the construction of seismically resistant buildings and structures.

One of the main goals of seismology is seismic zoning of areas and microzoning of construction sites.

According to the "Temporary seismic zoning map of Azerbaijan territory" [Ахмедбейли Ф. С. и др. 1991] (Fig. 1), the background level of seismic hazard of the Absheron Peninsula, as well as the territory of Baku is estimated at 8 points.

One of the important conditions for the correct compilation or specification of a seismic zoning map is to determine the seismic zones which can be a strong earthquake source, in other words, the activity of tectonic faults and a realistic assessment of their potential [T.Y. Mammadli, 2010].

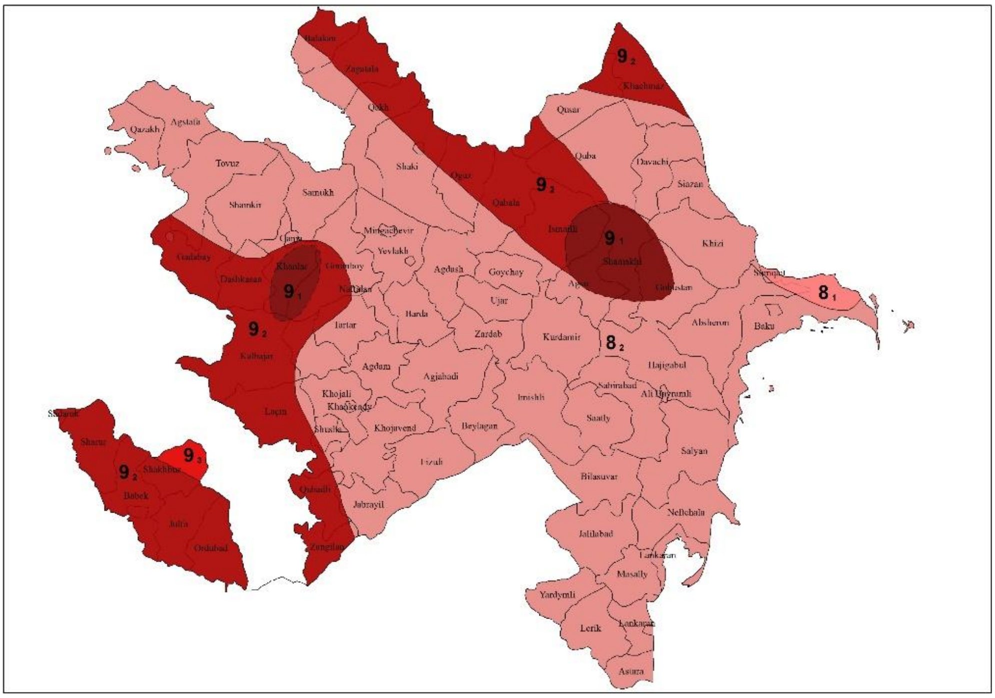

Figure 1. Temporary seismic zoning map of the Azerbaijan territory (1991).

- intensity 8_1 point
- intensity 8_2 point
- intensity 9_1 point
- intensity 9_2 point
- intensity 9_3 point

(İntensity by MSK-64 scale)

Research conducted in the field of seismic zoning mainly covers the issues of complex and detailed study of seismicity, seismotectonics. As a result of solving these problems, the maximum level (point) of possible seismic impact of the studied area in a certain time interval is estimated [T.Y. Mammadli, 2010].

The structure of the East Caucasus and especially the territory of Azerbaijan consists of the folded-blocks formation with different sizes and configurations, bounded by longitudinal (Caucasus) and transverse

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(anti-Caucasian) faults and flexure zones of the earth's crust [Shikhalibeyli, 1996]. These deep faults with great length have had a significant impact on the tectonic development of individual zones of the region.

In Azerbaijan territory predominate faults with the Caucasian direction: south-eastern and north-western. These faults have been identified on the basis of structural-tectonic observations, analysis of thicknesses, sedimentary facies and geophysical studies [Shikhalibeyli, 1970]. These faults or their various segments have been studied by many researchers [Khain, Shardanov, 1952; Shikhalibeyli, 1956,1966, 1970, 1996; Kirillova, Sorsky, 1960; Borisov, 1967; Rogozhin et al., 1988, 1993, 2014; Shikhalibeyli, Hasanov, 1979].

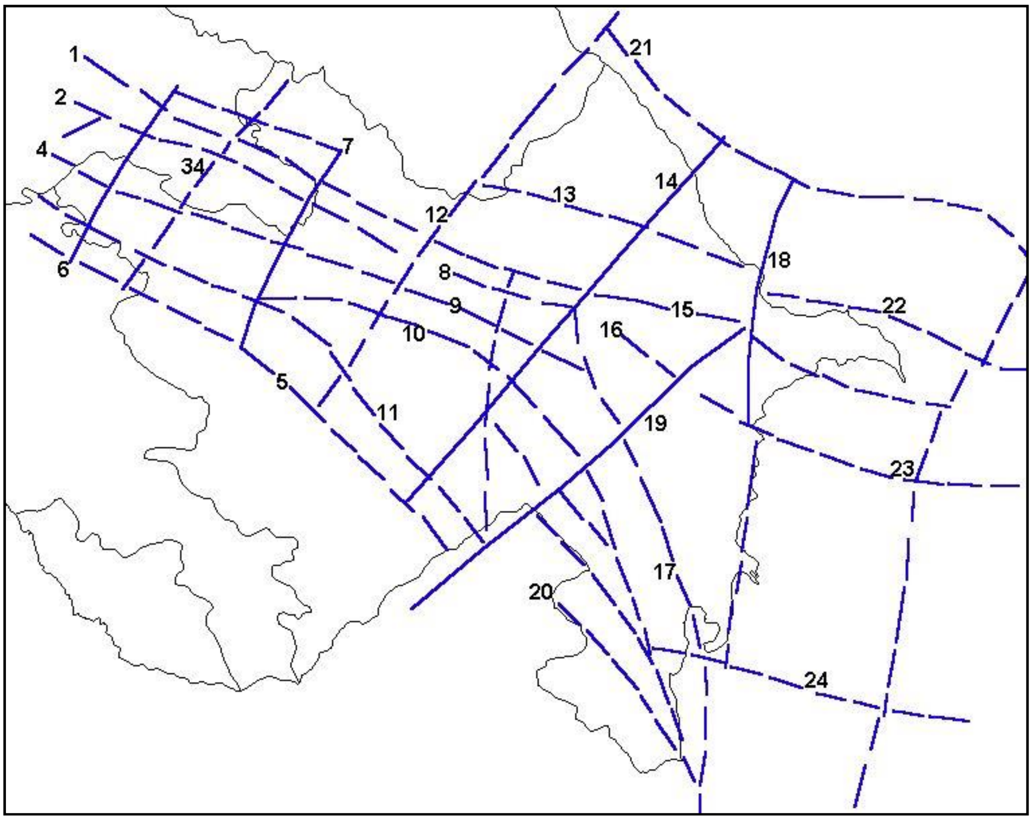

Figure 2. A part of the depth structure map of the Black Sea-South Caspian regional sedimentation zone [Map ..., 1992] (used source numbers are preserved).

Whole lines indicate the transverse faults and broken lines indicate the longitudinal faults of the Greater Caucasus.
1.Vandam; 5. Front Lesser Caucasus; 6.Qazakh-Signakh; 7. Gandja-Alazan; 8.North-Adjinour; 9. Goychay; 10. Mingachevir-Saatli; 11.Kura; 12.Arpa-Samur; 13. Siyazan; 14. Gizilboghaz-Davachi (Shabran); 15.Germian; 16. Adjichay-Alyat; 17. West-Caspian; 18. Yashma; 19. Lower-Araz (Palmir-Absheron); 20.Talish; 21. Central-Caspian; 22. Absheron-Balkhan; 23. Sangachal-Ogurchu; 24. Mil; 34. Tovuz - Aliabad; 35. Imishli – Gabala.

Studies show that the greatest seismic hazard to the area of Absheron Peninsula is expected from potential source zones located in high-activity Adjichay-Alyat, Palmir-Absheron, Goychay, Vandam, Siyazan and Makhachkala-Turkmenbashi depth faults. The strong earthquakes in these fault zones can be felt in the Absheron Peninsula, as well as in Baku with a magnitude of 8 on the CEC-64 scale.

However, there are other factors that affect the level of seismic hazard. These factors include geological, lithological, hydrogeological conditions of the fields, physical and mechanical properties of grounds (porosity (e), consistency (I_L), ground density (ρ_d), hydrogeology, etc.). For this reason, the study of engineering-geological and engineering-seismic conditions in the construction areas of large buildings and facilities is important.

Grounds serve as foundations (base hole) for construction sites. Therefore, during the engineering-geological study, first of all, the regularities of spatial differences in the composition and physical and mechanical properties of grounds should be determined.

If weak grounds (technogenic grounds, cast soil) with all physical and mechanical properties and seismic resistance (according to the load-bearing capacity) are excavated from construction sites and their place is filled with compacted grounds and at the same time, if the flow of groundwater to the foundations of buildings (fed by atmospheric sediments, domestic and sewage) , which can affect the foundations of buildings, is prevented by certain measures (eg drainage, piles), the seismicity of construction sites can be 8 points.

The engineering-geological and engineering-seismological conditions of the territories of Absheron region and Sumgayit city are almost similar. In order to study the impact of this condition on the level of seismic hazard, the lithological composition, physical and mechanical parameters of grounds under the foundations of high-rise buildings, as well as aggressive effects, resistance, seismic properties, hydrogeological conditions, transverse wave propagation velocities on the foundation have been studied, well data drilled at construction sites has been analyzed and the seismicity of these areas has been clarified.

Absheron region is one of the largest regions of the Azerbaijan Republic. The territory of Absheron region is 1966.1 km^2. This region consists of Khirdalan city, Saray, Mehdiabad, Djeyranbatan, Gobu, Guzdek, Hokmali, Digah settlements, Mammadli, Novkhani, Masazir, Fatmayi, Goredil, Pirakashkul, Gobustan villages.

1700 wells data have been analyzed in the reports of about 100 construction sites of the territory of Absheron region. Construction sites in the Absheron region are mostly in the city of Khirdalan and Masazir settlement.

The most common ground in the Absheron region is semi-hard clay ground. Physical and mechanical characteristics of semi-hard clay soil is:

Porosity coefficient	$e=0.500 \div 0.800$
Consistency	$I_L=<0 \div 0.20$
Density, in the dry state	$\rho d=1.50 \div 1.70$ g/cm^3
The velocity of propagation of transverse seismic waves in the layer	$V_s=350 \div 600$ m/sec
Water level in Absheron region	- between 4.40-25.0 m;
location level	- between 3.20-20.0 m;

Water is formed mainly on semi-solid clay grounds.

Construction sites in the Absheron region mainly belong to the eastern part of the area.

The specified seismicity of 10 construction sites in Absheron region is estimated at 9 points, which belong to Khirdalan and Masazir settlements.

In general, Absheron region is assessed as an 8-point area.

The special place of Sumgayit in the country life is not limited to its important role in the territory of the republic. Sumgayit is the second largest city in Azerbaijan in terms of population and the third largest in terms of area after Baku and Gandja. It is located 35 km northwest of Baku, on the western shore of the Caspian Sea, on a plain. Its area is 0.094 thousand km^2.

Both engineering-geological and hydrogeological conditions have a great influence on the level of intensity in Sumgayit. 670 wells data have been analyzed at about 45 construction sites in the city.

The most common grounds in Sumgayit city are hard and semi-hard clay grounds.

1. Clay ground, with solid consistency (thickness-4.0-25.0 m)

$e = 0,562 \div 0,717$
$\dot{I}_L = <0 \div 0,25$
$\rho_d = 1,45 \div 1,65$ q/sm^3
$V_s = 420 \div 580$ m/sec

1. Clay ground,with semi-solid consistency (thickness-4.0-21.0 m)

$e = 0,587 \div 0,849$
$\dot{I}_L = <0 \div 0,24$
$\rho_d = 1,45 \div 1,65$ q/sm^3
$V_s = 420 \div 580$ m/san

Water level in construction sites of Sumgayit city is - between 0.10 ÷ 8.90 m; settlement level - between 0.10 ÷ 7.0 m.

The water is formed mainly on ground and semi-solid clay sandy ground.

The impact of existing waters on coastal construction sites is significant. That is why the 9-point construction sites in Sumgayit city are mainly close to the sea.

In general, the city of Sumgayit is rated as an 8-point area.

According to the research conducted in Absheron region and Sumgayit city, water horizons were found in almost all drilled wells.

Detailed seismicity for high-rise buildings in Absheron district and Sumgayit city is shown in Figure 3.

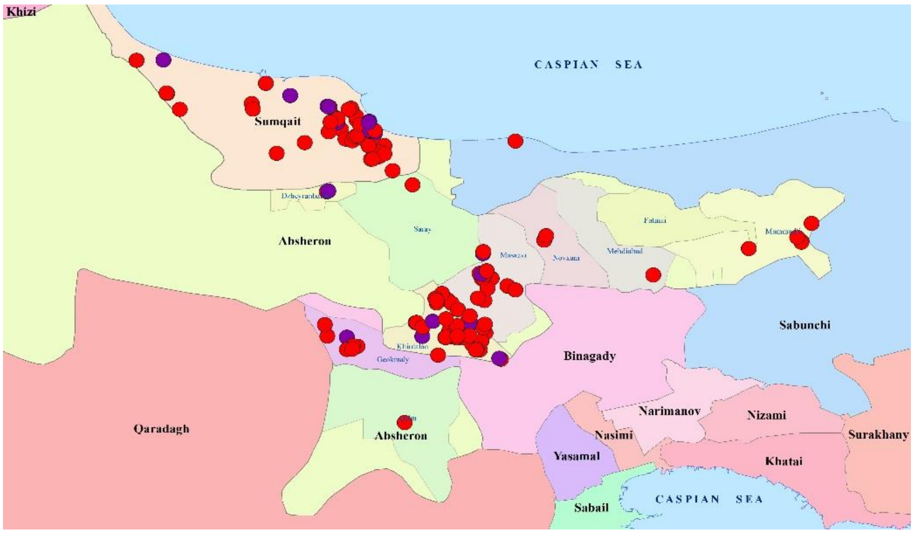

Figure 3. The map-scheme of construction sites with specified seismicity in territory of Absheron region and Sumgayit city (1998-2019 years).

- Zones with 8 (eight) points;
- Zones with 9 (nine) points.

The propagation velocity of transverse seismic waves (V_s) in the ground involved in geological sections at the construction sites of Absheron region and Sumgayit city and their class have been determined.

To accomplish these issues, initially, fund materials related to the research area and the surrounding area have been collected, studied and results have been obtained by summarizing.

According to the results of seismic studies, no grounds has been identified in the wells drilled to a depth of 25.0-30.0 m in the construction sites of Absheron region and Sumgayit city, and these grounds fully comply with the recommendations for seismic microzoning at construction sites.

Conclusion

1. A standard (widespread) ground has been assigned for the territory of Absheron district and Sumgayit city. The standard for Absheron region is semi-solid clay, and for Sumgayit - solid and semi-solid clay ground. Both grounds are appropriate with AzDTN2.3-1 "Construction in seismic areas" normative document.
2. Seismic hazard in both Absheron region and Sumgayit city is estimated at 8 (eight) points.
3. The level of seismic hazard in the coastal areas of Sumgayit is higher - 9 (nine) points.

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FEATURES OF THE DISTRIBUTION OF SWARM SEISMIC EVENTS AND EARTHQUAKES WITH M≥4 IN THE SHAMAKHI-ISMAYILLI ZONE IN 2003-2019

G.J.Yetirmishli[1], R.R.Abdullayeva[1], S.S.Ismayilova[1]

Introduction

The state of the geological environment is associated with its complex structural-tectonic structure. There is an accumulation of elastic energy in large structural elements of the medium and its periodic discharge through earthquakes. Energy is discharged into the surrounding space as a result of the destruction of the material of the earth's crust, i.e., a strong event, in those places where tectonic stresses reach the limit. It is often followed by aftershocks - aftershocks, which are a reflection of the relaxation processes of the medium in the region of the source of a strong earthquake [Arefyev, 2002]. However, the discharge of geodynamic stresses can also occur without the occurrence of the main shock with a sudden significant change in the stress state of the environment, through a swarm of earthquakes. This is a special type of manifestation of seismic activity, when a large number of earthquakes occur in a limited area in a short time. In contrast to earthquakes with aftershocks, when the remaining energy is released after the main rupture, the main shock, swarm sequences do not always have a main event and a characteristic decay of event energy in time (Slavina et al., 2010). They occur both in areas where strong earthquakes have occurred, and in areas where there have been no strong earthquakes. Earthquake swarms are known in various regions of Azerbaijan: in the Caspian Sea in 2000, in Gandja zone in 2001, in Sheki zone in 2004, in the Kura depression in 2011, in the north-west of the republic in Gazakh zone in 2014.

Formulation of the goal

The opening of new digital stations made it possible to register weak seismicity and obtain sufficiently complete seismological material. The presence of such material served as a database for studying the dynamics of seismic activity in the Shamakhi-Ismayilli zone, which is one of the seismically active zones of Azerbaijan.

Observations show that seismic processes are occurring in the Shamakhi-Ismayilli zone at the present stage, including relatively strong earthquakes with Ml≥4 (felt in the epicenter with an intensity of 5-6 points), which are accompanied by numerous aftershocks. At the same time, this is an area of constant stress discharge. A large number of earthquakes occur here, including swarms of earthquakes. It is of interest to reveal the features of the distribution in space and time of the aftershock and swarm sequences of earthquakes, as well as to consider the stress state of the territory under consideration.

The discussion of the results

From the regional catalog of earthquakes for the period 2003-2019 a group of earthquakes with close values of the coordinates of epicenters, compact in area, was distinguished. The sampling was carried out for events with M≥2.5.

For each group of earthquakes, a graph of the distribution of events by magnitude versus time was plotted. The shape of the graph was used to check whether events belong to one or another type. As an example, the distribution graphs of the aftershocks of the earthquake on June 3, 2015 with M=4.6 (Fig. 1.a) and the swarm sequence in 2013 (Fig. 1.b) are given. As can be seen from the graphs, the aftershock sequence is characterized by a hyperbolic form of the attenuation of the energy of the seismic process (F.Omori), while for swarms, this regularity is not observed, they are characterized by a weak attenuation of the energy in time [Slavina, 2010]. To determine the preferential depth of hypocenters, the depth distributions of events were constructed for both swarms and aftershocks. As can be seen from Figure 1a in 2015, the main shock occurred at a depth of 4 km, then, after some deepening, the depths stabilized and varied within 5–15 km. The prevailing depths are 10 km. On Figure 1b for swarms for 2013, they vary within 5–20 km. There are no dominant depths. The same picture is observed for other swarms.

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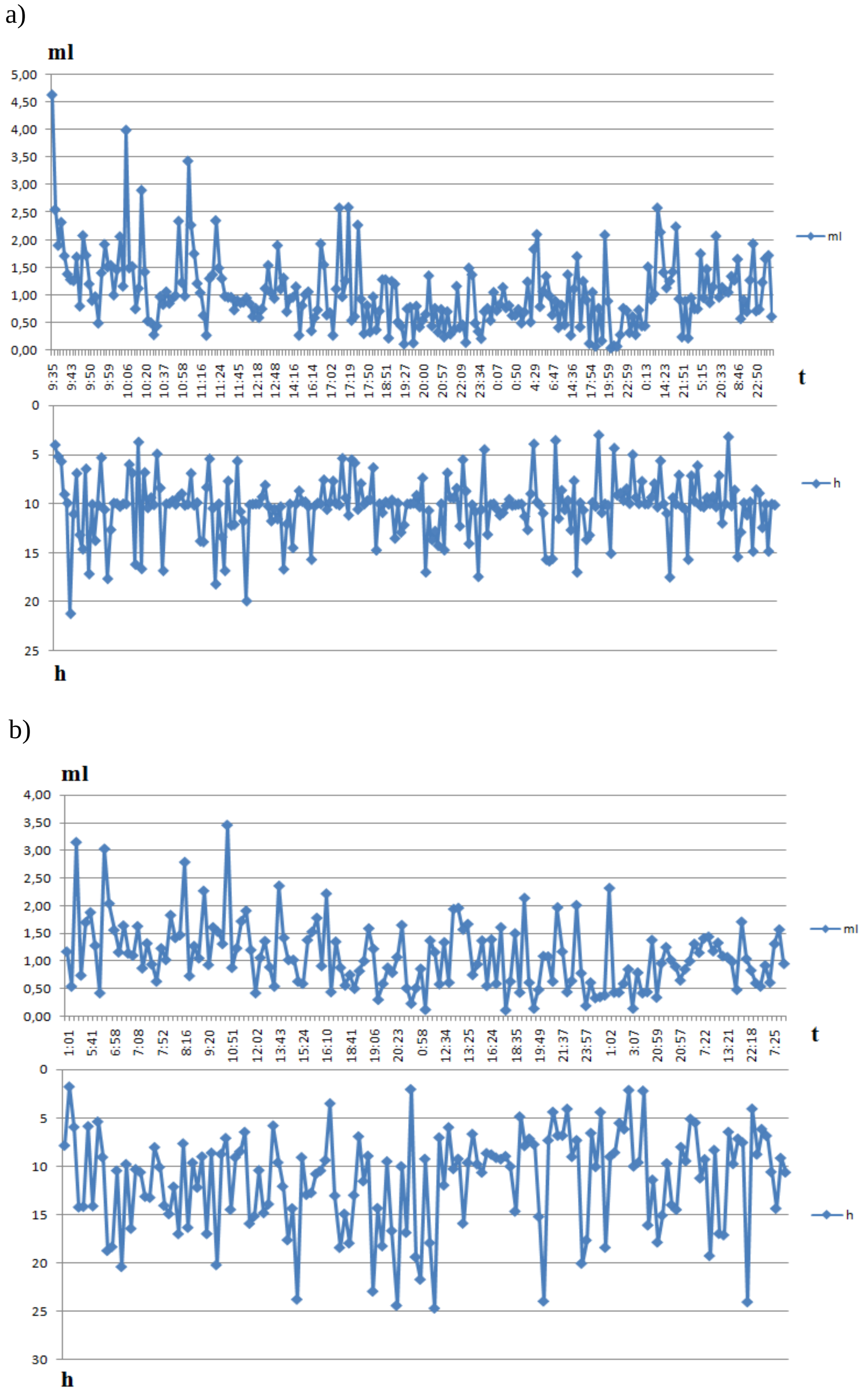


Figure 1. a, b Graphs of distribution of aftershocks of the earthquake on June 3, 2015 with M=4.6 (a) and the swarm sequence in 2013 with M_{max}=3.5 (b)

The catalogue of aftershocks and swarms of earthquakes is given in Tables 1 and 2. As can be seen from Table 1, for the period 2003-2019 7 earthquakes with a maximum magnitude M_{max}=5.3 occurred in the study area, which were accompanied by numerous aftershocks.

From the graph of the alternation of earthquakes with aftershocks in time (Fig. 2), it can be seen that for aftershock sequences there is a periodicity in their occurrence, they alternate in the southwest - northeast direction on separate structural blocks. For swarms, this regularity is not observed.

Table 1

Year	Date	Coordinate		D, km	Ml	N	The focal mechanisms of earthquakes
		φ	λ				
2007	23.08.2007	40.64 40.62	48.37 48.48	3 6	4.6 4.3	56	Strik -slip, normal fault
2008	19.12.2008	40.87	48.49	5	4.4	53	Reverse - thrust
2012	07.10.2012	40.70	48.35	41	5.3	95	Normal fault
2015	03.06.2015	40.92	48.57	4	4.6	377	Right lateral strike
2016	13.12.2016	40.80	48.41	8	4.5	23	Reverse – strike -slip
2018	01.01.2018	40.86	48.38	8	3.9	35	Normal fault
2019	05.02.2019	40.78	48.46	8	5.2	413	Right lateral strike

Table 2

Year	Date	Coordinate		D km	Ml	N	Continuation day	The focal mechanisms of earthquakes
		φ	λ					
2004	13.03.2004	40.59 40.72	48.46 48.52	15 22	3.5 3.4	21	2	
2011	07.10.2011	40.61	48.56	10	2.5	23	1	
2013	1-5.08.2013	40.73	48.64	7	3.5	100	5	Normal fault
2016	19.07.2016	40.74 40.71	48.68 40.70	10 8	3.2 3.0	36	2	Strik - slip
2018	18-20.09.2018	40.62 40.61	48.78 48.76	5 7	3.4 3.9	57	3	Normal fault Right lateral strike

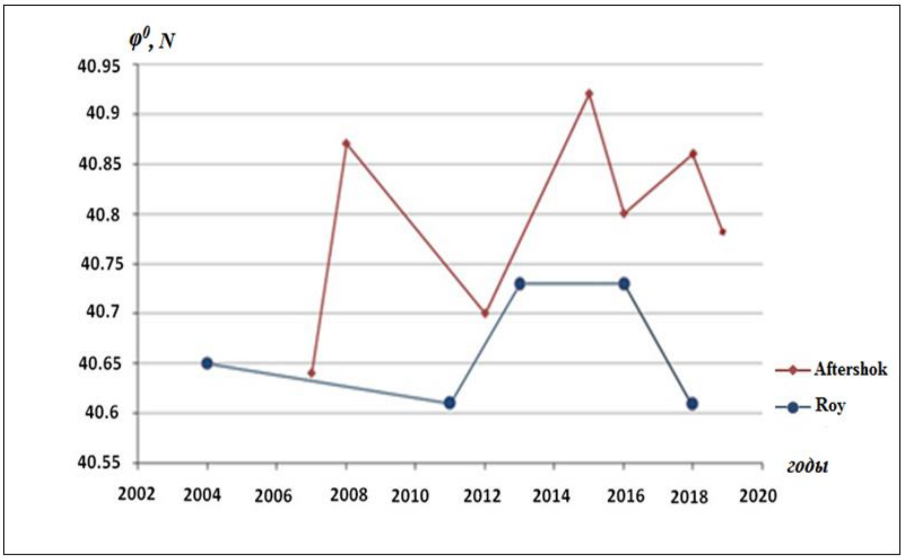


Figure 2. Graph of the distribution of aftershocks and swarms by latitude and by years.

An analysis of the spatial distribution of aftershocks from M≥4 earthquakes shows that they are located in the central part of the Shamakhi-Ismayilli zone (Fig. 3a, b). Peculiarities of their concentration on individual geotectonic structures bounded by longitudinal faults have been discovered. It should be noted that they are mainly associated with transverse structural elements, which is in good agreement with fault tectonics according to (Kengerli et al., 2018). The source mechanisms of the considered seismic events (Yetirmishli et al., 2017) also confirm the advantage of fault-shift movements that control seismic activity, which is typical for transverse structures. Of the considered earthquakes with Ml≥4, uplift faults in the sources were obtained only for two (Table 1).

a) b)

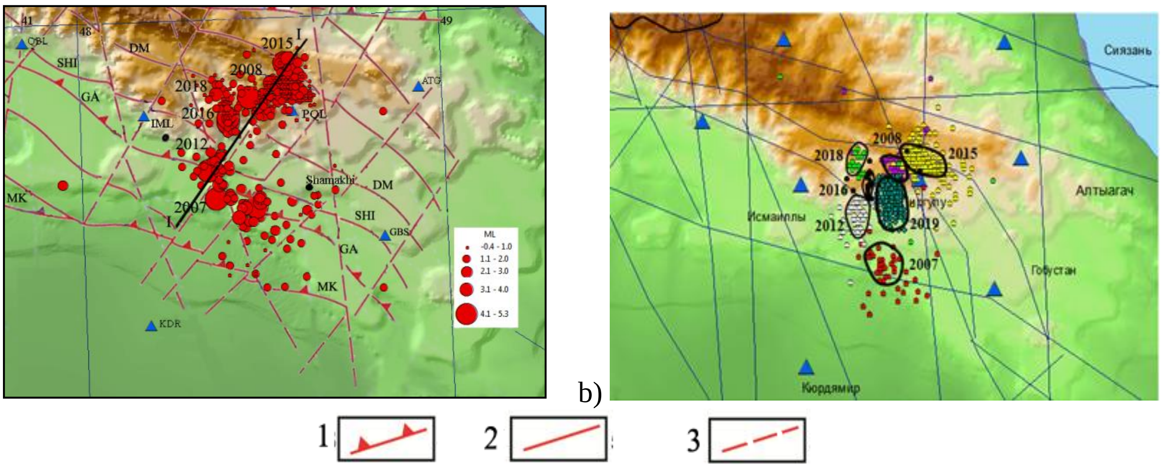


Figure 3. a, b Map of earthquake epicenters with Ml≥4 and their aftershocks with fault tectonics according to (Kangarli, 2018)

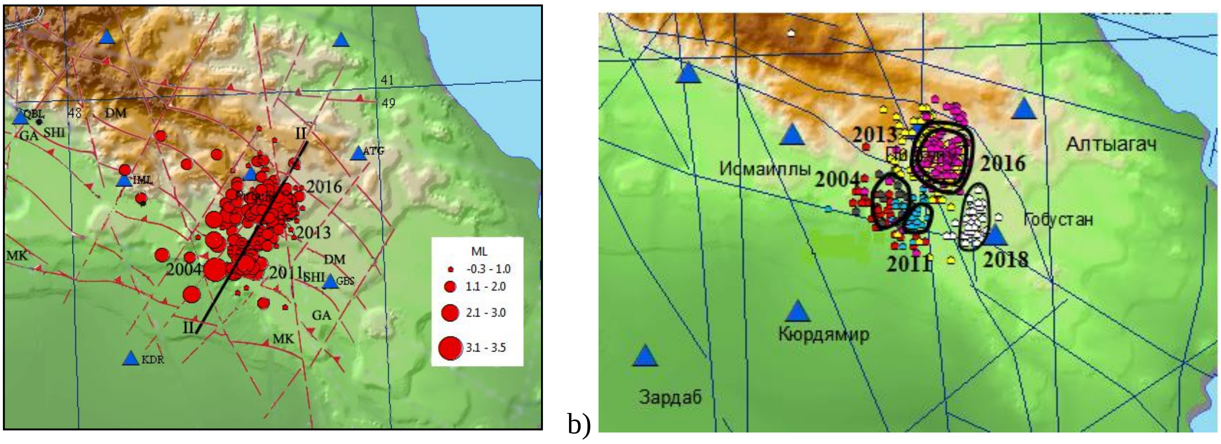
1 - Longitudinal deep faults at the boundaries of tectonic blocks: MK - Middle-Kura, GA - Ganikh-Ayrichay-Alyat; 2 - longitudinal deep faults: SHI - Shambul-Ismayilli, DM - Dashaghil-Mudrese, ZG-Zanghi-Gozluchay; 3 - faults and ruptures of the anti-Caucasian strike.

Thus, the field of earthquakes with aftershocks is located at the intersection of faults of general Caucasian strike: Zanghi-Gozluchay, Dashaghil-Mudrese, Shambul-Ismayilli, Ganikh-Ayrichay-Alyat with transverse faults of north-eastern and submeridional orientation [Shikhalibeyli, 1996; Kangarli et al., 2018].

Earthquake swarms with a maximum magnitude of 3.9 were also recorded in the Shamakhi-Ismayilli zone (Table 2). The duration of swarms varies from 1 to 5 days. The swarm field of earthquakes is located compactly in the form of an ellipse with a long SW-NE trending axis (Fig. 4 a, b). It is located in the eastern part of the Shamakhi-Ismayilli zone. The main concentration of swarm epicenters is observed southeast of

Pirgulu station. They are related to the events that took place in 2013 and 2016. In the first case, 100 earthquakes occurred within 5 days, with the highest magnitude Ml_{max}=3.5, in the second case, 36 events were registered in two days with Ml_{max}=3.1.

In tectonic terms, the swarm field of 2013 and 2016 is located at a complex intersection point of faults of general Caucasian strike with transverse faults of north-western and submeridional orientation (or at the intersection point of the Dashaghil-Mudrese uplift-thrust with the Pirsaatchay north-western fault-shift fault) (Kengerli et al., 2018). Swarm field 2004 and 2011 located somewhat to the south, at the intersection of the Ganikh-Ayrichay-Alyat and West Caspian faults. The location of the swarm field in the anti-Caucasian direction also confirms the presence of a transverse structure in this zone, which controls the location of earthquake swarms.



a) b)

Figure 4 a, b Map of the epicenters of swarm sequences in the Shamakhi-Ismayilli zone in 2003-2019 with fault tectonics by [Kangarli]

It can be concluded from the above that earthquakes with aftershocks and swarm sequences of earthquakes form two blocks with different levels of seismic activity (Fig. 5).

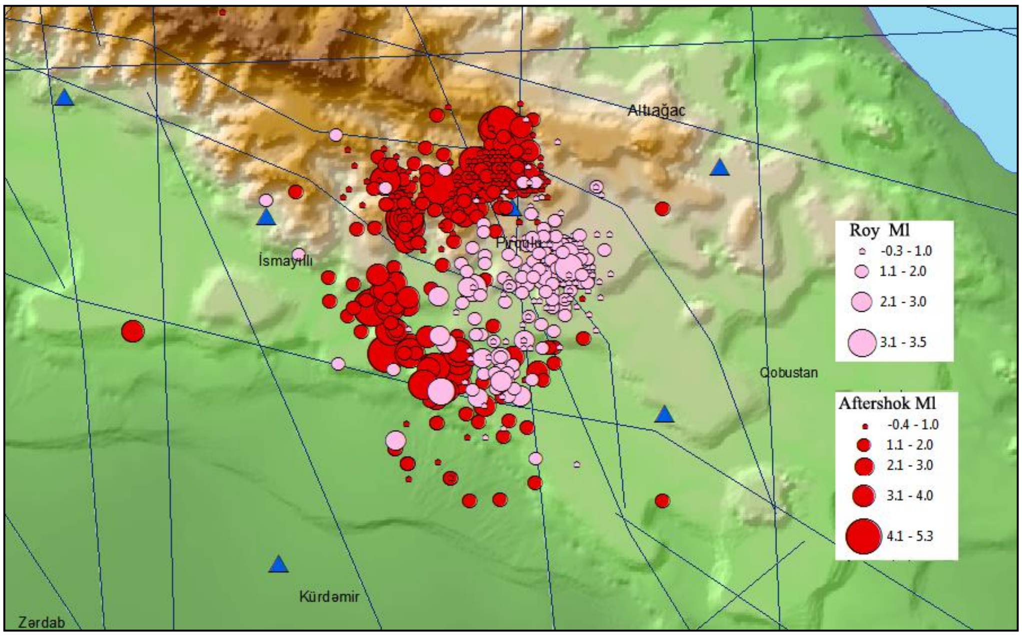
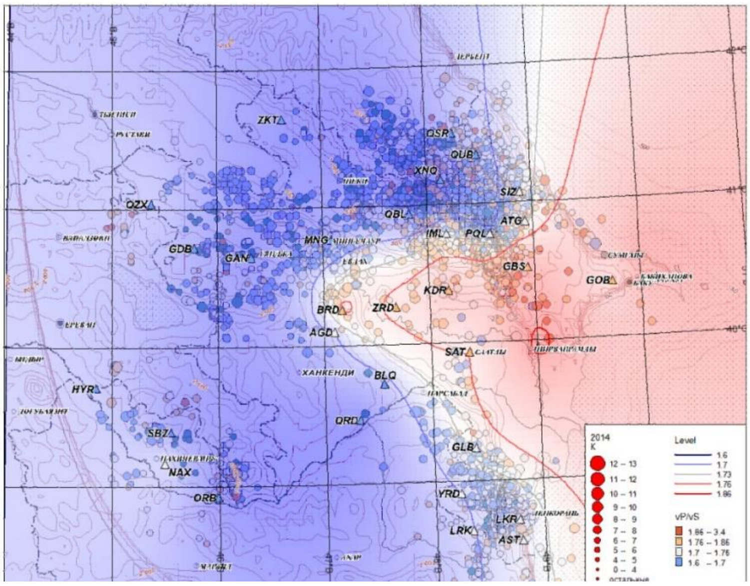


Figure 5. Map of the epicenters of swarm and aftershock sequences in the Shamakhi-Ismayilli zone in 2003-2019.

The considered seismic activity in the Shamakhi-Ismayilli zone is the result of the stressed state of the environment. The stress state of the earth's crust is one of the main factors determining the nature of geodynamic processes. It is of interest to consider the change in the TAU parameter (analogue V_p/V_s) in the study area. As is known, this parameter reflects the nature of the stress field, shows the state of the medium and the average stresses in the environment over a long time [Slavina et al., 2017]. In a seismically active zone, weak earthquakes occur under the influence of a stress field. With the dilatancy process of stretching, "cracking" of the medium, the ratio V_p/V_s decreases. Under compression (closure of cracks), the ratio V_p/V_s increases. When the ultimate strength is reached, earthquakes occur in the compression and tension regions. Figure 6 (a, b) shows maps of the stress field of the territory under consideration. The map clearly shows the zones of tension and compression. The considered swarms most likely sit in areas of extension or dilatancy, while earthquakes with aftershocks are located in the gradient zone (Fig. 7).

a)



b)

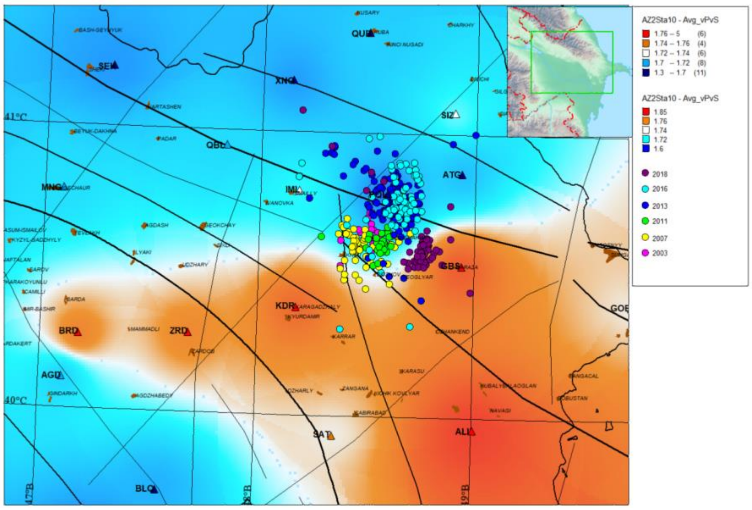


Figure 6 *(a,b). Map of the stress field of the territory of the republic (a), the study area with plotted swarms (b).*

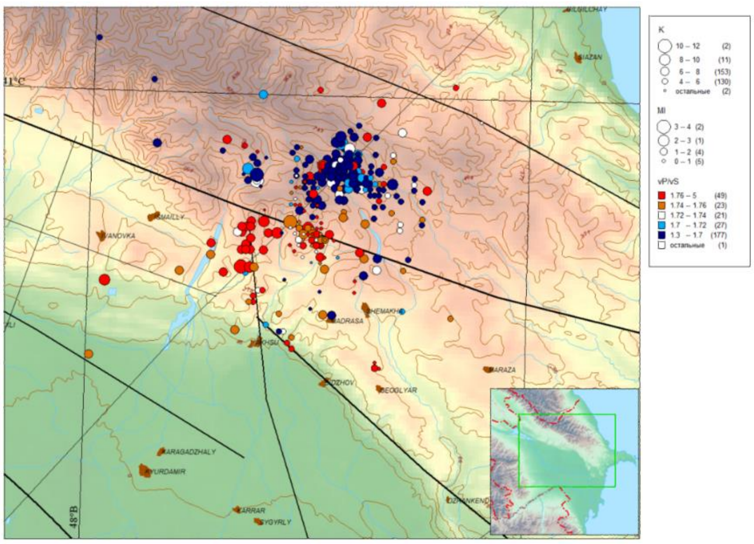


Figure 7. Distribution map of earthquakes with aftershocks, coloured by V_p/V_s.

An analysis of the distribution of hypocentres of earthquakes with Ml≥4 with aftershocks based on a schematic section along profile I-I SW-NE (Fig. 3) showed that the main shocks are relatively shallow within 3–8 km, with the exception of the earthquake in 2012 (Fig. 8). The shallow depth of 3 km and 4 km is characteristic of the main shocks that occurred in 2007 and 2015 with the same magnitudes Ml=4.4. However, aftershock activity propagates to a depth of 18–20 km, covering the upper part of the basement (Yetirmishli et al., 2011).

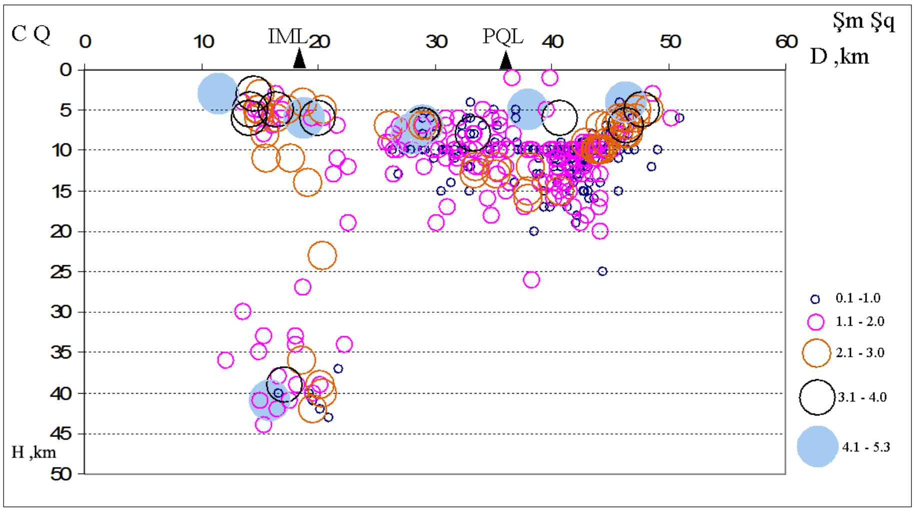


Figure 8. Seismological section along profile I-I.

Let us consider the depth distribution of swarm hypocenters based on a schematic section along profile II-II (Fig. 4) of SW-NE strike (Fig. 9). The main swarm shocks of 2011 2013 and 2016 located at depths of 6-10 km and confined to the sedimentary layer. A high density of hypocenters is observed down to a depth of 20 km, covering the upper part of the basement, slightly higher than the depth of the 2004 earthquake sequences.

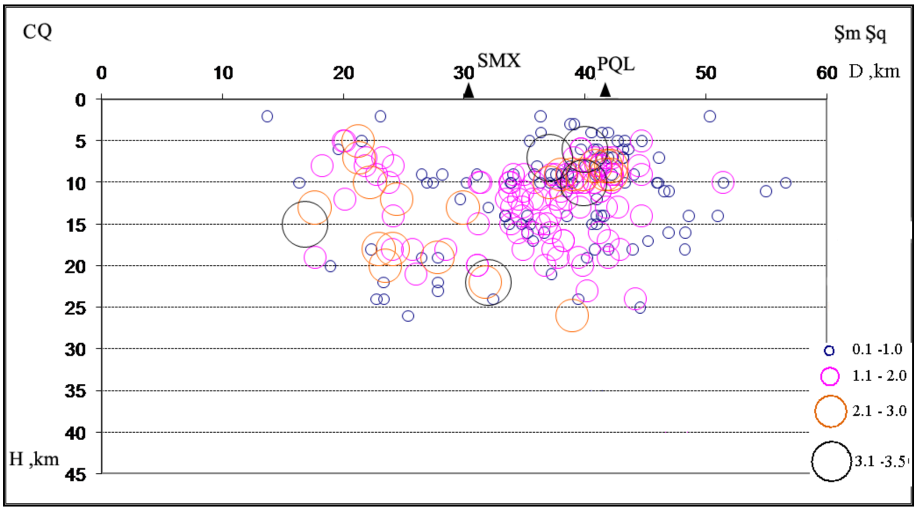


Figure 9. Seismological section along profile II-II.

As a result of the analysis of the spatial and temporal distribution of earthquake sources for the period 2003-2019 the dynamics of seismic activity in the Shamakhi-Ismayilli seismogenic zone has been traced. The study of the spatial distribution of earthquakes with M≥4 and their aftershocks, as well as swarm sequences in the considered zone, leads to the following conclusions:

- discharge of geodynamic stresses in the central part of the zone occurs due to earthquakes with aftershocks, in the eastern part due to swarms of earthquakes;

- sources of stronger earthquakes with Ml≥4 (Ml_{max}=5.3) are located in the central part of the Shamakhi-Ismayilli zone and migrate in the meridional and anti-Caucasian directions, the sources of earthquakes of the swarm sequence with Ml_{max}=3.9 are located in the eastern part of the zone and also migrate in the anti-Caucasian direction, which indicates the presence of transverse structures that control the placement of sources of seismic events;

- the centers of all considered events are located in zones located at the intersection nodes of multidirectional faults and controlled by the main structural elements of the West Caspian fault zone;
- Earthquakes with aftershocks are located in the gradient zone of the stress field, swarm sequences occur in extension areas;
- the hypocenters of the main seismic shocks with Ml≥4 have shallow depths of H≤8 km, except for 2012, and are located in the sedimentary strata of the Vandam and Shamakhi-Gobustan tectonic zones, while the hypocenters of most of their aftershocks are distributed at depths of up to 20 km. The hypocenters of shocks of the swarm sequence (6-26 km) are distributed both in the sedimentary sequence and in the upper part of the basement.

Thus, the release of geodynamic stresses in different parts of the Shamakhi-Ismayilli seismogenic zone occurs at different energy levels and is associated with the stressed state of the environment and with different levels of seismic activity of transverse faults.

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SEISMOGEODYNAMICS OF THE CASPIAN SEA FOR 2018-2020 years

S.S.Ismayilova[1] *S.E.Kazimova*[1]

Introduction

The Caspian aquatorium is a deep lake with a developed shelf zone.As it is known, the Caspian basin as a large tectonic structure was formed at the neotectonic stage in its present dimensions. Prior to the neotectonic stage, the Caspian basin had a long and complicated way of development. Here, due to the differential strengthening of the Earth's crust, the Caspian basin is divided into Northern, Middle and Southern basins [5].

According to P. Mammadov, the modern structure of the South Caspian Basin is the result of the multi-stage evolution of the lithosphere.Two main factors – geodynamics (that is, a system of operating forces) and the type of Earth’s crust, have determined many features of different types of sedimentary basins that existed in the Caucasus-Caspian region, including the nature and tectonics of deep processes [11].

During the geotectonic period in the region, the evolutionary chain (from rift, to the opening of the depression with the newly formed oceanic crust, to its closure, to the collision of plates and to its orogeny) of basins included rift hole, passive outlying basins, and subduction. At the same time, if the basin in the Greater Caucasus region underwent a complete evolutionary period without rift, the period ended at the end of the Miocene as a result of plate collisions in the South Caspian Basin.

The intersections that turn into fixed boundaries formed within the boundaries of successive stages in the evolution of the Earth's crustas a result of seismostratigraphic studies in the sedimentary cover of the South Caspian Basin and the surfaces of regional discrepancies are distinguished [12].

The geotectonic period in the South Caspian consists of divergent and convergent parts and four stages of development.

According to the latest geophysical data, a number of transverse faults have been discovered between the Black Sea and Caspian basins.Their age belongs to the Mesozoic-Cenozoic.The foundation of the Western Caspian fault was founded at the beginning of the Paleozoic.Mud volcanoes are characteristic of the neotectonic phase in the Caucasus.They are located in the western, north-western part of the Greater Caucasus, in the adjacent regions of Eastern Georgia and Western Azerbaijan.However, their maximum development was recorded in the eastern part of Azerbaijan - in the tectonic zones of Shamakhi, Gobustan, Ashagi Kura, Absheron, as well as in the South Caspian basin. The total number of mud volcanoes in these zones is up to 350 [6].

The Caspian Sea, the Absheron Peninsula, as well as Baku city are one of the strategic regions of the country.At present, Baku has become a megalopolis with intensive infrastructure development, population growth, construction of civil, industrial and residential buildings. In order to provide the Caspian littoral countries with hydrocarbon, the Caspian Sea has long attracted the attention of geologists, researchers and specialists to solve important problems.Currently, 17 hydrocarbon fields in the South Caspian Basin are in operation, and more than 100 promising structures have been identified.Numerous seismic and geophysical surveys have been conducted by foreign campaigns in the Azerbaijani sector of the Caspian Sea.A large amount of seismic exploration work has been carried out hereby Caspian Sea Oil Geophysics Exploration trust. On the basis of the collected rich geophysical materials, extensive information was obtained on the geological structure of individual structures of the Caspian Sea, their nature and regional tectonics.

The Caspian Sea is characterized by high seismic activity. And it should be noted that the activity is growing from year to year. It is known that during the exploration of oil and gas fields, the pressure in the productive layers and the surrounding aquifers gradually decreases. Changes in hydro and gas dynamics cause relevant changes in the geodynamics of the solid part of the Earth's crust and these can also cause earthquakes.Strong earthquakes are a great source of danger for strategic objects in the Caspian Sea - exploration and production facilities (platforms in the fields of Gunashli, Umid, Bahar, Azeri, Shakh Deniz, etc.).Occurrence of such seismic events can result in destruction of facilities and lead to large economic losses. For this reason, the spatial conditions of potential source zones in the Caspian Sea, which can generate strong earthquakes, are important for determining the seismic effects on the seabed and assessing the sustainability of strategic facilities.The solution of these issues can play an important role in identifying ways to reduce the impact of potential seismic hazards on facilities [14, 15].On the other hand, strong earthquakes, in turn, can affect the level of oil

[1] *Republican Seismic Survey Center of Azerbaijan National Academy of Sciences*

debit in the fields.Tectonic movements during an earthquake can cause oil migration in the fields or distortion of the drilling rig.

Thus, the study of seismicity in the Caspian Sea is always relevant and shows the need for geodynamic research.The main purpose in the article is to study the geodynamic conditions of the Caspian Sea in 2018-2020 years on the basis of the analysis of seismicity and earthquakes source mechanisms.

Seismicity of the Caspian Sea.

The Caspian Sea takes a special place in the seismic situation of Azerbaijan. The strong (M_{LH} ≥6.0) earthquakes in 1910, 1935, 1963, 1986, 1989 years were repeatedly felt at high intensity (V-VIII points according to MSK-64 scale) in the bottom of the Caspian Sea, Baku city and other coastal areas.

The first information about the earthquake in the Caspian Sea dates back to 957 year (Fig. 1). The earthquake recorded in 957 was felt in the Caspian coastal regions with a magnitude of 7. There were destructions in the Caspian coastal areas. The main parameters of the earthquake: φ = 42.10; λ = 49.00; magnitude M = 5.5 (± 1.0); energy class K = 13.9; the depth of the source was h = 7-60. It is believed that there were two earthquakes. After the earthquake, the sea retreated 150 m.

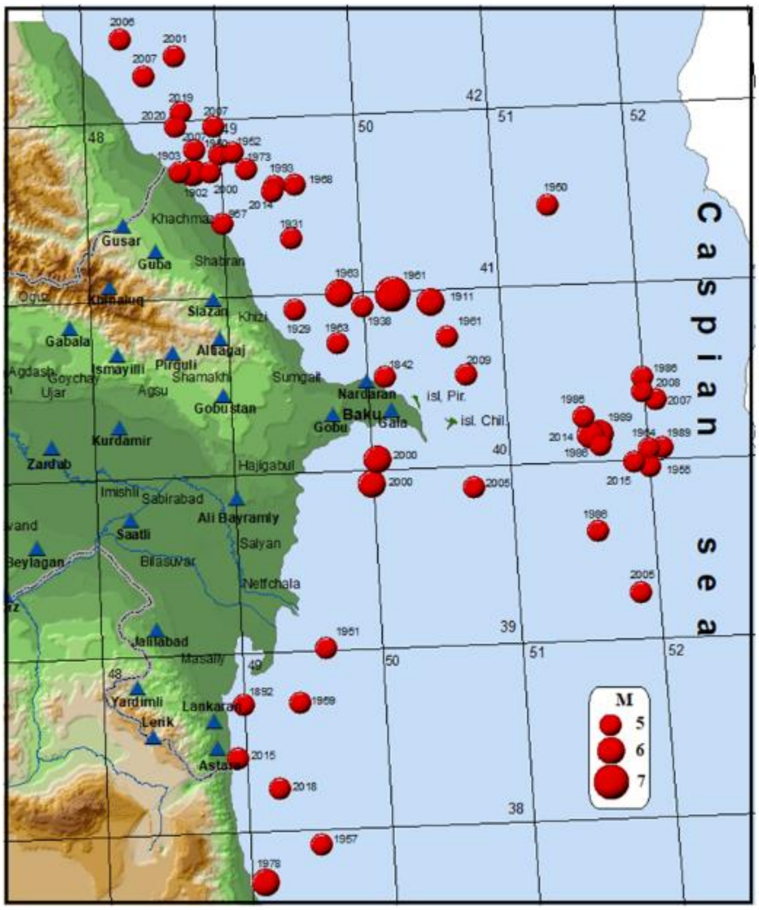

Figure 1. The map of epicenters of historical earthquakes in the Caspian Sea.

The strongest earthquake in the Caspian Sea so far was recorded on January 2, 1842 at 22:00 (± 1 hour). The magnitude of the earthquake was 8.The main parameters of the earthquake: φ = 40.50; λ = 50.0; magnitude M = 4.3 (± 0.5); energy class K = 11.7; the depth of the source was h = 3 (2-5). 700 houses were destroyed in Mashtaga, 5 people were seriously injured. After the Mashtaga earthquake, aftershocks continued until 12.01.

The last strong earthquake in the Azerbaijani part of the Caspian Sea (M = 6.2) occurred on November 25, 2000, 50-60 km south of Absheron and it was felt up to 8 points. The eartrhquake was also felt in Baku and a number of coastal areas with a magnitude of 6-7.In Baku, 34 houses were partially destroyed and 7,350 houses were damaged.The magnitude of the first shock was 5.2.According to the instrumental data, the main parameters of the earthquake are: φ = 40.15; λ = 50.15; energy class K = 12.7; depth of the source h = 25 km.The second shock occurred with 1.5 intervals. The magnitude of the second shock was M = 6.2.The main parameters of this earthquake: the coordinates of the epicenter - φ = 40.05; λ = 50.35; energy class K = 14.5; the depth of the sources varies between h = 40-45 km [4, 8].

Analysis of the number of earthquakes and the amount of seismic energy over the last 10 years (Fig. 2) shows that the amount of seismic energy in 2010-2013 years is stable.The number of earthquakes in 2014 was higher than in 2013, and the seismic energy was 23 times higher.This is due to strong earthquakes with magnitude 5 in the Caspian Sea. The number of earthquakes in 2015 was higher than in 2014, and the amount of seismic energy was reduced by half.

The number of earthquakes in 2016 was higher than in 2015, and the amount of seismic energy was 7 times less. While stability was observed in the seismic energy from 2016 to 2018 years, in 2019 the seismic energy was twice as much. The number of earthquakes in 2020 and seismic energy will increase compared to 2019 [1, 2, 3].

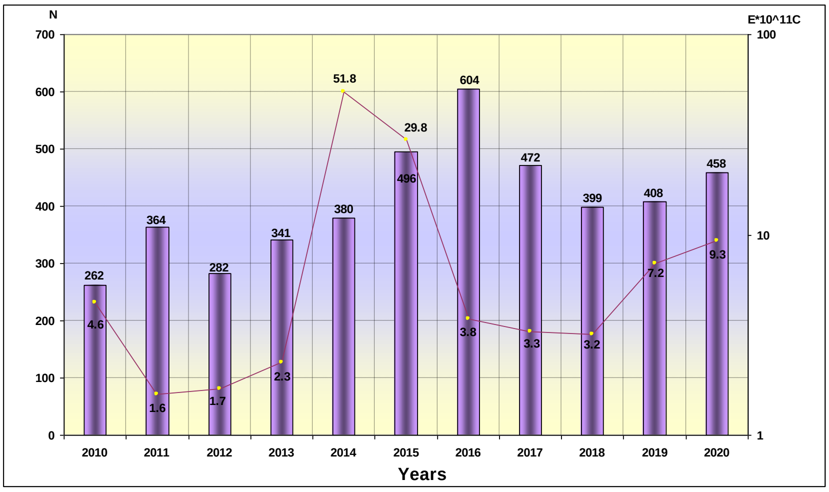

Figure 2. Number of earthquakes in the Caspian Sea during 2010-2020 years and a histogram of the distribution of seismic energy over the years

In order to study the geodynamic conditions of the Caspian Sea in 2018-2020 years, seismic sections have been created.

In order to study the depth distribution of earthquakes in the northern part of the Caspian Sea, a seismic section has been created on two profiles in the north-west and south-east directions (Fig. 3).

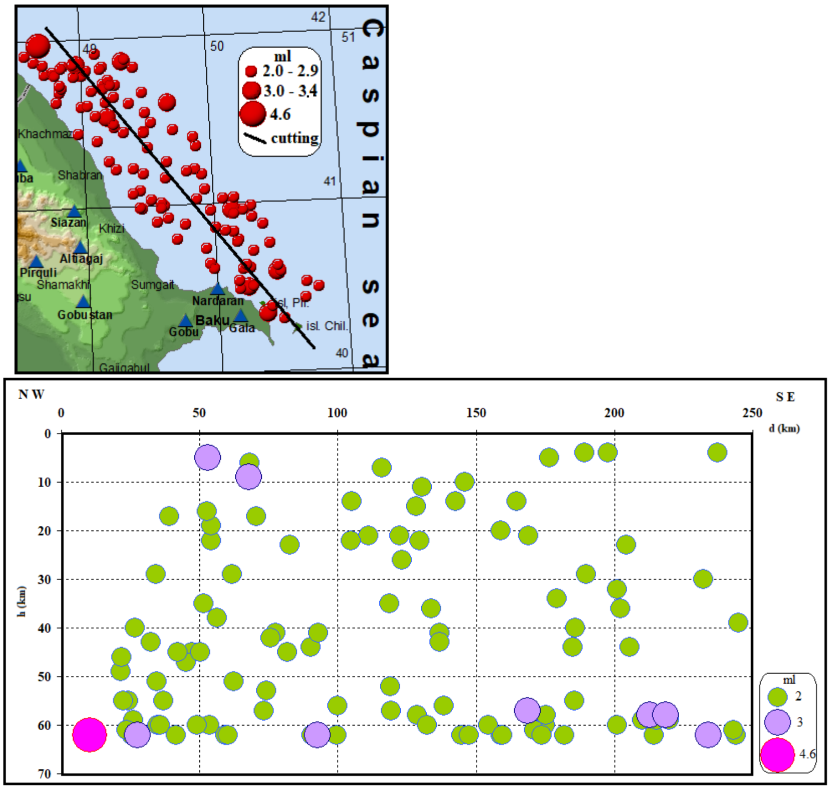

Figure 3. Seismological section of the northern part of the Caspian Sea on profile I-I.

As can be seen from the seismological section on profile I-I,shocks with a magnitude of ≥2.0 occurred in the north-western direction. Uneven distribution of earthquakes is observed. Throughout the section, the sources have been distributed at a depth of 4-62 km. As can be seen from the section, it is possible to come across superficial sources. The shocks with a magnitude of ≥3.0 were mainly distributed at a depth of 59-62 km. The earthquake with the highest magnitude recorded in the North Caspian Sea was ml = 4.6. It was recorded on November 3 at 16:16 local time in the Caspian Sea in Dagestan. The earthquake was felt by some people in the country and it occurred at a depth of 62 km.

Another profile was passed through the North Caspian basin and a seismic section has been made on profile II-II (Fig. 4).The profile passes through north-west, south-east direction. As can be seen from the section,earthquakes with a magnitude of ≥2.0 occured in the Caspian Sea. Most of the earthquakes were distributed at a depth of 2-62 km. Earthquakes of magnitude 3.0 occur mainly in the north-western part of the section. Earthquakes with a magnitude of ≥3.0 were distributed at a depth of 58-62 km.

As we move towards the central part of the Caspian Sea, there is an increase in the number of earthquakes and shocks with a magnitude of ≥ 3.0.The highest magnitude of the earthquake in the Central Caspian Sea during 2018-2020 years was ml = 4.8. The earthquake was recorded on 05.06.2019 at 16:33 local time.It was not felt and occurred at a depth of 62 km.

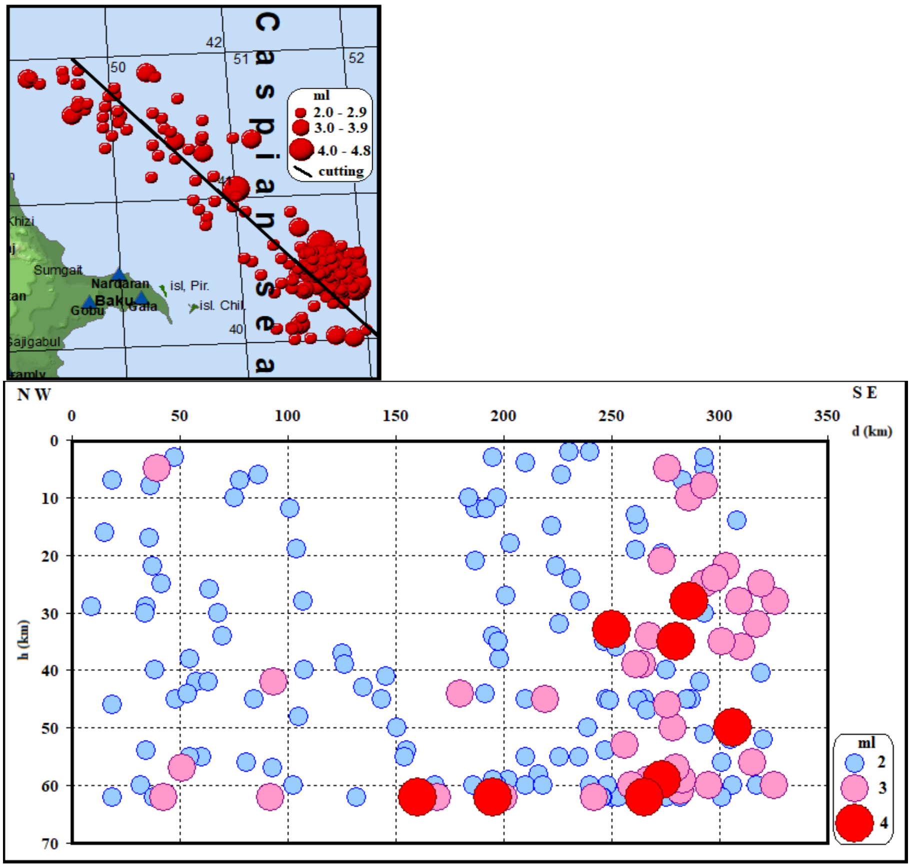

Figure 4. Seismological section of the northern part of the Caspian Sea on profile II-II.

In order to study the depth distribution of earthquakes occurred in the South Caspian Sea, a seismological section has been compiled on profile III-III in the north-west, south-east direction (Fig. 5). As can be seen from the section, the sources are concentrated in the north-western direction at a depth of 50-80 km. The earthquakes with a magnitude of 2 occurred.As we move towards the south-east of the section, we see that the number of earthquakes has increased.Also, the number of shocks with a magnitude of ml≥3.0 increased. The sources are spread at a depth of 2-62 km. The sources with a magnitude of 3.0 ml are mainly distributed at a depth of 35-62 km. The earthquakes with the highest magnitude occurred in the Central Caspian Sea during 2018-2020 years was 4.9. The earthquake was recorded on 12.10.2020 at 15:47 local time. The earthquake was not felt and it occurred at a depth of 62 km.

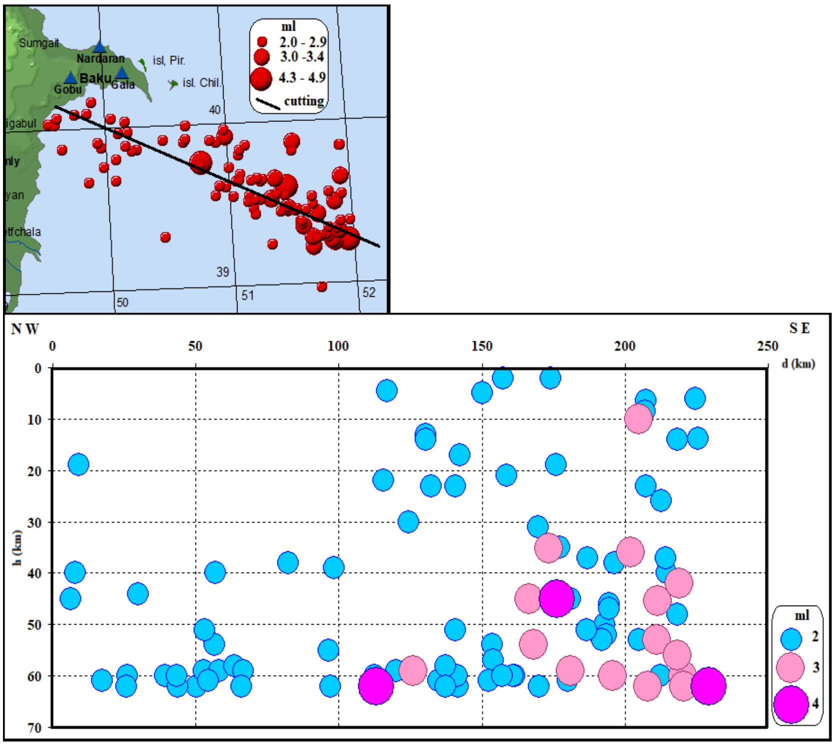

Figure 5. Seismological section of the southern part of the Caspian Sea on profile III-III.

Analysis of earthquakes occurred in 2018-2020 years

In recent years, the level of seismic activity in the Caspian Sea has increased. A map of the epicenters of earthquakes with a magnitude of ≥1.0 occurred in 2018-2020 years has been created (Fig. 6). Earthquakes with magnitude of 1.0 are observed in the North Caspian Sea. The earthquakes were caused by the activation of the Makhachkala-Krasnovodsk and Absheron-Near Balkhan faults. Earthquakes with a magnitude of ≥2.0, mainly with a magnitude of ≥3.0 occurred in the center of the Caspian Sea. The concentration of earthquakes is observed at the section of Agrakhan-Krasnovodsk, Makhachkala Krasnovodsk, Sangachal-Ogurchu and transverse Garabogaz Safidrud faults.

Earthquakes mainly with a magnitude of ≥1.0 were recorded in the South Caspian Basin.

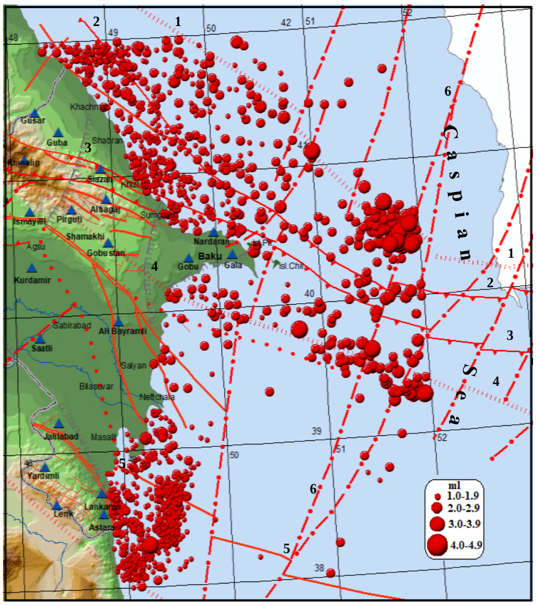

Figure 6. The epicenters map on faults of earthquakes with a magnitude of ≥1.0 occurred in the Caspian Sea in 2018-2020 years [9, 10].

Faults: 1– Agrakhan-Krasnovodsk; 2 - Makhachkala-Krasnovodsk; 3- Absheron- Near-Balkhan; 4 - Sangachal-Ogurchu; 5- Mil-Chikhishlar; 6 - Garabogaz-Safidrud

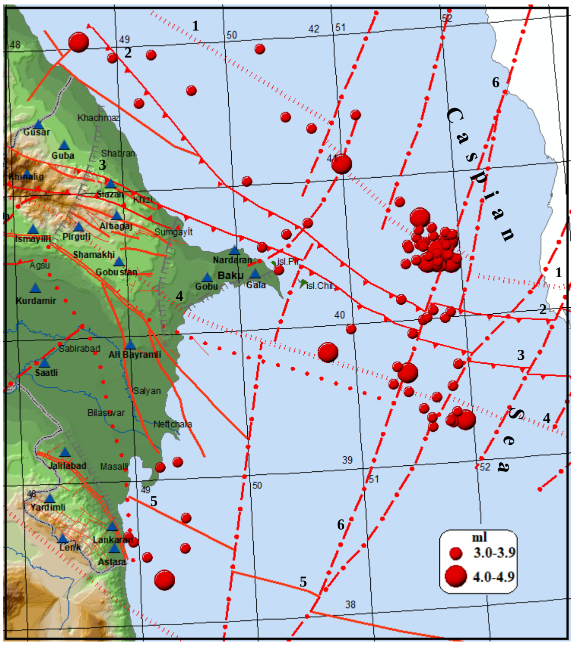

Fig. 7. The epicenters map on faults of earthquakes with a magnitude of ≥ 3.0 occurred in the Caspian Sea in 2018-2020 years[9, 10].

In 2018-2020 years, the earthquakes with a magnitude of 0.01 ml were recorded in the territory of Azerbaijan.A seismic activity map has been compiled based on the catalog and epicenter map. An activity map for 2018-2020 years has been compiled and analyzed to monitor the change of seismic regime over time. It is determined that the seismic activity is high in the northern part (A10 = 0.4-1.7), in the central part (A10 = 0.4-1.7) and in the southern part (A10 = 1.6-2.0) of the Caspian Sea. Thus, during 2018-2020 years, the activity was high in the northern, central and southern parts of the Caspian Sea (Fig. 8).

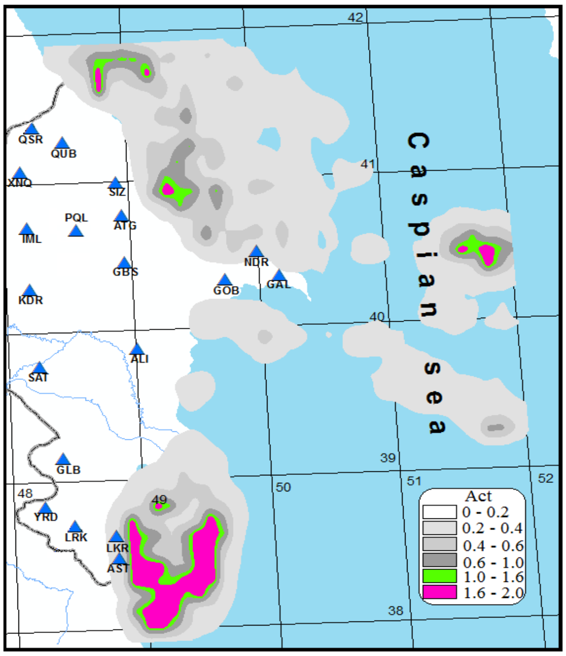

Figure 8. The activity map of the earthquakes in the Caspian Sea during in 2018-2020 years.

Earthquake source mechanisms

Study of the source mechanisms of strong earthquakes allows to determine the types of tectonic movements that are characteristic of different seismically active areas of the Earth’s crust and the maximum values of the movement acceleration of the soil on the surface, depending on these types of movement.Taking this into account, in 2018-2020 years, in order to study the stress and strain areas of the earth's crust, the mechanisms of earthquake sources have been evaluated and the stress areas have been analyzed (Fig. 9.).

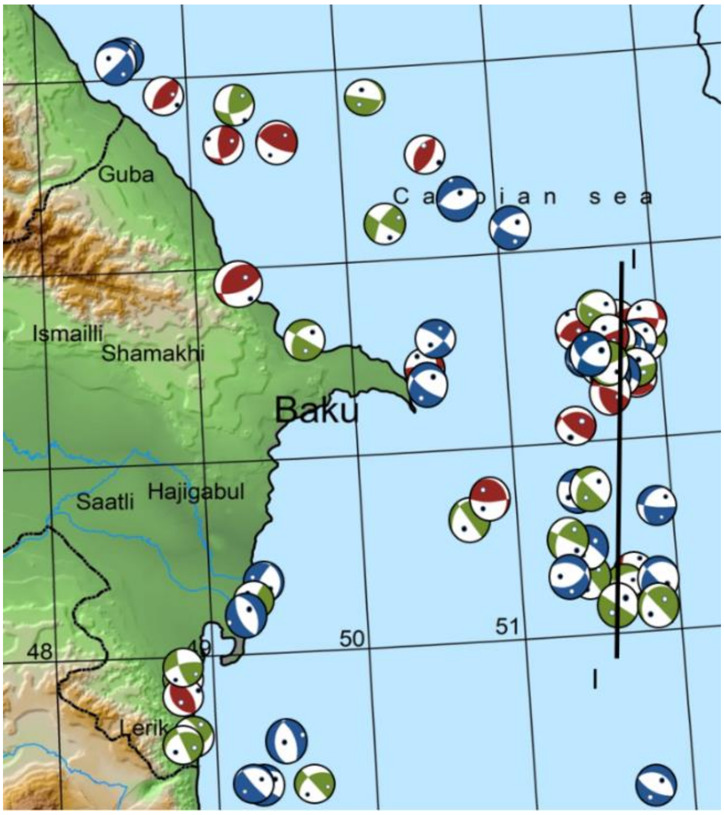

Figure 9. Source mechanisms of earthquakes with a magnitude of ≥3.0 occurred in 2018-2020 years.

It should be noted that in the modern structure of the Earth's crust, the foundation of the Caspian Basin has a giant intercontinental depression (mega-depression) of heterogeneous origin.Eastern European Platform, Scythian-Turan Plate and Mediterranean Sea (Alpine-Himalayan) were formed during the transition period from the Miocene to the Pliocene (10 million years ago), referring to the zone of submeridional bending over the structures of the folded belt [12]. A mega depression consisting of three (north, middle, south parts) secondary basins bordered by submarines from a regional point of view are represented by the western part of the South Caspian Basin and the southwestern part of the Middle Caspian Basin separated from the Absheron threshold with latitudinal direction in the seabed relief of the Azerbaijani sector of the water area[13].

In the central part of the Caspian Sea, 21 earthquakes with a magnitude of ≥ 3.0 in 2018, 29 in 2019 and 20 in 2020 were recorded.In 2018-2019, the central and northern part of the Caspian Sea was mainly active and was associated with the activity of the Central-Caspian, Absheron-Pribalkhan and Karabakh-Safidrud faults.The histogram of the percentage distribution of the earthquakes mechanisms in the Caspian Sea shows that 60% of earthquakes are characterized by slip-strike dislocation. Analysis of earthquakes showed that Makhachkala-Krasnovodsk and Shakhovo-Krasnovodsk and Shakhovo-Krasnovodsk and Shakhovo-Azizbayov faults were active in the depths of 10-65 km of the section zone.The seismic activation is observed in the 5-20 and 50-60 km depths of the Central-Caspian fault and it is characterized by a slip-strike. The Gizilaghadj fault was monitored with a slip-strike type of movement mainly at depths of 40-65 km.

In general, the highest density of hypocentes is observed at a depth of 30-65 km. Only a small part of earthquakes occurs at a depth of 10-25 km. In the last 20 years, 19 earthquakes with a magnitude of > 5.0 have been occurred in this area and are associated with active tectonic movements at the junction of the two largest structures of the Earth's crust (Turan and Kopetdagh mountain folds).

In percentage terms, the type of movement in 2020: horizontal displacement is 21%, slip-strike is 22%, and normal fault is 39% (Fig. 10).The values of displacement in the source indicate that the normal fault type movements are predominated. However, in the area of the Central Caspian and oil fields, slip-strike displacement type movements occur. Thus, the compression axes of earthquakes shown by the analysis of compression and extension axes are oriented in the SW-NE direction, and the extension axes are mainly oriented in the direction of NW-SE. (Fig. 11)

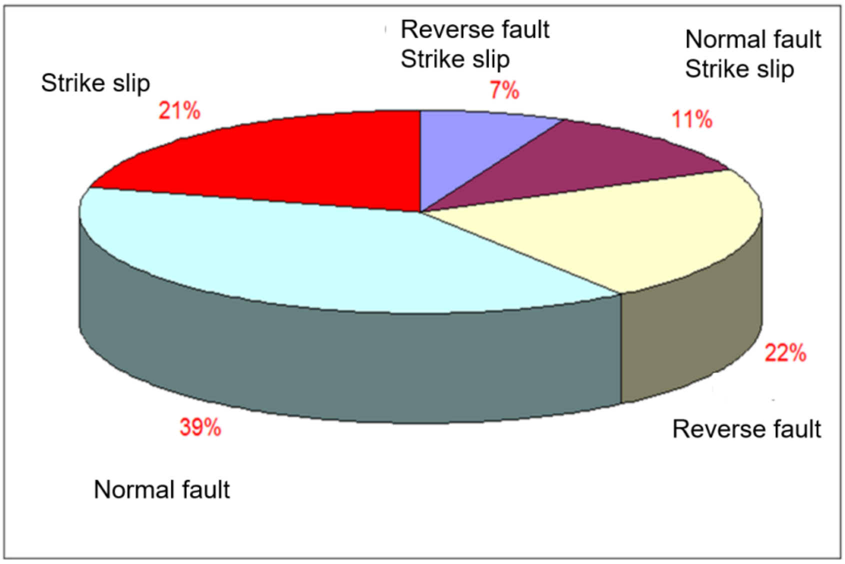

Figure 10. Percentage distribution histogram of the mechanisms of earthquakes in the Caspian Sea in 2020.

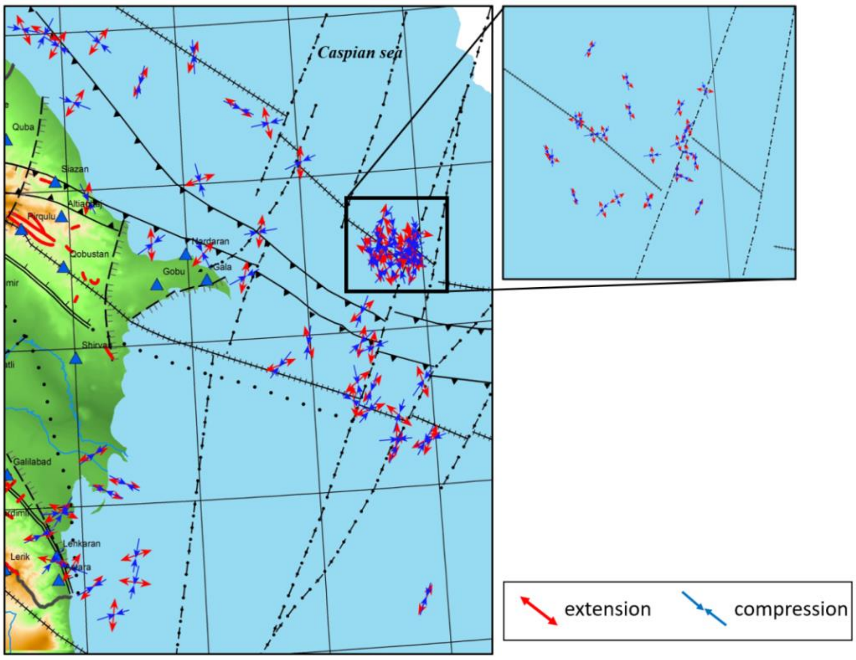

Figure 11. Scheme of compression and extension axes of earthquakes occurred during 2018-2020 years. Faults map - [9, 10].

At 11:51:21 local time on February 26, 2020, earthquake with magnitude of 4.6 was recorded in the Caspian Sea.The direction of the compression axis (P) of the earthquake is vertical (PL = 55), and the direction of the extension stress axis (T) is horizontal (PL = 15).A sharp drop angle has been determined for the first nodal plane (DP = 67) and a flat drop angle for the second nodal plane (DP = 39).The value of displacement in the source (slip = -57 - (- 142)) indicates the predominance of normal fault-type movement. At 14:17:34 local time on February 27, another earthquake with a magnitude of 4.5 was recorded, and it was characterized by the eruption right-sided displacement movements.

The analysis of the study showed that earthquakes in the Caspian Sea occur mainly in the section zone of the Agrakhan-Krasnavodsk-Shakhovo-Azizbayov and Sangachal-Ogurchu-Shakhovo-Azizbayov faults.

Thus, based on the data of the source mechanisms of the calculated earthquakes, the distribution map of the Lode-Nadayi stress coefficient and the depth cross section have beenconstructed (Fig. 12).The blue color indicates extension, red - compression, white - displacement stresses.As can be seen from the Figure 11, the stress situation in the study area varies over the years and is mainly characterized by extension stress. If we pay attention to the section, the compression part is characterized in the middle part of the Caspian Sea, at a depth of 1-65 km.

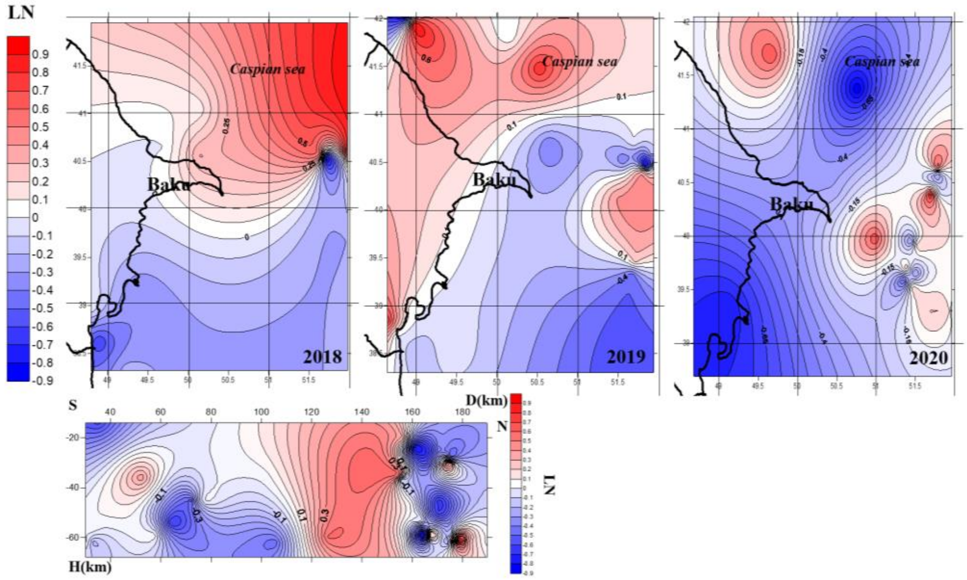

Figure. 12. Lode-Nadai coefficient distribution map and depth section calculated based on the mechanisms of earthquakes in 2018-2020 years.

Conclusion

Most of the hypogents accumulate in the consolidated layer and in the upper mantle, and are formed as a result of active tectonic movements at the junction of the two largest structures (Turan and Kopetdag mountainfolds). The highest density of hypogents is observed at a depth of 30-70 km. Only a small part of earthquakes occurs at a depth of 10-25 km.

In order to evaluatethe focal mechanisms parameters of earthquake sources to study the areas of stress and deformation of the Earth's crust, the conditions and analysis of their formation, the analysis of the stress areas of the Earth's crust have been carried out.The percentage is horizontal at 21%, slip-strike at 22% and normal fault at 39%.The values of displacement in the source indicate that the normal fault-type movements are predominant . However, in the area of the Central Caspian and oil fields, the slip-strike type movements occur. The compression axes of earthquakes shown by the analysis of compression and extension axes are oriented in the direction of SW-NE, and the tension axes are oriented mainly in the direction of NW-SE. The stress situation in the study area varies over the years and is mainly characterized by extension stress.

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ANNOTATIONS

1. CONTEMPORARY GEODYNAMICS OF THE EASTERN MEDITERRANEAN

G.J. Yetirmishli, I.E. Kazimov, A.F.Kazimova

The article provides an analysis of the tectonic structure, seismicity and modern geodynamics of the Eastern Mediterranean, including the regions of the Eastern Anatolian microplate, the Caucasus and the Bitlis-Zagros thrust fault. Analysis of the velocity field of GPS stations showed the heterogeneity of deformation processes in the region of the Eastern Mediterranean and the Caucasus. The considered results show the movement of the Arabian plate relative to the Eurasian one. Considering the speeds of movement of the Anatolian and Eurasian plates, and the Arabian and Anatolian plates, it was found that the shear rate along the North Anatolian fault was 20 mm/year, along the East Anatolian - 14 mm/year. This indicates the convergence of the Anatolian and Eurasian plates through the system of right strike-slip faults in eastern Turkey and the Thrust system in the Caucasus. The total reduction in the distance between the Lesser and Greater Caucasus is 10 mm per year.

Keywords*: geodynamics, GPS stations, tectonic plates, Anatolian plate.*

2. PROBABILISTIC ASSESSMENT OF THE SEISMIC HAZARD LEVEL OF THE “TAKHTA-KORPU” RESERVOIR LOCATION

T.Y.Mammadli, R.B.Muradov

The maximum risks of possible strong earthquakes in tectonic faults or potential sources, which are a source of seismic hazard for the Takhtakorpu reservoir, built in the Shabran area, have been quantitatively assessed. It turned out that the maximum value of the expected ground acceleration from an earthquake in the study area with a probability of 2% over 50 years is 0.27g, and the value of the maximum ground acceleration with a probability of 10% over 50 years is 0.16g.

Keywords*: seismic activity, earthquakes, depth faults, seismological sections, ground acceleration, intensity.*

3. CLARIFICATION OF ENGINEERING-GEOLOGICAL AND ENGINEERING-SEISMOLOGICAL CONDITIONS OF CONSTRUCTION SITES IN THE TERRITORY OF ABSHERON REGION AND SUMGAYIT CITY

Fattahova L.T., Mehdizade F.Z., Djalilova I.N.

Based on the seismicity of active longitudinal (all-Caucasian) and transverse (anti-Caucasian) fault zones in Azerbaijan, up to 2,400 wells drilled at construction sites in the Absheron region and Sumgayit city. As a result of the study of the factors determining the level of seismic hazard (geomorphological, hydrogeological, lithological), standart ground have been identified for both regions.
Keywords: *ground, engineering-geological, construction sites, physical-mechanical indicator, seismicity.*

4. FEATURES OF THE DISTRIBUTION OF SWARM SEISMIC EVENTS AND EARTHQUAKES WITH M≥4 IN THE SHAMAKHI-ISMAYILLI ZONE IN 2003-2019

G.J.Yetirmishli, R.R.Abdullayeva, S.S.Ismayilova

The space-time distribution of swarm sequences of earthquakes, as well as earthquakes with aftershocks within the Shamakhi-Ismayilli seismogenic zone in 2003-2019, is considered. The depth distribution of earthquake sources has been studied. The dependence of the occurrence of both aftershock and swarm sequences of earthquakes on the stress state of the medium and their confinement to the elements of transverse structures of the anti-Caucasian fault tectonics has been established.
Key words: *seismic activity, earthquake, swarm, relaxation, aftershocks, tectonics, seismicity, faults.*

5. SEISMOGEODYNAMICS OF THE CASPIAN SEA FOR 2018-2020 YEARS

S.S.Ismayilova, S.E.Kazimova

The seismogeodynamics analysis of the aquatorium of Caspian Sea in the Azerbaijani sector was conducted in 2018-2020 years.The first information about the earthquake in the Caspian Sea aquatorium dates back to 957 year and the last strong earthquake (M = 6.2) occurred on November 25, 2000, 50-60 km south of Absheron region.Analysis of the number of earthquakes and seismic energy shows that while the stability of seismic energy from 2016 to 2018 years was stable, in 2019 the seismic energy was twice as high.In 2020, an increase in the number of earthquakes and seismic energy compared to 2019 was observed.

Seismic analysis showed that the earthquakes in the North Caspian Sea (with magnitude of ≥1.0) are associated with the activation of the Makhachkala-Krasnovodsk and Absheron-Near Balkhan faults.Earthquakes with a magnitude of ≥2.0, mainly with a magnitude of ≥3.0 occurred in the center of the Caspian Sea.The concentration of earthquakes was observed at the intersection of Agrakhan-Krasnovodsk, Makhachkala Krasnovodsk, Sangachal-Ogurchu and transverse GarabogazSafidrud faults.

Analysis of the stress-strain areas of the Earth's crust showed that the values of displacement in the source are dominated by normal fault type movements.However, in the Central Caspian and oil fields (Azeri, Gunashli, Chirag) there are strike-slip movements.The compression and tension axes of the earthquakes show that the compression axes of the earthquakes are oriented in the direction of SW-NE, and the tension axes are mainly oriented in the direction of NW-SE. The stress situation in the study area varies over the years and is mainly characterized by extension stress.

Keywords: *seismogeodynamics, Caspian Sea, oil fields, mechanisms of earthquake sources*.

ANNOTASİYALAR

1. ŞƏRQİ ARALIQ DƏNİZİNİN MÜASİR GEODİNAMİKASI

Q.C.Yetirmişli, İ.E.Kazımov, A. F.Kazımova

Məqalədə Şərqi Aralıq dənizinin, o cümlədən Şərqi Anadolu mikroplitəsinin, Qafqaz ərazisinin və Bitlis-Zaqros üstəgəlmə bölgələrinin tektonik quruluşu, seysmikliyi və müasir geodinamikasının təhlili təqdim olunur. GPS stansiyalarının əsasında hesablanmış horizontal sürətlərin təhlili Şərqi Aralıq dənizi və Qafqaz regionunda deformasiya proseslərinin mütılif olduğunu göstərdi. Nəzərdən keçirilən nəticələr Ərəb plitəsinin Avrasiyaya nisbətən hərəkətini göstərir. Anadolu və Avrasiya plitələrinin, Ərəbistan və Anadolu plitələrinin hərəkət sürətlərini nəzərə alsaq, Şimali Anadolu qırılması boyunca kəsilmə sürətinin 20 mm/il, Şərqi Anadolu boyunca isə 14 mm/il olduğu müəyyən edilmişdir. Bu, Türkiyənin şərqində sağ tərəfli yerdəyişmə qırılmaların sistemi və Qafqazda üstəgəlmə sistemi vasitəsilə Anadolu və Avrasiya plitələrinin yaxınlaşmasını göstərir. Kiçik və Böyük Qafqaz arasında məsafənin ümumi azalması orta hesabla 10 mm/il təşkil edir.

Açar sözlər: *geodinamika, GPS stansiyaları, tektonik plitələr, Anadolu plitəsi.*

2. "TAXTAKÖRPÜ" SU ANBARI YERLƏŞƏN ZONANIN SEYSMİK TƏHLÜKƏ SƏVİYYƏSİNİN EHTİMAL METODLA QİYMƏTLƏNDİRİLMƏSİ

T.Y.Məmmədli, R.B.Muradov

Şabran rayonu ərazisində inşa olunmuş su anbarı üçün seysmik təhlükə mənbəyi sayılan tektonik qırılma və ya potensial ocaq zonalarında ehtimal olunan güclü zəlzələlərin yaradacağı maksimum təhlükə kəmiyyətcə qiymətləndirilmişdir. Məlum olmuşdur ki, 50 il ərzində 2% ehtimalla tədqiqat ərazisində zəlzələdən gözlənilən qrunt təcilinin maksimum qiyməti 0,27g, 50 il ərzində 10% ehtimalla qruntun maksimum təcilinin qiyməti 0,16g-dir.

Açar sözlər: *seysmik aktivlik, zəlzələlər, dərinlik qırılmaları, seysmoloji kəsilişlər,qrunt təcili, intensvlik.*

3. ABŞERON RAYONU VƏ SUMQAYIT ŞƏHƏRİ ƏRAZİSİNDƏ TİKİNTİ SAHƏLƏRİNİN MÜHƏNDİS-GEOLOJİ VƏ MÜHƏNDİSİ SEYSMOLOJİ ŞƏRAİTİNİN DƏQİQLƏŞDİRİLMƏSİ

L.T.Fəttahova, F.Z. Mehdizadə, İ.N.Cəlilova

Azərbaycan ərazisində aktiv uzununa (ümumi Qafqaz) və eninə (anti-Qafqaz) istiqamətli qırılma zonalarının seysmikliyinə, Abşeron rayonu və Sumqayıt şəhəri ərazilərindəki tikinti sahələrində qazılmış 2400-ə qədər quyu məlumatlarına əsaslanaraq, seysmik təhlükənin səviyyəsini şərtləndirən amillərin (geomorfoloji, hidrogeoloji, litoloji) araşdırıması nəticəsində hər iki bölgə üçün etalon qruntlar təyin edilmişdir.

Açar sözlər: *qrunt, mühəndisi-geoloji, tikinti sahələri, fiziki-mexaniki göstərici, seysmiklik.*

4. ZƏLZƏLƏ TOPLUSUNUN VƏ M≥4 OLAN ZƏLZƏLƏLƏRİN 2003-2019-CU İLLƏRDƏ ŞAMAXI-İSMAYILLI ZONASINDA PAYLANMASININ XÜSUSİYYƏTLƏRİ

Q.C.Yetirmişli, R.R.Abdullayeva, S.S.İsmayılova

2003-2019-cu illərdə Şamaxı-İsmayıllı seysmogen zonasında baş vermiş zəlzələ toplusunun, eləcə də zəlzələlərin və onların afterşoklarının zaman və sahə üzrə paylanması nəzərdən keçirilib. Zəlzələ ocaqlarının dərinlik üzrə paylanması öyrənilib. Müəyyən edilmişdir ki, həm afterşokların, həm də zəlzələ toplusunun baş verməsi ətraf mühitin gərgin vəziyyətindən asılıdır. Onlar antiqafqaz istiqamətində yerləşən qırılma tektonikasının eninə strukturlarının elementləri ilə əlaqədardır.

Açar sözlər: *seysmik aktivlik, zəlzələ, roy, relaksasiya, aftersok, tektonika, seysmiklik, qırılmalar.*

5. 2018-2020-Cİ İLLƏR ÜÇÜN XƏZƏR DƏNİZİNİN SEYSMOGEODİNAMİKASI

S.S. İsmayılova, S.E.Kazımova.

Məqalədə Azərbaycan sektorunun Xəzər dənizi akvatoriyasının 2018-2020-ci illərdə seysmogeodinamikasının analizi aparılmışdır. Xəzər akvatoriyasında zəlzələ haqqında ilk məlumat 957-ci ilə təsaduf edilir və sonuncu güclü zəlzələ (M=6,2) 2000-ci il noyabrın 25-də Abşerondan 50-60 km cənubda baş vermiş. Zəlzələlərin sayının və ayrılan seysmik enerjinin analizi göstərir ki 2016-cı ildən 2018-ci ilə kimi ayrılan seysmik enerjidə stabillik müşahidə olunurdusa, 2019-cu ildə isə ayrılan seysmik enerji 2 dəfə çox olmuşdur. 2020-ci idə zəlzələlərin sayı və ayrılan seysmik enerji 2019-cu ilə nisbətən artımı müşahidə olunur.

Seysmikliyin analizi göstərdi ki, Şimali Xəzər akvatoriyasında (maqnitudası ml≥1.0 olan) baş vermiş zəlzələlər Maxaçkala-Krasnavodsk və Abşeron-Pribalxan qırılmalarının aktivləşməsi ilə əlaqadardır. Xəzərin mərkəzində maqnitudası ml≥2.0, əsasəndə maqnitudası ml≥3.0 olan zəlzələlər baş vermişdir. Zəlzələlərin cəmlənməsi Aqraxan-Krasnavodsk, Maxaçkala Krasnavodsk, Sanqaçal-Oqurçu və eninə Qaraboğaz Safidrud qırılmalarının kəsişməsində müşahidə olunur.

Yer qabığının gərginlik və deformasiya sahələrini analizi göstərdi ki, ocaqda yerdəyişmənin qiymətləri qırılıb düşmə tipli hərəkətlərin üstünlük təşkil etdiyini göstərir. Lakin Mərkəzi Xəzər və neft yataqları sahəsində (Azəri, Günəşli, Çıraq) qırılıb qalxma tipli hərəkətlər əmələ gəlir. Sıxılma və gərilmə oxların analizi göstərdiki zəlzələlərin sıxılma oxalrı CQ-ŞŞ istiqamətində, gərilmə oxları isə əsasən ŞQ-CŞ istiqamətində oriyentasiya olunur. Tədqiq olunan ərazidə gərginlik vəziyyəti illər ərzində dəyişir və əsasən gərilmə gərginlik ilə səciyəlinir.

Açar sözlər: *seysmogeodinamika, Xəzər dənizi, neft yatağları, zəlzələ ocaqlarının mexanizmləri*.

АННОТАЦИИ

1. СОВРЕМЕННАЯ ГЕОДИНАМИКА ВОСТОЧНОГО СРЕДИЗЕМНОМОРЬЯ

Г.Дж.Етирмишли, И.Э. Казымов, А.Ф.Казымова

В статье приведен анализ тектонического строения, сейсмичность и современная геодинамика Восточного Средиземноморья включающий регионы Восточный Анатолийской микро плиты, Кавказа и надвиг Битлис-Загрос. Анализ поля скоростей GPS станций показал неоднородность деформационных процессов в регионе Восточного Средиземноморья и Кавказа. Рассмотренные результаты показывают движение Аравийской плиты относительно Евразийской. Рассматривая скорости движения Анатолийской и Евразийской плит, и Аравийской и Анатолийской плит, установлено, что скорость сдвига по Северо-Анатолийскому разлому оказалась равна 20 мм/г, по Восточно-Анатолийскому – 14 мм/год. Это свидетельствует о сближении Анатолийской и Евразийской плит через систему правых сдвигов в восточной Турции и Надвиговой системы на Кавказе. Суммарное сокращение расстояние между Малым и Большим Кавказом составляет 10 мм/г.

Ключевые слова: *геодинамика, GPS станции, тектонические плиты, Анатолийская плита.*

2. ВЕРОЯТНОСТНАЯ ОЦЕНКА УРОВНЯ СЕЙСМИЧЕСКОЙ ОПАСНОСТИ РАЙОНА РАСПОЛОЖЕНИЯ ВОДОХРАНИЛИЩА «ТАХТАКОРПЮ»

Т.Я.Маммадли, Р.Б.Мурадов

Количественно оценен максимальный риск возможных сильных землетрясений в тектонических разломах или потенциальных очагах, которые являются источником сейсмической опасности для водохранилища “Тахтакорпю”, построенного в районе Шабран. Выяснилось, что максимальное значение ожидаемого ускорения грунта от землетрясения в районе исследования с вероятностью 2% за 50 лет составляет 0,27g, а значение максимального ускорения грунта с вероятностью 10% за 50 лет составляет 0,16g.

Ключевые слова: *сейсмическая активность, землетрясения, глубинные разломы, сейсмологические разрезы, ускорение грунта, интенсивность.*

3. УТОЧНЕНИЕ ИНЖЕНЕРНО-ГЕОЛОГИЧЕСКИХ И ИНЖЕНЕРНО-СЕЙСМОЛОГИЧЕСКИХ УСЛОВИЙ СТРОИТЕЛЬНЫХ УЧАСТКОВ НА ТЕРРИТОРИИ АБШЕРОНСКОГО РАЙОНА И ГОРОДА СУМГАИТ

Л.Т.Фаттахова, Ф.З.Мехтизаде, И.Н.Джалилова

Результаты исследований сейсмичности активных продольных (обще-Кавказский) и поперечных (анти-Кавказский) зон разломов территории Азербайджана и анализа факторов (геоморфологические, гидрогеологические, литологические), влияющие на уровень сейсмической опасности, полученных из 2400 скважин, пробуренных на строительных участках в Абшеронском районе и города Сумгаит позволили установить эталонные грунты для обоих регионов.

Ключевые слова: *грунт, инженерно-геологический, строительные участки, физико-механические показатели, сейсмичность.*

4. ОСОБЕННОСТИ РАСПРЕДЕЛЕНИЯ РОЕВЫХ СЕЙСМИЧЕСКИХ СОБЫТИЙ И ЗЕМЛЕТРЯСЕНИЙ С M≥4 В ШАМАХЫ-ИСМАИЛЛИНСКОЙ ЗОНЕ В 2003-2019 гг

Г.Д.Етирмишли, Р.Р.Абдуллаева, С.С.Исмаилова

Рассмотрено пространственно-временное распределение роевых последовательностей землетрясений, а также землетрясений с афтершоками в пределах Шамахы-Исмаиллинской сейсмогенной зоны в 2003-2019гг. Исследовано глубинное распределение очагов землетрясений. Установлена зависимость реализации как афтершоковых, так и роевых последовательностей землетрясений от напряженного состояния среды и приуроченность их к элементам поперечных структур разломной тектоники антикавказского направления.

Ключевые слова: *сейсмическая активность, землетрясение, рой, релаксация, афтершоки, тектоника, сейсмичность, разломы.*

5. СЕЙСМОГЕОДИНАМИКА КАСПИЙСКОГО МОРЯ ЗА 2018-2020 ГОДЫ

С.С. Исмаилова, С.Э.Казымова

В статье анализируется сейсмогеодинамика азербайджанского сектора Каспийского моря в 2018-2020 годах. Первая информация о землетрясении в Каспийском море совпадает с 957 годом, а последнее сильное землетрясение (M = 6,2) произошло 25 ноября 2000 года в 50-60 км к югу от Абшерона. Анализ количества землетрясений и выделенной сейсмической энергии показывает, что, хотя стабильность сейсмической энергии, выделенной с 2016 по 2018 год, была стабильной, в 2019 году выделенная сейсмическая энергия была вдвое выше. Количество землетрясений в 2020 году и количество выделяемой сейсмической энергии увеличились по сравнению с 2019 годом.

Сейсмический анализ показал, что землетрясения в Северном Каспии (магнитудой ml≥1.0) связаны с активизацией Махачкалинско-Красаводского и Абшерон-Прибалханского разломов. Землетрясения с магнитудой ml≥2,0, произошли в центре Каспийского моря. Скопление землетрясений наблюдается на пересечении Аграхан-Красаводского, Махачкалинско-Красаводского, Сангачал-Огурчинского и поперечного Гарабогаз-Сафидрудского разломов.

Анализ зон напряжений и деформаций земной коры показал, что по величине смещения в очаге преобладают движения трещинного типа. Однако в Центральном Каспии и нефтяных месторождениях (Азери, Гюнешли, Чираг) наблюдаются взбросовые подвижки. Оси сжатия землетрясений, показанные на карте осей сжатия и растяжения, ориентированы в направлении ЮЗ-СВ, а оси растяжения в основном ориентированы в направлении СЗ-ЮВ. Напряженная ситуация в районе исследования меняется с годами и в основном характеризуется растягивающим напряжением.

Ключевые слова: *сейсмогеодинамика, Каспийское море, нефтяные скважины, механизм очага землетрясений.*

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