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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

CHARACTERISTICS OF SEISMICS OF AZERBAIJAN AND AROUND REGIONS IN 2020

Yetirmishli G.J.[1], Ismayilova S.S.[1]., Kazimova S.E.[1]

Introduction.

In 2020, seismic analysis was conducted on the basis of 40 digital data. During the year, 13.295 earthquakes were recorded. A map of the epicenters of earthquakes in the adjacentterritories of Azerbaijan and in the territory of Azerbaijan has been constructed (Figure 1).

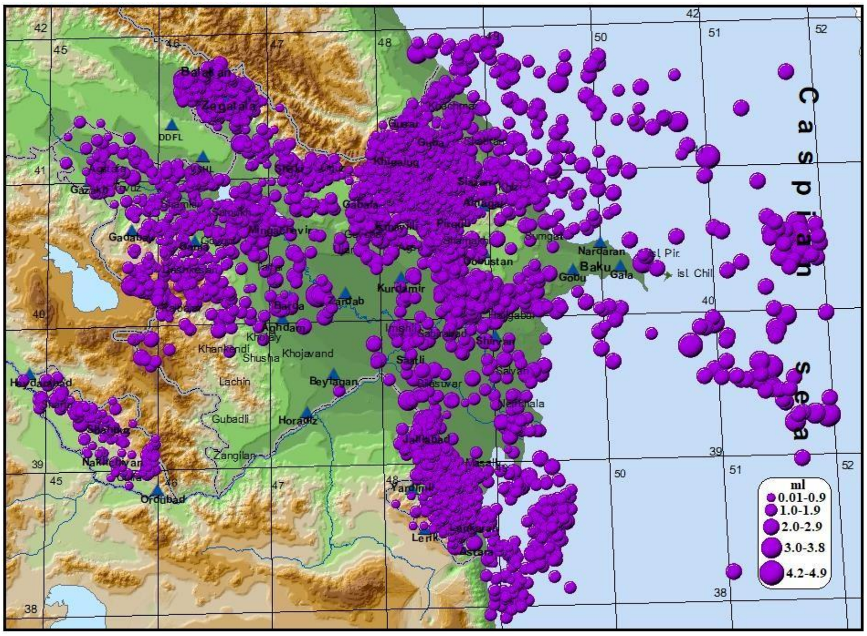

Fig. 1. Map of epicenters of earthquakes in Azerbaijan

77 earthquakes with a magnitude of ml≥3 were registered in Azerbaijan. A map of theepicenters of earthquakes with a magnitude of ml ≥3 has been constructed (Figure 2).

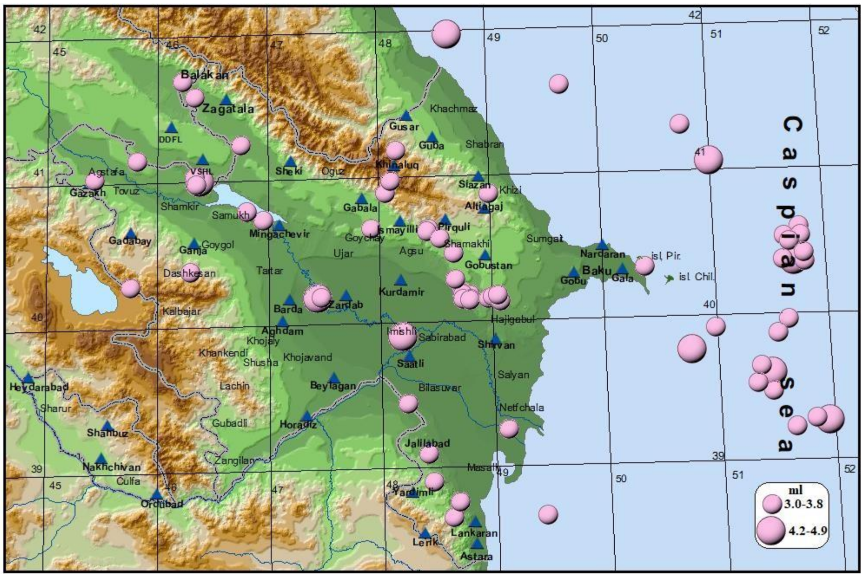

Fig. 2. Map of epicenters of earthquakes of magnitude ml≥3 forthe territory of Azerbaijan in 2020

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

In 2020, there were 20 tremors in Azerbaijan and adjacent areas. The map of the epicenters of earthquakes felt in Azerbaijan and adjacent areas in 2020 is shown in Figure 3.

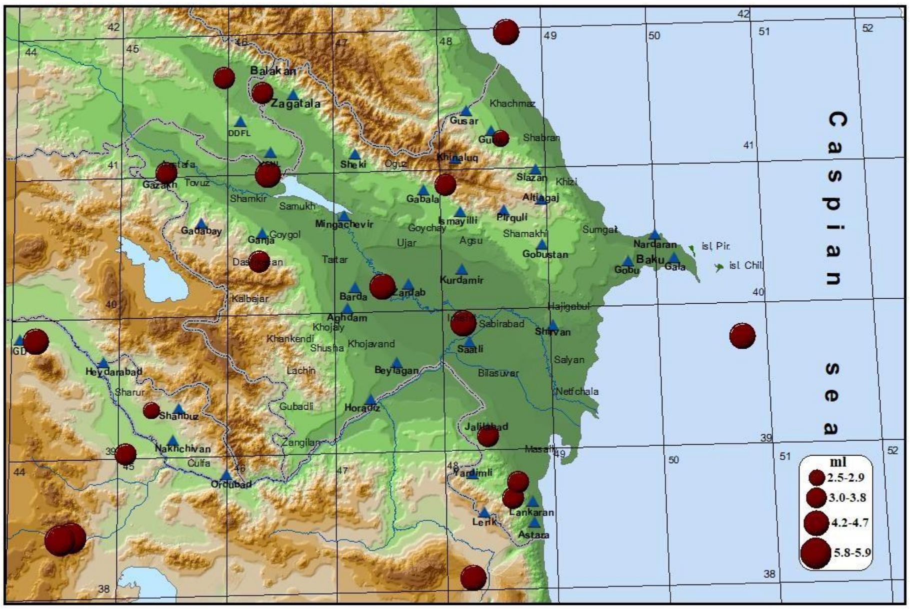

Fig. 3 Map of epicenters of earthquakes in Azerbaijan and adjacent areas in 2020

Compared to 2019, the number of earthquakes and the amount of seismic energy released in 2020 decreased. Thus, the number of earthquakes in the territory of Azerbaijan in 2019 is 5442, the amount of seismic energy released is $\sum E = 31.9 \cdot 10^{11}$J, the maximum magnitude is ml = 5.2, the number of earthquakes in 2020 is 4030, the amount of seismic energy released is $\sum E = 13.1 \cdot 10^{11}$J, the highest magnitude was ml = 4.9.

Analysis of the number of earthquakes and seismic energy released over the last 10 years (Figure 4) shows that the amount of seismic energy released since 2010 has been gradually increasing. In 2012, the amount of seismic energy released reached a maximum.

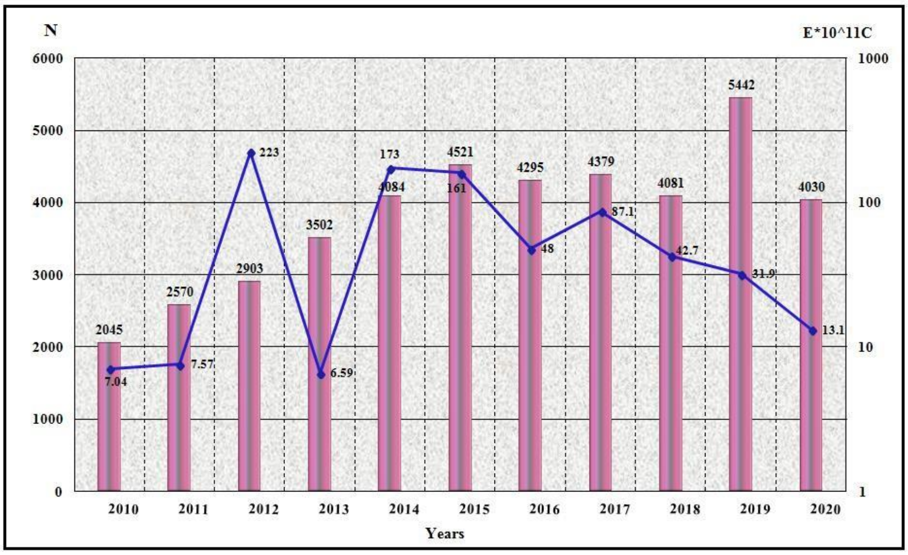

Fig. 4. Histogram of the number of earthquakes and the distribution of seismic energy in the territory of Azerbaijan in 2010-2020

This is due to the strong (ml = 4.0 ÷ 5.7) earthquakes in the country. In 2012, the amount of seismic energy released increased 25 times compared to 2011. The amount of seismic energy released in 2013 decreased by about 28 times compared to 2012. The increase in the number of earthquakes since 2010 is most likely due to the operation of new stations in 2009-2013. The number of earthquakes in 2014 increased compared to 2013 and the amount of seismic energy released was 25 times higher. In 2016, compared to 2014, seismic energy decreased by 3 times.In 2017, the seismic energy released was almost twice as high as in 2016. Starting from 2018, there is a decrease in seismic energy. The number of earthquakes in 2019 is higher than in other years. In 2020, there will be a decrease in the number of earthquakes and seismic energy.

A histogram of the number of earthquakes in Azerbaijan and adjacent areas and the monthly distribution of seismic energy (Figure 5) is shown.

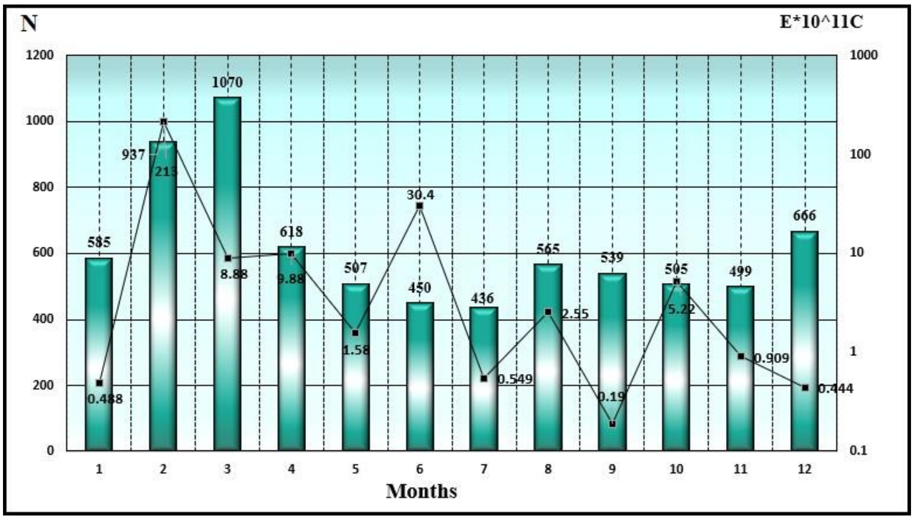

Fig. 5. Histogram of the number of earthquakes in Azerbaijan and adjacent areas in 2020 and the distribution of seismic energy per month

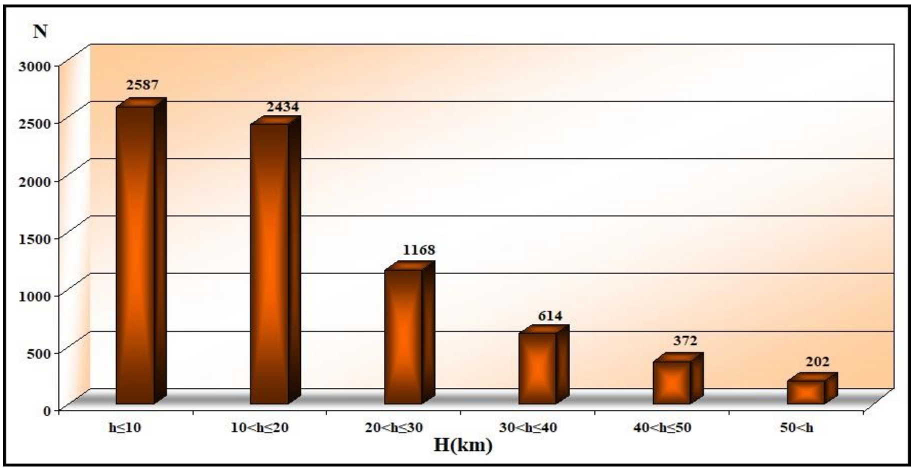

Fig. 6.a. Histogram of the depth distribution of earthquakes in Azerbaijan and adjacentareas in 2020

Analysis of the number of earthquakes in Azerbaijan and adjacent areas and the distribution of seismic energy by months shows that the allocated seismic energy was higher in February, April and June. This is due to earthquakes of magnitude 5.9 on the Turkish-Irania n border. Lets noted that, Mw-6.0 earthquake was registered on February 23, 110 km south-westof Nakhchivan station on the Turkish-Iranian border.

The number of earthquakes in February and March was higher than in other months. This is due to the aftershocks of an earthquake with a magnitude of ml = 5.9.

A histogram and map of the depth distribution of earthquakes in Azerbaijan and adjacent areas during 2020 have been constructed (Figure 6.a, 6.b.).During 2020, in Azerbaijan and adjacent territories, 2587 with a depth of h≤10 km, 2434 with a depth of 10 <h≤20 km, 1168 with a depth of 20 <h≤30 km, 614 with a depth of 30 <h≤40 km,40 <h≤50 372 earthquakes of km and 202 earthquakes of h> 50 km were recorded. Analys is of the depth distribution of earthquakes shows that 60% of them occurred at a depth of h≤20 km.

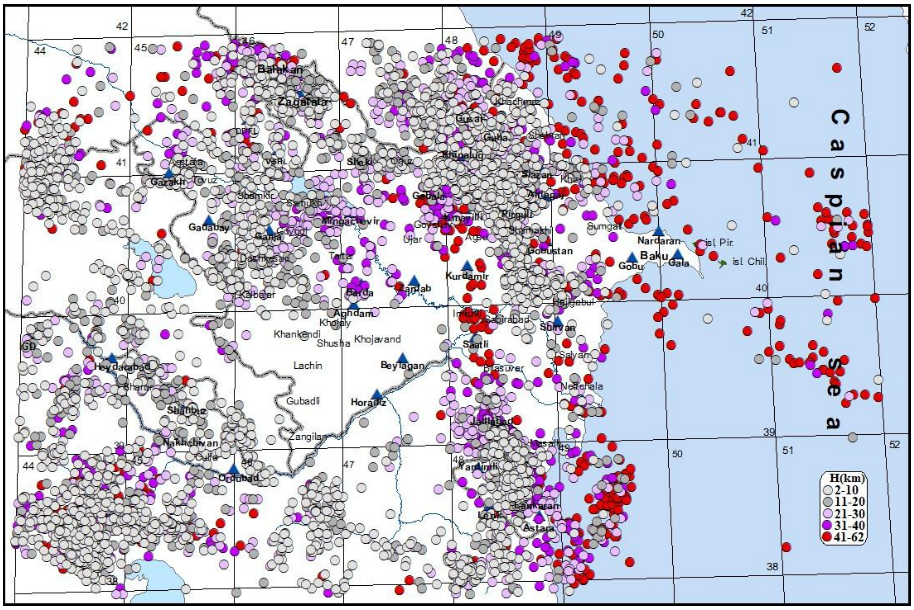

Fig. 6.b. Depth map of earthquakes in Azerbaijan and adjacent areas in 2020

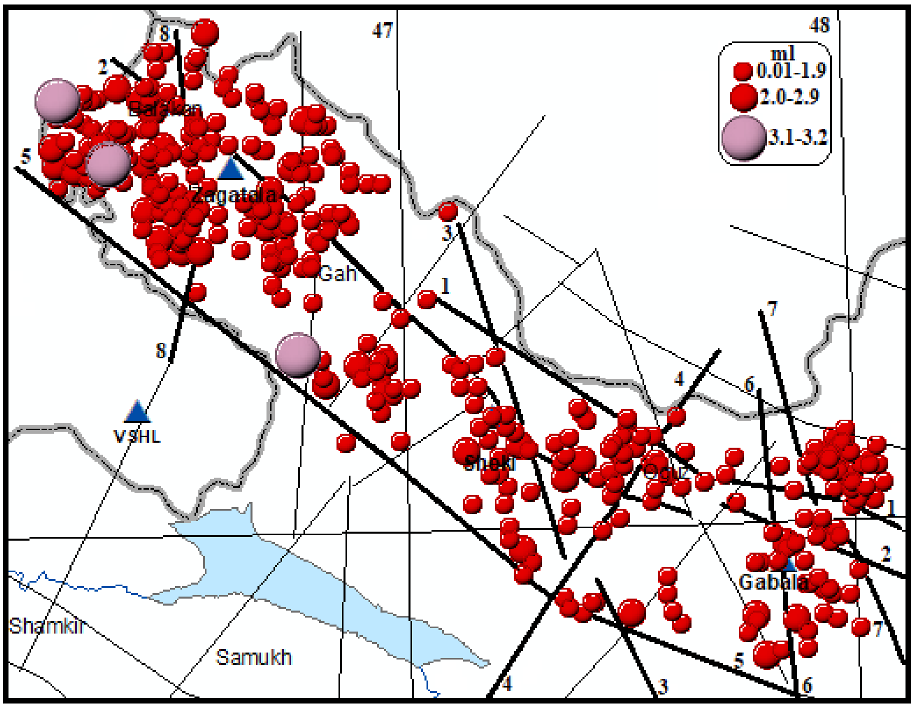

Fig. 7. Occurred in Balakan-Zagatala, Sheki, Gabala districtsmap of epicenters of earthquakes

Fractures: 1. Dashgil-Mudrasa 2. Vandam (longitudinal) 3. Akhvay (orthogonal)
4. Tar-Tar-Oguz (transverse) 5.Alazan-Ayrichay (longitudinal) 6. Chakhirli-Gabala (orthogonal)
7. Ismailli-Sighirli (orthogonal) 8. Sharur- Zagatala (transverse) (by T.N. Kangarli)

As can be seen from the depth distribution map of earthquakes (Figure 6.b.), the depth of earthquakes in the land area of Azerbaijan varies between 2-54 km, 2-62 km in the Caspian Sea, and mainly 2-35 km in regional areas.

During the reporting year, seismicity was at the background level in Zagatala.

From the tectonic point of view, the Zagatala-Balakan seismic zone is located in the north-western zone of the Azerbaijani part of the Greater Caucasus.

Compared to 2020 and 2019, seismicity was weak in the Zagatala-Balakan area. The highest magnitude earthquake in Balakan was ml = 3.2. At 12:35 local time on September 22, an earthquake was registered in Balakan region, 23 km north-west of Zagatala station. The quake was felt at the epicenter up to 3 points.

Map of epicenters of earthquakes in Balakan-Zagatala, Sheki, Gabala regions (Figure 7.). The figure shows the location of earthquakes in the intersection zones of depth cracks in different directions.

A seismic barrier was constructed along the Balakan-Gabala I-I profile passing through the seismically active zone of Azerbaijan (Figure 8). The profile extends in the all-Caucasia n direction along the Ayrichay-Alat deep fault.

Concentration of hypocenters is observed in the north-west of the intersection in the Zagatala-Balakan area. The hypocenters are clearly visible in the areas recorded at the intersection. Unlike in 2019, the number of earthquakes with a magnitude of 3.0 has decreased during the year. In the Zagatala-Balakan area, the hearths are mainly distributed at a depth of 2-40 km.

Earthquakes of magnitude 2.9 occurred in Zagatala region. Weak seismicity is observed. Compared to 2019, no earthquakes with a magnitude of ≥3.0 were recorded in the Zagatala zone.

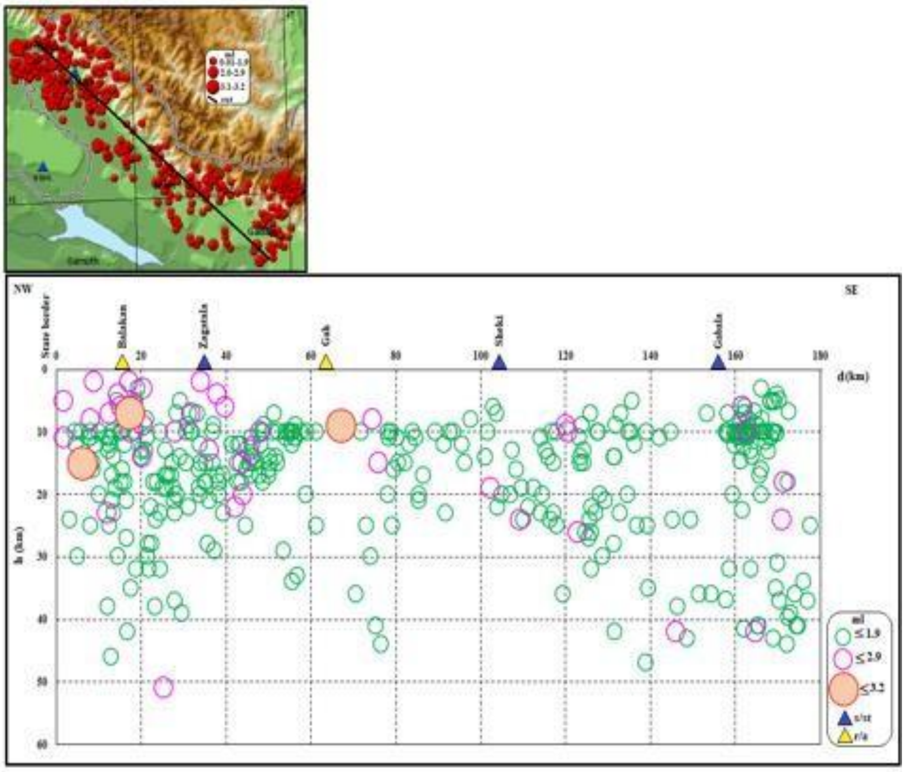

Fig. 8. Seismological section of Balakan-Gabala I-I profile

Earthquakes of magnitude 3.2 occurred in Balakan at a depth of 4-7 km. As can be seen from the intersection, the epicenters were located in the zone of impact of the Alazan-Ayric hay deep fault. An unseen tremor with a magnitude of ml=3.0 occurred in the Gakh area at a depth of 9 km. Earthquakes of magnitude 3.0 are located within the sedimentary layer.

As can be seen from the crossing, as in 2019, weak seismicity is observed in Sheki and Gabala. Earthquakes of magnitude 2.0 occurred in this zone. The outbreaks occurred at a depthof 6-30 km in Sheki and at a depth of 3-42 km in Gabala.

Seismicity is below the background level. The density of hypocenters in the Gabala area is mainly distributed at a depth of 10 km. The hearths are located within the sedimentary layer. The earthquakes in the Gabala zone are located at the intersection of the Dashgil-Mudrasa and Ismayilli-Sighirli orthogonal depth faults.

In the north-east of the country, the migration of earthquake epicenters in the meridio nal direction (Pirgulu-Mugan) is observed.

In order to study the geodynamic conditions of the Shamakhi-Ismayilli zone and the Lower Kura basin in 2020, a seismological section (Figure 9) was built on the II-II profile in the north-west, south-east direction.

The intersection was carried out in the area where the epicenters are located, in the zone of impact of the Taircalchay-Salyan orthogonal fracture. In the Shamakhi-Ismayilli zone in 2020, compared to 2019, seismicity fell below the background level.

As can be seen from the intersection, the hypocenters are condensing in the north-west.2 tremors of ml≥3.0 were registered in Ismayilli region. The hypocenters are mainly distributed at a depth of 2-20 km. Let me note that an insensitive earthquake with a depth of h = 44 km and a magnitude of ml = 3.3 can be found in the territory of Ismayilli. The magnitude of the strongestearthquake in Ismayilli region was ml = 3.6. The quake was registered on October 22 at 16:52 local time in Ismayilli, 20 km east of Gabala station. The quake was felt at the epicenter up to3 points. The outbreak occurred at a depth of 11 km within the subsidence layer. Two insensib le earthquakes with a magnitude of 3.0 and a depth of 14-15 km occurred in Agsu region.

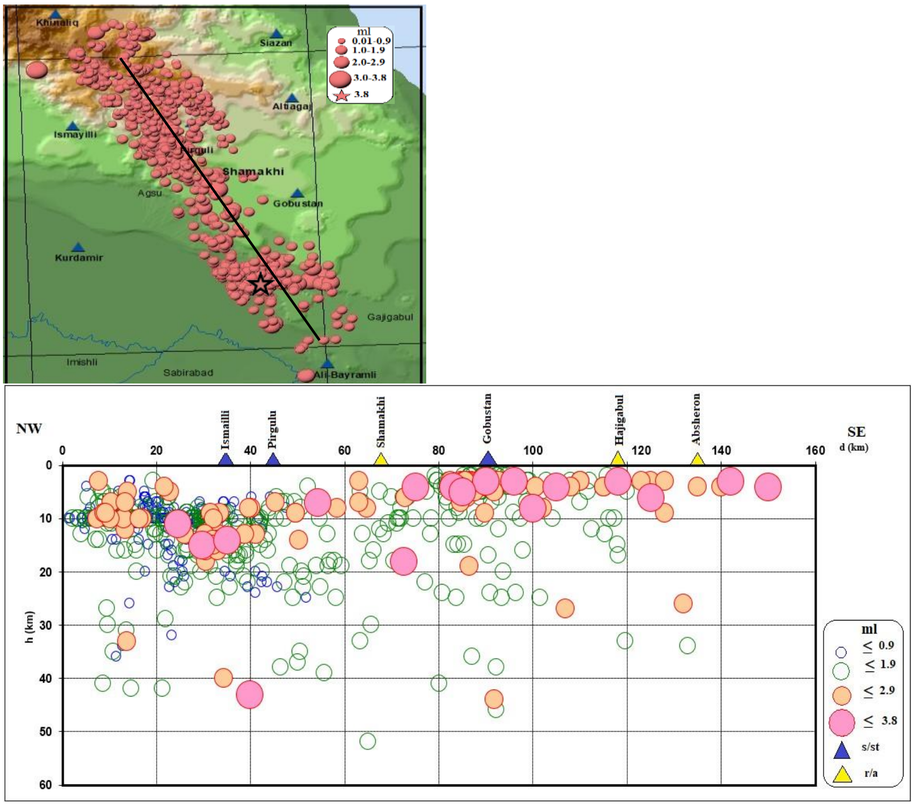

Fig. 9. II-II of the Shamakhi-Ismayilli seismogenic zone seismological section on the profile

As can be seen from the crossing, the earthquakes in the Shamakhi region were mainly distributed at a depth of 2-40 km. The damage with a magnitude of ≥3.0 was spread at a depth of 2-8 km. The strongest earthquake in Shamakhi region on February 16 had a magnitude of 3.8. The quake was not felt. The quake occurred at a depth of 2 km inside the subsidence layer.

In contrast to 2019, seismicity was higher than the background level in the Lower Kura basin in the south-eastern direction of the section. An increase of magnitude 3.0 was registered. Hypocenters are mainly distributed in the area at a depth of 2-25 km. Earthquakes of magnitude 3.0 occurred within the sedimentary layer at a depth of

2-8 km. An earthquake with a depth of 43 km and a magnitude of 3.1 ml can also be found in the area. The highest magnit ude earthquake recorded in Hajigabul and Absheron regions was ml = 3.8. No earthquakes were felt. The earthquakes in Shirvan are located at the intersection of the Palmir-Absheron and orthogonal Ismayilli-Sighirli (Kangarli T.N.) deep faults.

The earthquakes in the territory of Absheron are located at the intersection of the Palmir-Absheron and Sangachal-Ogurchu deep faults.

Density of hypocenters is observed in the transition to the Middle Kura basin. In 2020,unlike other years, there is an increase in seismicity in the Samukh region. Seismicity was higher than the background level. An increase of earthquakes with a magnitude of ≥3.0 was recorded in the zone. The magnitude of the strongest earthquake in Samukh was ml=4.3. The quake was registered on May 4 at 00:03 local time in Samukh region, 45 km north of Ganja station. The quake was felt at the epicenter up to 3 points. As can be seen from the intersect io n, the main shocks and aftershocks occurred between the consolidated layer and the subsidence layer at a depth of 10-26 km. The earthquakes in Samukh were located at the intersection of Ganjachay-Alazan and Goychay (A.S. Shikhalibeyli) deep faults.

Compared to 2019, seismicity in the Talysh zone in 2020 was below the background level. The highest magnitude earthquake in this zone was ml = 3.6. At 11:39 on May 27, local time, 19 km north-west of Lankaran station, an earthquake was registered in Lankaran. The quake was felt at the epicenter up to 3 points.

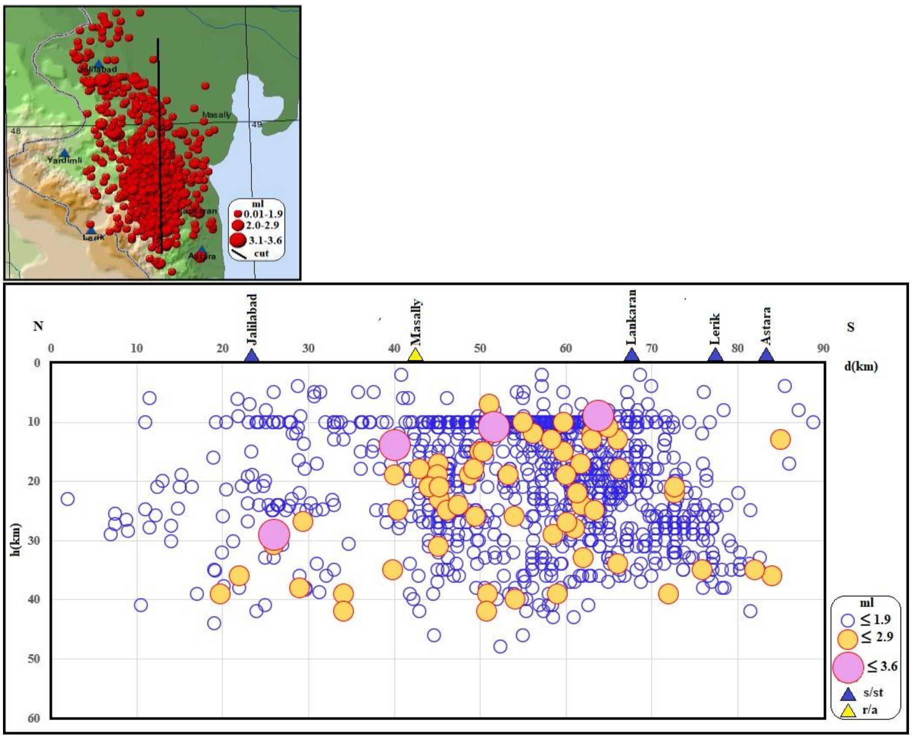

Fig. 10. Seismological section of Talysh mountain zone on profile IV-IV

In order to study the depth distribution of earthquake foci in the Talysh zone, a seismological section was built on profile IV-IV passing through the north-south direction. As can be seen from the cross-section, in contrast to 2019, there is a decrease in earthquakes witha magnitude of ml≥3.0. The profile was held in the meridional direction (Figure 10). In the northern part of the intersection, the number of tremors is small in the Galilabad region. The increase of earthquakes was registered starting from Masalli region. As can be seen from the crossing, the foci in the seismogenic zone are spread at a depth of 10-40 km. Weak tremors with a magnitude of ml≤1.9 mainly occurred in the Talysh mountainous zone. As can be seen from the cross-section, earthquakes with a magnitude of ml≥3.0 were distributed within the sedimentary layer at a depth of 9-11 km. The main part of the earthquakes is concentrated in the fracture zone intersecting in different directions, in the central part of the active Astara- Derbent orthogonal and longitudinal Talysh and Ontalish fractures of the profile.

In 2020, as every year, seismic activity in the areas bordering Nakhchivan, in the Zangazur range, was below the background level.

Analysis of the number of earthquakes and the distribution of seismic energy by months in the border areas of Nakhchivan AR (Figure 11) shows that weak seismicity is observed. The number of earthquakes in September and December was higher than in other months. As can be seen from the graph, the seismic energy released was higher in September and October than in other months. On September 14, at 16:23 local time, 20 km west of Shahbuz station, an earthquake with a magnitude of ml = 2.9 was registered in Babek region of Nakhchivan AR. The quake was felt at the epicenter up to 3 points.

It should be noted that earthquakes with a magnitude of Mw≤6.0 on the Turkish-Ira nian border were felt in the territory of Nakhchivan AR up to 4-3 magnitude

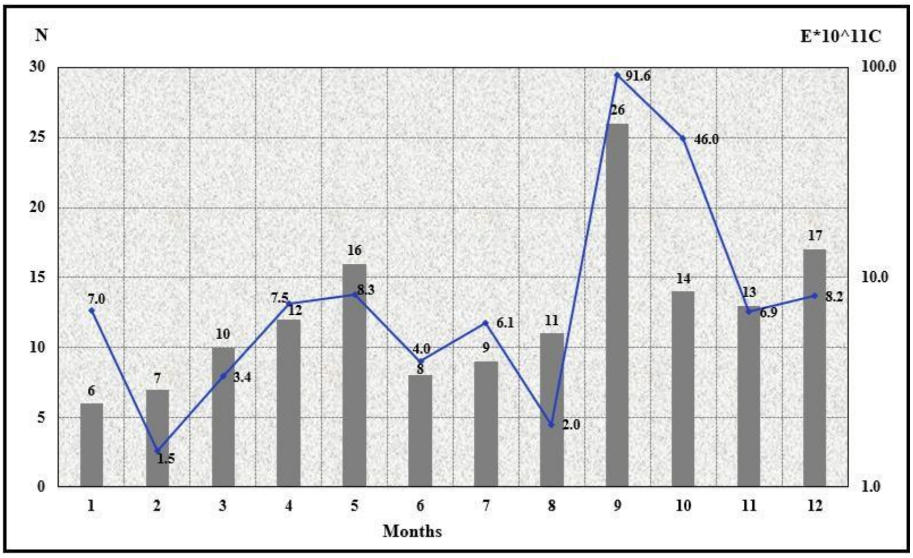

Fig. 11 Histogram of the number of earthquakes in the border area of Nakhchivan AR in 2020 and the distribution of seismic energy by months.

In 2020, compared to 2019, the seismicity of the Caspian Sea was higher than the background level.

Analysis of the number of earthquakes and seismic energy released over the last 10 years (Figure 12) shows that the amount of seismic energy released in 2010-2013 is stable. The number of earthquakes in 2014 was higher than in 2013, and the seismic energy released was 23 times higher. This is due to strong earthquakes of magnitude 5 in the Caspian Sea. The number of earthquakes in 2015 was higher than in 2014, and the amount of seismic energy released was reduced by half. The number of earthquakes in 2016 was higher than in 2015, and the amount of seismic energy released was 7 times less. While stability was observed in the seismic energy released from 2016 to 2018, in 2019 the seismic energy released was twice as much. The number of earthquakes in 2020 and the amount of seismic energy released will increase compared to 2019.

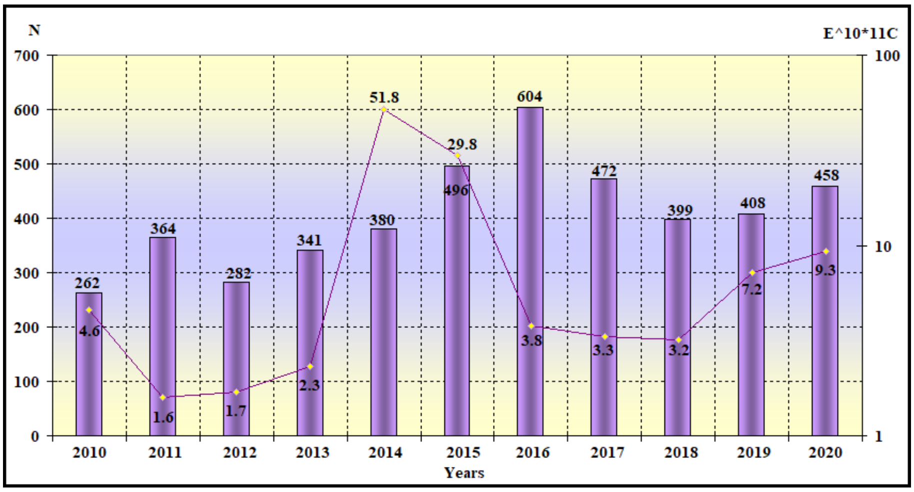

Fig. 12 Histogram of the number of earthquakes in the Caspian Sea and the distribution of seismic energy over the years 2010-2020

Analysis of the number of earthquakes in the Caspian Sea in 2019 and the distributionof seismic energy by months (Fig. 13) shows that the seismic energy released in February and October was higher than in other months. The high seismic energy released in February and October is due to earthquakes with a magnitude of ≤4.9. The number of earthquakes was higher in September.

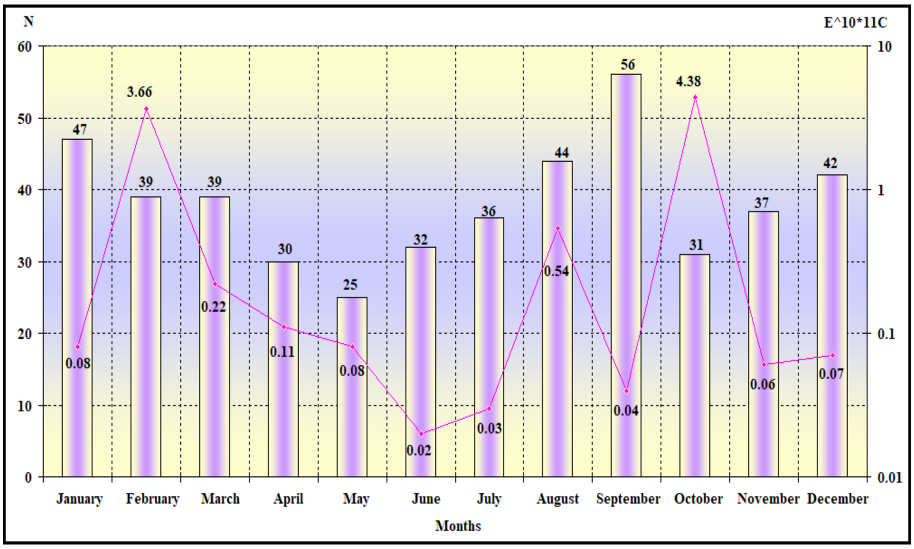

Fig. 13 Number of earthquakes in the Caspian Sea in 2020 and a histogram of the seismic energy distribution over the months

During the reporting year, 24 earthquakes with a magnitude of ml≥3 occurred in the Caspian Sea. The highest magnitude earthquake recorded in the Caspian Sea was ml = 4.9. The quake was not felt.

In order to study the depth distribution of earthquakes in the northern part of the Caspian Sea, a seismic section was drawn on two profiles in the north-west and south-east directions (Fig. 14).

As can be seen from the seismological section on profile VI-VI, in the north-western direction, mainly tremors with a magnitude of ml≥1.0 occurred. Uneven distribution of earthquakes is observed. Throughout the intersection, the hearths were distributed at a depth of 2-62 km. The tremors with a magnitude of 3.0 ml were distributed at a depth of 60-62 km. The highest magnitude earthquake recorded in the North Caspian Sea was ml=4.6. The quake was recorded on November 3 at 16:16 local time in the Caspian Sea in Dagestan. The quake was felt by some people in the country. The quake occurred at a depth of 62 km.

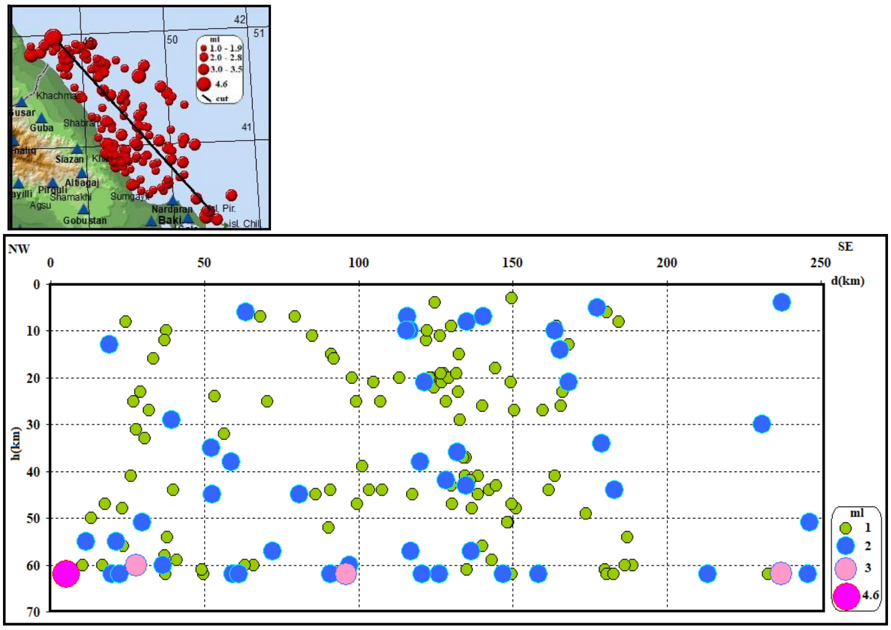

Fig. 14. Seismological section of the northern part of the Caspian Sea on profile VI-VI

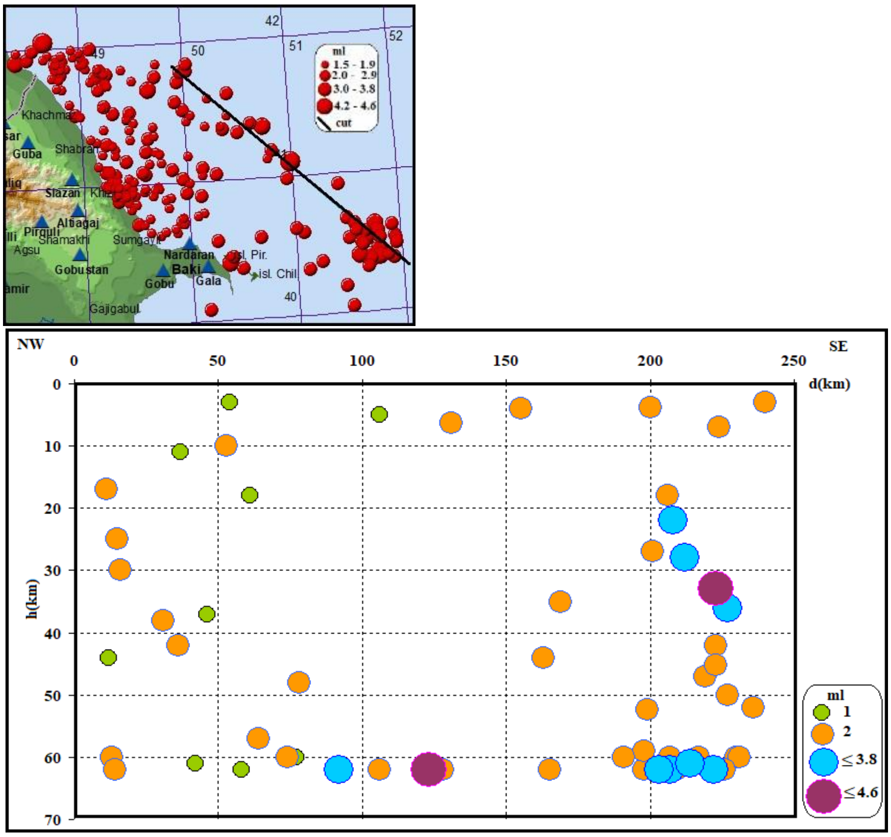

Fig. 15 Seismological section of the northern part of the Caspian Sea on profile VII-VII

Another profile was passed through the North Caspian basin, a seismic section was made on profile VII-VII (Figure 15). The profile runs in a north-west, south-east direction. As can be seen from the section, earthquakes with a magnitude of ml≥1.0 occur. Most of the earthquakes were distributed at a depth of 29-62 km. Surface foci are also observed at the intersection. In the central part of the Caspian Sea, an increase of earthquakes with a magnit ude of ≥3.0 is observed. The quake with a magnitude of ml = 4.2 occurred at a depth of 33 km, andthe earthquake with a magnitude of ml = 4.6 occurred at a depth of 62 km.

In 2020, compared to 2019, there was an increase in the number of earthquakes in the South Caspian Sea.

In recent years, the level of seismic activity in the Caspian Sea has increased. A map of the epicenters of earthquakes in 2020 has been constructed (Figure 16).

The occurrence of earthquakes with a magnitude of 4.6 ml in the North Caspian Sea is due to the activation of the Arpa-Samur fault.

The concentration of earthquakes in the center is observed at the intersection of Agrakhan-Krasnavodsk and transverse Garabogaz Safidrud faults. The concentration of earthquakes in the south is observed at the intersection of Sangachal-Ogurchu and transverse Garabogaz Safidrud faults. Weak seismicity is observed along the Makhachkala-Krasnavodsk deep fault.

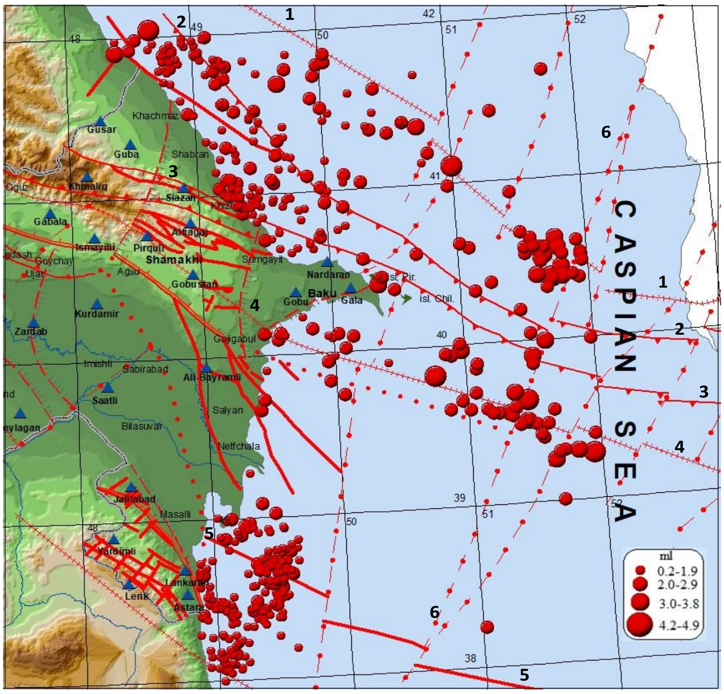

Fig. 16 took place in the Caspian Sea in 2020map of epicenters of earthquakes:

Fractures: 1– Agrakhan-Krasnavodsk; 2 - Makhachkala-Krasnavodsk;
3- Absheron- Pribalkhan; 4 - Sangachal-Thief;
5- Mil-Speeches 6 - Garabogaz-Safidrud

Seismic activity of Azerbaijan and adjacent territories in 2020

The analysis of seismic activity of the surveyed area was carried out on the basis of earthquakes selected from the catalog of earthquakes in 2020, recorded without loss. In 2020, as in previous years, earthquakes were recorded in the territory of Azerbaijan without loss. A seismic activity map was compiled based on the catalog and epicenter map.

In order to monitor the change of seismic regime over time, an activity map for 2019 and a comparative analysis were made for 2020.

In 2019, the activity was high on the south-eastern slope of the Greater Caucasus - Zagatala-Balakan (A_{10}=1.6-2.0), Shamakhi-Ismayilli (A_{10}=1.6-2.0), Talish (A_{10}=1.6-2.0). Inthe south-northern part of the Lesser Caucasus (A_{10}=0.6-1.0) seismic activity was weak. At the same time, in the Caspian Sea in the north (A_{10}= 0.6-1.0), in the center (A_{10}= 0.9-1.6), in the southern part of the active areas (A_{10}=1.0-1.7), in the Iranian zone (Tabriz) (A_{10}=0.6-1.8) corresponds (Figure 17).

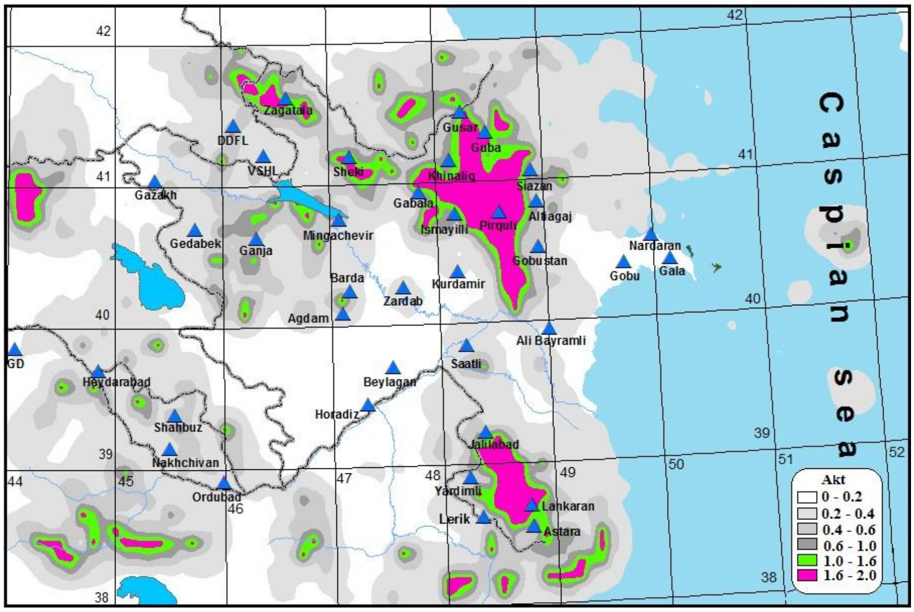

Fig. 17 Azerbaijan and adjacent territories during 2019 seismic activity map

In 2020, it was on the south-eastern slope of the Greater Caucasus - Zagatala-Balaka n, on the Georgian border (A10=1.0-1.6). Activity was high in Shamakhi-Ismayilli (A10=1.6-2.0) and Talish (A10=1.6-2.0) zones. In the south-northern part of the Lesser Caucasus (A10=0.6-1.0) seismic activity was weak. In 2020, it was high in the Samukh region (A10= 1.6-2.0) in the Middle Kur depression. At the same time, the active areas in the Caspian Sea in the north (A10= 0.6-1.0), in the center (A10=0.9-1.6), and in the south (A10=1.0-1.7) correspond. High activity is observed on the Iran-Turkey border (A10=2.0). (Figure 18.).

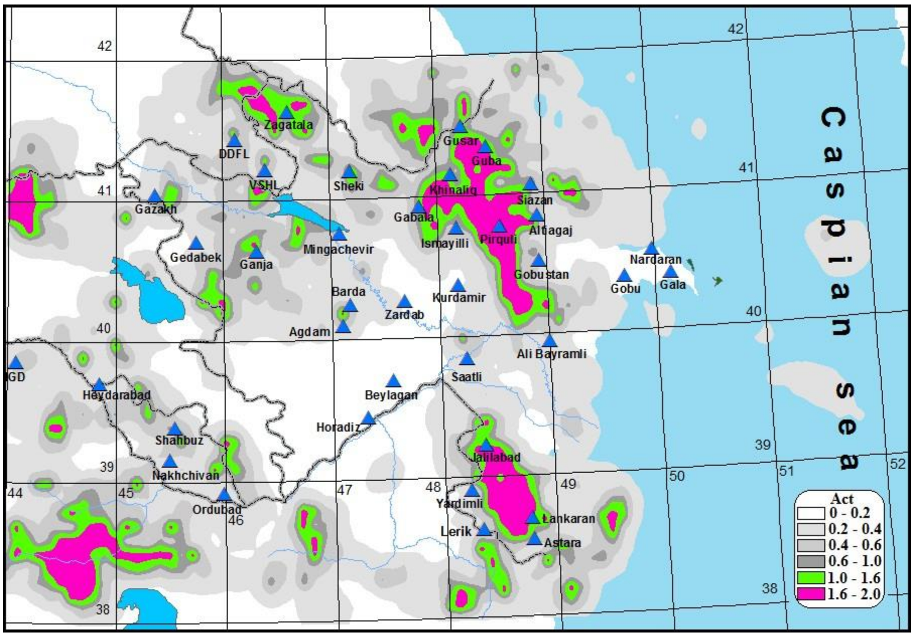

Fig. 18 Azerbaijan and adjacent territories by 2020seismic activity map

Study of the mechanisms of earthquakes.

The study of the epicenter mechanisms of strong earthquakes allows to identify the types of tectonic movements that are characteristic of different seismically active areas of the earth's crust and to determine the maximum values of soil motion acceleration, depending on these types of movements. This plays a key role in solving the problems of seismic zoning and seismic micro-zoning. Taking this into account, in 2020, in order to study the stress and deformation areas of the Earth's crust, the mechanisms of earthquake centers, the dynamic parameters of earthquake centers, the conditions of their formation and the analysis of stress areas of the Earth's crust were conducted. Thus, in 2020, the hearth mechanism of 65 earthquakes (ml3.0.0) was developed (Fig. 19).

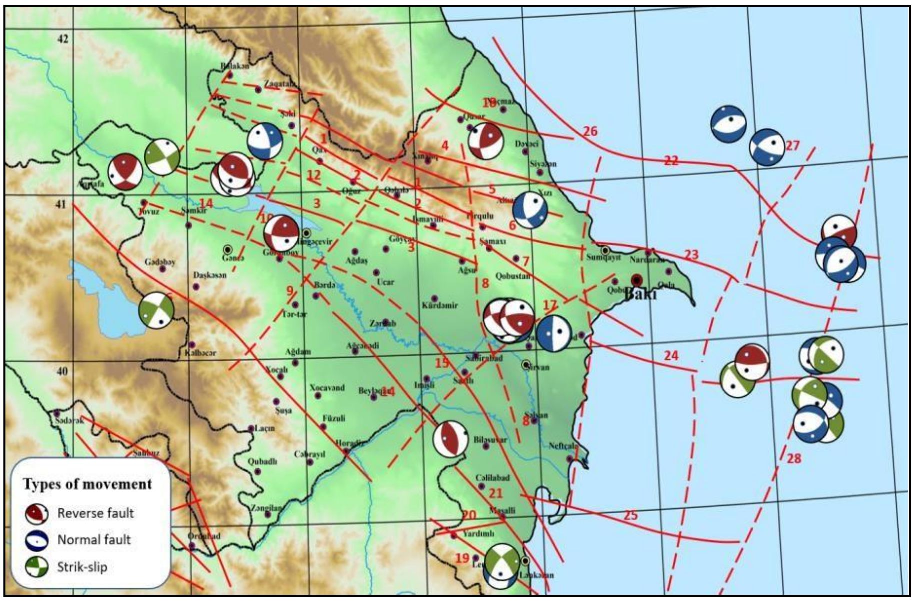

Fig. 19. Mechanisms of earthquakes of magnitude 3.0 in 2020 (Compiled the fracture map: Shikhalibeyli (1996), Kangarli (2007))

Fractures: 1-Dashgil-Mudrasa, 2-Vendam, 3-Gokchay, 4-Siyazan, 5-Zangi-Kozluchay, 6-Germian, 7-Ajichay-Alat, 8-West-Caspian, 9-Arpa-Samur, 10- Ganjachay-Alazan, 11-Gazakh-Signakh, 12-North-Acinour, 13-Iori, 14-Kur, 15-Mingachevir-Saatli, 16-Bashlibeli, 17-Palmir-Apsheron, 18-Akhti-Nugedi-Kiliziali, 19 - Talysh, 20 - Yardimli, 21 - Ontalish, 22 - Central-Khazar, 23 - Apsheron-Pribalkhan, 24 - Sangachal-Ogurchi, 25 -Chikishler, 26 - Yashma flexure, 26a - Gizilagaj, 27 - Shakhov-Azizbeyov, 28 - Garabogaz -Safidru.

Analysis of the characteristics of the distribution of earthquakes in Azerbaijan shows that they are unevenly distributed. Strong earthquakes are rare and occur in certain areas. It is known that high seismic activity is characteristic of fracture zones separating geologic a l structures or blocks of different tectonic regimes and occurs as a result of contrasting tectonic movements in these zones. The level of contrasting movements and tectonic stress determines the level of seismic activity.

As in recent years, the seismicity of the territory of Azerbaijan, and especially the Greater Caucasus, remains high.

At 20:53:04 local time on January 20, an earthquake with a magnitude of ml=3.1 was registered in Siyazan, 12 km north-east of Altiagaj station. The value of displacement in the furnace (Slip = -35-(-152)) indicates that left-sided displacement or right-sided displacement is predominant. As a result of tension situations, the earthquake coincides with the transverse fracture of Gushchu-Dizavar. It should be noted that at 09:43:05 local time on May 10, an earthquake with a magnitude of 2.5 was registered in the territory of Guba, 11 km south-east of Guba station.

In contrast to 2019, in February 2020, an increase in seismicity is observed in the collision of Shamakhi and Hajigabul seismogenic zones. At 16:32:54 local time on February 16, earthquakes with a magnitude of ml=3.8 and at 17:21:06 on February 18 with a magnitude of ml=3.1 were registered in Shamakhi region, 33 km south-west of Gobustan station. The value of displacement in the furnace indicates that the right-hand displacement is dominated by the fracture-type movement. For nodal planes (DP = 88-79), a sharp drop angle was determined. This area is located at the intersection of the Western Caspian and Palmyra-Absheron fractures. At 12:41:44 local time on June 3, an earthquake with a magnitude of 3.0 was registered in Gakh, 38 km south of Zagatala station. The direction of the compression axis (P) of the earthquake and the direction of the tensile stress axis (T) are oriented horizontally (PL = 32-16). For nodal planes (DP = 79-55), the acute drop angle was determined. The breaking value of the displacement in the hearth indicates that a left-sided displacement-type movement has occurred and is consistent with the Ganjachay-Alazan transverse fracture.

February 22 at 07:05:24 local time, 07:56:27, 08:22:39 and February 23 at 04:43:45 local time, Gobustan with magnitude ml = 2.6-3.8 4 more earthquakes were registered in Hajigabul area 35 km south-west of the station. The cost of displacement at the hearth indicates that right-sided displacement is predominant and is consistent with the Western Caspian fault. It should be noted that earthquakes are located in the subsidence layer (3-6 km). On March 2, at 17:33:15 local time, another earthquake with a magnitude of 3.2 was registered in Hajigabul. The value of displacement in the furnace (Slip = 47-142) indicates that a break-up moveme nt of left-handed displacement is predominant. In general, the seismic process lasted until April. At 18:24:27 local time on April 25, 2 earthquakes with a magnitude of 3.6 and at 00:24:00 on April 26 with a magnitude of 3.8 were recorded in Hajigabul region and were characterized by tectonic movements. The nodal planes of the hearth mechanisms show that these earthquakes were directed along the Ajichay-Alat fault.

Also, unlike in 2019, the seismicity of the Middle Kura basin increased in 2020. At 05:35:58 local time on January 27, an earthquake with a magnitude of ml = 3.4 was registered in the territory of Mingachevir reservoir 10 km west of Mingachevir station. The value of displacement in the hearth (Slip = 130-11) indicates that the break-up is dominated by right- hand displacement, and is consistent with the longitudinal break of the Geokchay. At 07:58:38 local time and 03:40:27 local time on February 1, 2 earthquakes occurred in Agstafa (ml = 3) and Tovuz (ml = 3.1) regions. Both earthquakes are characterized by right-sided displaceme nt and right-sided Gazakh-Signakh fault. 9-10 km

At 00:03:00 local time on May 4, an earthquake with a magnitude of 4.3 was recorded in Samukh, 45 km north of Ganja station. The quake was felt at the epicenter up to 3 points. At 02:00:36 local time, an aftershock with a magnitude of 3.1 was recorded that day. Another earthquake occurred on June 15 at 12:47:23 local time (ml = 3.0). The depth of earthquakes varies between 10-15 km. It should be noted that earthquakes occur as a result of compressive stress (breaking and rising) and coincide with the Chatma-Geokchay break (Fig. 20).

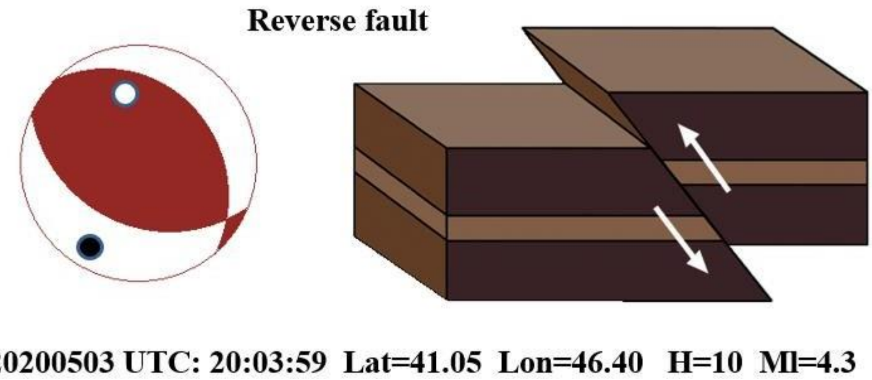

Fig. 20. The epicenter of the 4.3 magnitude earthquake in Samukh region on May 20 at 00:03:00 local time.

The Caspian Sea is the most seismically active region in 2020. 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 M> 5.0 have occurred in this area and are associated with active tectonic movements at the junction of the two largest crustal structures (Turan and Kopetdag folds) (Fig. 21).

Percentage in 2020 determines the type of movement: horizontal displacement 35%, break-up 15%, break-fall 50%. The values of displacement in the furnace indicate that predominant movements are broken.

However, in the area of the Central Caspian and oil fields, break-up movements are taking place. Thus, the analysis of the compression and tension axes is oriented in the direction of SW-NE.

At 11:51:21 local time on February 26, a magnitude 4.6 earthquake 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 tensile stress axis (T) is horizontal (PL = 15). A sharp drop angle was 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 furnace (Slip = -57 - (- 142)) indicates the predominance of fracture-type movement. At 14:17:34 local time on February 27, another earthquake with a magnitude of 4.5 was recorded, and the eruption was characterized by right- sided displacement movements.

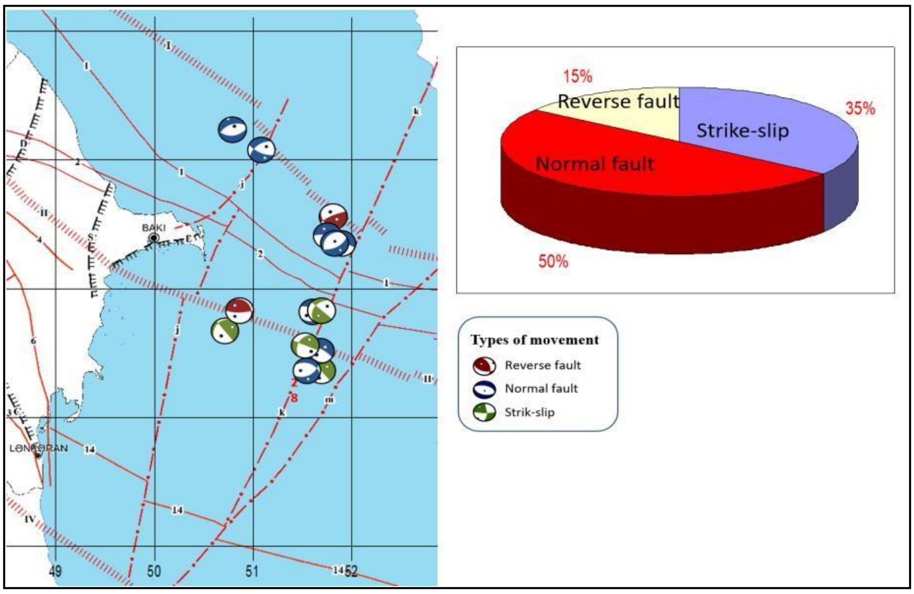

Fig.21. Focal mechanisms of earthquakes in the Caspian Sea with a magnitude of 3.0 in 2020

A total of 20 earthquakes with a magnitude of 3.0 have been developed in the Caspian Sea. The analysis showed that the earthquakes occurred mainly in the Caspian Sea at the intersection of the Agrakhan-Krasnavodsk-Shakhovo-Azizbayov and Sangachal-Ogurchu-Shakhovo- Azizbayov faults.

Conclusion

During 2020, seismicity was observed in the Greater Caucasus, the Middle Kura Basin and the Caspian Sea. Seismic activation is observed along the West-Caspian, Palmir-Absheron, Ajichay-Alat, Ganjachay-Alazan, Gazakh-Signakh, Talish, Akhvay, Sangachal Ogurju, Garabogaz-Safidrud, Agrakhan-Kasnavodsk, Khachinchay faults. In 2020, the number of earthquakes and the amount of seismic energy released will decrease.

In 2020, 20 felt (ml=2.5-5.9) earthquakes occurred. In the north-western region of Azerbaijan, an increase in seismicity is observed in the Shamakhi-Ismayilli seismogenic zone, in the Talish mountainous zone, in the Caspian Sea, on the Iran-Turkey border.

In 2020, it was on the south-eastern slope of the Greater Caucasus - Zagatala-Balaka n, on the Georgian border (A_{10}=1.0-1.6). Activity was high in Shamakhi-Ismayilli (A_{10}=1.6-2.0) and Talish (A_{10}=1.6-2.0) zones. In the south-northern part of the Lesser Caucasus (A_{10}= 0.6- 1.0) seismic activity was weak. In 2020, the activity (A_{10}= 1.6-2.0) was high in the territory of Samukh in the Middle Kura basin. At the same time, the active areas in the north of the Caspian Sea (A_{10} = 0.6-1.0), in the center (A_{10} = 0.9-1.6) and in the southern part (A_{10}= 1.0-1.7) correspond. High activity is observed on the Iran-Turkey border (A_{10} = 2.0).

The area of tension in the territory of Azerbaijan is divided into two areas along the Geokchay fault and the Imishli-Geokchay flexure: the north-eastern part of the republic is characterized by tension, and the southwestern part by compression. Tension is observed in the Absheron region and the Caspian Sea. The southern and northern parts of the Caspian Sea are relatively calm. However, its middle part is in a highly tense situation. The largest part of hypocentes is observed in the basalt layer (45-65 km) and in the upper mantle, and coincides with the Sangachal Ogurju, Garabogaz-Safidrud, Agrakhan-Kasnavodsk faults.

Analysis of compression and tension axes based on the data of the obtained seismic hearth mechanisms was directed in the direction of NE-SW in Shamakhi-Ismayilli, Middle and Lower Kura basin, Caspian Sea and Talysh zone, and tension axes in the direction of SW-NE in each seismically active region.

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ANALYSIS OF MODERN MOVEMENTS OF EARTH CRUST BLOCKS IN AZERBAIJAN ACCORDING TO THE DATA OF GPS STATIONS IN 2020-2021

Yetirmishli G.J.[1], Kazimov I.E [1]., Kazimova A.F.[1]

Introduction

The tectonic activity of the Mediterranean was completely determined by the processes of closure of the relict basins of the Tethys Ocean with residual oceanic-type crust, taking place against the general background of the convergence of the African and Eurasian plates. The type of seismotectonic deformation of the earth's crust of the Caucasus corresponds to the setting of a thrust formation with a subhorizontal orientation of the main axis of compression (in the north-northeast direction, in the cross direction of the Caucasian structures) and a subvertical orientation of the main axis of extension, established on the basis of reconstruction according to a representated set of earthquake source mechanisms. On the whole, it is quite consistent with the ideas developed in the plate tectonic concept about a strong transverse narrowing of the Caucasian segment of the Alpine-Indonesian mobile belt as a result of the convergence of the Arabian and Eurasian lithospheric plates [5]. The tightness of the territory of the Caucasian Isthmus in the zone of collision of these lithospheric plates determines its modern geodynamic and, accordingly, seismic activity. At the same time, the southern slope of the Greater Caucasus remains one of the most seismically active regions of the Caucasian Isthmus, where large seismic events periodically occur, accompanied by the spontaneous release of large amounts of energy from the earth's interior.

A huge meridional depression of the Caspian Sea adjoins Azerbaijan from the east. The northern part of Azerbaijan covers the eastern segment of the intricately constructed southern wing of the Greater Caucasus meganticlinorium, while the Lesser Caucasus system and the Talysh Mountains are located in the southern part of Azerbaijan. Each zone separately is characterized by its seismicity and geodynamic conditions. 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 and ionospheric disturbances. Previous GPS studies have helped quantify regional deformation in the plate interaction zone. Regional studies of plate movement use fault orientation, local observations, and constraints on relative plate movement. In order to determine the velocities and directions of horizontal movements of individual tectonic blocks on the territory of Azerbaijan, according to the data of 24 GPS stations, the values of the error of signal modulat ion and deviations in the ionosphere were calculated depending on the terrain of the stations during the day. Thus, taking into account previous studies, this article presented the results of the study for 2020-2021.

Seismicity of Azerbaijan for 2020-2021

The analysis of the seismicity of the territory of Azerbaijan in 2020-2021 was carried out on the basis of 40 digital data in the "Earthquake Research Bureau". To process the earthquakes recorded by the RSSC telemetry network, we used the dbloc2 program from the Antelope Real- Time System, v. 5.6 using the averaged velocity model of the deep geological structure of Azerbaijan [1, 2]. In 2020, parameters of 4030 earthquakes with M_{Lmax}=4.9 and released energy $\sum E=13.1\cdot10^{11}$J were determined within Azerbaijan. In 2021, the parameters of 4173 earthquakes with maximum magnitude M_{Lmax}=5.1 and released energy $\sum E=14.3\cdot10^{11}$J were determined.

An analysis of the number of earthquakes and released seismic energy by months in Azerbaijan and adjacent areas shows that in 2020, seismic energy was highest in February, April and June. This is due to an earthquake with a magnitude of 5.9 that occurred on the Turkish-Ira nian border. 20 perceptible earthquakes (M_L=2.5-5.9) were recorded on the territory of the republic. The maximum seismic activity was observed in the Shamakha-Ismayilli seismogenic zone, in the Talysh mountain zone, on the Iranian-Turkish border. Compared to 2019, activity in the Caspian Sea has increased.

In 2021, unlike other years, an increase in seismic activity was recorded in the Shakhbuz region of Shamakha, Agstafa district and the Nakhchivan Autonomous Republic. In the Zakatalo - Balakan zone on the southeastern slope of the Greater Caucasus, seismicity has notice ably decreased. At the same time, as in 2020, activity is observed in the central and northern parts of the Caspian Sea.

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

An analysis of the spatial distribution of epicenters showed that the events of this period are confined to transverse (northwestern, northeastern, and submeridional strike) disjunct ive dislocations, but the epicentral zones as a whole have a "all Caucasian" elongation, being located along and north of Ganikh-Ayrichay-Alyat deep over thrust within the Kakheti-Vandam-Gobusta n longitudinal structural block. In addition, high seismic activity in 2020-2021 was associated with the activation of the Tayraldjachay-Salyan, Dashgil-Mudrese, Ismayilli-Sighirli, Arpa-Samur, West Caspian, Sangachal-Ogurchu, Garabogaz-Safidrud and Palmir-Absheron faults.

GPS surveys on the territory of Azerbaijan for 2020-2021

In order to determine the velocities and directions of horizontal movements of individ ual tectonic blocks of the earth's crust on the territory of Azerbaijan, an analysis of the data obtained in 2020-2021 was carried out. The error in determining the velocity varies mainly within the limit of less than 0.6 mm/year, which makes it possible to fairly accurately estimate the convergence of plates across the Caucasus mountain system (i.e., the error is 5% of the total convergence rate) [7]. As one of the main sources of GPS positioning errors, ionospheric delays play a very important role in data processing. Because it is difficult to accurately model ionospheric attenuation, virtua lly all GPS data processing programs always use a no-ionosphere (LC) linear combination to avoid ionospheric delay effects, including GAMIT, Bernese, GIPSY, and PANDA [3].

It has been established that in 2020 in the Greater Caucasus the average velocity was 6.8 mm/year, in the Lesser Caucasus - 8.7 mm/year, in the territory of the Middle and Lower Kura 7.6 mm/year, in the territory of the Talysh region 9.8 mm/year, on the Absheron Peninsula 3.7 mm/year. The maximum values of horizontal velocities were noted at the stations of Aghdam, Lerik, Lankaran, Djalilabad, Fizuli and Saatly. The average value of velocities throughout the republic was 7.3 mm/year.

In 2021, on the territory of the Greater Caucasus, the average velocity value was 5.4 mm/year, in the Lesser Caucasus - 8.9 mm/year, on the territory of the Middle and Lower Kura 8.8 mm/year, on the territory of the Talysh region 11.6 mm/year, on the Absheron Peninsula 4.2 mm/year. The average value of velocities throughout the territory of the republic was 7.6 mm/year. The maximum velocities were noted at Yardimly (12.2 mm/year), Lankaran (13.1 mm/year), and Saatly (12.3 mm/year) stations. Compared to 2020, the velocity values in 2021 have decreased. On a comparison graph between 2019-2020 and 2020-2021 we put strong earthquakes that occurred in this period (Fig.1).

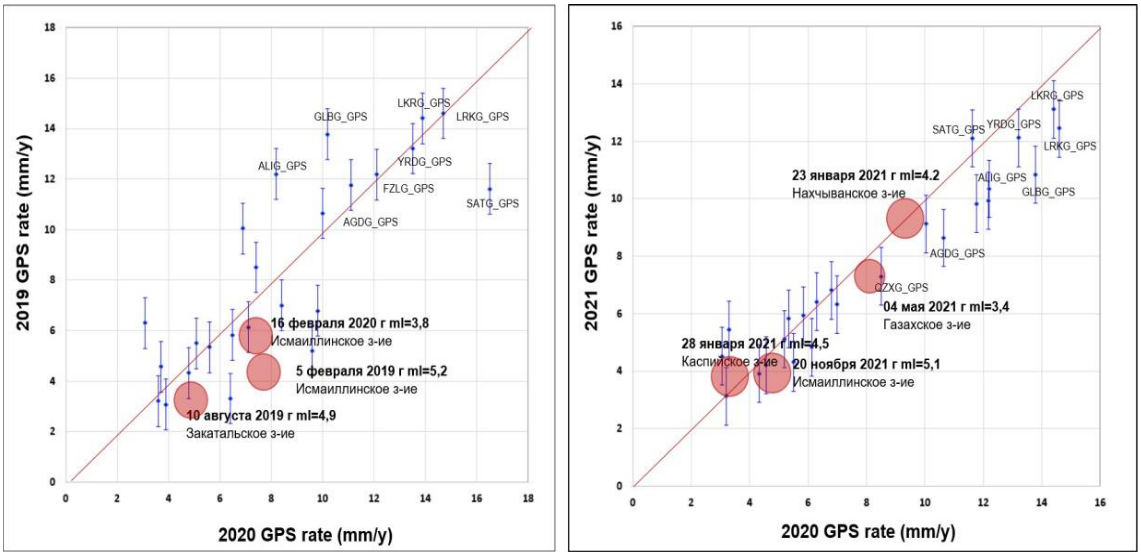


Fig. 1. Graph of changes in velocity values according to GPS stations for 2020-2021

The trend of horizontal movements on the territory of Azerbaijan predetermines the activation of seismic processes in the zones of accumulation of elastic stresses and in adjacent areas [6]. As a result of horizontal movements of the lithosphere, plastic deformation of the crust occurs. At the same time, the Kura depression descends and the Greater and Lesser Caucasus rise. The boundaries between the depression and the surrounding mountain blocks are marked by clear breaks. As can be seen in the Figure in 2019-2020 activation was observed mainly in the Ismayill i and Zagatala seismogenic zones. In 2021, strong earthquakes with ML>4.0 were observed in the Caspian, Ismayilli and Nakhichevan regions.

Consideration of data on the distribution of velocity vectors of horizontal displacements of data from GPS stations on the territory of Azerbaijan leads to the conclusion that there is a significant displacement velocity in the north-north-east direction of the southwestern side and the central strip of the South Caucasian microplate, including the territory of the southeastern segment of the Lesser Caucasus, Kura depression and Talysh (Fig. 2, 3).

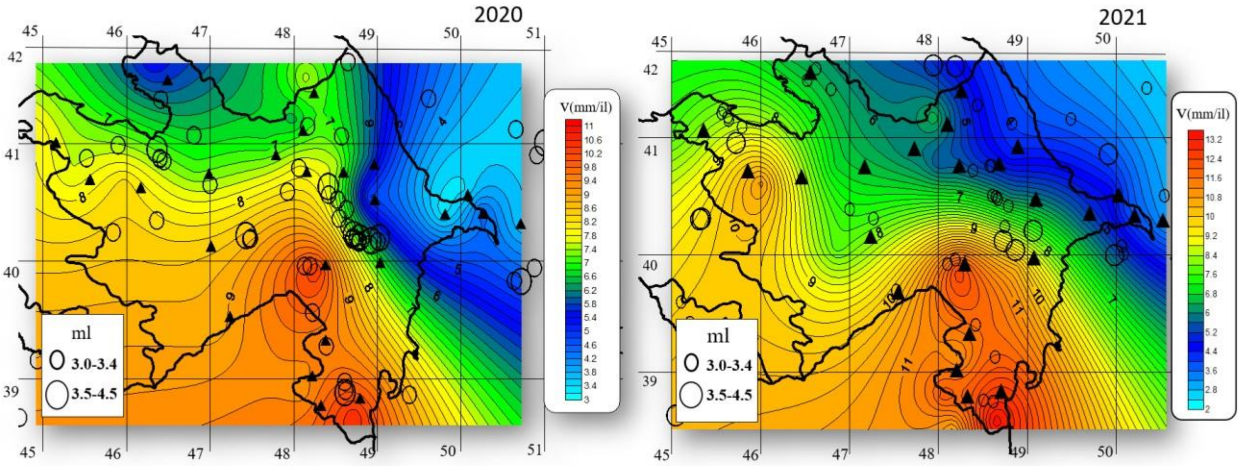


Fig. 2. Scheme of the spatial distribution of velocities according to GPS station data for 2020-2021

It has been established that along the Kura depression in the direction from the Middle Kura depression to the Lower Kura depression (i.e. from NW to SE) there is a gradual increase in the rates of horizontal movements from 7.3 to 11.3 mm/year, which is characterized by the condition of compression. It should be noted that in the last 3 years, the zone of the Lower Kura depression is characterized by the manifestation of high seismic activity, expressed in several earthquakes witha magnitude of more than 5, characterized by a uplift type of movement [8].

At the same time, within the northeastern side of the microplate corresponding to the Vandam-Gobustan megazone of the Greater Caucasus, the velocity vectors experience a decrease to 10-12 mm/year, and further to the north, i.e. directly within the accretionary prism, and completely decreases to 3.5-5 mm/year. In general, the tangential shortening of the earth's crust in the region is estimated at 6.1-11 mm/year. This is confirmed by the observed directions and velocities of movement of the earth's surface in the territory of Azerbaijan and adjacent regions according to the results of measurements at GPS points in 2017-2021, as well as strong earthquakes that occurred during this period. Comparative analysis of GPS station data for the last 5 years is shown in Fig.4. At the same time, the presented graph clearly shows the peculiarity of the velocity field - a contrasting decrease in velocity at the observation points located in the southern flank of the Zanga thrust, compared with the velocities recorded within the Kura and Lesser Caucasus. This phenomenon reflects the process of successive accumulation of elastic deformations in the zone of subduction interaction between the structures of the northern side of the South Caucasian microplate [7]. In turn, it should be noted that the regional patterns of neotectonic and modern geodynamic development and landforms of the Caucasus region can be considered as a result of mechanical impacts on it of adjacent geodynamic active areas. The Scythian part of the Scythian- Turanian Plate, which occupies the plain territories of the Crimea and C iscaucasia and is limited from the north by the East European Platform, experiences compressive forces from the folded structures of the Greater Caucasus and the Mountainous Crimea, the latest and modern geodynamic movements of which are due to pressure from the Alpine fold belt, which thrust of the Arabian plate. The southern part of Turan is also subject to the same effects of submeridional compression [11].

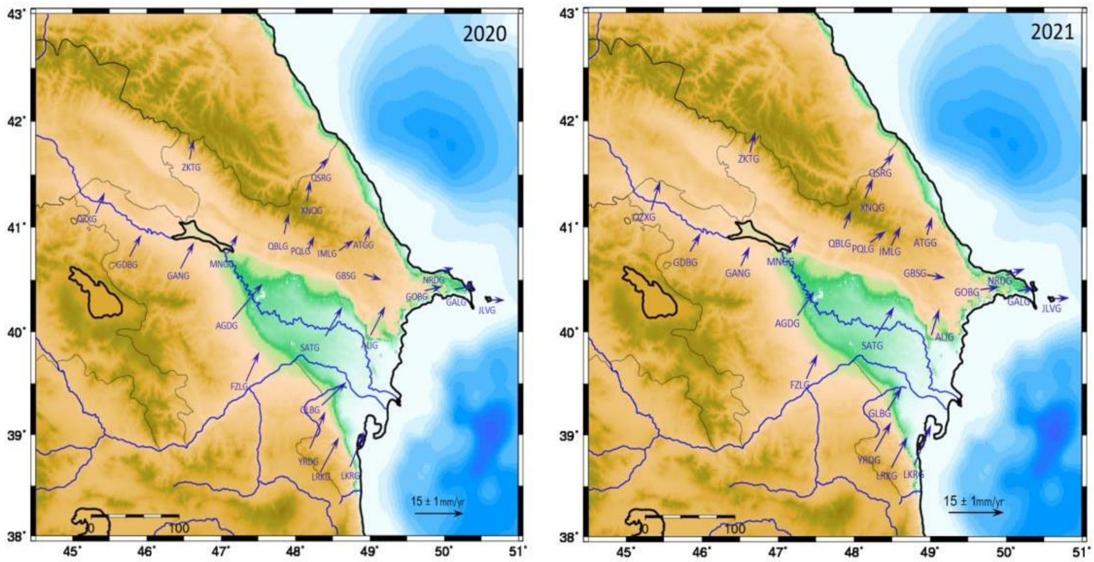


Fig. 3. GPS horizontal velocity vectors for 2020-2021

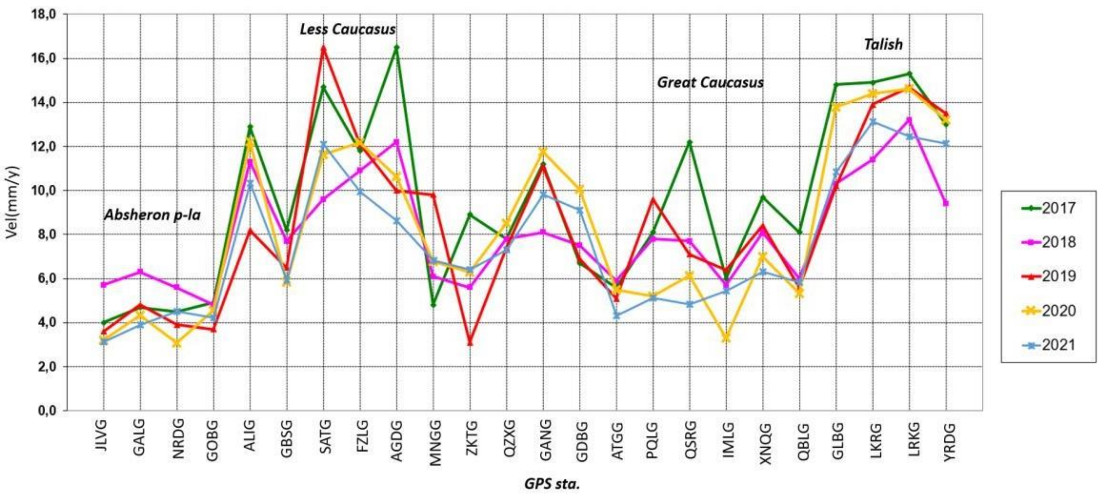
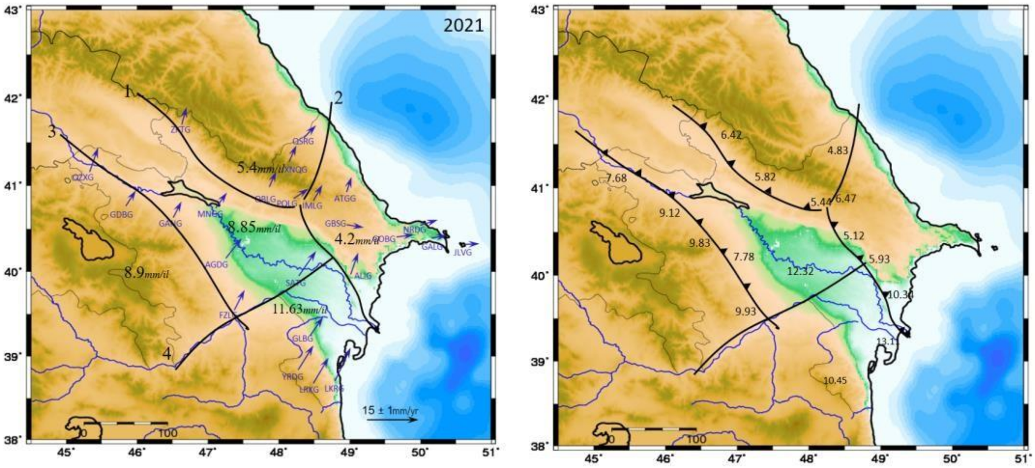


Fig. 4. Comparative graph of GPS station data for the last 5 years

At GPS stations Nardaran, Gobu, Gala and Zhiloy Island, which are part of the Absheron zone, almost similar values of horizontal displacement rates are traced (3.8 mm/year; 4.9 mm/year; 4.1 mm/year; 3.2 mm/year, respectively). In the direction from the Talysh region to the Absheron Peninsula (SW-NE direction), there is a noticeable decrease in the northern component of displacement velocities compared to high values of points located in the southwestern part of the selected profile (LKRG_GPS=13.8 mm/year; LRK_GPS=12.5 mm/year; GLBG_GPS = 12.3 mm/year; YRDG_GPS = 12.7 mm/year). It should be noted a noticeable increase in the azimut hal angles of the Absheron stations, indicating a clockwise movement in the east-southeast direction up to 88^o.

The discussion of the results

Thus, taking into account the above, we identified several tectonic blocks along large tectonic faults, which differ in the value of the horizontal movement velocities: Artvin Karabakh megazone of the Lesser Caucasus, the Middle Kura megazone, the megazone of the southern slope of the Greater Caucasus, the Talysh megazone (Fig. 5).



Fault map by Shikhalibeyli E.: 1-1 – Ganix-Ayrichay-Alat,2-2 – West-Caspian,3-3 – Pre-Lesser Caucasus Fault,4-4 – Palmir - Absheron

Fig. 5. Schematic maps of identified tectonic blocks and average velocities according to data of GPS stations

It is interesting to note that the rate of modern vertical movements covering the GPS points of Gabala, Zagatala, Gusar and Khinalig on the southern slope of the Greater Caucasus lags behind the rate of the general uplift. Modern movements along the line stretching from the Lesser to the Greater Caucasus (from south to north) have a wave nature, which is the result of the interfere nce of various tectonic waves, i.e. the result of a complex combination of horizontal and vertical movements of the earth's crust (possibly, the asymmetry of its movements is due to the simultaneous manifestation of waves with different lengths and amplitudes) [10]. Consequently, wave-like deformations are not linear, and this determined all the main features of the neotectonics of the region. The average value of the megazone of the Southern slope of the Greater Caucasus varies within 4.2-5.4 mm/year. The Middle Kura megazone is characterized by the values of 8.85 mm/year.

Comparison of the obtained measurement data of GPS stations shows that the stations located in the Lesser Caucasus and in the zone of the Talysh Mountains move in the northeast direction almost identically. These facts allow us to state that the Lesser Caucasus and Talysh participate in the horizontal movement as a single bloc. On the other hand, the stations located on the territory of the Talysh Mountains are characterized by high horizontal movement rates, which allow us to delineate this region with average horizontal movement rates of 11.6 mm/year.

Conclusion

On the basis of GPS space geodesy data and seismological data, the current geodynamicconditions of the territory of Azerbaijan for 2020-2021 are analyzed. One of the most pronouncedfeatures of the velocity field of horizontal movements is the decrease in velocity values perpendicular to the direction of the Greater Caucasus strike from south to north. The velocity field clearly illustrates the movement of the earth's surface in the N-NE direction. This phenomenon reflects the process of successive accumulation of elastic deformations in the zone of subductioninteraction between the structures of the northern side of the South Caucasian microplate (Vandam- Gobustan megazone) with the accretionary prism of the Greater Caucasus.

In addition, within the Middle Kura depression and in the Lesser Caucasus, there is a trend towards horizontal displacement, which is reflected in an increase in the velocity of movement from west to east along the continuation of the ridge. It has been established that on the Absheron Peninsula the earth's crust is shortening at a rate of ~ 5 mm/year. The earthquakes that occurred during this period are located in the gradient zones of transition from maximum to minim um velocities. These are mainly Ismayilli, Shamakha, Aghdam and Shamkir districts (Fig.). In this zone, there is a change in the magnitude of the GPS velocity vectors, which can be explained as the main reason for the accumulation of stress.

It was found that in 2020 the maximum values of horizontal velocities were noted at the stations of Aghdam, Lerik, Lankaran, Djalilabad, Fizuli and Saatly, and the average value of velocities throughout the republic was 7.3 mm/year. In 2021, the average velocity across the entire territory of the republic was 7.6 mm/year. The maximum velocities were noted at Yardimly (12.2 mm/year), Lankaran (13.1 mm/year), and Saatly (12.3 mm/year) stations.

Along the Kura depression in the direction from the Middle Kura depression to the Lower Kura depression (i.e. from NW to SE), a gradual increase in the rates of horizontal moveme nts from 7.3 to 11.3 mm/year is observed, which is characterized by the condition of compression. In the direction from the Talysh region to the Absheron Peninsula (SW-NE direction), there is a noticeable decrease in the northern component of displacement velocities compared to high values of points located in the southwestern part of the selected profile (LKRG_GPS=13.8 mm/year; LRK_GPS=12.5 mm/year; GLBG_GPS = 12.3 mm/year; YRDG_GPS = 12.7 mm/year).

Considering the above, we have identified several tectonic blocks that differ in the value of horizontal movement velocities: the Artvin Karabakh megazone of the Lesser Caucasus, the Middle Kura megazone, the megazone of the Southern Slope of the Greater Caucasus, and the Talysh megazone. The average value of the mega zone of the Southern slope of the Greater Caucasus varies within 4.2-5.4 mm/year. The Middle Kura megazone is characterized by the values of 8.85 mm/year.

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CHANGES IN COULOMB STRESSES AFTER STRONG EARTHQUAKES OCCURRED IN THE TERRITORY OF THE GREATER CAUCASUS FOR THE PERIOD 2012-2021

Kazimova S.E.[1]

Introduction

In the last decade, significant progress has been made in research related to the interaction of faults and how the occurrence of an earthquake perturbs the stress field in its vicinity, which can cause aftershocks and subsequent earthquakes. These studies are of great importance for assessing the seismic hazard of the region, since voltage changes can either delay or accelerate the occurrence of future earthquakes. In addition, since the seismic hazard assessment depends on the destruction parameters of past earthquakes, it is important to reliably estimate such parameters, viz. rupture location, geometry and extent of past earthquakes [11].

For many years, the territory of the Republic of Azerbaijan was characterized by high seismic activity. From a tectonic point of view, this is due to the dynamics of the Caucasus region, which is under the influence of the Arabian and Eurasian lithospheric plates.

It should be noted that since 2012, a number of strong earthquakes with Ml≥5.0 have been occurring on the territory of the republic. In 2012 and, after some lull, in 2014-2018. a series of strong earthquakes occurred here: Zagatala on May 7, 2012 with Ml=5.6, 5.7, Balakan on October 14, 2012 with Ml=5.8, which were felt in the epicenter with J0=7 b.; Ismayill i 07.10.2012 with Ml=5.3; Caspian 10.01.2014 with Ml=5.0, Hajigabulskoe 10.02.2014 with Ml=5.8, Zagatala 29.06.2014 with Ml=5.3, Gabala series 29.09 and 04.10.2014 with Mlmax=5.5; as well as Okhuz on September 4, 2015 with Ml=5.9, Imishli on August 1, 2016 with Ml=5.6, Lerik on August 28, 2018 with Ml=5, etc. The intensity of shaking in some of them at the epicenter reached 7 points. An analysis of the spatial distribution of epicenters shows that most of the sources of perceptible earthquakes are located in the zone of the junctio n of the Kura depression and the southeastern subsidence of the Greater Caucasus or the activation of the southern side of the Kura depression in the zone of transition to the fold system of the Lesser Caucasus [1].

With the deployment of regional and local networks of digital seismological stations and the accumulation of data, in the conditions of intensive growth of computer technologies, seismologists face completely new opportunities and prospects in studying the physics of earthquakes and seismic hazard prediction. In particular, an extensive instrumental database of digital data on earthquakes, including weak ones with M<2, makes it possible to study in detail the fine structure of the spatial and temporal distribution of sources, their energy characterist ics, and to reveal the relationship of seismic processes with the features of the deep structure of the region and the seismotectonic setting.

Knowledge of the seismic moment tensors of the sources makes it possible to study the dynamics of seismic activity, taking into account the seismotectonic and structural-geological conditions of the region within the framework of deterministic models of the seismic flow of rock masses [5, 13, 16] or the interaction of faults, which use, for example, the concept of transfer of the dropped Coulomb stress on neighboring faults [6]. In turn, further quantitat ive development and experimental verification of these dynamic models in different seismotectonic conditions are of direct practical importance for the creation of methods for reliable earthquake prediction and an objective quantitative assessment of seismic hazard.

Coulomb stresses

A change in the stress state can be critical in relation to the initiation of large technogenic earthquakes, we will consider using the approach used in seismology when analyzing aftershock sequences of large earthquakes [7]. According to this approach, a change in the stress field, as it were, “pushes” the neighboring fault somewhat closer to the threshold of Coulomb destruction. This process is often described by estimating the variation of the so-called Coulomb function on a site oriented in a certain way

$$\sigma c=\tau-\mu(\sigma n-p), \tag{1}$$

where δ_n and τ - normal and tangential stresses to the fault plane; p is the pore pressure; μ is the coefficient of friction. At the stage of preparing a dynamic breakdown $\delta_c<0$. In the case of an increase in shear stress τ or a

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

decrease in effective normal stress (σ_n-p), the fault approaches the critical state δ_c=0. Although it is rather difficult to determine stress values at seismogenic depths in natural conditions, it is possible to estimate the stress change and, using this estimate, calculate the change in shear and normal stresses on nearby discontinuities. Thus, even without knowing the absolute values of stresses, one can calculate the change in the Coulomb function using the incremental equation

$$\Delta\sigma_c=\Delta\tau- \mu (\Delta\sigma_n -\Delta p) \quad (2)$$

from which it can be understood whether the fault was brought closer to the critical state (positive increment $\Delta\delta_c>0$), or, conversely, moved to a more stable state ($\Delta\delta_c <0$). Note that these calculations do not require information about the stress zone in the region and do not consider stress fields from other sources. The Coulomb theory of initiation has become widespread, being one of the popular explanations for the fact that earthquake aftershocks manifest themselves not only within the fault zone, but also in neighboring areas [2, 3]. Usually, the best correspondence between the change in the Coulomb stress and the distribution of aftershocks is observed at distances exceeding several kilometers from the earthquake fault, since the unknown details of the distribution of displacements and geometry play a signific ant role closer.

An important result of the research is the presence of negative Coulomb stresses for a large part of the faults, which are actually considered active in recent times. If the Coulomb stresses are greater than zero (≥ 0), then this means that the given stress state is above the dry friction line - the crack can become active. If they are close to the brittle strength limit, then crack activation becomes the most probable. Negative values of the Coulomb stresses mean the excess of friction forces over shear stresses on cracks

Based on the above, we constructed and analyzed the distribution of Coulomb stresses for the Zakatala, Gabala and Ismayilli earthquakes. The model parameters are set according to the two-dipole approximation of the seismic moment tensor [4]. The calculations were made in the Coulomb 3.3 program. [8] for depths of 8-12, 42 km, the friction coefficient is assumed to be μ' = 0.4.

Influence of change in stress state on trigger seismicity

As mentioned above for the period 2012-2021. Several strong earthquakes with magnitude ml > 5.0 occurred in the Azerbaijan territory of the Greater Caucasus. In this article, we examined the most significant of them, namely: the Zakatala earthquake of 2012, the Balakan earthquake of 2012, the Gabala earthquake of 2014, the Okhuz earthquake of 2015 and the Ismayilli earthquake of 2012-2021. Let's consider each earthquake separately.

On May 7, 2012 in the Zakatala region with an interval of about 10 hours (t0=04h40m and t0=14h15m GMT) earthquakes with magnitudes of 5.6 and 5.7, respectively, occurred, characterized by intense aftershock (magnitude 3.5-5.0) activity.

According to instrumental observations, the coordinates of the earthquake are: φ=41,50°N, λ=46,58°E и φ=41,56°N, λ=46,63°E, depth h=8-12 km (Fig. 1). Earthquakes were felt in the cities of Zagatala, Belakany, and Gakh and in other environs with an intensity of 2-5 points. On fig. 1. The wave pattern of the first Zagatala earthquake that occurred at $t_0=04^h40^m$ is presented.

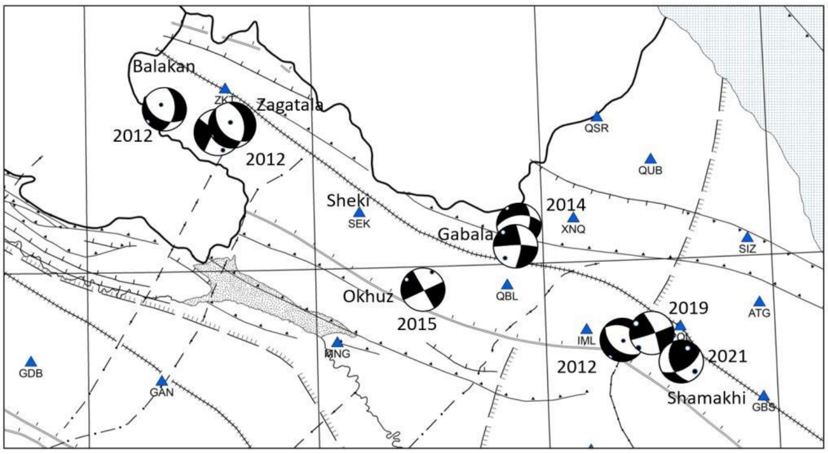

Fig. 1. Map of focal mechanisms of strong earthquakes (Mw>5.0) for the period 2012-2021. (fault mapaccording to [15])

The Zakatala seismically active zone is located in the extreme northwest of theAzerbaijani part of the Greater Caucasus. Conventionally, its boundary in the east should beconsidered the Zakatalo-Shamkir transverse uplift. In the north, west and south, the zone merges with the highly active seismic zones of Southern Dagestan and Western Georgia. The area of the Zagatala seismically active zone within Azerbaijan is about 3500 km2. It should be notedthat only one large earthquake is known in this zone for the entire seismostatistical period, which occurred in 1936 with a 7-point effect in a number of settlements. More often shockswith an intensity of 7 points in the Zagatala seismically active zone were felt from strongDagestan and Georgian earthquakes, which sometimes caused excitations in local sources [10].

The focal mechanism of these earthquakes was characterized by near-horizo ntal (PLP=10°) compressive and tensile (PLT=14°) stresses. The type of movement along both steep (DP1=87°, DP2=72°) planes is shear. Plane NP1 has a southeast (STK1=125°) strike with a right-hand slip type, and NP2 has a south-west strike (STK2=216°), with a left-hand slip type. Comparison of the strike of nodal planes with fault lines shows the agreement of the first nodal plane NP1 with the right-sided Kazakh-Signakh and Ganjachay-Alazani transverse faults, which allows us to consider the NP1 plane to be active. The focal mechanism of the second earthquake occurred under the action of near-horizontal tensile stresses (PLT=1°). The type of slip along the first nodal plane NP1 is a fault with elements of a right-sided shear, along the second - a fault with elements of a left-hand shear.

On October 14, 2012 at 10h13m36s, 28 km to the west of the city of Zagatala, an earthquake with magnitude ml=5.6 occurred in the Belakan region. According to instrume ntal observations, the coordinates of the earthquake are: lat=41.66N, lon=46.27E, and the depth h=8 km. On the basis of instrumental observations, it was revealed that the earthquake was felt with the greatest intensity in the territory of such villages as Halatala, Mesheshambul, Sharif, Yeni Sharif, Saribulak, Talalar, Tulu, Kaisa and Kazma. Here, the intensity of the earthquakeaccording to the MSK-64 table was estimated at 7 points.

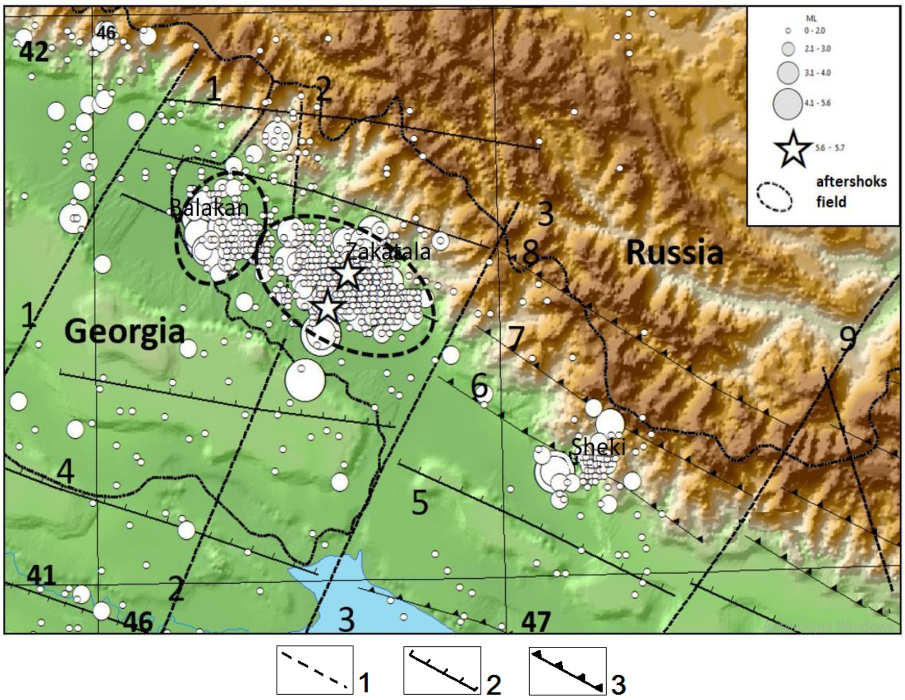

Fig.2. Map of epicenters of earthquakes in the study region that occurred in 2012 and diagram of the fault structure of the southern slope of the Greater Caucasus (fault map according by [12])

The main seismogenic faults that determine the features of the geodynamic regime of the earth's crust: 1-shifts 2-faults, 1-reverse faults. Faults: 1 - Kazakh-Signakh, 2 - Sharur-Zakatala [1], 3 - Ganjachay-Alazan, 4 - Iory, 5 - North Adjinour, 5 - Vandam, 6 - Dashgil-Mudresa, 7 - Zangi-Kozluchay, 8 - Arpa-Samur.

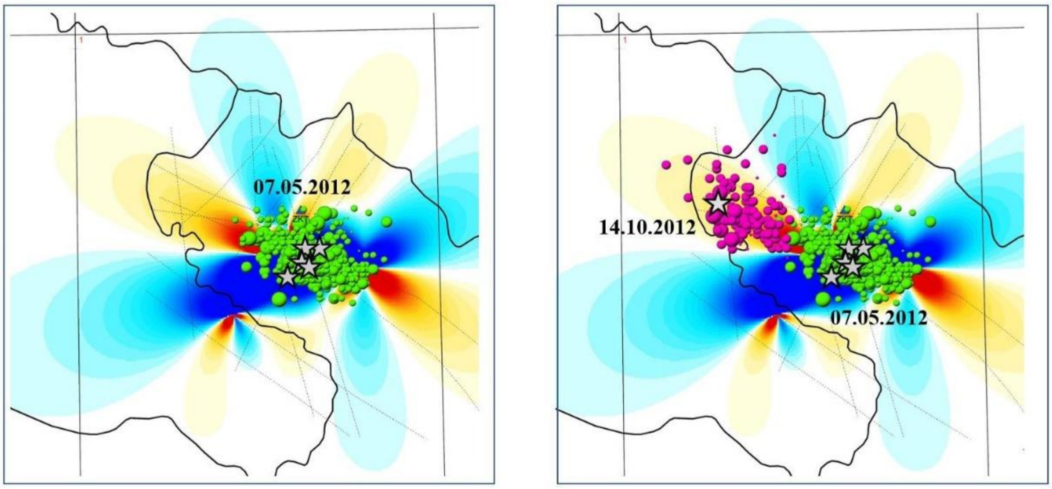

Fig. 3 Increment of critical Coulomb stresses initiated by Zakatala earthquakes in 2012

Based on the above, we analyzed the Coulomb stress after the strong Zagatala earthquake (Fig. 3). It can be assumed that the Zakatala earthquakes are a consequence of the geodynamic regime of the earth's crust of the Zakatala focal zone, the parameters of which are determined by the movements of the earth's crust along the system of longitudinal (general Caucasian strike) and transverse (anti-Caucasian strike) faults; among the latter, the main role probably belongs to a pair of transverse right-sided strike-slip faults – Kazakh-Signakh and Ganjachay- Alazan.

As seen in fig. The Zakatala earthquakes, as well as the aftershock field, are in the zone of negative values of the Coulomb stress, i.e. in the zone of released energy. However, after it, the zones of positive values are distributed in the NW-SE direction. As mentioned above, on October 14, 2012, a strong earthquake with a magnitude of ml=5.6 and an aftershock field radius of 25 km occurred in the NW stress state accumulation zone (Balakan region).

From a tectonic point of view, the earthquakes that occurred in Balaken are located in the southwest of the Azerbaijan part of the Greater Caucasus, surrounded by the Ayrichay- Alat and Vandam deep faults. It should be noted that the Tfansky anticlinorium is distinguished as the central uplift of the Mesozoic core of the meganticlinorium of the Greater Caucasus. On the southern wing of the Tfansky anticlinorium, the Zakatalo-Kovdagsky synclinorium is distinguished, filled with Cretaceous formations. The source mechanism of the Balakan earthquake on October 14, 2012 was characterized by horizontal (PLP=0°) tensile southwest orientation (AZM=239°) and nearly vertical compressive (PLT=48°) northwest orientatio n (AZM=329°) stresses (Fig. 10, Table 4). The type of movement along both (DP=57°) planes is fault with shear elements. Plane NP1 has east strike (STK1=115°), NP2 – north strike (STK2=2°). Comparison of the strike of nodal planes with fault lines shows the agreement of the second nodal plane NP2 with two transverse Kazakh-Signakh and Sharur-Zakatal faults. An analysis of the mechanisms of these earthquakes showed that one pair of tectonic faults was confined to the zone of influence. As seen in fig. The 3rd earthquake that occurred in the Zakatala region is a kind of trigger (initiated). On September 29 and October 4, 2014, to the NE of the city of Gabala, two earthquakes occurred with ml=5.5 and ml=5.0, respectively. The focal zone is controlled by the Damiraparanchai right-slip strike-slip fault, which complicates here the belt of the underthrust junction of the Kakheti-Vandam-Gobustan zone and the accretionary prism of the Greater Caucasus. Near-vertical (PLP=48°) compressive stresses oriented to the southwest (AZM=265°) prevailed in the source mechanism of the first earthquake. Type of movement on both steep (DP1=64°, DP2=53°) planes - fault-shift. Plane NP1 is latitudinal (STK1=265°), and NP2 is meridional (STK2=17°). Comparison of the strike of nodal planes with fault lines in Figs. 6 shows the agreement of the second nodal plane NP2 with the Ismaili-Gabala orthogonal fault.

The movement in the source of the second earthquake arose under the action of near- horizontal (PLP=23°) compressive stresses. The type of movement along both planes is shear with reset elements. Plane NP1 is latitudinal (STK1=268°), and NP2 is meridional (STK2=1°). Comparison of the strike of nodal planes with fault lines shows agreement of the first nodal plane NP1 with the Arpa-Samur transverse fault. Most likely it is this plane that is active.

One of the strongest earthquakes over the past 10 years is the earthquake that occurred in the Okhuz region on September 4, 2015. The seismic vibrations of this earthquake were recorded by 18 world agencies and almost 400 seismic stations in a wide azimuthal environme nt at distances from 300 to 13407 km from the epicenter. Based on macroseismic studies, it was revealed that the earthquake was felt with the greatest intensity in the territories of the Okhuz and Sheki regions (Fig. 4). Here, the intensity of the earthquake according to the MSK-64 table was estimated at 7 points. The earthquake was accompanied by more than 80 aftershocks with magnitudes from 0.5 to 4, of which 33 occurred on the first day. As seen in fig. 4, the epicenter of the earthquake is confined to the zone of intersection of the longitudinal Dashgil- Mudresinsky and transverse Arpa-Samur faults [9, 15]. It should be noted that the Arpa-Samur deep fault of ancient origin at all times from the Paleozoic to the present is a zone of active manifestation of tectonic movements, a conductor of magmatic melts, ore-bearing solutions and seismicity. According to Shikhalibeyli E.Sh. [15] The Arpa-Samur Transcaucasian seismica l ly active metal-bearing fault zone unites the Mrovdag-Zod, Terter and Khachin faults of deep origin. Of the total number of aftershocks, the most significant occurred on October 13 at 00h 13m.

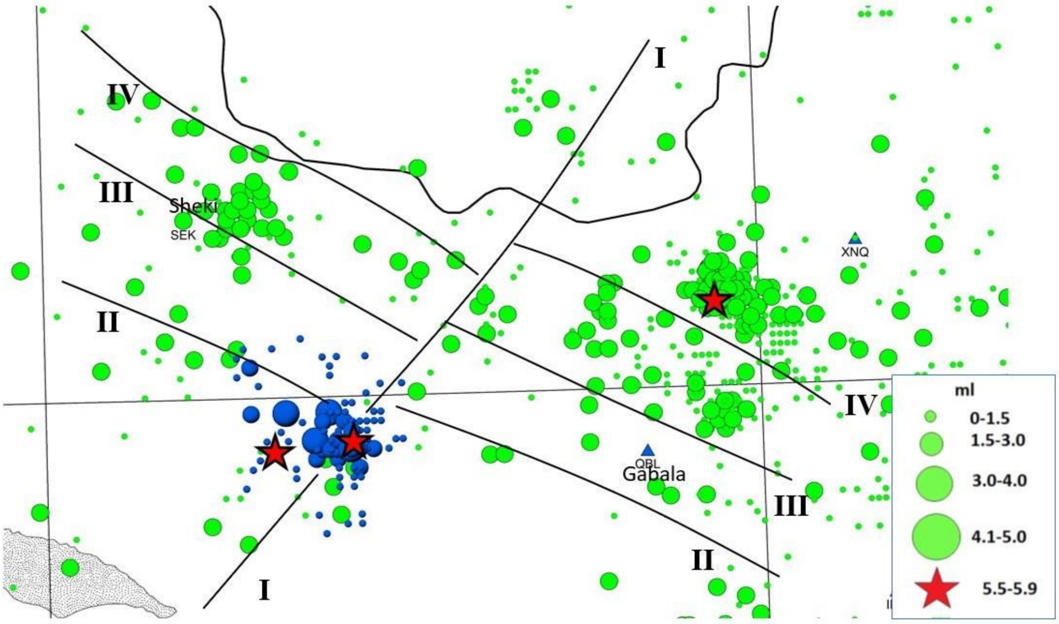

Fig. 4. Aftershock field of strong Gabala (2014) and Okhuz (2015) earthquakes Faults:
I - Arpa-Samur, II - North Adzhinour, III - Vandam, IV - Dashgil-Mudrese [15]

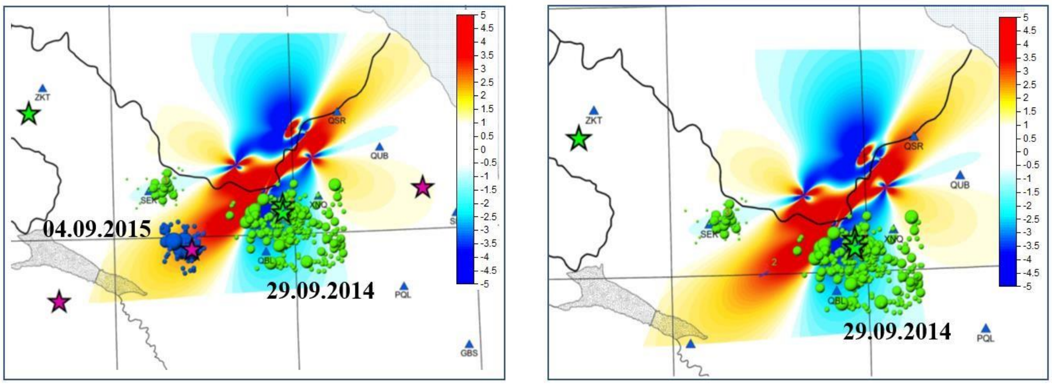

Fig. 5 Increment of critical Coulomb stresses initiated by the 2014 Gabala earthquake

For the reliability of the result, the mechanisms of two earthquakes were built and analyzed: 09/04/2015 with ml=5.9 (main shock) and 10/13/2015 with ml=4.0. The earthquakes that occurred in the Okhuz region on September 4 at 04h 49m and on October 13 at 00h 13m occurred under the action of close tensile and compressive stresses. Table 3 shows that the first nodal fault plane extends in the SE direction (153º), the second nodal plane has a NE strike (63º). At the same time, the compression stresses in the earthquake source were oriented in the northeast direction (azimuth 18) and acted near-horizontally (angle with the horizon 0-7), and the tensile forces were directed in the west-southwest direction (287-288) at an angle of 0-2 to the horizon. The type of slip of these earthquakes is left-sided slip (Fig. 1).

An analysis of the distribution of Coulomb stresses for the Gabala and Okhuz earthquakes showed that after the 2014 earthquakes in the Gabala and Sheki regions, the accumulated energy was released (Fig. 5). However, the areas of positive values in 2014 were distributed in SW- NE orientation, which indicated that the faults (Arpa-Samur transverse fault) were in a subcritical, metastable state.

This was confirmed by seismic activity in 2015, when an earthquake with a magnit ude of 5.9 occurred in the Okhuz region on September 4, 2015. The aftershock cloud spread up to 23 km in the S-N direction and 9 km in the W-E direction, however, the area of the main mass of the earthquake cluster was 88 km2. Despite the fact that the main source is located at a depth of 16 km in the granite layer, the depth of aftershocks varies between 11-34 km.Over the past 15 years, one of the strongest earthquakes in this region is the earthquake that occurred on October 7, 2012, at 15^h42^m, 17 km southeast of the Ismayilli seismic station in the Ismayill i region with ml = 5.3. The intensity at the epicenter of this earthquake on a 12-point scale was estimated at 6 points; in the nearby settlements of Pirkulu, Shamakhi, Ismaili and Akhsu, the earthquake was felt up to 4-2 points.

As is known, the epicentral zone of the Shamakhi earthquakes is located on the southeastern subsidence of the meganticlinorium of the Greater Caucasus. This region is composed of thick volcanogenic and sedimentary strata of the Meso Cenozoic. All strata are collected in large linear folds, elongated in the general Caucasian direction. The follow ing structural units are distinguished in the Shamakhi zone: Zagatala-Kovdag synclinorium, Lagich synclinorium, Vandam anticlinorium, Shamakhi-Qobistan synclinorium (Marazi trough), Alazan-Agrichay trough.

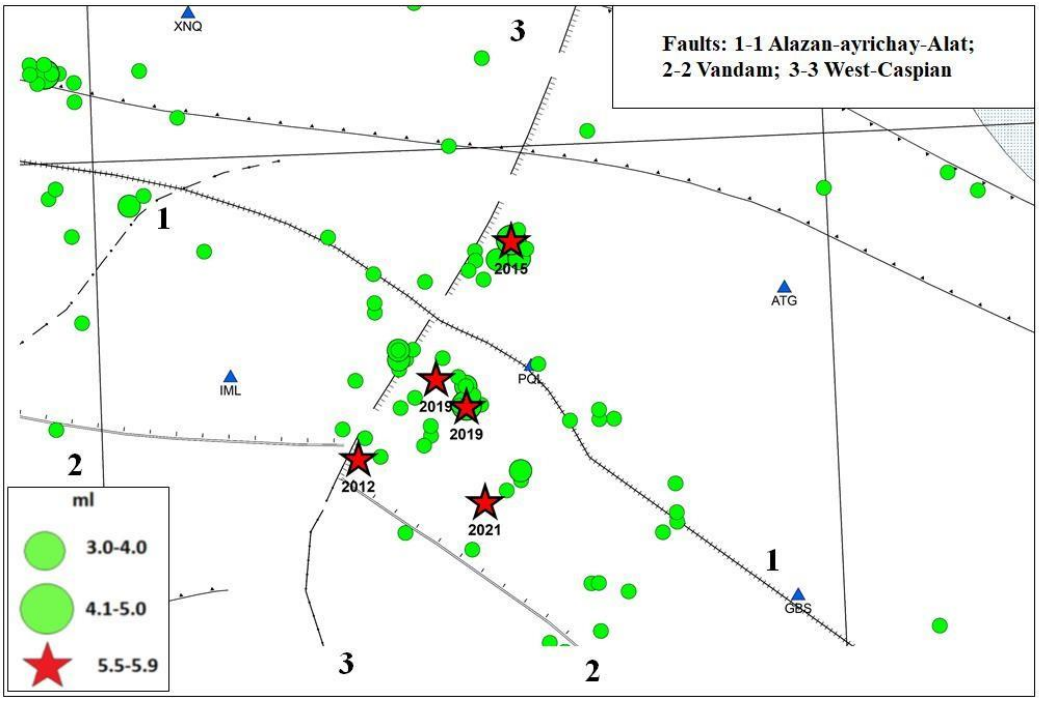

Fig.6. Map of the epicenters of strong earthquakes in the Shamakhi-Ismayilli seismogenic zone for 2012-2021. (fault map according to [15])

The earthquake that occurred on February 5, 2019 at $19^{h}31^{m}$ with ml=5.2, h=8 was no exception. The seismic activity in this zone began with the February 5 earthquake at $19^{h}\ 19^{m}54^{s}$, with ml=4.4 which occurred 11 minutes before the main shock and is considered to be its strong foreshock, felt up to 3-4 points. In addition, a large number of weak foreshocks with ml<3 were recorded. Aftershock activity was also high. The most powerful aftershocks had magnit udes with ml>3.4, 3.0, 3.9. It should be noted that on the same day at 13:24:51 an earthquake occurred in the Talish region with ml = 3.9. According to instrumental observations, the coordinates of the Ismayilli earthquakes $19^{h}\ 19^{m}\ 54^{s}$ (foreshock) and $19^{h}\ 31^{m}\ 37^{s}$ (main shock) are equal: φ=40.77ºN, λ=48.50ºE and φ=40.78ºN, λ=48, 46ºE, depth h=8-11 km.

The highest magnitude earthquake of 2021 (ml = 5.1) occurred on November 20 at 16:46 local time in Shamakhi, 17 km south of Pirgulu station. It should be noted that this shock was major seismic earthquake recorded in the territory of Azerbaijan during the year. The magnitude of the earthquake was 5 in the epicenter and 4-3 in the surrounding areas. Both the compression (P) and tensile stress (T) axes of the earthquake are oriented close to the horizon (PL = 17-36). A sharp (DP = 78-51) angle of incidence was determined for both nodal planes. The value of displacement in the furnace (SLIP = 140-15) indicates that the right- hand displacement-break- up movement is predominant. At 16:48 local time, an aftershock with a magnitude of ml = 4.5 was recorded in Shamakhi, 13 km south of Pirgulu station. The value of displacement in the furnace (SLIP = -109 - (- 64)) indicates that the fracture is dominated by right-sided displacement type movement and is associated with the West-Caspian fracture.

Analyzing the residual stress of the Shamakhi-Ismailli region, we interpolated these Coulomb stresses of 4-magnitude earthquakes that occurred in the period 2012-2019.

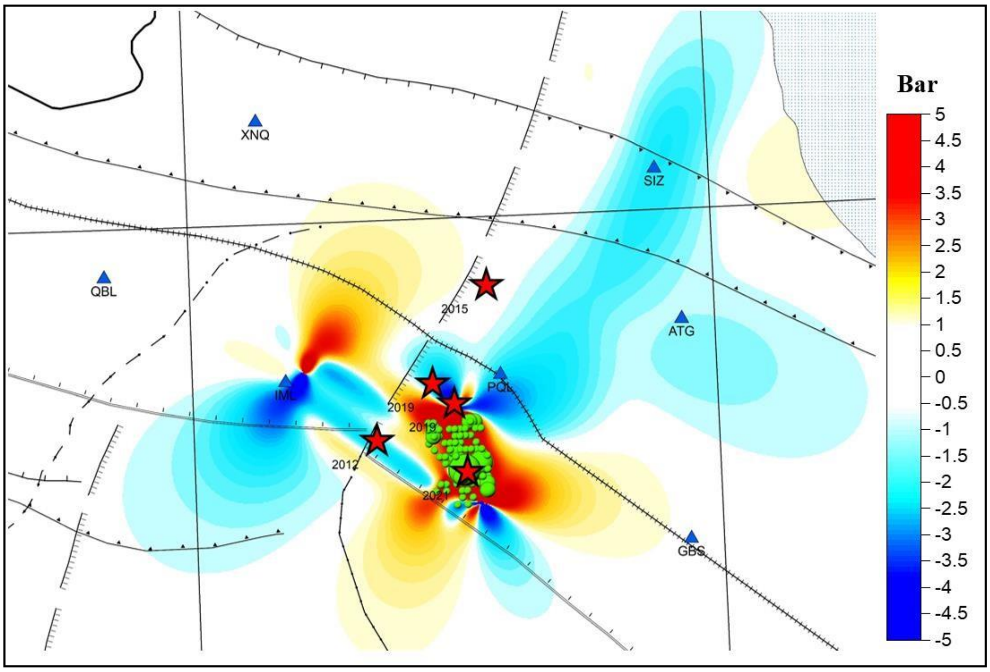

Fig. 7. The emergence of critical Coulomb tensions initiated by the Ismaili earthquakes in 2012-2019. (breakingmap on [15])

A slow deformation process, the contribution of which to the integral value of the accumulated deformation can be quite significant. The displacement consists of a dynamic (co- seismic) and a slow (post-seismic) component. The ratio of the amplitudes of dynamic and slow displacement is determined by the stress-strain state of the contact. If the dynamic component prevails on weakly stressed contacts, then as the static load approaches the Coulomb limit, the amplitude of the slow movement can greatly exceed the initiating dynamic movements. The characteristics of the contact do not remain unchanged during the deformation process. In this case, both an increase and a decrease in the rigidity of the interblock contact, and, consequently, the rate of accumulation of the interblock displacement, can be observed. The increase in stiffness is due to two factors. The first one, the gradual increase in contact stiffness under multiple cyclic loading, is known for quasi-static cyclic loading. Under dynamic loading of cracks, this effect is less pronounced, but it is also quite significant. If the deformation of the contact occurs at a rate below some critical value, then the stiffness increases in proportion to the logarithm of time. In our case, the critical value of the rate of relative displacement of blocks is 4.0–5.0 mm/year, which is relatively small. As a result of the accumulation of the stress- strain state over the past 10 years, residual energy has accumulated at the junction of the Agsu and Shamakhi regions, which manifested itself in 2021 with a magnitude of 5.1 and an aftershock field radius of 15 km.

Conclusions:

The analysis showed that dynamic stresses alone cannot explain the spatial distribut ion of seismicity. So, for example, at a close level of dynamic stresses in the Zakatal and Balakan regions, in the first case, initiated seismicity was observed, and in the second, not. Based on this, an assumption arose that the faults on which initiated earthquakes occur must be in a subcritical, metastable state. This is supported by the fact that all triggered events occurred in areas of increased background seismicity. Many of the areas of initiation were areas, as a rule , confined to the boundaries of large geotectonic elements of the earth's crust and the intersect ion nodes of faults of various directions.

The foregoing suggests that the Zakatala earthquakes are a consequence of the geodynamic regime of the earth's crust of the Zakatala focal zone, the parameters of which are determined by the movements of the earth's crust along the system of longitudinal (general Caucasian strike) and transverse (anti-Caucasian strike) faults; among the latter, the main role probably belongs to a pair of dextral strike slips – Kazakh-Signakh and Ganjachay-Alazan.

Thus, the solutions of the focal mechanisms of the considered earthquakes are normal and antithetic sinistral strike-slip faults. The latter solution seems to be preferable, especially for the first Zagatala earthquake, since the presence of a sublatitudinal or general Caucasian reverse fault in this area is rejected by the geodynamic model of the region under study, as well as a pure normal fault without a horizontal component for the second earthquake.

Analyzing the sequence of seismic processes, one can notice that the sources considered have a certain relationship. It should be noted that the coincidence of the angles of dip DP, slip SLIP and strike azimuths STK of shears and normal faults does not exclude the possibility of movements of such types along the planes of some faults. Perhaps the Zagatala earthquake was the first shock that caused a series of strong earthquakes in the Balakan, Sheki, Okhuz, Gabala and Ismayilli regions. All these zones are in similar seismotectonic conditions. The geologic a l structure of these zones involves the structural elements of the Tfan anticlinorium, the Zagatala – Govdag synclinorium, the Vandam anticlinorium, and the superimposed Alazano–Agric hai trough [14]. These structures of the general Caucasian direction are separated from each other by deep sublatitudinal faults.

A positive increment of the Coulomb stresses can be interpreted as an approach to the destruction threshold, while a negative increment, as it were, postpones the moment of the earthquake. To estimate the Coulomb stresses initiated by the Zakatala, Gabala and Ismayill i earthquakes, the source model was considered, which is set by the plane of east-southeast dip. The eastward dip of the plane along which the shift occurred is in the best agreement with the geological data of the regions. The spatial position of the earthquake epicenters (aftershock field) that occurred from 2012 to 2021 correlates with the zones of positive increments of critical Coulomb stresses. Their occurrence, apparently, is associated with the accumulation of tectonic stresses of sublatitudinal extension and the localization of static stresses initiated by the Zakatala earthquakes of 2012, which together led to the emergence of instability and shear movements along the fault. The obtained results testify to the prospects of the chosen approach for the rapid assessment of seismic shaking for implementation in automated monitor ing systems.

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ENGINEERING SEISMO-GEOLOGICAL JUSTIFICATION OF THE BAYIL LANDSLIDE IN 2018

E.S. Garaveliyev[1]

Objective

Determining the contours of a probable landslide-prone territory based on the method ofengineering seismic exploration and studying the deep structure of fractured environment.

Research method

The refracted microseismic method (Refraction Microtremor, Louie 2001) was used to study the fractured area observed on the Bayil slope in the area of the TV Tower using the seismic microtremor method. The method is a cost-effective seismic method for establishing a shear wave profile in a study area. This method provides useful seismic data directly in noisy urban areas. The refracted microseismic method (Refraction Microtremor, Louie 2001) uses the phase data of a given wave field.

Fig. 1. General view of the landslide with observed main fractures in the area

Symbols: - *cracks observed in the area,*

- *the area of influence of the prognosed landslide,* - *Alley of Martyrs*

To study fractured microseisms, an engineering seismic station GEODE-24 (made in the USA), 24 seismic receivers with a frequency of 4.5 Hz, a seismic streamer 115 m long, and an impact sledgehammer weighing 11 kg were used.

As seismic waves, seismic signals from environmental noise and from sledgehammer blows were received.

The Seismodule Controller software package was used to acquire records in the study area, and programs such as ReMiVspect4.0 and ReMiDisper4.0 were used to process the resulting records.

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

Fig. 2. View of houses in the affected area of the prognosed landslide (width 200 m, length 220 m).

Symbols:

- the direction of the prognosed landslide and the area of landslide affection

Fig. 3. Scheme of seismic profiles in the study area (16 different profiles developed)

spr1 ÷16 - *seismic profiles,*

- cracks observed in the area,

- observed groundwater places

16 seismic profiles were built and processed in the area. Profiles 1, 2, 4, 5, 6 and 15 were constructed by cutting through the fractured zone observed in the area. Profiles № 1÷12 have a length of 55 m, and profiles № 13÷16 - 115 m.

Before the start of the study, the site was visually inspected and a number of anthropogenic interventions affecting landslide activation were noted. These include the cutting of a slope in the form of a terrace for growing tree seedlings and for building houses, as well as the absence of asewer line in these houses.

Fig. 4. Visual observations at the site

Fig. 5. Water leaks in sandstone layers in the northwestern flank of the landslide zone


Fig. 6. Slope cut in front of the landslide zone and rock sampling from a shallow depth


Fig. 7. Slope cut in front of the landslide zone


Fig. 8. Placement of seismic receivers on the profiles of the study area and egistration of seismic waves

Seismic line №1 is associated with an engineering exploration well drilled to a depth of 50 m. The relative height of the wellhead is 107 m. This well was drilled approximately 20 m south of the main fracture found in this area.

As can be seen from the geological section of the well, the upper lithological section of the study area is composed of a complex of rocks of the Quaternary (Q4) age (semi-hard clays, clastic limestones, fine-grained sands and sandy clays). Sandstone formations are often found among the engineering-geological elements mentioned. Groundwater was not observed during drilling (Fig. 9).

At the same time, 60-70 m to the north-west of the exploration well at a relative height of 95 m, groundwater leaks were found through sandstone layers, and when sampling soil from a depth of 2 m from the front of the fractured area, clay-loamy soils were found in the form of porridge (Fig. 5, 6).

One of the factors substantiating the reality of landslide risk is the deepening of sandstonelayers, where water leaks were observed, under the predicted landslide massif (the area where cracks were observed) and the identification of clay-loamy soils in the form of a porridge on the front of the massif (based on sampling from 2 meter depth).

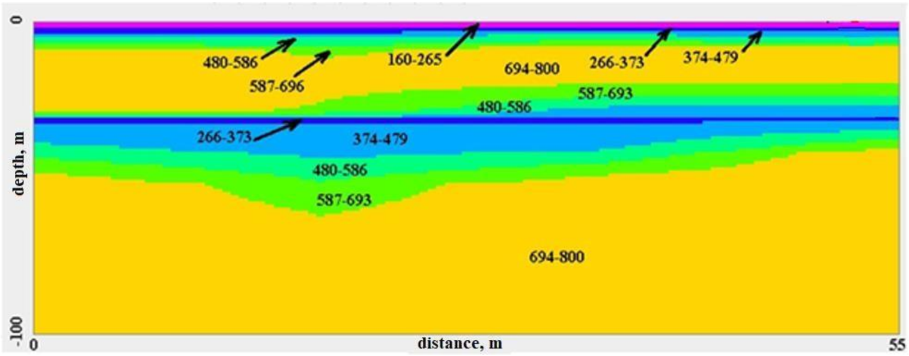


Fig. 9. 2D shear wave velocity section on seismic profile №.1

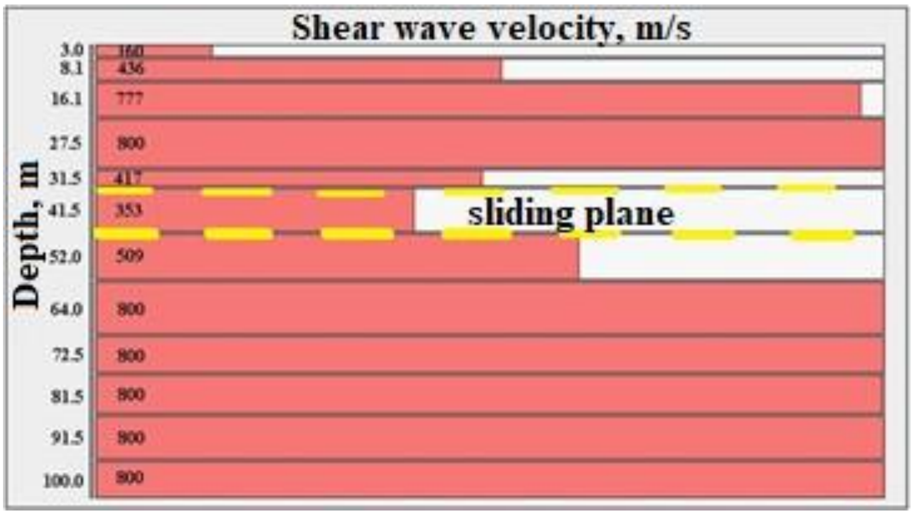


Fig. 10. 1D shear wave velocity section on seismic profile № 1

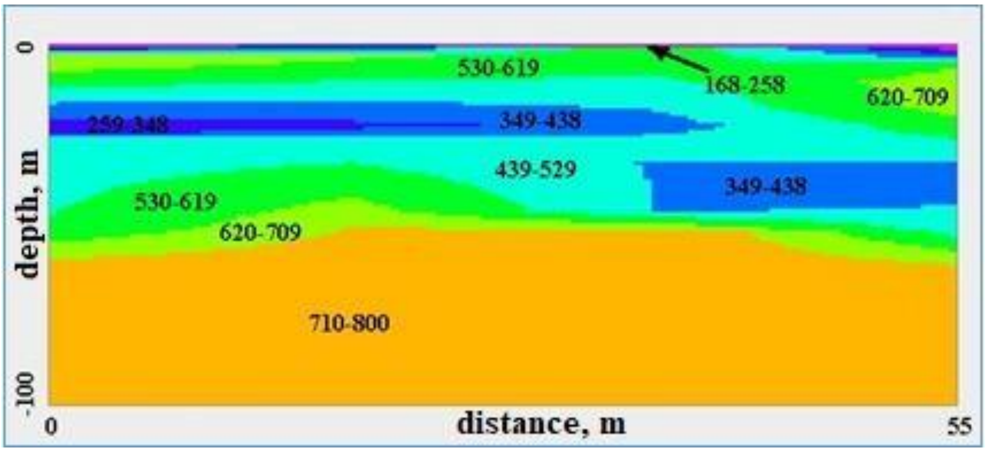


Fig. 11. 2D shear wave velocity section on seismic profile № 3

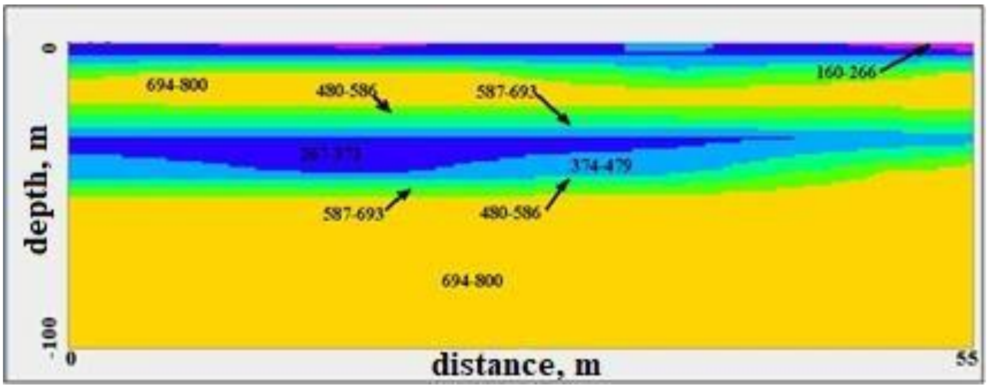


Fig. 12. 2D shear wave velocity section on seismic profile № 5

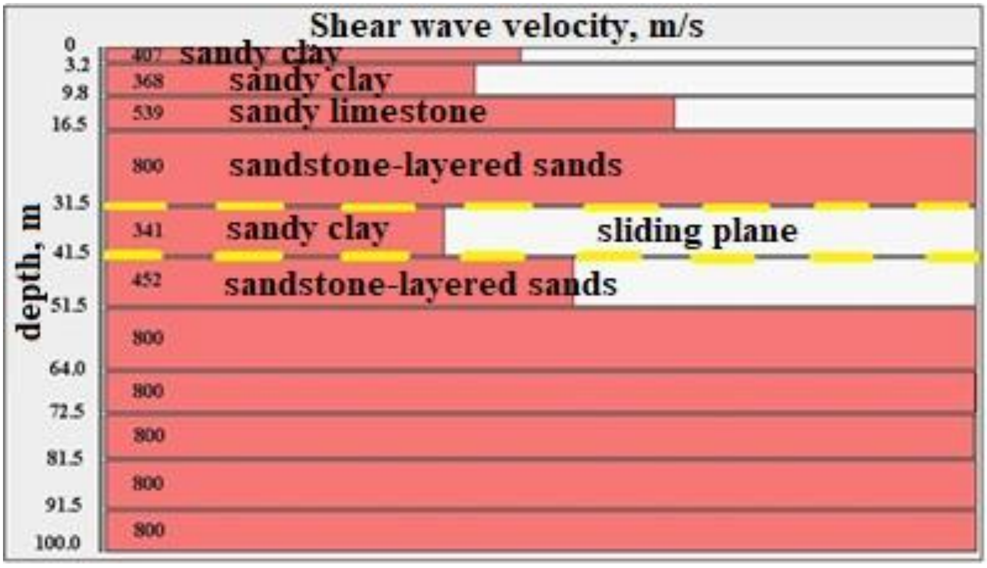


Fig. 13. 1D shear wave velocity section on the seismic profile № 5 and seismic georeferencing

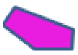
According to seismogeological data on seismic profiles № 1, 5 and 6, sandy-argillaceous rock layers were revealed at a depth of 31.5-41.5 m, with a thickness of 10 m and a low wave speed of 350 m/s (on profile 1), 340 m/s (on profile 5), 360 m/s (on profile 6) and at a depth of 28-44 m, with a thickness of 16 m (on profile 7) with a wave velocity of 360 m/s.

On February 10, 2018, a landslide occurred in the study area, four houses, fences and outbuildings were destroyed, cracks formed in the remaining houses and a very dangerous situatio n arose (Figure 15-18).

Thanks to the timely notification of the landslide to the relevant government agencies and the accuracy of the research work, the residents were evacuated from the risk zone even before the incident and it was possible to avoid human casualties.

Fig. 14. Landslide on February 10, 2018

Symbols:

 *-the area of the real landslide,*  *- the area of the prognosed landslide*

b 

Fig. 15. Terrain change observed at a depth of about 10 m at a distance of 19 m at the top of the landslide

Fig. 16. Relocation of a stone fence

Fig. 17. Destruction, observed cracks and uplifts on the surface at a distance of 130 m from the edge of the landslide

Conclusion

- it was found that the slip plane is located in the form of a thin lens on the roof of the layers of sandy-argillaceous (loam) rocks at a depth of 31.5-41.5 m (the shear wave speed in the layer is 350 m/s), at the border with a layer of fine-grained sands containing interlayers of sandstone;

- it was established that the landslide occurred as a result of water flowing out of the upper part of the slope and moistening of the Quaternary (Q4) clay-sand layers with sewage water, as well as a cut in many places of the slope;

- the total area of the landslide territory was determined as 11430 m^2, the volume of the observed landslide mass was 360000 m^3.

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GRAVIMETRIC RESEARCHES IN ASSESSMENT THE CAUSES OF THE APPEARANCE OF GAS ON THE COAST OF ZAGULBA

E.M.Baghirov[1]

In order to assess the causes of gas contamination of the sea in the north of the Absheron Peninsula, the village Zagulba, gravimetric studies were carried out with a modern Canadian CG- 5 AutoGrav gravimeter and a Russian GNU-KS gravimeter (Fig. 1). The measurements were carried out in a network of profiles (Fig. 2-4) with full coverage of the area.

Modern gravimetric methods include modeling areas close to the site of observation of the manifested gas, the selection of its geometric elements, the selection of zones with active stress dynamics and the identification of dangerous, hazardous places associated with geodynamic tension in the area of activity.

Research work by gravimetric methods, gravimetric measurements on profiles in differe nt directions in order to assess the causes of the occurrence of gas pollution in the sea near the villa ge of Zagulba in the north of the Absheron Peninsula were carried out. The studies were carried out at a distance of 100 meters between observation points.

Fig. 1. Canadian gravimeter CG-5 AutoGrav and Russian gravimeter GNU-KS

Fig. 2. Scheme of gravimetric observation points carried out in the study area Symbols:

Observation points
Profiles
Methane gas

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

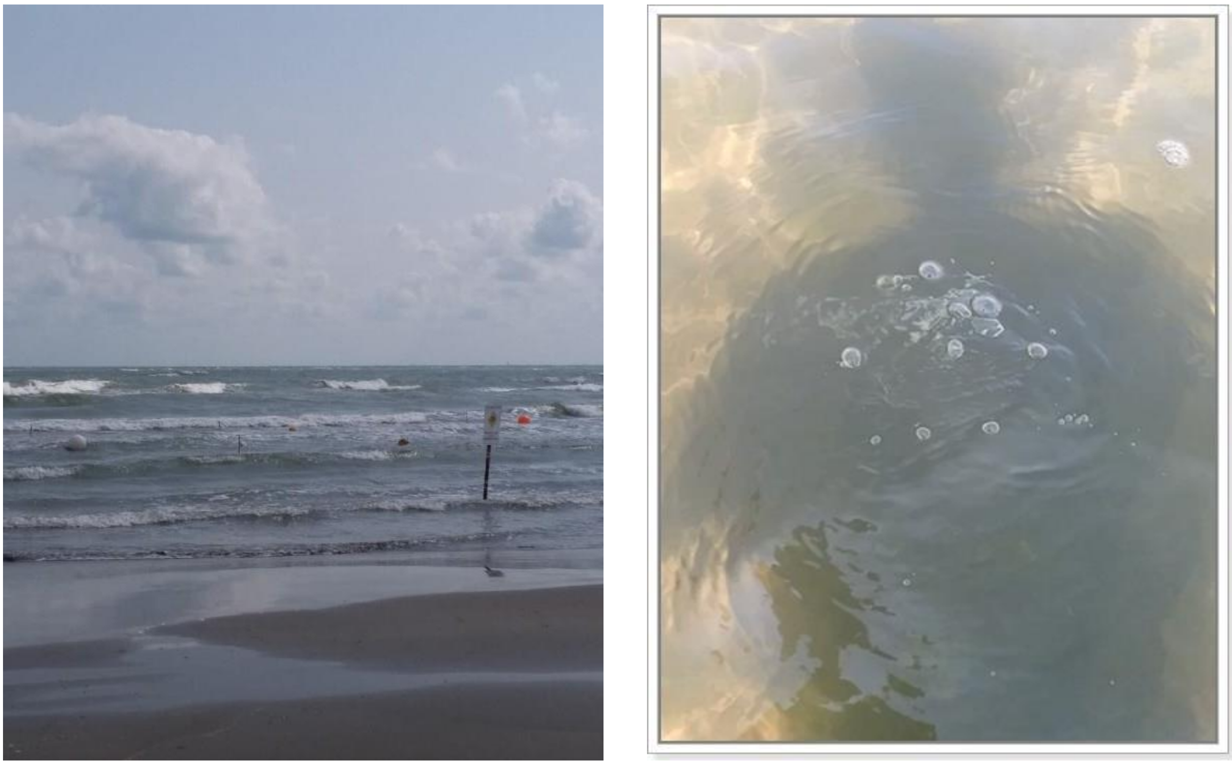


Fig. 3. Methane release and photos of the surroundings

Fig. 4. Gravimetric and magnetometric measurements in the area of methane gas manifestation

Great attention is paid to field planning. The methods of field observations with high- precision gravimeters is determined in accordance with the requirements for identifying subjective and other factors that affect microseismicity, accuracy and reliability of observations, acceleration of free fall of non-tidal variations in time. For field gravimetric observations, as mentioned earlier, Russian GNU-KS and Canadian CG-5 Autograv were used. These devices make it possible to detect changes in gravity in the proposed polygons during repeated gravimetric measurements.

In order to assess the causes of gas contamination of the sea in the north of the Absheron Peninsula of the village of Zagulba (Fig.5), a gravimetric network was created to measure the relative gravity, measurements for each profile and measurements with the aim of "0" point were taken.

As can be seen from the isoanomalous map of the gravitational field, the anomalous zones are covered by a variable value of the relative gravity (Molodensky M.S., p. 128). Thus, the relative gravity remains open in the west and closed in the east, with a minimum value in the northeast and southeast of the study area, and the anomaly extends from 0.185 mGal to 3.514 mGal from west to east.

This anomaly is completely extended from west to east from the first observation point of profile V, from observation points 2 and 3 of profile I. If you pay attention to the 3D model of the stress-strain state of the geological environment the above interpretations are more accurate (Fig. 6).

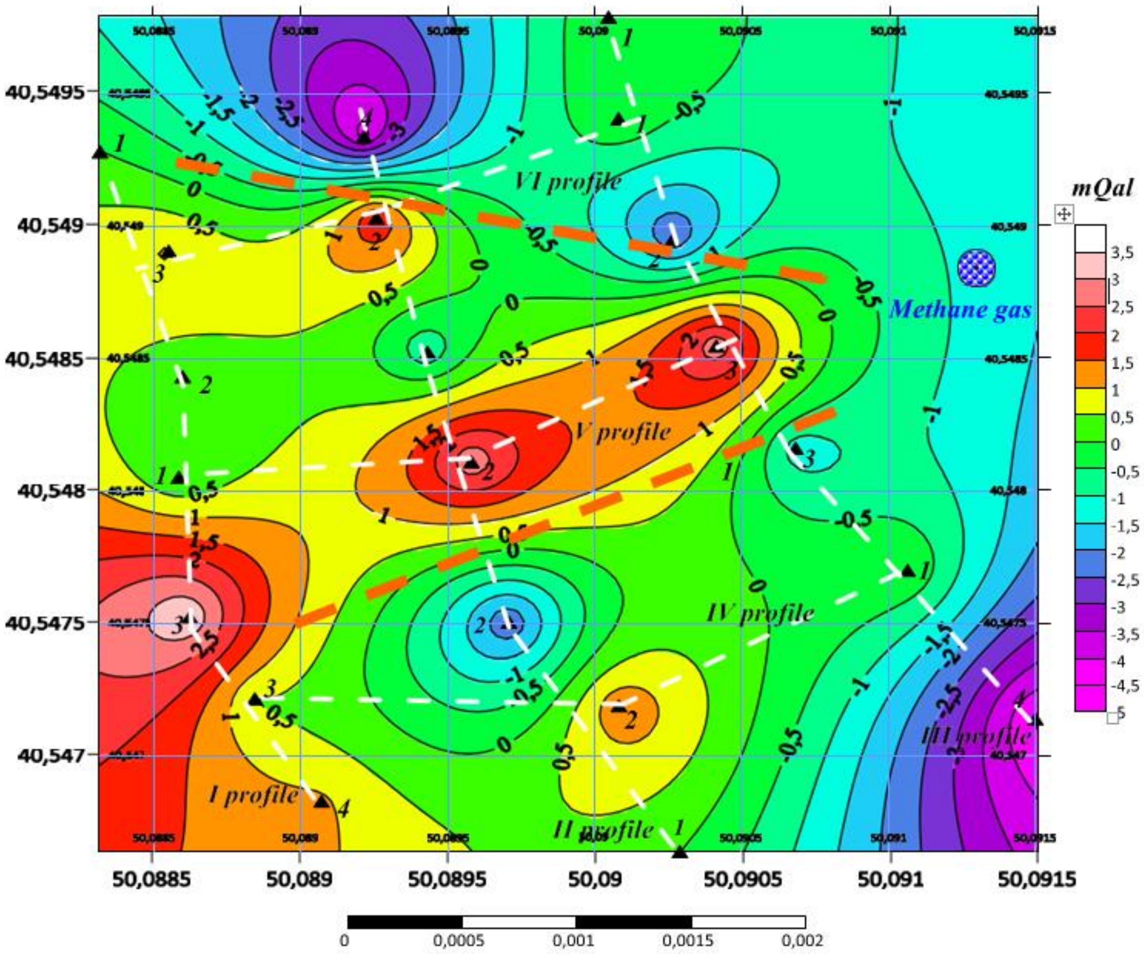
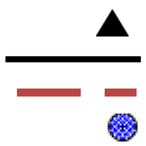


Fig. 5. Isoanomalous map of the gravity field, reflecting the stress-strain state of the study area



Observation points
Profiles
Destruction zones
Methane

In local areas, including spectral analysis on the shadow map, gravity is accompanied byan increase and decrease in the intensity of the gravitational field, which is also visible (Fig. 7).

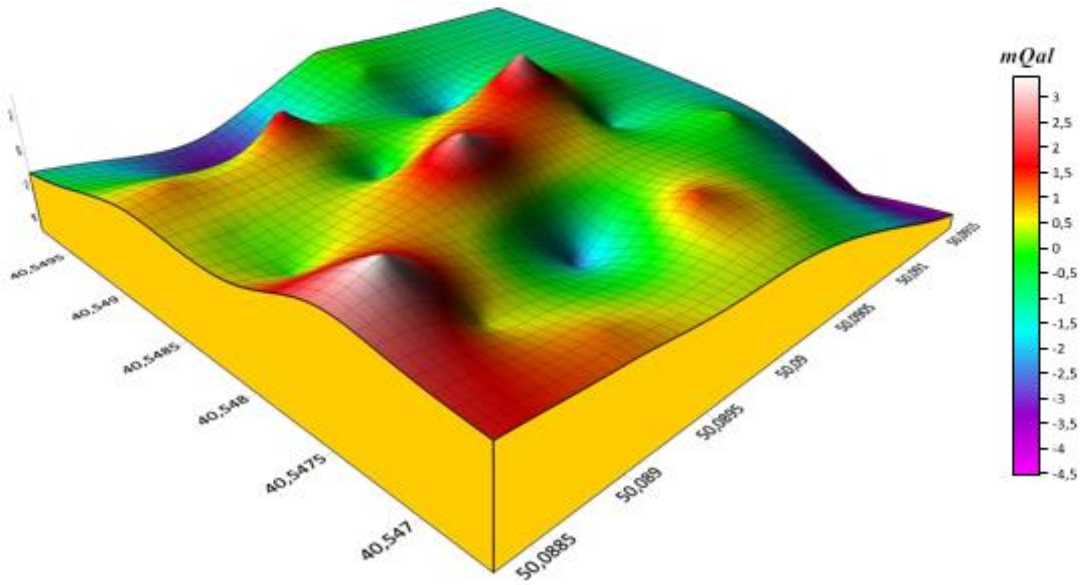


Fig. 6. 3D model reflecting the stress-strain state of the study area

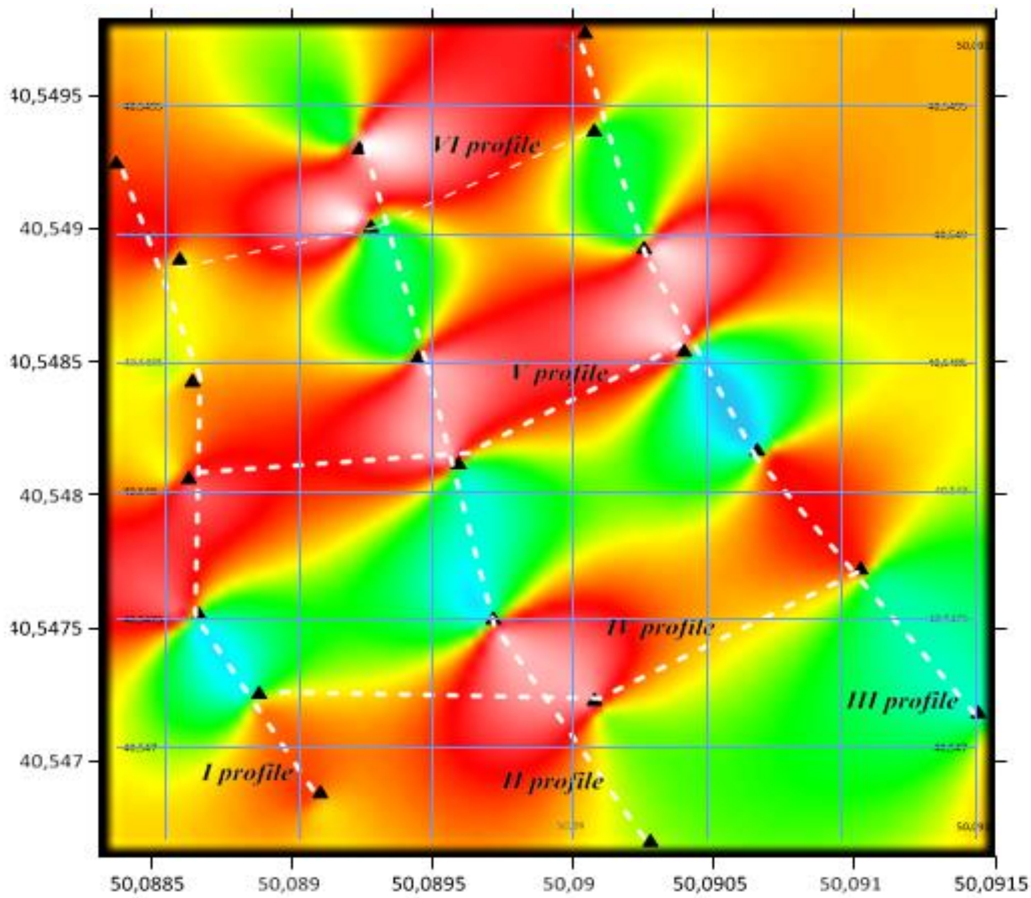


Fig. 7. Spectral analysis of the gravitational field reflecting the stress-strain state of the study area

CONCLUSION

1. The nature of the change in gravity at the polygons was studied by repeated gravimetric observations, 2D and 3D isoanomalous maps of the gravitational field were compiled. The field revealed anomalous zones with variable values of relative gravity. Relative gravity is observed in the northeast and southeast of the study area with a minimum value, and from west to east from 0.185 mGal to 3.514 mGal.

2. The geodynamically stressed conditions of the ground and gas-bearing areas adjacent to the sea are high. Earthquakes occur regularly (ml=3.0-4.0) in the vicinity, the influence of relatively strong earthquakes (ml $\geq$ 4.0) is felt here.

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ANOMALOUS CHANGE IN THE GEOMAGNETIC FIELD BEFORE THE ZAGATALA EARTHQUAKE (ML=4.2) 01.03.2022

M.K. Mammadova,[1] A.N. Sultanova[1], A.M. Guliyeva[1]

The first information about earthquakes in the northwestern part of the Azerbaijani segment of the Greater Caucasus was received in 1850. Strong earthquakes in the region with magnit ude ml>5 occurred in 1936 and 1948 (Agamirza yev, 1987). After the noted seismic events, the next strong earthquake in the Zagatala-Balakan zone occurred in 2012 on May 7th with magnit ude ml>5.6 (h=9 km, φ=41.50°N, λ=46.58°E). After the main shock, aftershocks intensified in the region, which lasted for several days. Their number in the first day reached 170. After this event, 6 years later, a strong Zagatala earthquake with ml=5.5 (h=10 km, φ=41.5°N, λ=46.67°E) occurredin the same source on June 5, 2018. The coordinates of both sources of the Zagatala earthquakes coincide (Rzayev 2012).

As can be seen from Fig.2, the stress-strain state of the environment at the test site is characterized by local anomalies of stress zones in the Gabala-Sheki, Shamakhi-Ismayilli, and Zagatala-Balakan sections. A sharp change here in the increment of the geomagnetic field strength gradient in short sections of the profile indicates sharp changes and disturbances in the environment.

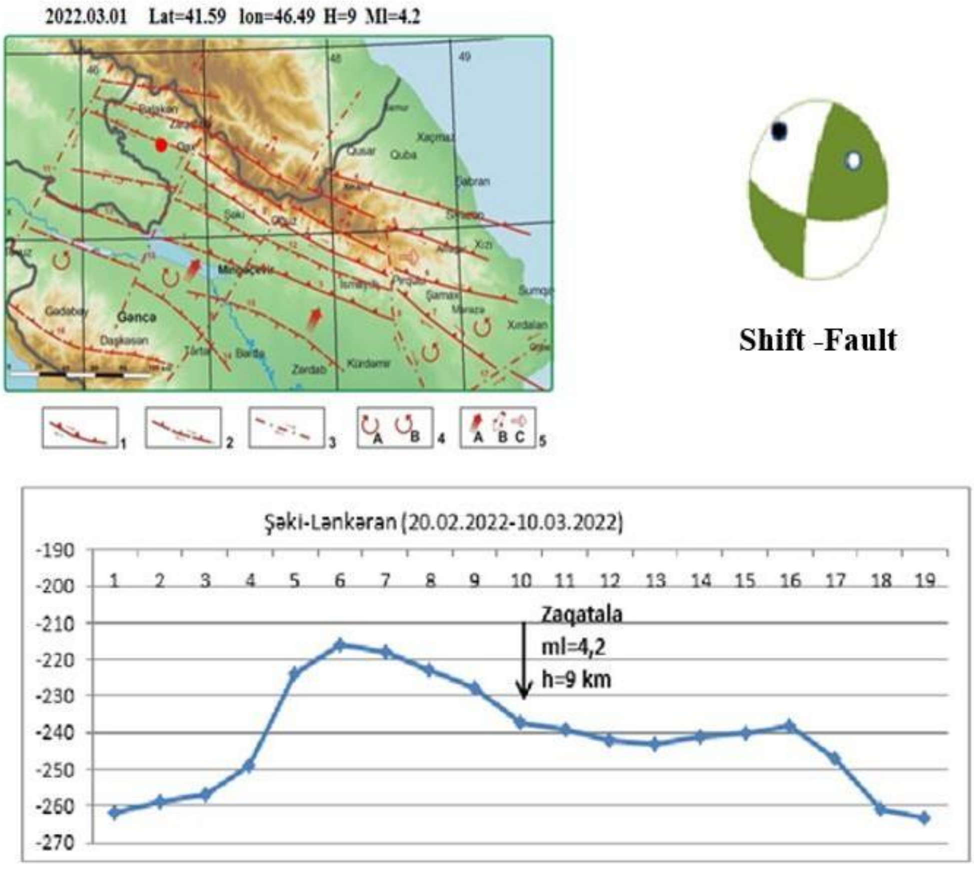

Fig. 1. Seismomagnetic effect and source mechanism of the Zagatala earthquake (01/03/2022)

In the northwestern part of the polygon, at the Zagatala-Balakan section, a sharp drop in field strength by -300 nT is observed. Against the background of the formed closed local anomalies on the area of the polygon, in the northwestern part, namely in the Zagatala-Balakan region, a sharp change in the gradient ΔT~f(t) is observed and the formation of an extensive negative local anomaly of the geomagnetic field strength is observed here.

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

Monitoring of the geomagnetic field strength at the Shamakhi-Sheki-Zagatala-Balaka n prognostic range is recorded around the clock by modern magnetic variation stations and transmitted online to the RSSC. Operational data processing allows timely detection of the seismomagnetic effect and its temporal changes. The data are presented as T~f(t) and ΔT~f(t) graphs.

In the case of the Zagatala earthquake on March 1, 2022, analyze the changes in tension before and after the seismic event in order to identify the SME and study its characteristics in connection with geodynamic processes in the earthquake source.

Analysis of magnetic variations ΔT~f(t) at ml≥4 indicates that the seismomagnetic effect is determined by the parameters of the earthquake source mechanism (Rzayev, 2005, 2006, 2010, 2016). These data are in full agreement with the results of our analysis of the geomagnetic field during the Zagatala earthquake of 2022 (Fig. 1).

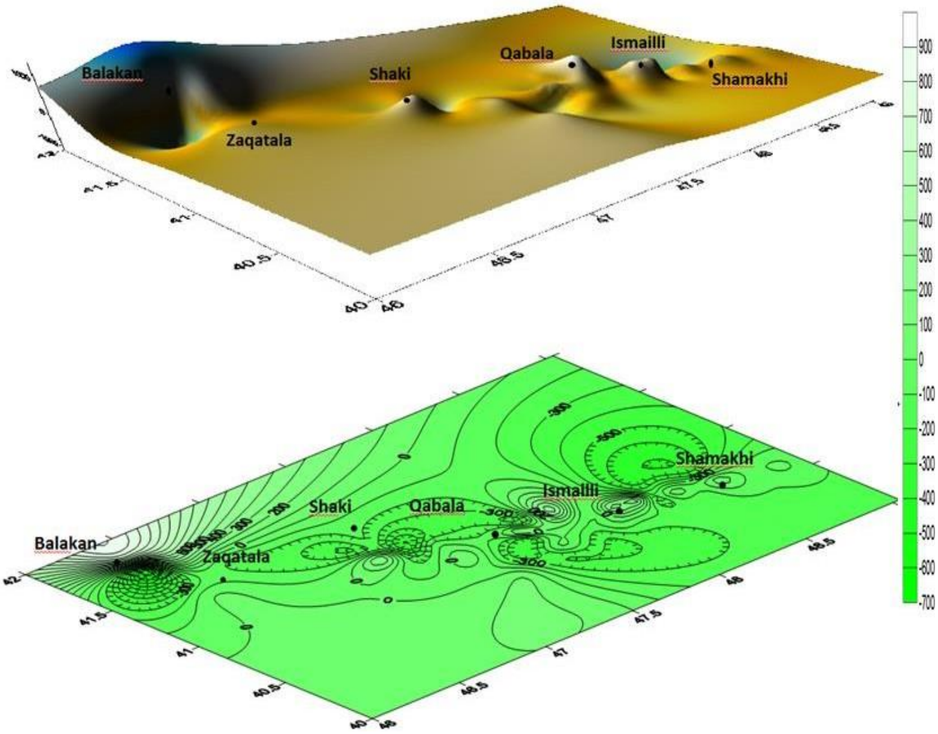

Fig. 2. Stress-strain state of the geological environment of the Shamakhi-Zagatala-Balakan polygon according to magnetic data in 2D and 3D formats

As can be seen from Fig.1, the seismomagnetic effect reflects the geodynamic situation in the earthquake source, located in a mobile block of the earth's crust and expressed in shear-thrust deformation. Shear-thrust deformation in the source is clearly reflected in the positive local anomaly of the field strength increment, which forms the seismomagnetic effect (SME).

An analysis of the results of studies of the seismomagnetic effect available in the literat ure shows that with the mechanism of compression in the source, the seismomagnetic effect is formed with positive dynamics of the increase in the geomagnetic field strength. In cases where tensile stresses predominate in the source, the seismomagnetic effect has a negative increment in the geomagnetic field strength (Rzayev, 2005, 2006, 2010, 2016).

In the case of the Zagatala earthquake on March 1, 2022, as noted above, the geodynamics of the source is characterized by shear-thrust deformation with the predominance of compressive stresses in the source. At the same time, for 3-5 days at the magnetic variation stations of Sheki and Lankaran, an increase in the intensity of the geomagnetic field was observed. The seismomagnetic effect in this case reached 25–30 nT. After the earthquake, for 5-6 days, a decrease in the intensity of the geomagnetic field was observed with its complete relaxation to the level of intensity on February 20, 2022.

In 2021, a discrete magnetic survey was carried out on the area of the Shamakhi-Balaka n test site. An analysis was made of spatiotemporal increments of the geomagnetic field strength gradient ΔT~f(t). The stress-strain state of the geological environment at the site was presented in the form of maps ΔT~f(t) in 2D and 3D formats (Fig. 2).

The earthquake on March 1, 2022 occurred within the Zagatala-Balakan zone of excess stresses identified by us in 2021, was characterized by a sharply differentiated increment gradient ΔT~f(t) (Fig. 2).

CONCLUSION

1. The analysis of magnetometric data made it possible to identify the seismomagnetic effect, which was formed 3-5 days before the Zagatala earthquake on March 1, 2022. The nature of the SME fully corresponds to the mechanism of the earthquake source, where the predominance of compressive stresses with the “shear-thrust” source mechanism was observed. As a consequence, we have a positive local increase in the geomagnetic field strength and the formation of a seismomagnetic effect (SME) with positive dynamics.

2. Identified by magnetic data in 2021, the Zagatala-Balakan zone of the stress-strain state of the environment with a sharp differentiation of the geomagnetic field strength gradient, was the zone of formation of the source of the Zagatala earthquake on 01/03/2022 and is well reflected on 3D maps ΔT~f(t).

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ANNOTATIONS

1. CHARACTERISTICS OF SEISMICS OF AZERBAIJAN AND AROUND REGIONS IN 2020

Yetirmishli G.J., İsmyailova S.S., Kazimova S.E.

In 2020, seismic analysis was conducted on the basis of 40 digital data. During the year, 13,295 earthquakes were recorded. Of them, 4030 are local (Azerbaijani territory), 3347 regional and 3123 remote earthquakes. At the same time, 1463 weak tremors (recorded by a single station), 1332 explosions were recorded. Compared to 2019, the number of earthquakes and the amount of seismic energy released in 2020 decreased. Thus, the number of earthquakes in 2020 was 4030, the amount of seismic energy released was $\sum E=13.1 \cdot 10^{11}$ J, the maximum magnitude was ml=4.9. During 2020, seismicity was observed in the Greater Caucasus, the Middle Kura Basin and the Caspian Sea. Seismic activation is observed along the West- Caspian, Palmir-Absheron, Ajichay-Alat, Ganjachay-Alazan, Gazakh-Signakh, Talish, Akhvay, Sangachal Ogurchu, Garabogaz-Safidrud, Agrakhan-Kasnavodsk, Khachincha y faults.

The area of tension in the territory of Azerbaijan is divided into two areas along the Geokchay fault and the Imishli-Geokchay flexure: the north-eastern part of the republic is characterized by tension, and the south-western part by compression. Tension is observed in the Absheron region and the Caspian Sea.

Keywords: seismic analysis, West-Caspian, Palmir-Absheron, Ajichay-Alat tectonic faults, analysis of hearth mechanisms.

ANALYSIS OF MODERN MOVEMENTS OF EARTH CRUST BLOCKS IN AZERBAIJAN ACCORDING TO THE DATA OF GPS STATIONS IN 2020-2021

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

The article presents a method for calculating the velocity fields of modern horizonta l displacements of the tectonic blocks of Azerbaijan, obtained from the results of observations at 24 stationary GPS_RSSC stations, a characteristic aspect of which is a noticeable horizont a l displacement in the northeast direction at a rate of 4–12 mm/year. In this article, the velocit y field of tectonic blocks on the territory of Azerbaijan was studied based on the results of GPS measurements calculated using the GAMIT program (Global Navigation Satellite System (GNSS) at the Massachusetts Institute of Technology) [4]. It has been established that along the Lesser Caucasus, in the Kura basin, the Nakhchivan Autonomous Republic and the border regions of Iran, there is a compression zone oriented to the NE. The maximum value of the strain rate throughout the territory of Azerbaijan fluctuates within 13.7 mm/year; the average value for all stations is 7.9 mm/year. Analysis of the velocity field also showed low velocit y values in the Greater Caucasus (4-6 mm/year). In addition, a correlation analysis of the value of velocities with the seismic activity of the region was carried out. It is concluded that there is a certain relationship between the change in the values of the velocities of horizont a l movements and the distribution of strong earthquakes in the field of the rate of deformation of the earth's crust.

Keywords: GPS stations, geodynamics, tectonic blocks, South Caucasian microplate.

3. CHANGES IN COULOMB STRESSES AFTER STRONG EARTHQUAKES OCCURRED IN THE TERRITORY OF THE GREATER CAUCASUS FOR THE PERIOD 2012-2021

S.E. Kazimova

The article examines the seismotectonic position of a strong earthquake that occurred on the territory of the Azerbaijan part of the Greater Caucasus for the period 2012-2021. In Bali, the focal mechanisms of strong earthquakes were analyzed: Zagatala on May 7, 2012 with Ml=5.6, 5.7, Balakan on October 14, 2012 with Ml=5.8,; Ismayilli 07.10.2012, 2019, 2021 with Ml=5.1-5.3; Gabala series on September 29 and October 4, 2014 with Ml=5.5; as well as Okhuz on 09/04/2015. The analysis showed that as a result of dynamic stresses in the Zakatal-Gabala and Balakan-Okhuz-Ismayilli regions, in the first case, initiated seismicity was observed, and in the second - no. Based on this, an assumption arose that the faults on which initia ted earthquakes occur must be in a subcritical, metastable state. It was found that the spatial position of the earthquake epicenters (aftershock field) that occurred from 2012 to 2021 correlates with the zones of positive increments of critical Coulomb stresses. Their occurrence, apparently, is associated with the accumulation of tectonic stresses of sublatitudinal extension and the localization of static stresses initiated by the Zakatala earthquakes of 2012, which together led to the emergence of instability and shear movements along the fault.

Keywords: earthquake, focal mechanisms, Coulomb stress, aftershock field.

4. ENGINEERING SEISMO-GEOLOGICAL JUSTIFICATION OF THE BAYIL LANDSLIDE IN 2018

E.S. Garaveliyev

Landslides on the Bayil slope have been recorded since ancient times. Information about landslides in this zone was noted in the works of the oil geologist G.V.Abikh. It was reported that in 1874 and 1877, along the western shore of the Baku Bay, on a slope about 200 meters long, landslides occurred in areas of gray clay. Later, in 1927, 1929, 1951, 1968, 1973, 1996, activation of landslides was observed on the Bayil slope.

On March 6-7, 2000 landslide demolished houses, gas stations, outbuildings, a factory floor, a highway, etc. and caused significant damage to the economy of the state.

In the materials on all landslides in this area, it is noted that preventive measures were not carried out in full; on the contrary, work was carried out to promote the reactivation of the landslide. So, in the lower part of the Bayil slope, from the Intourist hotel to the Sabayil district fire department, construction work was underway, the road was dug, heavy equipment was used on the roads on the slope and traffic was more intense than before. All these factors are the reasons for the activation of the landslide.

Keywords: landslide, engineering seismic exploration, transverse wave velocity

5. GRAVIMETRIC RESEARCHES IN ASSESSMENT THE CAUSES OF THEAPPEARANCE OF GAS ON THE COAST OF ZAGULBA

E.M.Baghirov

To assess the causes of gas formation in the sea, anomalous zones were identified in the field of gravimetric studies, accompanied by a variable value of the relative gravity, and isoanomalous maps were compiled.

Keywords: gravity, anomalous zones, stress conditions.

6. ANOMALOUS CHANGE IN THE GEOMAGNETIC FIELD BEFORE THE ZAGATALA EARTHQUAKE (ML=4.2) 01.03.2022

M.K. Mammadova, A.N. Sultanova, A.M. Guliyeva

Annotation: The anomalous behavior of the geomagnetic field strength near the source zone of the Zagatala earthquake (ml=4.2) of March 1, 2022 was studied. It is shown that the nature of the formation of the seismomagnetic effect (SME) reflects the geodynamic regime in the source zone. The Zagatala-Balakan seismogenic zone is clearly outlined on the map of spatio-temporal increments of the geomagnetic field strength gradient.

Keywords: SME seismomagnetic effect, nanotesla (nT), earthquake source mechanis m, geodynamic regime, geomagnetic field strength, magnitude ml.

ANNOTASİYALAR

1. 2020-Cİ İL ƏRZİNDƏ AZƏRBAYCAN VƏ ƏTRAF BÖLGƏLƏRİN SEYSMİKLİYİNİN XÜSUSİYYƏTLƏRİ

Q.C.Yetirmişli, S.S.İsmayılova, S.E.Kazımova

2020-ci ildə 40 rəqəmsal məlumatlar əsasında seysmikliyin analizi aparılmışdır. İl ərzində 13295 yeraltı təkan qeydə alınmışdır. Onlardan 4030 yerli (Azərbaycan ərazisi), 3347 regional və 3123 uzaq zəlzələlərdir. Bununla yanaşı zəif 1463 təkan (tək stansiya tərəfindən qeydə alınmış), 1332 partlayış qeydə alınmışdır. 2019-cu ilə nisbətən 2020-ci il ərzində zəlzələlərin sayı və ayrılan seysmik enerjinin miqdarı azalmışdır. Belə ki 2020-ci ildə zəlzələlərin sayı 4030, ayrılan seysmik enerjinin miqdarı $\sum E=13.1 \cdot 10^{11}$C, ən yüksək maqnituda ml=4.9 olmuşdur. 2020-ci il ərzində seysmiklik Böyük Qafqaz, Orta Kür çökəkliyi və Xəzər dənizi ərazisində müşahidə olunub. Seysmik aktivləşmə əsasın Qərbi-Xəzər, Palmir- Abşeron, Aciçay-Ələt, Gəncəçay-Alazan, Qazax-Siqnax, Talış, Axvay, Sanqaçal Oqurcu, Qaraboğaz-Safidrud, Aqraxan-Kasnavodsk, Xaçinçay qırılmaları istiqaməti boyu müşahidə olunur.

Azərbaycan ərazisinin gərginlik sahəsi Geokçay qırılması və İmişli-Geokçay fleksuras ı boyu iki sahayə bölünür: Respublikanın şımal-şərq hissəsi gərilmə, cənub-qərb hissəsi isə sıxılma ilə xarakterizə olunur. Gərilmə gərginliyi isə Abşeron ərazisi və Xəzər dənizində müşahidə olunur.

Açar sözləri: seysmikliyin analizi, Qərbi-Xəzər, Palmir-Abşeron, Aciçay-Ələt tektonik qırılmalar, ocaq mexanizmlərinin analizi.

2. 2020-2021-Cİ İLLƏRDƏ GPS STANSİYALARININ MƏLUMATLARINA ƏSASƏN AZƏRBAYCANDA YER QABIĞININ BLOKLARININ MÜASİR HƏRƏKƏTİNİN TƏHLİLİ

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

Məqalədə Azərbaycanın tektonik bloklarının müasir üfüqi yerdəyişmələrinin 24 sabit GPS_RCSS stansiyalarında aparılmış müşahid ələrin nəticələrindən əldə edilmiş sürət sahələrinin hesablanması metodu təqdim olunur. Xarakterik cəhət şimal-şərq istiqamətində 4-12 mm/il sürətlə nəzərə çarpan üfüqi yerdəyişmədir. GAMIT proqramı (Massaçusets Texnologiya İnstitutunda Qlobal Naviqasiya Peyk Sistemi (GNSS)) ilə hesablanmış GPS ölçmələrinin nəticələri əsasında Azərbaycan ərazisindəki tektonik blokların sürət sahəsi tədqiq edilmişdir. Müəyyən edilmişdir ki, Kiçik Qafqaz boyu, Kür çökəkliyi, Naxçıvan Muxtar Respublikası və İranın həmsərhəd rayonlarında şərq istiqamətli sıxılma zonası mövcuddur. Bütün Azərbaycan ərazisində deformasiya sürətinin maksimal qiyməti 13,7 mm/il daxilində dəyişir, bütün stansiyalar üzrə orta qiymət 7,9 mm/il təşkil edir. Sürət sahəsinin təhlili Böyük Qafqazda da aşağı sürət dəyərlərini göstərdi (4-6 mm/il). Bundan əlavə, sürətlərin qiymət inin regionun seysmik aktivliyi ilə korrelyasiya təhlili aparılmışdır. Demək olar ki, üfüqi hərəkətlərin sürətlərinin dəyərlərinin dəyişməsi ilə yer qabığının deformasiya sürəti sahəsində güclü zəlzələlərin paylanması arasında müəyyən əlaqə var.

Açar sözlər: GPS stansiyaları, geodinamika, tektonik bloklar, Cənubi Qafqaz mikroplitəsi.

3. 2012-2021-Cİ İLLƏR ƏRZİNDƏ BÖYÜK QAFQAZ ƏRAZİSİNDƏ BAŞ VERMİŞ GÜCLÜ ZƏLZƏLƏLƏRDƏN SONRA KULON GƏRGİNLİYİN TOPLANMASI

S.E.Kazımova

Məqalədə 2012-2021-ci illər ərzində Böyük Qafqazın Azərbaycan hissəsi ərazisində baş vermiş güclü zəlzələnin seysmotektonik xüsusiyətlər tədqiq olunur. Güclü zəlzələlərin ocaq mexanizmləri təhlil edilmişdir: 7 may 2012-ci ildə Zaqatala zəlzələsi Ml=5,6, 5,7, Balakən zəlzələsi14 oktyabr 2012-ci ildə Ml=5,8; İsmayıllı zəlzələsi 07.10.2012, 2019, 2021 Ml=5,1-5,3 ilə; Qəbələ zəlzələləri 29 sentyabr və 4 oktyabr 2014-cü il tarixlərində Ml=5,5 ilə; eləcə də 09.04.2015-ci il tarixində Oğuz zəlzələsi.Təhlil göstərdi ki, gərginliklər nəticəsində Zaqatal-Qəbələ və Balakən-Oğuz-İsmayıllı rayonlarında birinci halda təşəbbüslü seysmiklik müşahidə olunub, ikinci halda isə yox. Buna əsaslanaraq, təşəbbüslü zəlzələlərin baş verdiyi qırılmala r ın subkritik, metastabil vəziyyətdə olması ilə bağlı bir fərziyyə yarandı. Müəyyən edilmişdir ki, 2012-ci ildən 2021-ci ilə qədər baş vermiş zəlzələ episentrlərinin məkan mövqeyi (afterşok sahəsi) kritik Kulon gərginliklərinin müsbət artım zonaları ilə əlaqələndirilir. Göründüyü kimi, onların baş verməsi 2012-ci ildə baş vermiş Zaqatala zəlzələləri nəticəsində yaranmış statik gərginliklərin lokalizasiyası və gərilmə tektonik gərginliklərinin toplanması ilə əlaqədardır ki, bu da birlikdə qırılma boyunca qeyri-sabitlik və sürüşmə hərəkətlərinin yaranmasına səbəb olmuşdur.

Açar sözlər: zəlzələ, zəlzələlərin ocaq mexanizmləri, Kulon gərginliyi, afterşok sahəsi.

4. 2018-Cİ İL BAYIL SÜRÜŞMƏSİNİN MÜHƏNDİSİ SEYSMO-GEOLOJİ ƏSASLANDIRILMASI

E.S.Qaravəliyev

Bakı şəhəri ərazisində çoxlu torpaq sürüşmə sahələri mövcuddur (Bayıl yamacı, Badamdar qəsəbəsinin cənub-şərq yamacı, Yasamal yaylasının cənub-şərq yamacı, Xocahəsən vadisinin cənub-şərq yamacı, Bakıxanov dağının şərq və cənub-şərq yamacı, Bülbülə gölünün ətrafı, Əhmədli yaylası, Zığ vadisi və s.) və bu sürüşmələr zaman-zaman aktivləşərək dövlət iqtisadiyyatına maddi zərərlər vurmuşlar.

Bayıl yamacı ərazisində baş verən sürüşmələr daha təhlükəli olmuşlar. Yamacda 1927, 1929, 1951, 1968, 1973, 1996, 2000, 2011-ci illərdə sürüşmələr qeydə alınmışdır.

Ərazidə son təhlükəli vəziyyət 2018-ci ilin yanvar ayında müşahidə olunmuşdur (kiçik dinamika ilə aktivləşmə 2017-ci ilin dekabrında qeydə alınmışdır). Belə ki, Dövlət Televizi ya Qülləsinin şimali-şərq istiqamətində, 250-300 metr məsafədə torpaqda müxtəlif ölçülü çatlar yaranmışdır. Çatların uzunluğu 80-100 metr, eni 1-1.2 metr, dərinliyi 5-7 metr olmaqla sürüşmə riski yaradan kütlə xeyli ərazini əhatə edirdi. Fevralın 10-u isə sürüşmə aktivləşərək uçqun və dağıntılara səbəb olmuşdur.

Ərazinin tədqiqi zamanı kompleks geofiziki üsullardan və geoloji kəşfiyyat quyu məlumatlarından istifadə edilmişdir.

Mühəndisi-seysmogeoloji tədqiqat işləri əsasında sürüşmə müstəvisinin 31.5-41.5 m dərinlikdə yatan qumlu-gilli süxur laylarının tavanında (layda eninə dalğa sürəti 350 m/s), tərkibində qumdaşı layları olan narın dənəli qumlar ilə sərhəddində yerləşməsi müəyyə n olunmuş və sürüşmənin yamacın üst hissəsindən olan su sızmalarının və kanalizasiya sisteminin olmaması səbəbindən məişət sularının Dördüncü dövr (Q4) yaşlı qumlu-gilli süxur laylar ını sululaşdırması, həmçinin yamacın bir çox yerlərdə kəsilməsi səbəbindən baş verməsi müəyyə n olunmuşdur.

Açar sözlər: torpaq sürüşməsi, mühəndisi seysmik kəşfiyyat, eninə dalğa sürəti

5. ZAĞULBA SAHİLİNDƏ QAZ TƏZAHÜRÜ SƏBƏBLƏRİNİN QİYMƏTLƏNDİRİLMƏSİ ÜZRƏ QRAVİMETRİK TƏDQİQATLAR

E.M.Bağırov

Dənizdə qaz əmələ gəlməsinin səbəblərini qiymətləndirmək üçün qravimetrik tədqiqatlar sahəsində nisbi ağırlıq qüvvəsinin dəyişən qiyməti ilə müşayiət olunan anomalzonalar müəyyən edilmiş, izoanomal xəritələr tərtib olunmuşdur.

Açar sözlər: qravitasiya, anomal zonalar, gərginlik şəraiti.

6. ZAQATALADA 01.03.2022-Cİ İLDƏ BAŞ VERMİŞ ZƏLZƏLƏDƏN (ML=4.2) ÖNCƏ MAQNİT SAHƏSİNİN ANOMAL DƏYİŞMƏLƏRİ

M.K.Məmmədova,A.N.Sultanova, , A.M.Quluyeva

Məqalədə zəlzələ ocaqlarının yaxınlığında geomaqnit sahə gərginliyinin anomal dəyişmələri haqqında məlumatlar öyrnilir. Seysmomaqnit effektin yaranma xarakteri ocaqdakı geomaqnit rejimlə təyin olunur. Geomaqnit sahəsinin gərginlik qradiyentinin məkan-zamana görə paylanması Zaqatala-Balakən zonasının geodinamik rejimini əks etdirir.

Açar sözlər: SME-seysmomaqnit effekt, nT- nanotesla, zəlzələ ocağının mexanizmi, geodinamik rejim, geomaqnit sahə gərginliyi.ml-maqnituda

АННОТАЦИИ

1. ОСОБЕННОСТИ СЕЙСМИЧНОСТИ ТЕРРИТОРИИ АЗЕРБАЙДЖАНА ИБЛИЗЛЕЖАЩИХ ТЕРРИТОРИЙ ЗА 2020 г.

Г.Дж.Етирмишли, С.С.Исмаилова, С.Э.Казымова

В 2020 году был проведен анализ сейсмичности на основе 40 цифровых сейсмических станций. В течение года было зарегистрировано 13295 землетрясений. Изних 4030 местных землетрясений (произошедших на территории Азербайджана), 3347 региональных и 3123 отдаленных землетрясений. Кроме этого было зафиксировано 1463 слабых толчка (зафиксированых одной станцией) и 1332 промышленных взрывов. По сравнению с 2019 годом количество землетрясений в 2020 году и количество выделяемой сейсмической энергии уменьшились. Так, в 2020 г. произошло 4030 землетрясений : количество выделившейся сейсмической энергии $\sum E=13{,}1\cdot10^{11}$С, максимальная магнитуда ml = 4,9. В течение 2020 года сейсмичность наблюдалась на Большом Кавказе, в бассейне Средней Куры и Каспийском море. Сейсмическая активизация наблюдается по Западно-Каспийскому, Пальмирско-Апшеронскому, Аджичай-Алатскому, Гянджачай-Алазанскому, Газахско-Сигнахскому, Талышскому, Ахвайскому, Сангачал- Огурджускому, Гарабогаз-Сафидрудскому,Аграханско-Каснаводскому, Хачинчайскому разломам.

Область растяжения на территории Азербайджана делится на две области по Геокчайскому разлому и Имишли-Геокчайскому прогибу: северо-восточная часть республики характеризуется растяжением, а юго-западная - сжатием. Напряженность наблюдается в Абшеронском районе и в пределах акватория Каспия.

Ключевые слова: сейсмический анализ, Западно-Каспийский разлом, Пальмиро-Абшеронский, Аджичай-Алатский тектонические разломы, анализ механизмов очагов.

2. АНАЛИЗ СОВРЕМЕННЫХ ДВИЖЕНИЙ БЛОКОВ ЗЕМНОЙ КОРЫ АЗЕРБАЙДЖАНА ПО ДАННЫМ GPS- СТАНЦИЙ ЗА 2020-2021 гг.

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

В статье представлена методика расчета полей скоростей современных горизонтальных смещений тектонических блоков Азербайджана, полученных по результатам наблюдений на 24 стационарных станциях GPS_RCSS, характерным аспектом которых является заметное горизонтальное смещение в северо-восточном направлении со скоростью 4–12 мм/год. В данной статье изучено поле скоростей тектонических блоков на территории Азербайджана по результатам GPS измерений, рассчитанных по программе GAMIT (Global Navigation Satellite System (GNSS) в Массачусетском технологическом институте) [4]. Установлено, что вдоль Малого Кавказа, в Куринской котловине, Нахчыванской АР и приграничных районах Ирана имеется зона сжатия, ориентированная на СВ. Максимальное значение скорости деформации на всей территории Азербайджана, колеблется в пределах 13,7 мм/год, среднее значение по всем станциям 7,9 мм/год. Анализ поля скоростей также показал низкие значения скоростей на Большом Кавказе (4-6 мм/год). Кроме того, был проведен корреляционный анализ значения скоростей с сейсмической активностью региона. Сделан вывод о наличии определенной связи между изменением значений скоростей горизонтальных движений и распределением сильных землетрясений поля скорости деформации земной коры.

Ключевые слова: GPS станции, геодинамика, тектонические блоки, Южно-Кавказская микроплита.

3. ИЗМЕНЕНИЕ КУЛОНОВСКИХ НАПРЯЖЕНИЙ ПОСЛЕ СИЛЬНЫХ ЗЕМЛЕТРЯСЕНИЙ НА ТЕРРИТОРИИ БОЛЬШОГО КАВКАЗА ЗА ПЕРИОД 2012-2021 гг.

С.Э.Казымова

В статье исследуется сейсмотектоническая позиция сильного землетрясения, произошедшего на территории Азербайджанской части Большого Кавказа за период 2012-2021 гг. Бали проанализированы механизмы очагов сильных землетрясений: Загатальские 7.05.2012 с Ml=5.6, 5.7, Балакенское 14.10.2012 с Ml=5.8,; Исмаиллинское 07.10.2012, 2019, 2021 гг. с Ml=5,1-5.3; серия Габалинских 29.09 и 04.10.2014 г. с Ml=5.5;

а также Огузское 04.09.2015 г. Анализ показал, что в результате динамических напряжений в районах Закатал-Габала и Балакан-Огуз-Исмаиллы, в первом случае наблюдалась инициированная сейсмичность, а во втором – нет. Исходя из этого, возникло предположение, что разломы, на которых происходят инициированные землетрясения, должны находиться в субкритическом, метастабильном состоянии. Было установлено что пространственное положение эпицентров землетрясений (афтершоковое поле), произошедших с 2012 по 2021 г., коррелирует с зонами положительных приращений критических Кулоновских напряжений. Их возникновение,по всей видимости, связано с накоплением тектонических напряжений субширотного растяжения и локализацией статических напряжений, инициированных Закатальскими землетрясениями 2012 г. что в совокупности привело к возникновению неустойчивости и сдвиговым перемещениям по разлому.

Ключевые слова: землетрясение, механизмы очага, Кулоновское напряжение, афтершоковое поле.

4. ИНЖЕНЕРНО СЕЙСМОГЕОЛОГИЧЕСКОЕ ОБОСНОВАНИЕ БАИЛОВСКОГО ОПОЛЗНЯ 2018 ГОДА

Э.С. Гаравелиев

Оползни на Баиловском склоне зафиксированы с древних времен. Сведения об оползнях в этой зоне отмечены в работах геолога-нефтяника Г. В. Абиха. Сообщалось, что в 1874 и 1877 годах вдоль западного берега Бакинской бухты, на склоне длиной около 200 метров, на участках серой глины произошли оползни. Позднее, в 1927, 1929, 1951, 1968, 1973, 1996 годах, на Баилском склоне наблюдались активизации оползней.

6-7 марта 2000 года были волнующие моменты когда оползень снеся дома, заправку, подсобные строения, заводской цех, шоссе и т.д. нанес значительный ущерб экономике государства.

В материалах по всем оползням в этой территории отмечено, что профилактические мероприятия не проводились в полной мере, наоборот, велась работапо содействию реактивации оползня. Так, в нижней части Баиловского склона, от гостиницы «Интурист» до Сабаильского районного пожарного управления, велись строительные работы, дорога была прорыта, на дорогах на склоне использовалась тяжелая техника и движение транспорта было более интенсивным, чем раньше. Все эти факторы являются причинами активизации оползня.

Последняя опасная ситуация в районе наблюдалась в январе 2018 г. (активизацияс небольшой динамикой зафиксирована в декабре 2017 г.). Так, в северо-восточном направлении от Государственной Телебашни на расстоянии 250-300 метров, в грунте появились трещины различных размеров. Трещины имея длину 80-100 м, ширину 1-1,2 м и глубину 5-7 м объём создающий оползневой риск покрывали большую площадь (рис.1, 4).

В стенах домов, заборах, асфальтовых покрытиях, пристройках и перед домами наблюдались новые трещины.

Хотя склон был озеленен, чтобы предотвратить эрозию, и было посажено много деревьев, но система орошения не была установлена должным образом, на некоторых участках не проводилось капельное орошение, и чувствуется паводковое орошение. Построенный водопровод, резервуары, питомники, дополнительные сооружения, грунтовые дороги по склону проложены без плана. Новые постройки - жилые дома и др.без канализации не были построены должным образом с инженерной точки зрения

Ключевые слова: оползень, инженерная сейсморазведка, скорость поперечной волны.

5. ГРАВИМЕТРИЧЕСКИЕ ИССЛЕДОВАНИЯ ДЛЯ ОЦЕНКИ ПРИЧИНПОЯВЛЕНИЯ ГАЗА НА ПОБЕРЕЖЬЕ пос. ЗАГУЛЬБА.

Э.М.Багиров

Для оценки причин газообразования в море в области гравиметрических исследований были выделены аномальные зоны, сопровождающиеся переменнымзначением относительной силы тяжести, и построены изоаномальные карты.

Ключевые слова: гравитация, аномальные зоны, сила тяжести, напряженныеусловия.

6. АНОМАЛЬНОЕ ИЗМЕНЕНИЕ ГЕОМАГНИТНОГО ПОЛЯ ПЕРЕДЗАГАТАЛЬСКИМ ЗЕМЛЕТРЯСЕНИЕМ (ML=4.2) 01.03.2022 г.

М.К.Маммедова, А.Н.Султанова, А.М.Гулиева

Изучено аномальное поведение напряженности геомагнитного поля вблизи очаговой зоны Загатальского землетрясения (ml=4.2) 01.03.2022 г. Показано, что характер формирования сейсмо-магнитного эффекта (СМЭ) отражает геодинамический режим в очаговой зоне. Загатало-Балакянская сейсмогенная зона четко оконтуривается на карте пространственно-временных приращений градиента напряженности геомагнитного поля.

Ключевые слова: сейсмомагнитный эффект СМЭ, нанотесла (нТл), механизм очага земле-трясения, геодинамический режим, напряженность геомагнитного поля, магнитуда ml.

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Republican Seismic Survey Center
of Azerbaijan National Academy of Sciences
Phone: +994 12 492-34-37;
Fax: +994 12 492-31-65;
E-mail: qebul@rsxm.science.az

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