MODERN GEODYNAMICS AND SEISMICITY OF THE LOWER KURA OIL AND GAS BEARING REGION

Yetirmishli G.J.[1], Guseyn-zade G.E.[1], Kazimova S.E.[1]

Introduction

The Lower Kura depression oil and gas bearing region, as an integral part of the South Caspian depression, is a recognized oil and gas generating basin, characterized by positive stratigraphic, lithofacies and structural-tectonic criteria for oil and gas potential. The southwestern part of the area - the Mugan-Salyan syncline and the Mugan monocline, where the deposits of the productive stratum (PT) are completely wedged out, is also highly promising in terms of the genesis of hydrocarbons and the formation of oil and gas deposits [3]. As is known, the Kura depression is an intermountain synclinal trough, bounded in the north by the Greater Caucasus, in the southwest by the ridges of the Lesser Caucasus, in the west by the Suram ridge and is composed mainly of a thick layer of Cenozoic and Mesozoic deposits. In addition, it should be noted that Azerbaijan is a classic mud volcanic province. In terms of the number of mud volcanoes, their diversity and intensive activity, this region has no equal in the world. There are over 350 mud volcanoes here. Almost all manifestations of mud volcanism in Azerbaijan are associated with oil and gas bearing structures. Six oil and gas bearing regions are distinguished here, within which mud volcanoes are located: the Caspian-Guba, Shamakhi-Gobustan, Absheron, Lower Kura depression, Baku archipelago, the deep-water part of the South Caspian [12]. The seismicity of the Lower Kura depression is considered to be moderate. However, seismic analysis of recent years has shown an increase in activity in this region. The Lower Kura depression belongs to the zone of 8-point. However, it is important to study the seismicity of the southern part of the basin, where the population density is the highest, and settlements are located near active faults. Spatial migrations of the seismic process, as reflections of changes in the stress-strain state of the earth's crust, are interpreted in different ways [6].

At the same time, the trigger effects of strong earthquakes (stress transfer) are widely known, when events comparable in energy follow each other with a small (years, first decades) interval. At the same time, it is assumed that stress transfer can occur quickly as a result of the elastic reaction of the upper crust [1], and slowly as a result of the viscous-elastic reaction of the lower crust and upper mantle over long distances [2], which can affect the change in oil production in wells and activation of mud volcanic activity.

The Lower Kura depression oil and gas region occupies the northeastern part of the depression of the same name [4, 5, 13]. On the territory of this region, several large oil and gas fields have been discovered and are being developed, mainly associated with the productive strata (Kyurovdag, Garabagly, Neftchala, Kursanga, Mishovdag, Galmaz, Kalamaddyn (Fig. 1).

In tectonic terms, from the north-northeast, the region borders on the Shamakhi-Gobustan highlands through the Lengebiz-Alyat anticline belt. The southern limb of the belt serves as the northern edge of the Lower Kura depression. The western boundary of the depression is considered to be the West Caspian and Lower Araz faults, to the west of which the Goychay-Saatly uplifted zone and the Yevlakh-Agdjabady trough are located [7]. The southern side of the depression is known in the geological literature as the Mugan monocline (according to the Pliocene layers) and stands out as an independent promising and gas-bearing region - the Milsko-Mugan. The most submerged part of the modern depression, the Mugan-Salyan synclinal trough, serves as the boundary of these oil and gas bearing regions [11, 9].

To the east, the Lower Kura depression spreads to the junction with the Baku archipelago, tectonically separated from it by the Alyat-Gyzylagach transverse fault. The depression on the surface of the Mesozoic in the regional plan is the centroclinal part of a vast trough, the main part of which is located within the South Caspian.

The Lower Kura depression oil and gas bearing region is tectonically a complex geological body subjected to wave and fold movements of a regional and local nature. In the Neogene and Anthropogene,

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

it experienced the greatest subsidence, which was compensated by sedimentation. The thickness of sedimentary formations here exceeds 15–16 km. The zone covers the southern side of the Lengebiz-Alyat anticlinorium, the Gargaly synclinorium, and the Harami-Salyan anticlinorium and is called the Shirvan tectonic zone [11].

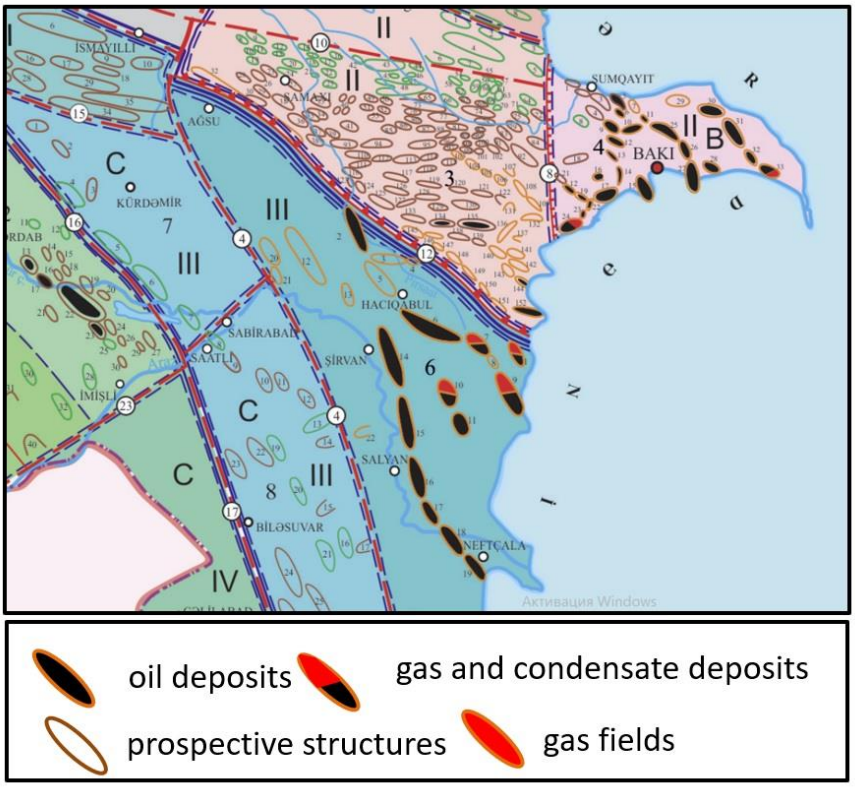

Figure 1. Map of the oil and gas bearing zone of the Lower Kura depression [14].

With the exception of the Kursangi and Padar folds identified by seismic exploration, the rest of the uplifts of the Lower Kura depression were identified by geological surveys and studied by structural mapping and exploration drilling. In the geological section of the folds, mainly Anthropogenic-Pliocene deposits take part. Within some uplifts, deep boreholes also uncovered Oligocene-Miocene deposits (Kalamaddyn, Harami, Kyurovdag). In most cases, on the vaults of anticlines, an eroded productive stratum protrudes to the day surface from above, successively bordered by the Akchagyl and Apsheron layers. Anticlinal belts are complicated by regional longitudinal faults along the crests of folds, sometimes doubled. Transverse discontinuous disturbances are frequent, giving the folds a blocky character. In the northwestern part of the region (Kala-Maddyn-Kharami zone), through (regional) transverse faults are also observed [11]. On the vaults of many folds, mud volcanoes are active, associated with faults. Among the ejecta of mud volcanoes there are pieces of rocks up to the Cretaceous age. There are also buried mud volcanoes (Padar) and layered hilly breccias (Kalamaddyn, Harami, etc.)

The main object for prospecting and exploration of industrial deposits of oil and gas are the productive strata, the Akchagyl and Apsheron stages, as well as in the near future Paleogene-Miocene deposits and, probably, Mesozoic deposits on the sides of the depression.

Seismicity of the Lower Kura depression

The Lower Kura depression is one of the regions of Azerbaijan where the probability of strong earthquakes is not high. As mentioned above, the Lower Kura depression belongs to the zone of 8-point. In addition, in recent years, active construction of oil and gas production and processing facilities and related infrastructure has been carried out on the territory of the region under study. New lines of gas

and oil pipelines are stretching, which pass through seismically dangerous territories. It should be noted that similar studies were carried out earlier and were presented in [8].

The seismicity of the Lower Kura depression is considered to be moderate. Throughout the history of seismic observations, earthquakes have been recorded here. As an example, we can note the earthquakes that occurred in the Imishly region on February 5, 1985 with an intensity of I=5-6 points, on April 24, 1989 with an intensity of I=5 points, on January 1, 1991 with an intensity of I=6 points and the Saatly-Sabirabad earthquake that occurred on April 19, 1989 with intensity I=5 points.

In depression zones, earthquakes with magnitude M=4-5, intensity I=V-VI points can be generated. The Kurovdag-Neftchala seismogenic zone is caused by an active fault, which is practically a seismogenic in plastic media. Within the Lower Kura depression, the maximum magnitude of expected events associated with local seismogenic structures in the West Caspian zone is 5.4 and 5.7, and in the Kurovdag-Neftechala zone - 5.5.

In recent years, in connection with the modernization of the seismic network and the increase in seismic stations, new data on the seismicity of the territory of the Lower Kura depression have appeared, which require systematization and analysis. Figure 2 shows a map of the epicenters of earthquakes that occurred within the study region for the period 2003-2022 with $m_l \geq 3.0$ and $m_l \geq 4.0$. The catalog of earthquakes was taken from the Scientific Reports of the RSSC ANAS [15]. As can be seen in the Figure, earthquakes are not evenly distributed. It is possible to single out an accumulation in the zone of Saatly-Imishli and Gobustan-Shirvan regions. This accumulation indicates the presence of seismogenic zones in this region. As can be seen on the seismic profiles in the NW-SE direction, two zones of distribution of hypocenters 0-10 km and 10-25 km are distinguished with a slight tendency to dip. On the seismic profile in the SW-NE direction, at a depth of 35-60 km, the Saatly-Imishli seismogenic zone is distinguished, at the epicentral distance of 60-85 km, the Hadjigabul, at the epicentral distance of 85-110 km, the Shamakhi seismogenic zone (Fig. 3).

Over the past 20 years, there has been a gradual increase in seismic activity in the study region.

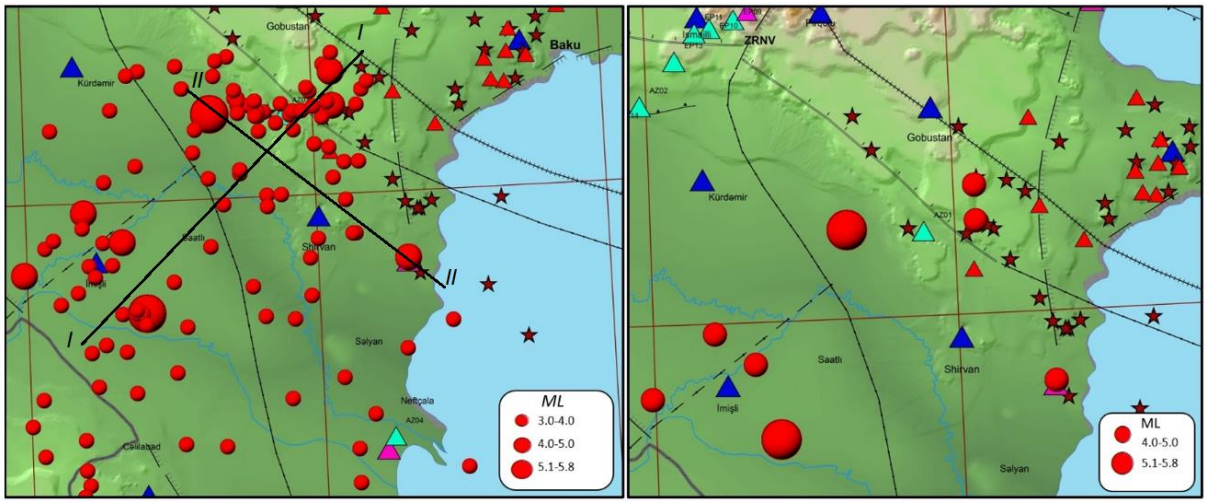

Figure 2. Maps of earthquake epicenters that occurred on the territory of the Lower Kura depression in 2003-2022

A burst of released seismic energy observed in 2014 and 2017 was recorded in August ($E=38.6\times10^{11}$ Joule), when an earthquake occurred on August 1 at 04^h46^m with K=12.3, ML=5.6 in the Kura depression. In 2014, on the territory of the Lower Kura depression on February 10 at 12:06 pm, the strongest seismic event occurred on the territory of the republic with Ml=5.7. This earthquake occurred at a significant depth h=46 km and was felt at the epicenter with an estimated intensity of 6 points. The source of the earthquake is confined to the surface of Moho. Eight aftershocks with $Ml \leq 2.0$ were registered. A small number of aftershocks after strong earthquakes is characteristic of relatively deep seismic events in the Kura Depression. Their source area is located in the zone of action of the orthogonal Astara-Derbent and transverse Palmyr-Absheron faults [10].

In 2017, a burst of released seismic energy was registered in May ($E=30.4\times10^{11}$J) and in July ($E=59.1\times10^{11}$ Joule), when strong earthquakes with Ml>5 occurred: May 11 at 03^h24^m with Ml=5.4 and November 15th at 19^h48^m with Ml=5.7. These earthquakes also occurred in the Kura depression and near it, in the territory of the Lesser Caucasus.

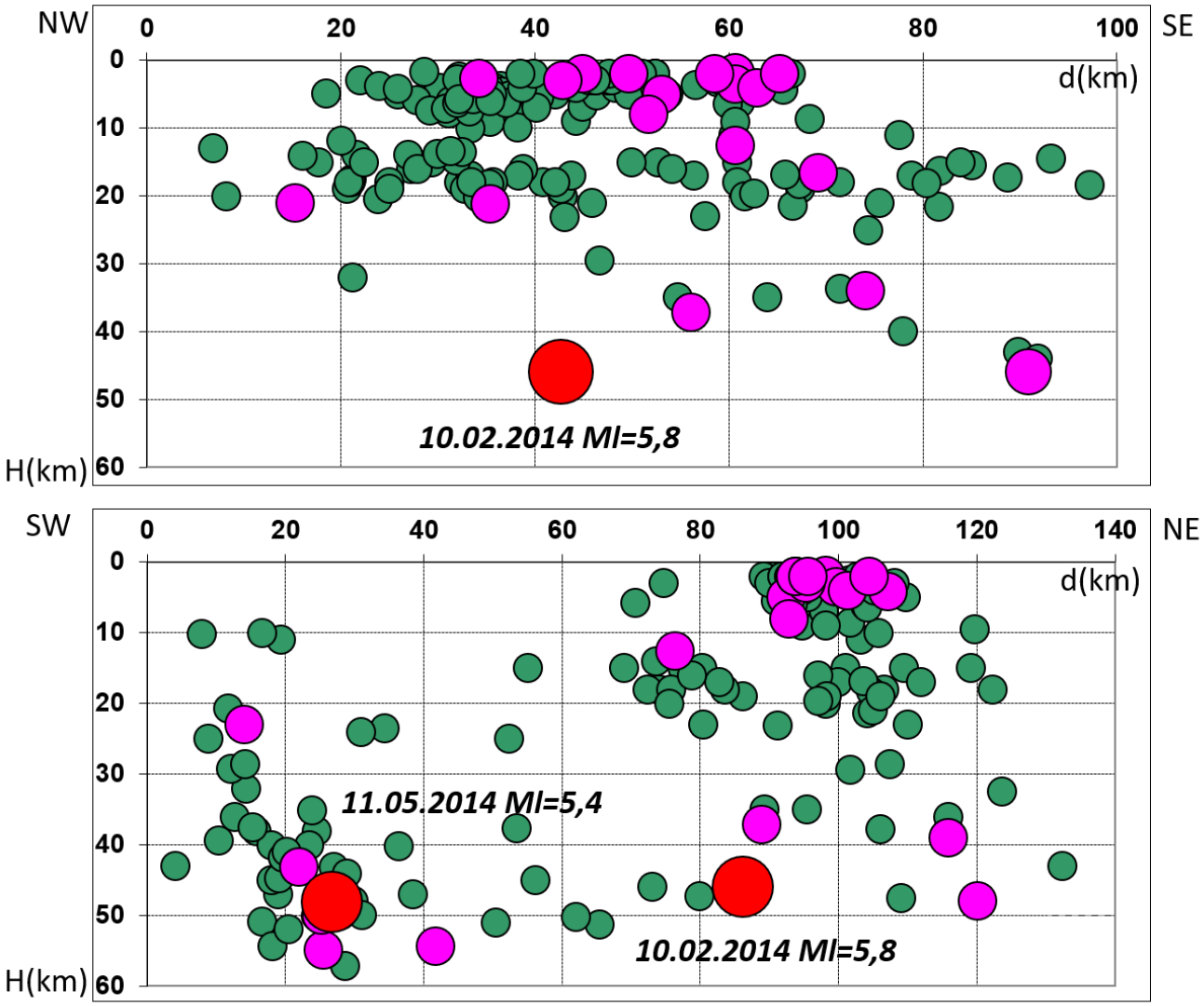

Figure 3. Seismological profiles along and across the strike of the Lower Kura depression

It should be noted that in 2016 the strongest earthquake on the territory of the republic was the earthquake on August 1 with Ml=5.6, which occurred on the territory of the Kura depression, adjacent to the northeastern part of the Lesser Caucasus. 14 aftershocks with Ml=1.0–4.1 were registered. The earthquake was felt at the epicenter with an intensity of 5 points. The strongest aftershock with Ml=4.1 occurred on the same day at 07^h51^m and was felt with an intensity of up to 3 points. The focal area is located in the zone of action of the Kura longitudinal and Chakhirly-Gabala orthogonal faults. In addition, on May 11 at 03^h24^m with Ml=5.4 another earthquake occurred in the territory of the Lower Kura Depression. The earthquake caused tremors in settlements with an intensity of up to 3-4 points. Eight aftershocks were registered. The increase in the number of earthquakes in 2019-2020-2021 is also associated with activity on the border of the Gobustan and Shirvan regions.

As can be seen on the maps of the distribution of seismic activity, activity with values A=1.6-2.0 was noted at the junction of the Shamakhi and Shirvan seismogenic zones, and the Saatly-Imishli seismogenic zone is also distinguished (Fig. 4).

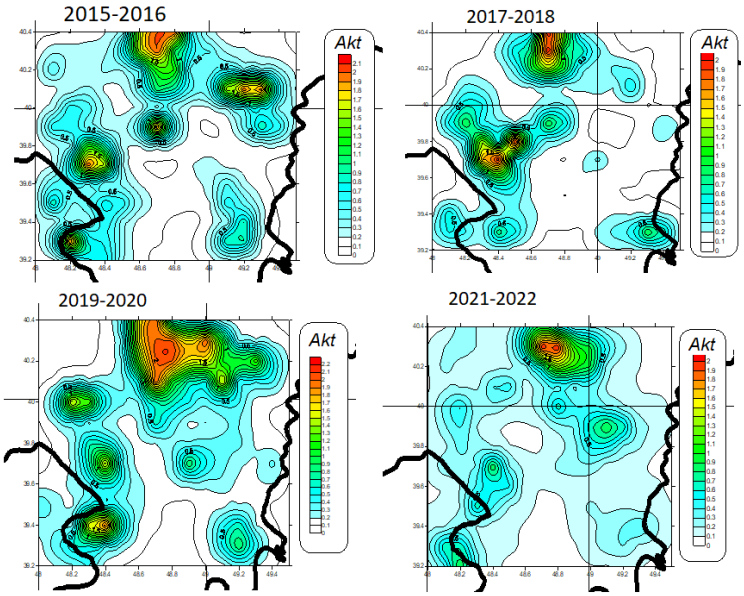

Figure 4. Map of the distribution of seismic activity in the Lower Kura depression for 2015-2022

Source parameters of earthquakes in the Lower Kura depression

The study considered seismological data recorded by a network of telemetry stations for the period 2003-2022. The earthquake source mechanisms were calculated from the signs of the first arrivals of P-waves at digital stations, which are located in the range of epicentral distances of 15-350 km with a fairly uniform distribution in azimuths. For a perceptible earthquake that occurred on February 10 in the Hadjigabul region, the compressive stresses are oriented near-latitudinal (AZM=87°) and near-vertical (PLP=61°), and the tensile stresses are near-meridional (AZM=192°) and near-horizontal (PLP=8°) (Fig. 5). Type of movement along both planes (DP1=59°, DP2=44°) – fault with shear elements. Plane NP1 has a southeast trend (STK1=125°), and NP2 has a west-southwest trend (STK2=253°). The source region is located in the zone of action of the orthogonal Astara-Derbent and transverse Palmyro-Absheron.

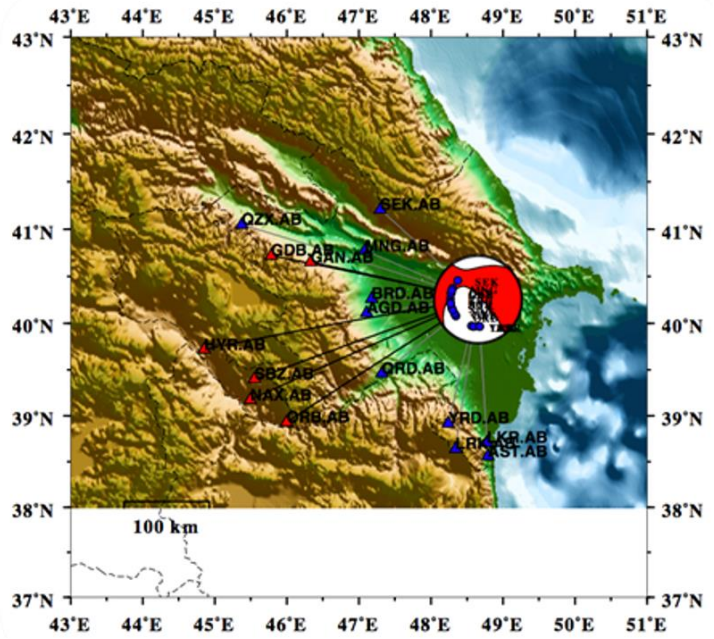

Figure 5. Source mechanism of the Hadjigabul earthquake that occurred on February 10, 2014

For the earthquake on August 1, 2016 at 04^h46^m with Ml=5.6 that occurred in the Imishli region of the Kura depression, the focal mechanism stereogram is shown in Fig.6. According to this solution, the movement in the source occurred under compression conditions: the compressive stress axis is near-horizontal (PLP=18°) and oriented in the NE direction (AZM=47°), while the tensile stress axis is near-vertical (PLT=70°) and oriented to the SW direction (AZM=254°). The movement in the source along the NP1 plane is a reverse fault (DP1=63°), along the NP2 plane it is a thrust (DP2=28°). Plane NP1 has a northwest strike (STK1=324°), NP2 - southeast (STK2=123°). The focal area is located in the zone of action of the Kura longitudinal and Chakhirly-Gabala orthogonal faults.

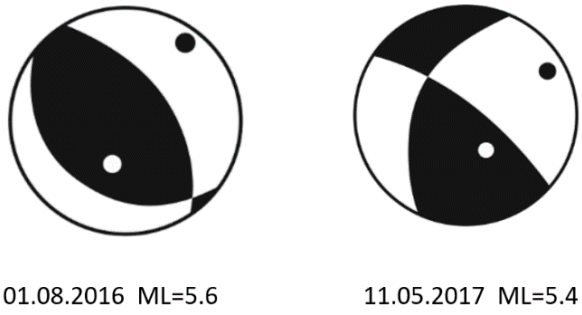

Figure 6. Source mechanisms of earthquakes on August 1, 2016 with ML=5.6 and May 11, 2017 with Ml=5.4

For the Saatly earthquake on May 11, 2017 at 03^h24^m with Ml=5.4 that occurred on the territory of the Lower Kura depression, the main tectonic stresses that acted in the source correspond to near-horizontal (PLP=19°) extension of the northeast orientation and intermediate (PLT=41°) extension south-southeast orientation. The slope of the first nodal plane is DP1=77°, the second one is DP2=46°. The movement along the first plane NP1 of northwestern orientation is a reverse fault, along the second plane NP2 of southwestern orientation it is a right-sided strike-slip with small elements of reverse fault. The focal area is located in the zone of action of the Savalan-Absheron transverse fault.

After analyzing 105 earthquake source mechanisms, it was revealed that in 2003-2014 fault-shear movements prevailed on the territory of the Lower Kura depression, in 2015-2022 surges are observed. An analysis of the orientations of the axes of compression and extension of the region under study showed that the axis of compression in the Shamakhi-Gobustan region is oriented in the NE-SW direction, however, in the Saatli and Imishli regions, the orientation changes and fluctuates within the azimuth angles of 300-340 and 110-150 (Fig. 7). An analysis of the stress state coefficient of the Lower Kura depression showed the predominance of tensile stresses.

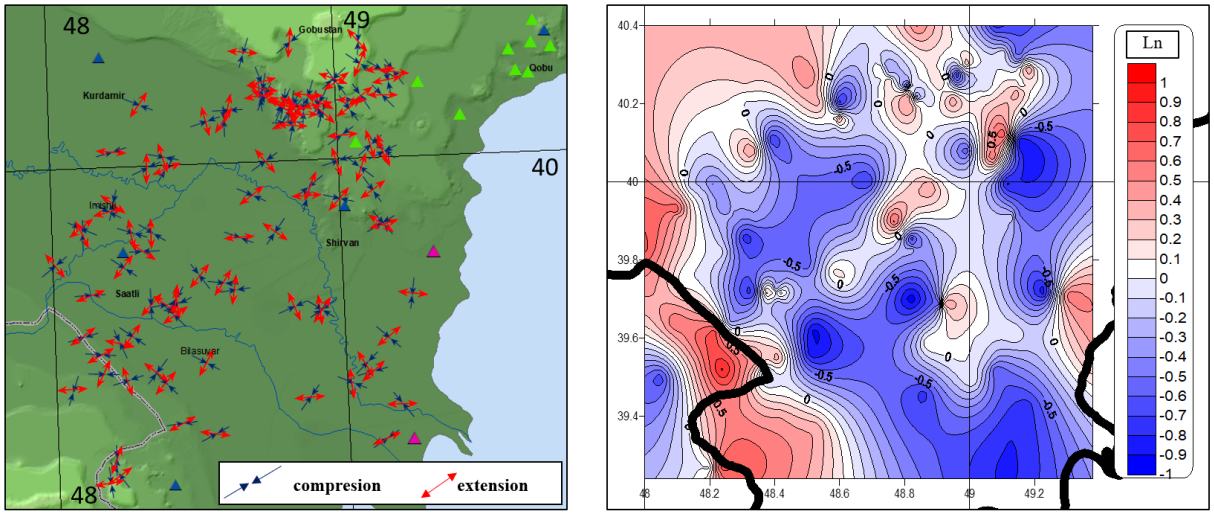

Figure 7. Map of the distribution of compression and tension axes, as well as the stress state coefficient of the Lower Kura depression

Results

The distribution of earthquake epicenters by area occurred within the study region for the period 2003-2022 showed an uneven distribution of earthquake sources. The accumulation of earthquakes is highlighted in the zone of Saatly-Imishli and Gobustan-Shirvan regions. This accumulation indicates the presence of seismogenic zones in this region. The change in the magnitudes of earthquakes over time showed a periodicity in the release of energy: after a burst of energy, its decline is observed. Analysis of seismic profiles in the NW-SE direction made it possible to identify two zones of distribution of hypocenters 0-10 km and 10-25 km with a slight tendency to subside. On the seismic profile in the SW-NE direction, at a depth of 35-60 km, the Saatly-Imishli seismogenic zone is distinguished, at the epicentral distance of 60-85 km, the Hadjigabul, at the epicentral distance of 85-110 km, the Shamakhi seismogenic zone.

An analysis of 105 earthquake focal mechanisms made it possible to identify in the territory of the Lower Kura depression in 2003-2014, fault-slip movements mainly prevailed, in 2015-2022 surges are observed. An analysis of the orientations of the axes of compression and extension of the region under study showed that the axis of compression in the Shamakhi-Gobustan region is oriented in the NE-SW direction, however, in the Saatli and Imishli regions, the orientation changes and fluctuates within the azimuth angles of 300-340 and 110-150. An analysis of the stress state coefficient of the Lower Kura depression showed the predominance of tensile stresses.

REFERENCES

1. Chery J., Merkel S., Bouissou S. A Physical Basis for Time Clustering of Lage Earthquakes //Bull. Seismol. Soc. Am. 2001. Vol. 91. P. 1685-1693.
2. Pollitz F., Vergnolle M., Calais E. Fault interaction and stress triggering of twentieth century earthquakes in Mongolia // J. Geophys. Res. 2003. Vol. 108. № B10. 2503. doi: 10.1029/2002JB002375.
3. Алекперов Э.Ф. Геологические условия формирования нефтегазовых залежей в неструктурных ловушках Муганской моноклинали, Геология, поиски и разведка нефтяных и газовых месторождений, Автореферат, Баку, 2000, 21 с.
4. Алиев А.К. Геология и нефтегазоносность Кура-Араксинской области.Баку: Азернешр, 1960, 362 с.
5. Али-заде А.А., Ахмедов Г.А., Ахмедов А.М. и др. Геология нефтяных и газовых месторождений Азербайджана. - М.: Недра, 1966, 392 с.
6. Быков В.Г. Деформационные волны Земли: концепция, наблюдения и модели//Геология и геофизика. 2005. Т. 46. № 11. С. 1176-1190.
7. Геология Азербайджана, Том IV Тектоника, ред. Хаин В.Е., Ализаде Ак.А. 2005. Баку, Из-во Nafta-Press, С. 214-234.
8. Етирмишли Г.Дж., Казымова С.Э. Динамика сейсмичности Нижнекуринской впадины на основе цифровых сейсмологических данных // Azərbaycan ərazisində seysmoproqnoz müşahidələr, Bakı. 2012, 167-173
9. Етирмишли Г.Дж. Распределение нефтяных и газовых месторождений в сейсмо-геодинамических условиях Нижнекуринской Депрессии. Кандидатская дисс., Баку, 2000, 180 с.
10. Кенгерли Т.Н., 2007 г. Особенности геолого-тектонического строения юго-восточного Кавказа и вопросы нефтегазоносности, Elmi əsərlər, №9, Гос. Нефт. Компания Респ. Азербайджан. с. 3-12
11. Керимов К.М Геофизические исследования в Азербайджане. Баку, ШаргГарб 1996, 400 с
12. Устюгов Г.В., Ершов В.В. Извержения грязевых вулканов Азербайджана и их корреляция с сильными землетрясениями // ВЕСТНИК ВГУ. СЕРИЯ: ГЕОЛОГИЯ. 2019. № 4, с. 1-13
13. Шихлинский А.Щ. Геология и перспективы нефтегазоносности плиоценовых отложений Нижнекуринской впадины;- Баку: АзГосиздат, 1967, 233 с
14. Hüseynov B., Salmanov Ə., Məhərrəmov B. Azərbaycanın quru ərazisində neft-qaz-geoloji rayonlaşdırma (monoqrafiya), Bakı,"Mars Print"nəşriyyatı 2019, 309 s.
15. Seysmoloji bölmənin 2012-2021-ci illərdə Azərbaycanın seysmoaktiv bölgələrində apardığı tədqiqatların hesabatları, İşin rəhbəri Q.C.Yetirmişli, Bakı.