SEISMOGEODYNAMICS OF THE CASPIAN SEA FOR 2018-2020 years

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Introduction

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

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

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

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

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

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

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

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

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

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

Seismicity of the Caspian Sea.

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

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

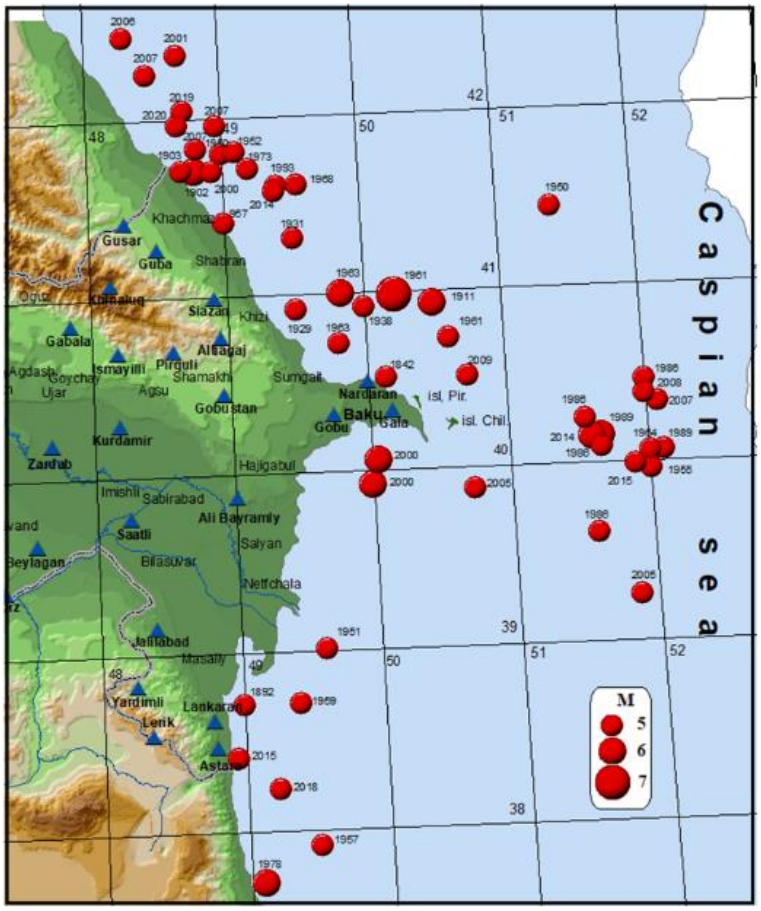

Figure 1. The map of epicenters of historical earthquakes in the Caspian Sea.

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

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

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

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

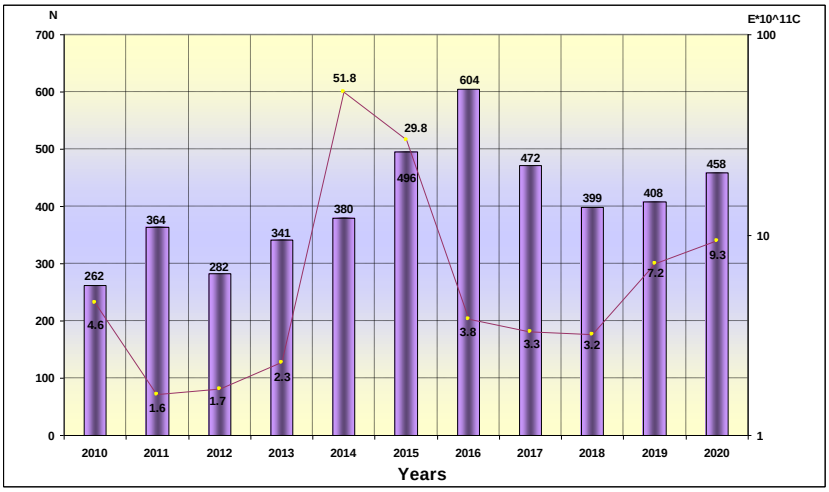

Figure 2. Number of earthquakes in the Caspian Sea during 2010-2020 years and a histogram of the distribution of seismic energy over the years

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

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

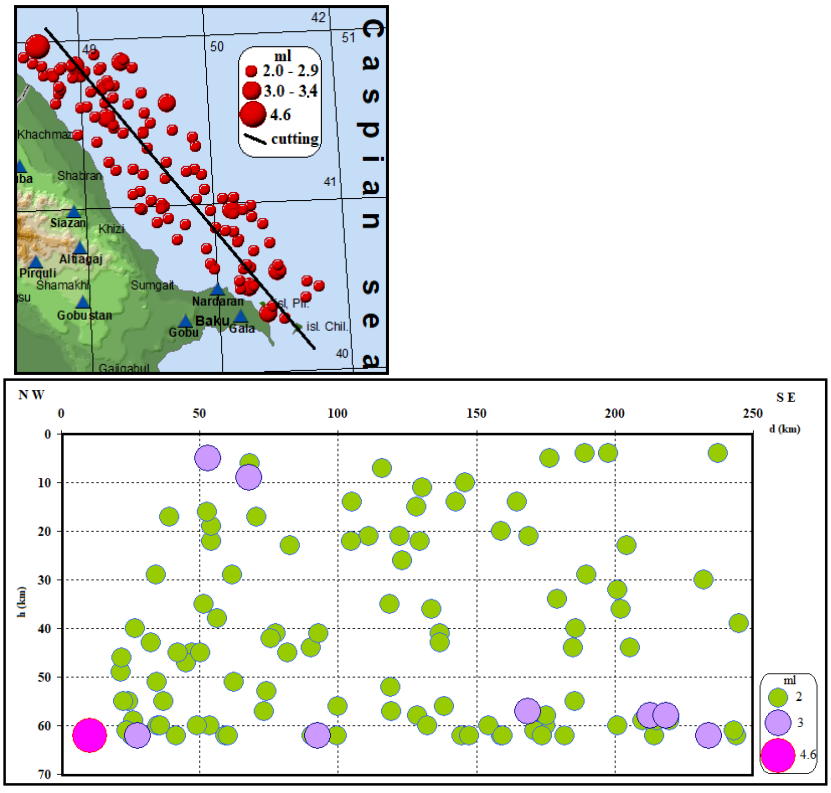

Figure 3. Seismological section of the northern part of the Caspian Sea on profile I-I.

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

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

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

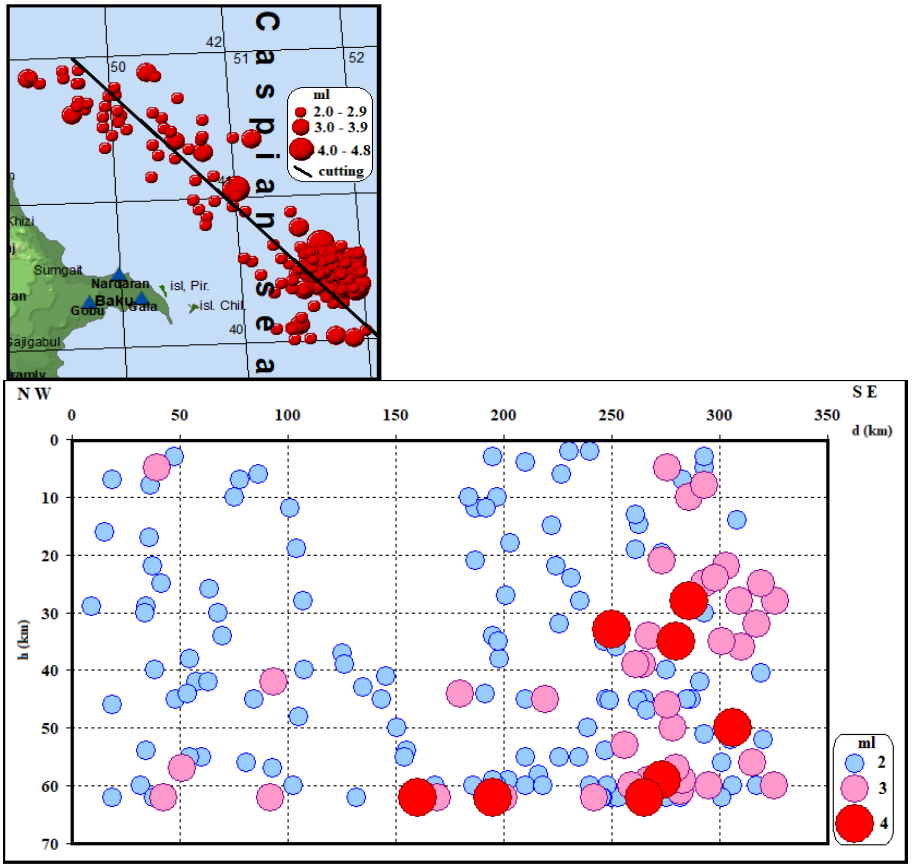

Figure 4. Seismological section of the northern part of the Caspian Sea on profile II-II.

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

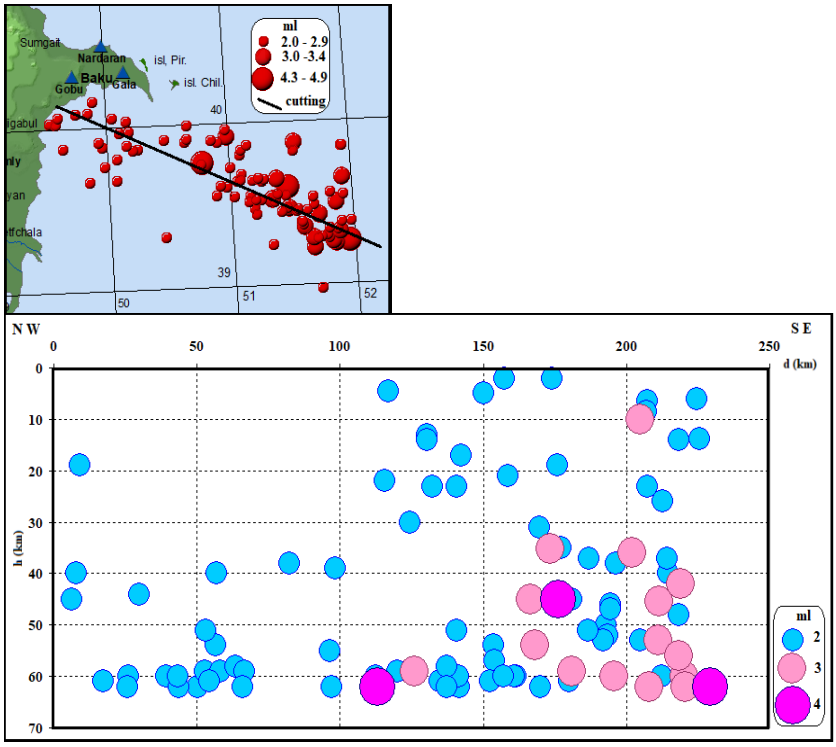

Figure 5. Seismological section of the southern part of the Caspian Sea on profile III-III.

Analysis of earthquakes occurred in 2018-2020 years

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

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

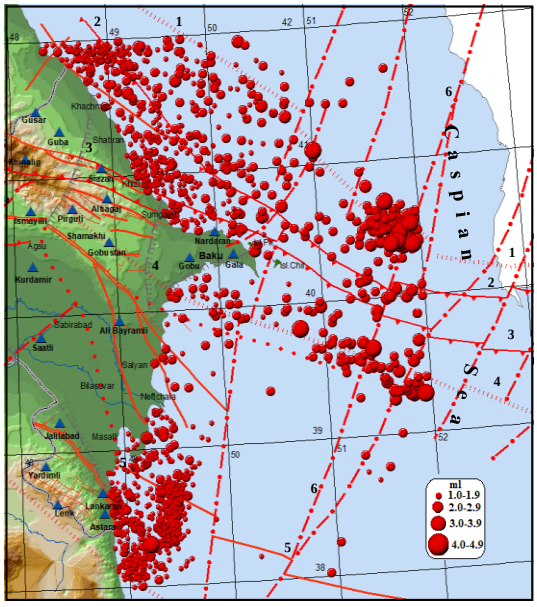

Figure 6. The epicenters map on faults of earthquakes with a magnitude of ≥1.0 occurred in the Caspian Sea in 2018-2020 years [9, 10].

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

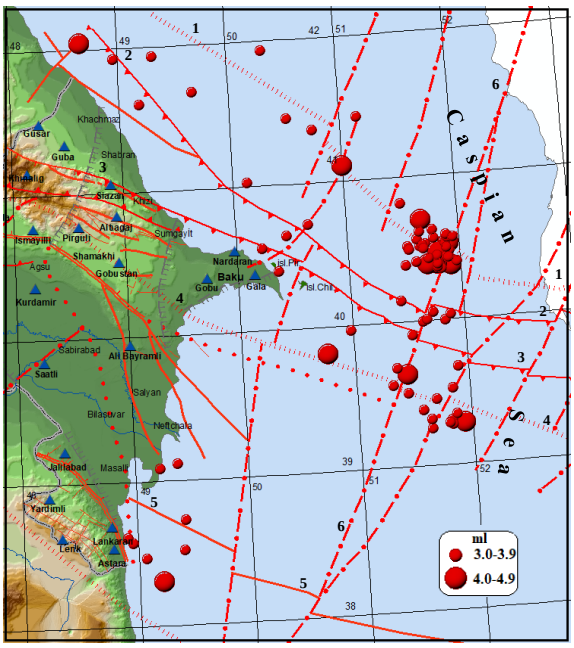

Fig. 7. The epicenters map on faults of earthquakes with a magnitude of ≥ 3.0 occurred in the Caspian Sea in 2018-2020 years[9, 10].

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

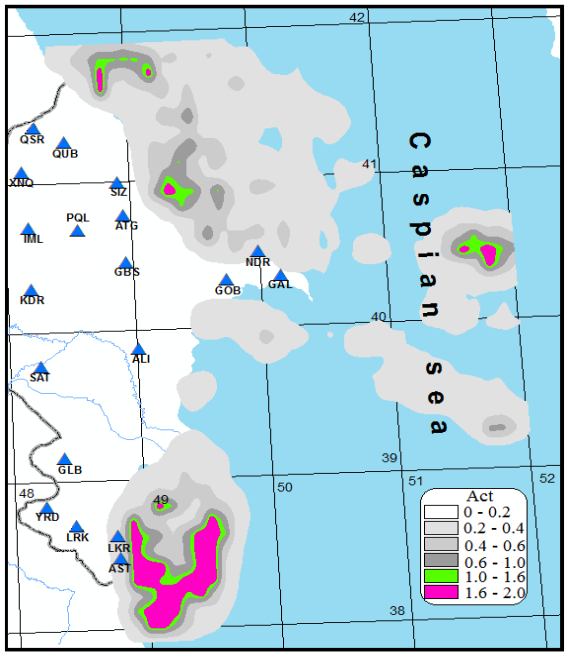

Figure 8. The activity map of the earthquakes in the Caspian Sea during in 2018-2020 years.

Earthquake source mechanisms

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

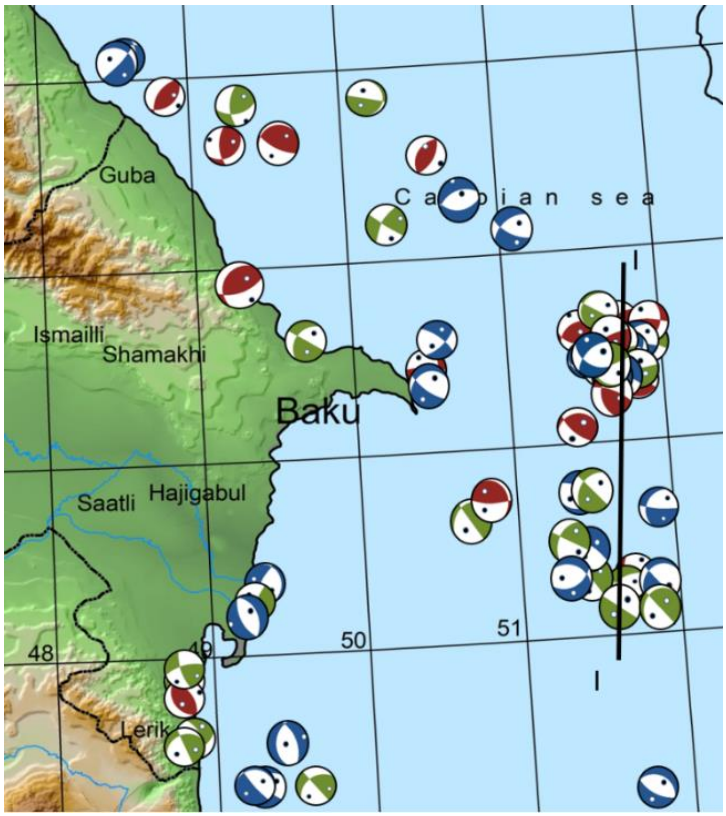

Figure 9. Source mechanisms of earthquakes with a magnitude of ≥3.0 occurred in 2018-2020 years.

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

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

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

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

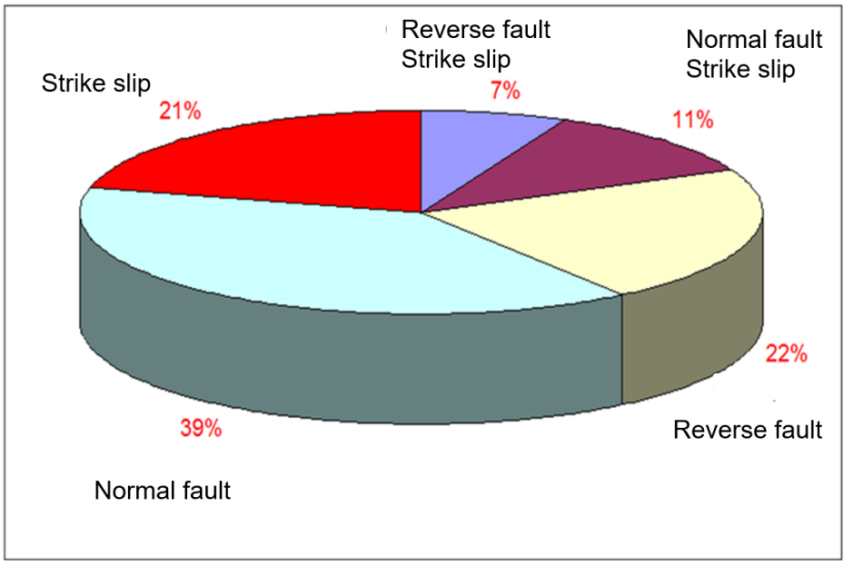

Figure 10. Percentage distribution histogram of the mechanisms of earthquakes in the Caspian Sea in 2020.

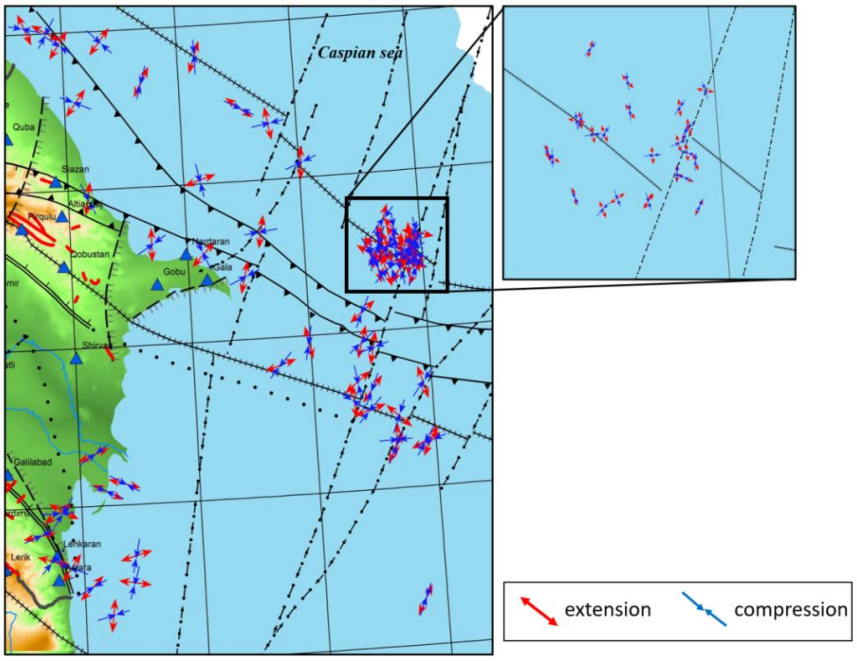

Figure 11. Scheme of compression and extension axes of earthquakes occurred during 2018-2020 years. Faults map - [9, 10].

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

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

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

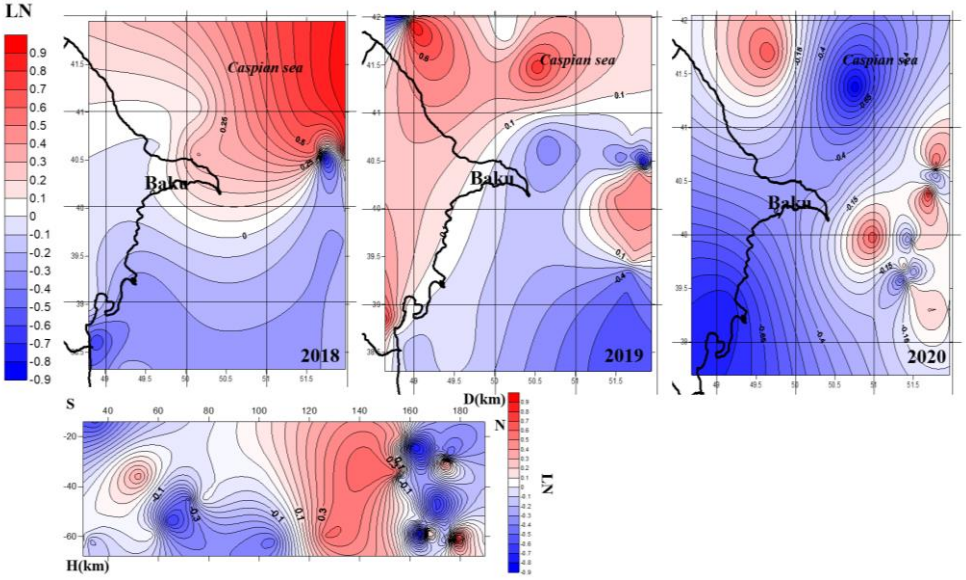

Figure. 12. Lode-Nadai coefficient distribution map and depth section calculated based on the mechanisms of earthquakes in 2018-2020 years.

Conclusion

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

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

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