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ASSESSMENT OF SEISMIC HAZARD AROUND THE FILIZCHAY PYRITE POLYMETAL DEPOSIT

G.J.Yetirmishli[1], G.I.Bekdemirova[1], G.A.Musayeva[1]

Abstract

In Azerbaijan, much attention is paid to the exploitation of mineral deposits in the non-oil sector. The Filizchay deposit, considered one of the largest deposits in Europe in terms of ore reserves and is very rich in base metal reserves throughout the world, is one of the largest projects that the AzerGold organization preparing for operation. The Filizchay deposit is located in the Zagatala-Balakan seismogenic zone. The article analyzes the seismicity of this zone and considers the assessment of seismic hazard around the field. As the analysis showed, the Filizchay pyrite-polymetallic deposit is located in one of the most seismically active regions of Azerbaijan. Such strong earthquakes as the Zagatala earthquake on May 7, 2012, the Balaken earthquake on October 14, 2012, and the Zagatala earthquake on June 5, 2018 have repeatedly occurred here. In addition, it should be noted that this field is affected not only by local earthquakes, but also by strong earthquakes located in neighboring regions. Such as the Oguz earthquake of 2015 and the Gabala earthquakes of 2014. All of the above earthquakes were characterized by an intensity of 7 points at the source and 5-6 points in the territory of the Filizchay field. As can be seen from the seismic activity maps, the Zagatala-Balakan zone is characterized by activity values of 1.6-2.0. Analysis of the depth distribution of hypocenters within the study region showed that the bulk of earthquakes are concentrated at a depth of 2-25 km.

Key words : Filizchay collichedan polymetal deposit, Zagatala-Balaken seismogenic zone, seismic activity, mechanism of earthquake foci, seismic hazard

FİLİZÇAY KOLİÇEDAN POLİMETAL YATAĞI ƏTRAFINDA SEYSMİK TƏHLÜKƏNİN QİYMƏTLƏNDİRİLMƏSİ

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Xülasə

Azərbaycanda qeyri neft sektorunda faydalı qazıntı yataqlarının istismarına diqqət artmışdır. Filiz ehtiyatlarının həcminə görə Avropanın ən iri yataqlarından biri hesab edilən və dünya miqyasında polimetal ehtiyatına görə çox zəngin olan, Filizçay yatağı "AzerGold" QSC-nin istismarına hazırlıq gördüyü ən böyük layihələrdən biridir. Filizçay yatağının yerləşdiyi Zaqatala-Balakən seysmogen zonası güclü seysmik aktivliklə səciyələnir. Məqalə işində bu zonanın seysmikliyi analiz edilmişdir və yataq ətrafında seysmik təhlükənin qiymətləndirilməsinə baxılmışdır. Təhlil göstərdiyi kimi, Filizçay pirit-polimetal yatağı Azərbaycanın ən seysmik aktiv rayonlarından birində yerləşir. 2012-ci il mayın 7-də Zaqatala zəlzələsi, 14 oktyabr 2012-ci ildə Balakən, 5 iyun 2018-ci ildə Zaqatala zəlzələsi kimi güclü zəlzələlər burada dəfələrlə baş verib. Bundan əlavə, qeyd etmək lazımdır ki, bu yatağa təkcə yerli zəlzələlər deyil, həm də qonşu rayonlarda yerləşən güclü zəlzələlər də təsir edir. Məsələn, 2015-ci ilin Oğuz zəlzələsi və 2014-cü ilin Qəbələ zəlzələləri. Yuxarıda göstərilən bütün zəlzələlər ocağda 7 bal, Filizçay yatağının ərazisində isə 5-6 bal intensivliyi ilə xarakterizə olunub. Seysmik aktivlik xəritəsən göründüyü kimi Zaqatala-Balakın zonası 1.6-2.0 aktivlik geyimləri ilə mümkündür. Tədqiq olunan rayon daxilində hiposentrlərin dərinlik paylanmasının təhlili göstərdi ki, zəlzələlərin əsas hissəsi 2-25 km dərinlikdə cəmləşib.

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Açar sözlər : Filizçay koliçedan polimetal yatağı, Zaqatala- Balakən seysmogen zonası, seysmik aktivlik ,zəlzələ ocaqlarının mexanizmi, seysmik təhlükə.

ОЦЕНКА СЕЙСМИЧЕСКОЙ ОПАСНОСТИ ВОКРУГ ФИЛИЗЧАЙСКОГО МЕСТОРОЖДЕНИЯ КОЛЧЕДАНОВЫХ ПОЛИМЕТАЛЛОВ

Г.Д. Етирмишли, Г.И. Бекдемирова, Г.А. Мусаева.

Аннотация

В Азербайджане большое внимание уделяется эксплуатации месторождений полезных ископаемых в не нефтяном секторе. Месторождение Филизчай, считающееся одним из крупнейших месторождений в Европе по объему запасов руды и очень богатое запасами полиметаллов во всем мире, является одним из крупнейших проектов, который организация "AzerGold" готовит к эксплуатации. Месторождение Филизчай находится на территории Загатало-Балаканской сейсмогенной зоны. В статье проанализирована сейсмичность этой зоны и рассмотрена оценка сейсмической опасности вокруг месторождения. Как показал анализ, Филизчайское колчеданно-полиметаллическое месторождение располагается в одном из самых сейсмоактивных регионов Азербайджана. Здесь неоднократно происходили такие сильные землетрясения как: Закатальское 7 мая 2012 г., Балакенское 14 октября 2012 г., Закатальское 05 июня 2018 гг. и т.д. Кроме того нужно отметить, что на данное месторождение влияют не только локальные землетрясения, но и сильные землетрясения расположенные в соседних регионах. Такие как Огузское землетрясение 2015 г. и Габалинские землетрясения 2014 г. Все выше указанные землетрясения характеризовались интенсивностью 7 баллов в очаге и 5-6 баллов на территории Филизчайского месторождения. Как видно из карт сейсмической активности, зона Загатала-Балакан характеризуется значениями активности 1,6-2,0. Анализ глубинного распределения гипоцентров в пределах исследуемого региона показал, что основная масса землетрясений сконцентрирована на глубине 2-25 км.

Ключевые слова: Филизчайское колчеданно-полиметаллическое месторождение, Загатала-Балакенская сейсмогенная зона, сейсмическая активность, механизм очагов землетрясений, сейсмическая опасность.

Introduction.

Azerbaijan has been and remains the most important mineral resource base of the South Caucasus. On this basis, the mining industry of precious and non-ferrous metals has been created and is successfully developing [5]. By analyzing favorable geological preconditions, direct and indirect prospecting signs, as well as analyzing the patterns of location of identified deposits for the metallogenic zones of the Greater and Lesser Caucasus, the identification of new ore objects is predicted [3]. Ore mineral raw materials, with rare exceptions, are of igneous or metamorphic origin, and therefore are confined to folded tectonic structures, shields and faults of the earth's crust.

The development of deposits in a zone of active seismic influence is correlated with geodynamic processes in the lithosphere. The efficiency of exploitation of mineral deposits, along with other indicators, is characterized by the seismicity of natural and man-made processes, which is taken into account when designing field development technologies. As a result of the combined action of gravitational, seismic and tectonic forces, stresses arise in the massifs, which cause them to deform and collapse if they exceed the tensile strength of the rocks. The seismic hazard of ore-bearing massifs is understood as a risk management system for technology-induced seismic vibrations. The phenomenon of destruction of massifs is explained by the addition of the potential energy of elastic compression of rocks and the energy of elastic deformations during mining [11]. Mining facilities occupy a large area and are characterized by high risk. A local seismic observation network makes it possible to monitor the state of arrays with sufficient sensitivity only in rare cases. The territory of the North Caucasus is the arena of modern intensification of catastrophic processes. Most of the territory is an arena for the formation of folded structures and is characterized by the loss of

rock strength properties. Dynamic phenomena are catastrophic in nature, which is expressed by displacement along faults, the appearance of ditches and cracks, and provoke the subsidence of large blocks of rocks, landslide processes, mudflows, landslides and snow avalanches. Linking tectonic, gravimetric and seismometric factors in the exploitation of deposits is an important area of research into the problems of geomechanical safety of mining mineral deposits in seismic zones [11].

The Filizchay deposit ranks second in Europe. The deposit of polymetallic ores was discovered 60 years ago, during the geological survey and prospecting work carried out by the Geology Department of Azerbaijan in the Belokan and Zagatala regions. The deposit is represented by such minerals as pyrite, sphalerite, galena, chalcopyrite, pyrrhotite. The main useful components are copper, zinc, lead, silver, gold, sulfur, etc. Large reserves of the deposit have propelled the region into an independent metallogenic province and as a mineral resource base for the future metallurgical industry of Azerbaijan [5].

Filizchay pyrite-polymetal deposit

Filizchay pyrite-polymetal deposit is located in the territory of Balakan district, 18 km north of the district center, near the state borders of Azerbaijan with Georgia and the Russian Federation. Orographically, the bedrock area consists of a mountainous terrain with steep slopes and rocky deep valleys. Relative heights vary between 800-1600 meters. The area is bounded by the Great Gubakh and Kasdag mountains in the western part, the watershed range of the Great Caucasus and Chugak mountain in the north, Karabchay and Bulanigchay in the east [1].

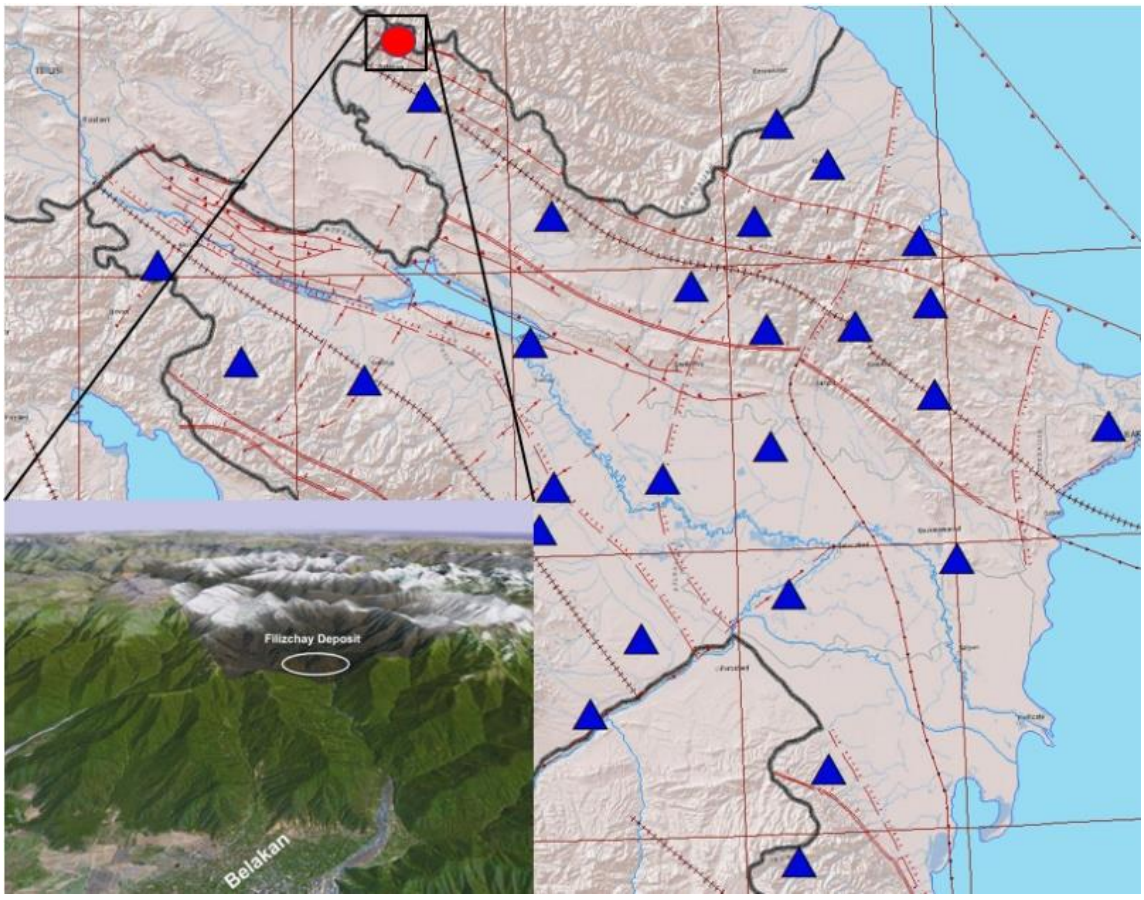

Figure 1. Filizchay field location map

The deposit was discovered in 1959. Filizchay deposit is considered the second deposit in Europe in terms of industrial reserves of pyrite-polymetallic ores. At present, 90% of the reserves of pyrite-polymetallic ores of the Republic of Azerbaijan are concentrated in the Balaken-Zagatala ore region located on the southern slope of the Greater Caucasus (Fig. 1). In addition to the Filizchay deposit, there are small deposits of Kasdag, Katekh, Sagator, Garabchay and Mazymchay pyrite-polymetallic deposits, as well as the Gumbulchay-Cheder pyrite-copper-polymetallic ore group, the composition of which is mainly represented by pyrite, sphalerite, galena, chalcopyrite, pyrrhotite, from secondary metals - arsenopyrite, cobalt, various metal sulphosalts, etc. The main useful components are copper, silver, zinc, lead, sulfur, and auxiliary components are represented by gold, bismuth, cobalt, cadmium, selenium, tellurium, indium [2].

It is possible to create a highly profitable mining-metallurgical complex based on the industrial resources of the Filizchay field, which will provide raw materials for more than 50 years. In 2022, the estimated amount of underground resources of "Filizchay" polymetal deposit, which is one of the most complex projects due to its geological structure, was increased. Thus, as part of the process of bringing the field into operation, ore samples were studied in the laboratory of the prestigious "Petrolab" company of Great Britain for mineralogical research. The resources of "Filizchay" were calculated in accordance with the requirements of JORC (Joint Ore Reserves Committee) standards, which is an international classification system for the economic evaluation of mineral deposits. As a result of the calculation, a 20% increase was recorded compared to the results included in the state budget in 1983 during the USSR [1]. As a result, it was confirmed that the estimated amount of underground ore resources of "Filizchay" is 112.71 million tons.

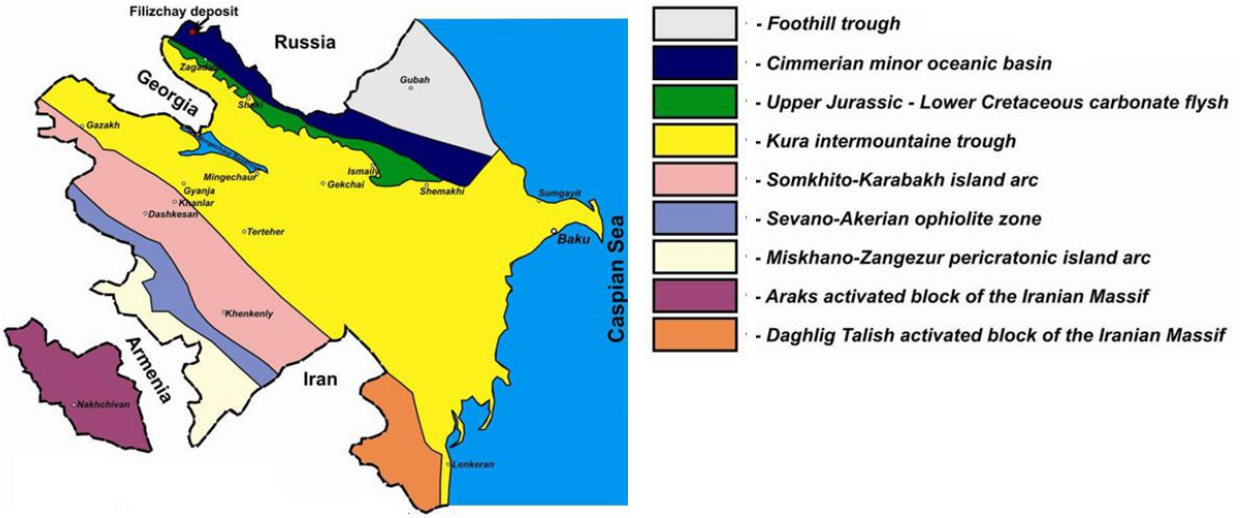

Figure 2. Position of the Filizchay Deposit on the Tectonic & Metallogentic Sketch Map ofAzerbaijan [1]

The structural elements of the central Tfan anticline, the Zagatala-Kovdag syncline, the Vandam anticline and the superimposed Alazan-Agrichay depression take part in the Zakatala zone. The latter within the considered zone, expanding strongly to the north, almost completely overlaps the Vandam anticlinorium [10].

The Tfan anticlinorium extends in a narrow strip along the northern edge of the Zagatala zone. Within the zone, it is characterized by a significant complication of the structure of the southern wing of the western extension of the Bazarduzu anticlinorium and the appearance of new uplifted lower horizons of the aalena, and in some cases, the toar. Here E.Sh.Shikhalibeyli (1956) singled out an independent Sarybash anticlinorium, in the cross-section of which two large anticlinals, Attagay and Suvagil, are distinguished [16]. Further to the west, they are replaced by the Kehnameidan and Karabchai uplifts, and in the south, the third Gyumbulchay uplift appears, which constitutes a new, sufficiently extended single structural zone. In

the section under consideration, the Tfan anticlinorium is complicated by the Main Caucasus fault-thrust, which separates the northern, highly uplifted part of the wing from its southern part, which differ significantly in the age of the deposits and the morphology of the folded structure. [10, 16]

The Zagatala-Kovdag synclinorium is located to the south of the Tfan anticlinorium. This large deflection zone extends from the western border of Azerbaijan to the Absheron Peninsula, originating in the river basin. Belakanchay in the form of a narrow depression made by valangine, crumpled into small folds, the synclinorium is gradually opened to the east, its section is filled with younger neocomic deposits. [8]

Seismic activity of Zagatala-Balakan seismic zone

The Zagatala-Balakan seismogenic zone, where the Filizchay deposit is located, is characterized by strong seismic activity.

The Zagatala-Balakan seismically active zone is located in the extreme north-west of the Azerbaijani part of the Greater Caucasus. Conventionally, its border in the east should be considered the Zagatala-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 km^2. It should be noted that in this zone, during the entire seismostatistical period, only one large earthquake is known, which occurred in 1936 with a magnitude 7 effect in a number of populated areas. More often, tremors with an intensity of 7 points in the Zagatala seismically active zone were felt from strong Dagestan and Georgian earthquakes, which sometimes caused disturbances in local sources.

In the research work, the analysis of the earthquakes that occurred in that area in 2010-2023 was carried out.

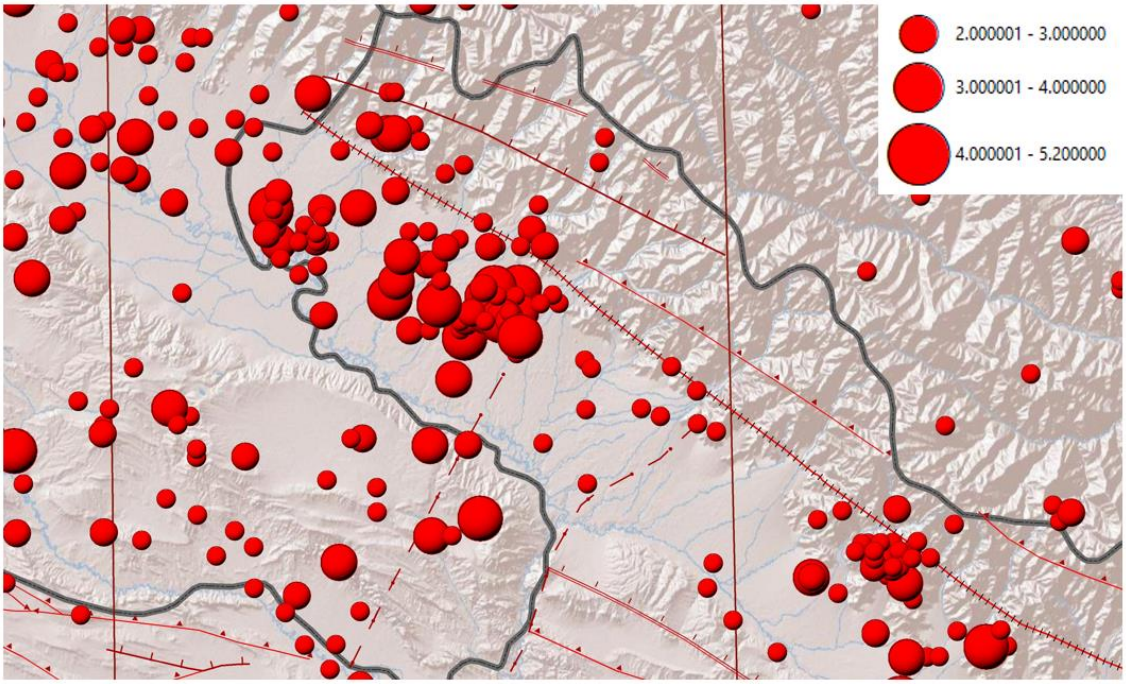

Figure 3. Map of epicenters of earthquakes that occurred in the northwestern part of Azerbaijan during the years 2003-2023

In the research work, the analysis of the earthquakes that occurred in that area in 2010-2023 was carried out. In 2010-2011, seismicity in the Zagatala-Balakan zone was at the background level. In 2012, seismic activation in the north-western part of the Greater Caucasus was observed with a series of strong earthquakes. On 07.05.2012, earthquakes with a magnitude of M=5.6-5.7 occurred in Zagatala region with

an interval of about 10 hours (t0=04h40m and t0=14h15m GMT), the earthquake was characterized by numerous aftershocks (magnitude 3.5-5.0) [15, 9].

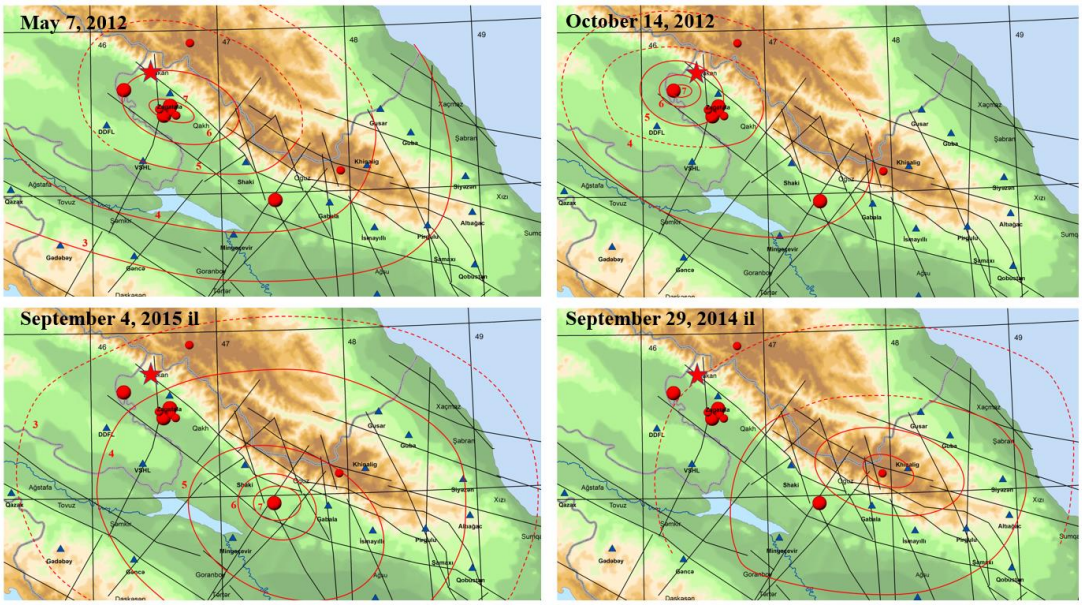

Figure 4. Isoseist maps of strong earthquakes that occurred in the northwestern part of Azerbaijan [9, 15]

The earthquake was felt in the cities of Zagatala, Balaken, Gakh and other surrounding regions with a magnitude of 2-5. In Zagatala district, 274 buildings were completely destroyed, 2052 buildings became unusable. Although there was no damage in Balakan district, 35 houses were damaged. A total of 19 earthquakes with a magnitude higher than 4.7 were recorded in the Zagatala-Balakan seismoactive zone, which were felt in one or more settlements. It should be noted that after the strong Zagatala earthquakes on 14.05.2012 in Sheki region, 2, 14.10. In 2012, 2 earthquakes (5-6 points) occurred in Balakan region, the earthquake was characterized by numerous aftershocks. The intensity values of strong earthquakes were taken from the articles of E.Garaveliyev [6, 13].

In 2014, the seismic activity in the Zagatala-Balakan zone increased compared to 2013, the seismicity was higher than the background level. The strongest earthquake that occurred in this zone on 29.06.2014 was M=5.3, H=9 km. The earthquake was felt up to level V in the epicenter and level III-IV in nearby settlements. After the main shock, there were aftershocks with a weak magnitude of M≤1.5. In 10 days, 55 aftershocks and 321 weak aftershocks were recorded by Zagatala station alone [7, 13].

On June 5, 2018, another strong earthquake with magnitude M=5.5 occurred in Zagatala. In 2020, compared to 2019, seismicity was weaker in the Zagatala-Balakan area. The highest magnitude earthquake that occurred in the Balakan area was ml=3.2 [8].

In 2021, seismicity was at the background level in the Zagatala-Balakan seismogenic zone. In the area of Zagatala-Balakan, tremors with a magnitude of ml≤1.9 occurred. In the area of Zagatala-Balakan, the sources were mainly distributed at a depth of 2-25 km. In 2022, the seismicity in the Zagatala-Balaken seismoactive zone was higher than the background level compared to 2021. The highest magnitude earthquake that occurred in the Zagatala area was ml=4.2.

Longitudinal and transverse deep faults pass through the territory of the region: Bash Qafqaz, Gaynar-Zangi, Vandam, Zagatala-Shamkir, etc. In particular, numerous violations and dissections are observed here. The sources of the earthquakes occurring in the Balakan-Zagatala seismoactive zone correspond to the intersection zones of the faults in different directions. As can be seen from the seismic activity maps, the zone of Zagatala-Balakan is characterized by activity values of 1.6-2.0 (Fig. 4).

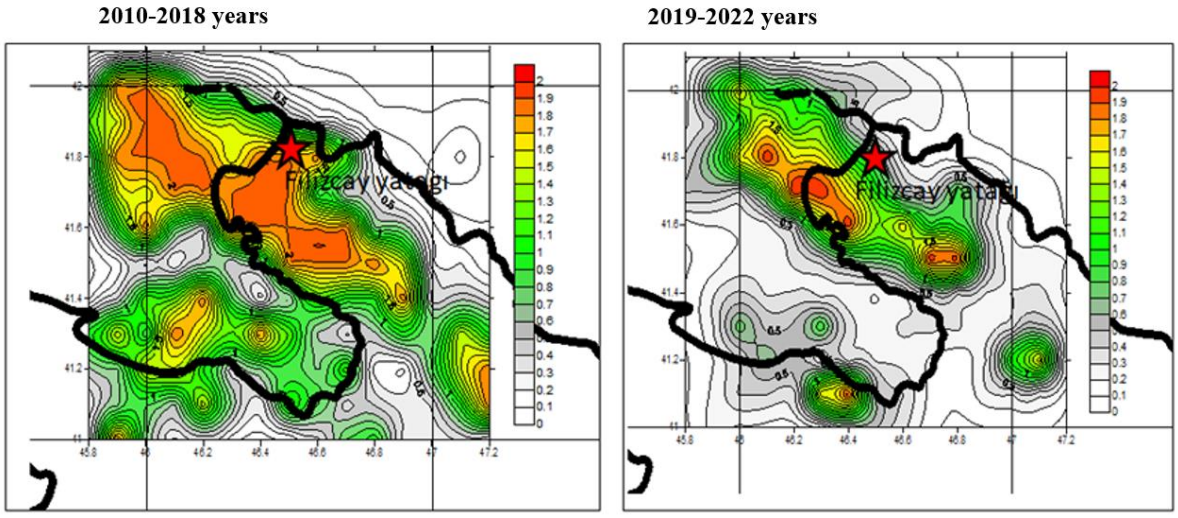

Figure 5. Map of seismic activity in the territory of Azerbaijan in 2010-2022

In order to study the depth distribution of the earthquakes that occurred in the Balakan-Zagatala seismogenic zone, a seismic cross section was constructed on the I-I profile in the southwest-northeast direction (Fig. 4). The earthquake catalog was taken from the Bureau of Earthquake Research. The density of earthquake epicenters is observed on the map of epicenters of earthquakes with the established magnitude (Ml≥3.0) for this zone. As can be seen from the picture, strong earthquake epicenters (Ml≥5.0) are observed in the northern, southwestern and southern parts of the region surrounded by the Filizchay field (Fig. 4b). The vast majority of earthquakes occurred at a depth of 2-25 km in the seismological section established along the southwest and northeast direction profile.

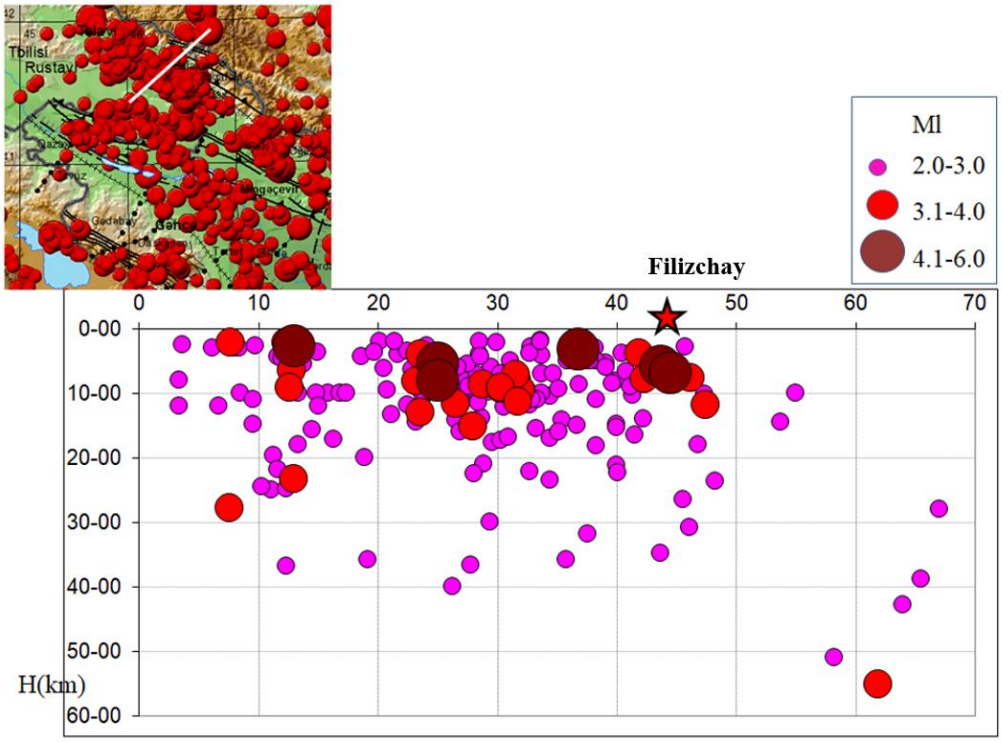

Figure 6a. Seismological cross-section of the I-I profile in the Balakan-Zagatala seismogenic zone

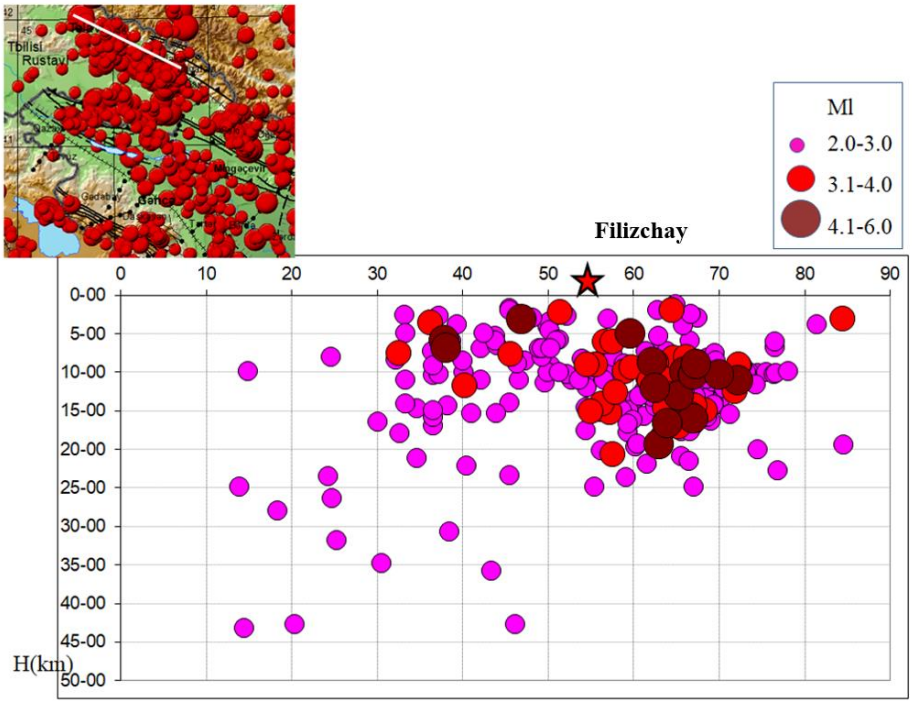

Figure 6b. Seismological section on the II-II profile in the Balaken-Zagatala seismogenic zone

Mechanisms of earthquake sources

Zagatala earthquakes are a consequence of the geodynamic regime of the earth's crust of the Zagatala source zone, the parameters of which are determined by the movements of the earth's crust along the system of longitudinal (over-the-Caucasus) and transverse (anti-Caucasian) faults; among the latter, the main role belongs in all probability to a pair of right-handed shifts - Kazakh-Signakh and Ganjachay-Alazan [5].

Based on the definition of the mechanism of the source of the earthquake, it is established that the mechanism of the source of the first Zakatala earthquake (GMT 4:40, Mw=5.6) is a strike-slip, and the second earthquake (GMT 14:15, Mw=5.7) is a strike-slip. Comparison of the azimuths of the longitudinal axes with the spread of the nodal planes of the mechanism of the aftershock center shows that the first nodal plane is aligned in the NW-SE direction, corresponding to the Balaken-Dzhunut longitudinal fault (thrust-type movement), and the second nodal plane is in the SW-SW direction, corresponding to the Salavat transverse fault (thrust-thrust type of movement). The mechanisms of the majority of aftershocks also point to reset and shear displacements in the focal zone with a subordinate number (5 events) of shock displacements confined to the plane of the Ganyh-Airichai thrust and its rear scales.

Balaken focal zone was active in 2012, 2013 and 2016. Seismic events of October-November 2012. They manifested themselves in a series of aftershocks with a maximum M = 5.60 (14.10.2012). The events of the following years differed in relatively low power with M = 3.14-4.37. As in the first case, the focal zone is confined to the complex intersection of faults of different widths, the majority of hypocenters are located in the upper part of the pre-Jurassic basement, and also confined to the surface of the basement and the base of the Alpine cover, the depth interval is 4-13 km. Seismic events are mainly associated with the activation of the Khimrich-Khalatali (2012) and Balaken (2013 and 2016) faults of the Anti-Caucasian thrust.

The mechanisms of earthquakes in the focal zone indicate the predominance of thrust and shear movements with a subordinate role of shock-type displacements. In particular, the earthquake on October 14, 2012. with M=5.6 and H=8 km was characterized by horizontal (PLP=0°) stretching southwest

orientation and bivertical compression (PLT=48°) northwest orientation stresses. Type of motion on both (DP=57°) planes – shift. Plane NP1 has a southeast orientation (STK1=115°), NP2 – north (STK2=2°). Comparison of the extension of nodal planes with fault lines shows the agreement of the first of them (NP1) with the Shambul-Ismailli longitudinal fault.

The Gabala focal zone, activated at the end of September-beginning of October 2014, manifested itself with two perceptible aftershocks with M = 5.0-5.5 and a swarm of weak aftershocks. The focal zone is controlled by the right-striking fault of the northeast strike, which complicates here the subthrust junction of the Kakheti-Vandam-Gobustan zone and the accretionary prism of the Greater Caucasus. The focal zone is characterized mainly by shear displacements along the rupture plane. As an example, it is possible to point to the event of 29.09.2014, when an earthquake occurred with M-5.5 at a depth of 13 km, that is. in the pre-Jurassic base of the Kakheti-Vandam-Gobustan zone.

Results

The problem of monitoring and prevention of dangerous natural processes on the territory of mining landscapes should be solved with a comprehensive consideration of macro phenomena occurring during the development of mineral deposits. This is possible only on the basis of the use of modern methods of seismic hazard assessment by fixing tension, tectonics and seismic arrays.

The development area of the Filizchay deposit crosses seismically active faults, which should be paid close attention to when planning mining operations. The differentiation of the physical properties of the rocks of the section and the presence of active fracture structures cause complex mining and geological conditions for the development of deposits. There is a clear increase over time in man-made seismic activity in active mines. As the analysis showed, the Filizchay pyrite-polymetallic deposit is located in one of the most seismically active regions of Azerbaijan. Such strong earthquakes as: Zagatala on May 7, 2012, Balaken on October 14, 2012, Zagatala on June 05, 2018 have occurred here several times. and etc. In addition, it should be noted that this deposit is affected not only by local earthquakes, but also by strong earthquakes located in neighboring regions. Such as the Oguz earthquake in 2015 and the Gabala earthquake in 2014. All of the above-mentioned earthquakes were characterized by an intensity of 7 points in the center and 5-6 points on the territory of the Filizchay deposit. As can be seen from the seismic activity maps, the zone of Zagatala-Balakan is characterized by activity values of 1.6-2.0.

The analysis of the depth distribution of hypocenters within the studied region showed that the main mass of earthquakes is concentrated at a depth of 2-25 km. The observed picture can be interpreted as follows. In the zone of the transverse Shamkhor-Zagatala structure with a highly raised sub-Alpine base in the region of the meganticlinorium of the Great Caucasus, the thrusts observed on the surface have a shallow foundation and do not determine the seismicity of this area, which is mainly associated with steeply dipping lateral (southern and northern) to the limitations of uplifted blocks of the subalpine base, saturated with magnetically active magmatic rocks, as well as with transverse shears. To the east of the Ganjachay-Alazan fault, where the surface of the pre-Alpine base gradually sinks to the east up to 6 and 8 km, along with the thrusts, the seismogenic character of thrust-thrusts is manifested, the development of which at depth under the general regime of compression of the B. Caucasus was not prevented by the high position of the surface subalpine foundation, as it had a place in the region of the transverse structure.

Thus, seismic waves can act as a trigger and initiate the dynamic destruction of sections of the massif of rocks that are in an extremely stressed state. At the same time, the increase in seismic activity can lead not only to the collapse of rocks from the roof and walls of the underground workings of this deposit, but also to the displacement of blocks under the action of horizontal stresses during an earthquake.

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