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SEISMOPROGNOSIS OBSERVATIONS IN THE TERRITORY OF AZERBAIJAN

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ASSESSMENT OF SEISMICITY IN AZERBAIJAN AND ADJACENT REGIONS IN 2022 BASED ON DATA FROM "KINEMETRICS" SEISMIC STATIONS

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ABSTRACT

In 2022, seismicity analysis was conducted based on 62 digital seismic stations. Throughout the year, 12,284 earthquakes were recorded. Of these, 3,383 were local earthquakes (occurring in the territory of Azerbaijan), 3,314 were regional, and 4,011 were distant earthquakes. Additionally, 1,463 weak tremors (registered by a single station) and 1,575 industrial explosions were recorded. Compared to 2021, the number of earthquakes in 2022 and the amount of released seismic energy decreased. In 2021, there were 6,071 earthquakes: the amount of seismic energy released was $\sum E = 6.02 \times 10^{12}$ *J, with a maximum magnitude of ml = 5.1. In 2022, the amount of released seismic energy was* $\sum E = 8.55 \times 10^{11}$ *J, with a maximum magnitude of ml = 4.9. Throughout 2022, seismicity was observed in the Greater Caucasus, the Middle Kura Basin, and the Caspian Sea. Seismic activation was noted in the West Caspian, Palmira-Absheron, Aji-Chay-Alat, Ganja-Chay-Alazan, Gazakh-Signakh, Talysh, Akhvai, Sangachal-Ogurjuq, Garabogaz-Safidrud, and Agrahan-Kasnawod regions. Another mud volcano eruption occurred in Lokbatan, and based on the arrival time of waves from the stations, the period of mud volcano eruption activation, the depth of the focus, the duration of the eruption, and the energy released during the eruption were determined. The mechanisms of 48 earthquake foci were identified. Analysis of compression and extension axes, based on data from earthquake focus mechanisms, showed that the central and western parts of the republic's territory are mainly characterized by compressive stress. Tensile stress is observed in the Gobustan-Absheron region, the central parts of the Caspian Sea, and the Guba-Gusar regions.*

Keywords: seismic analysis, West Caspian fault, Palmira-Absheron, Aji-Chay-Alat tectonic faults, earthquake focus mechanism analysis, mud volcano.

"KİNEMETRİKS" SEYSMİK STANSİYALARININ MƏLUMATLARI ƏSASINDA 2022-Cİ İLDƏ AZƏRBAYCAN VƏ ƏTRAF BÖLGƏLƏRİN SEYSMİKLİYİNİN QİYMƏTLƏNDİRİLMƏSİ

Yetirmişli Q.C., İsmayilova S.S., Kazimova S.S., Islamova Ş.K.

XÜLASƏ

2022-ci ildə 62 rəqəmsal seysmik stansiya əsasında seysmiklik təhlili aparılmışdır. İlin ərzində 12 284 zəlzələ qeydə alınmışdır. Onlardan 3383-ü yerli zəlzələ (Azərbaycan ərazisində baş verən), 3314-ü regional

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

və 4011-i uzaq zəlzələlərdir. Bundan əlavə, 1463 zəif təkan (yalnız bir stansiya tərəfindən qeydə alınan) və 1575 sənaye partlayışı qeydə alınmışdır. 2021-ci illə müqayisədə 2022-ci ildə zəlzələlərin sayı və ayrılan seysmik enerji miqdarı azalmışdır. Belə ki, 2021-ci ildə 6071 zəlzələ baş vermişdir: ayrılan seysmik enerjinin miqdarı $\sum E = 6.02\times10^{12}$ C, maksimum maqnitud ml = 5.1 olmuşdur. 2022-ci ildə ayrılan seysmik enerji miqdarı $\sum E = 8.55\times10^{11}$ C olmuş, maksimum maqnitud ml = 4.9 olmuşdur. 2022-ci il ərzində seysmiklik Böyük Qafqazda, Orta Kür hövzəsində və Xəzər dənizində müşahidə edilmişdir. Seysmik aktivləşmə Qərbi-Xəzər, Palmir-Abşeron, Aciçay-Alat, Gəncəcay-Alazan, Qazax-Siqnağ, Talış, Axvay, Sanqaçal-Oğurcuq, Qaraboğaz-Səfidrud, Aqraxan-Krasnovod zonalarında müşahidə edilmişdir. Lökbatanda növbəti palçıq vulkanı püskürmüş, stansiyalardan gələn dalğaların gəlmə vaxtı əsasında palçıq vulkanlarının püskürmə dövrü, ocağın dərinliyi, püskürmənin davamlılığı və püskürmə zamanı ayrılan enerji müəyyən edilmişdir.

48 zəlzələnin ocaq mexanizmləri müəyyən edilmişdir. Zəlzələ ocaq mexanizmlərinin məlumatları əsasında sıxılma və gərilmə oxlarının analizi göstərmişdir ki, respublikanın mərkəzi və qərb hissələri əsasən sıxılma gərginliyi ilə xarakterizə olunur. Gərilmə gərginliyi Qobustan-Abşeron ərazisində, Xəzərin mərkəzi hissələrində və Quba-Qusar bölgələrində müşahidə olunur.

Açar sözlər: seysmik təhlil, Qərbi-Xəzər qırığı, Palmir-Abşeron, Aciçay-Alət tektonik qırılma zonaları, zəlzələ ocağı mexanizmlərinin təhlili, palçıq vulkanı.

ОЦЕНКА СЕЙСМИЧНОСТИ АЗЕРБАЙДЖАНА И ПРИЛЕГАЮЩИХ РЕГИОНОВ В 2022 ГОДУ НА ОСНОВЕ ДАННЫХ СЕЙСМИЧЕСКИХ СТАНЦИЙ “KINEMETRICS”

Етирмишли Г.Дж., Исмаилова С.С., Казымова С.Э., Исламова Ш.К.

АННОТАЦИЯ

В 2022 году был проведен анализ сейсмичности на основе 62 цифровых сейсмических станций. В течение года было зарегистрировано 12284 землетрясений. Из них 3383 местных землетрясений (произошедших на территории Азербайджана), 3314 региональных и 4011 отдаленных землетрясений. Кроме этого, было зафиксировано 1463 слабых толчка (зафиксированых одной станцией) и 1575 промышленных взрывов. По сравнению с 2021 годом количество землетрясений в 2022 году и количество выделяемой сейсмической энергии уменьшились. Так, в 2021 г. произошло 6071 землетрясений: количество выделившейся сейсмической энергии $\sum E=6.02\cdot10^{12}$ Дж, максимальная магнитуда ml = 5.1. В 2022 г. количество выделившейся сейсмической энергии составило $\sum E=8.55\cdot10^{11}$ Дж, максимальная магнитуда ml = 4,9. В течение 2022 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. В Локбатане произошло очередное извержение грязевого вулкана, и на основе времени прихода волн от станций были определены период активизации извержения грязевых вулканов, глубина очага, продолжительность извержения и энергия, высвобожденная во время извержения.

Были определены механизмы очагов 48 землетрясений. Анализ осей сжатия и растяжения, выполненный на основе данных о механизмах очагов землетрясений, показал, что центральная и западная части территории республики в основном характеризуются сжимающим напряжением. Напряжение растяжения наблюдается в районах Гобустан-Абшерон и в центральных частях Каспия, а также в районах Губа-Гусар.

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

Introduction

In the article, the seismic activity of Azerbaijan and neighboring regions in 2022 is analyzed within the framework of 38.0–42.0° north latitudes and 44.5–52.0° east longitudes. The high seismicity of this region is mainly related to large tectonic structures such as the south-east sinking of the Greater Caucasus, the Kura depression, the northeastern slope of the Lesser Caucasus, Talysh and the Caspian Sea water area. As in previous years, seismic monitoring in the mentioned region was carried out by the Republican Seismological Service Center of the Azerbaijan National Academy of Sciences. In 2021, the seismic station network of RSXM ANAS consisted of 35 digital stations and also included data from three Georgian stations (BGD, DDFL, VSHL) and two Turkish stations (IGD, Hakkart). The technical equipment of stations of RSXM ANAS is described in detail in the article [3]. [2] in the article, earthquakes with a magnitude of ml=3.0 and greater are recorded in a wide area of the republic, including in the areas of the shelf zone of the Caspian Sea. In the remaining water area of the Caspian Sea and in the territories of neighboring countries, it is possible to register shocks with ml>3.0.

Processing Methodology

The methods of determining the main characteristics of earthquakes have remained the same. Antelope Real-Time System, version 5.6, dbloc2 software was used for the localization of earthquakes, and the average velocity model of the deep geological structure of Azerbaijan was applied [7, 9]. In the article, two approaches were used for the calculation of focal mechanisms: the analysis of the first signs of P-waves and the wave inversion method. Time-Domain Moment Tensor INVerseCode (TDMT INVC) algorithm was used for waveform inversion [4, 5]. The main seismogram source was the Republic Seismological Service Center, from where the data was downloaded in MiniSEED format and converted to SAC format. Broadband seismograms were selected according to distance (70–350 km) and had to be of sufficient length (interval from P-waves to S-waves) and quality (high signal-to-noise ratio and no clipping). Preparation of seismograms for inversion consisted of several stages: removal of the input part of P-wave, deconvolution (restoration of real ground displacements), determination of epicentral distance, straight and reverse azimuths, calculation of radial and transverse components and filtering. Deconvolution was performed in the time domain, and a 4th-order Butterworth filter was used for the bandpass filter.

Analysis of seismicity

During 2022, 62 seismicity analyzes were conducted based on digital data. During that year, 12,284 earthquakes were recorded. 3383 of them are local (territory of Azerbaijan), 3314 are regional and 4011 are remote earthquakes [10]. In addition, 1575 explosions and 1 volcano were recorded. A map of the epicenters of the earthquakes that occurred in the territory of Azerbaijan was drawn up (Figure 1).

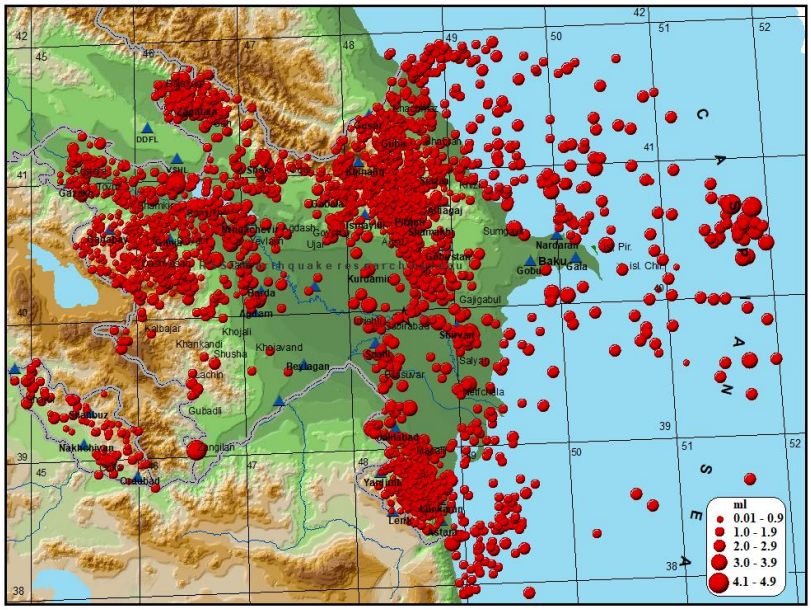


Figure 1. Map of epicenters of earthquakes that occurred in Azerbaijan

In 2022, 52 earthquakes with magnitude ml≥3 were recorded in the territory of Azerbaijan. 19 perceptible earthquakes were recorded in Azerbaijan and adjacent areas. A map of epicenters of earthquakes with magnitude ml≥3 and felt was constructed (Figure 2).

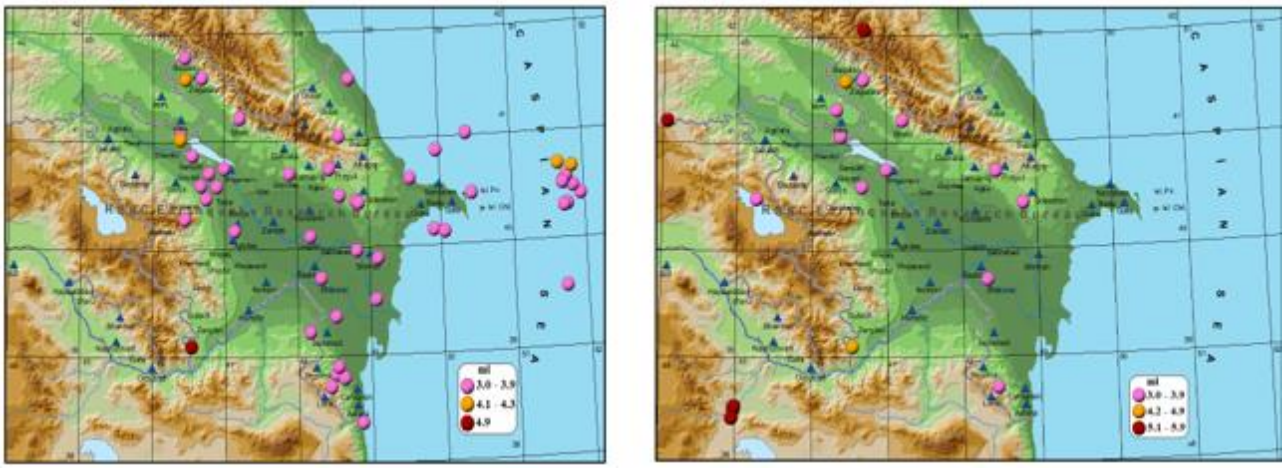


Figure 2. Map of epicenters of earthquakes with a magnitude ml≥3 in the territory of Azerbaijan and felt in Azerbaijan and adjacent territories during 2022

The analysis of the number of earthquakes that occurred in Azerbaijan and the distribution of the released seismic energy by month (Figure 3.) shows that the released seismic energy was higher in January than in other months. This is related to the strong magnitude ml=4.9 earthquake that occurred in Zangilan region. In May, the number of earthquakes was higher than in other months.

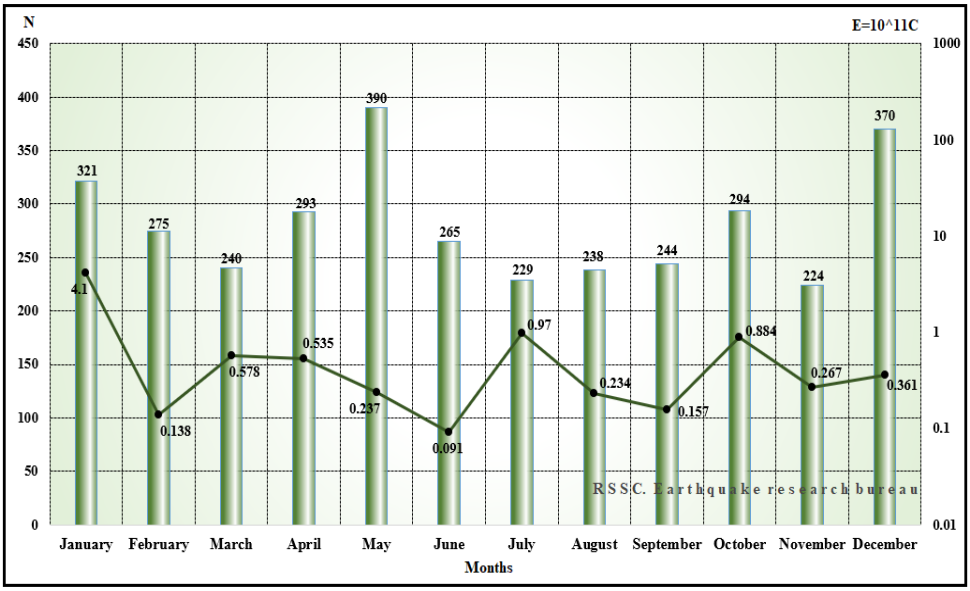


Figure 3. Distribution of the number of earthquakes in Azerbaijan and the released seismic energy by month

An activity map of 2022 was drawn up and analyzed to monitor the change of the seismic regime over time (Fig. 4). In 2022, high seismic activity is observed in some areas, while other areas are characterized by low seismicity.

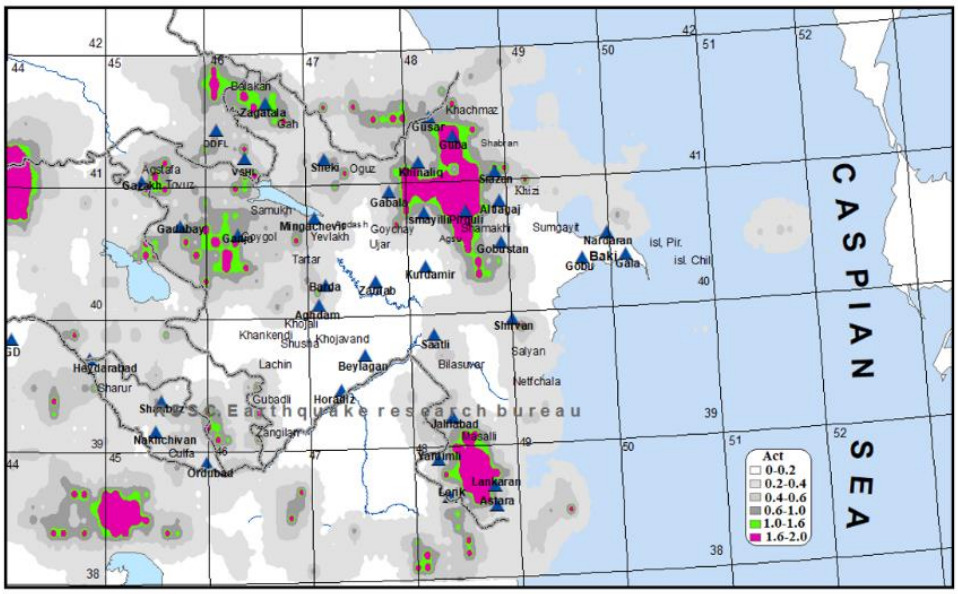


Figure 4 Activity map of Azerbaijan and adjacent territories in 2022

As can be seen from the map, activity was high in Shamakhi-Ismayilli (A10=1.7-2.0), Gusar-Guba, (A10=1.5-1.7), Talish (A10=1.6-2.0) zones. Zagatala-Balaken, Azerbaijan-Georgia border on the southeastern slope of the Greater Caucasus is characterized by values (A10=1.3-1.8). In 2022, an increase in seismicity was recorded in the Small Caucasus, Middle Kur (Kazakh-Aghstafa, Samukh area (A10=1.0-1.6). In addition, in the north and center of the Caspian (A10=0.4-0.6), in the south of the Caspian (A10=1.0- 1.6) increased seismicity was recorded on the Georgia-Armenia border (A10=1.6-2.0).

Greater Caucasus area. A seismological fault has been established along the Balaken-Gabala II profile passing through the seismoactive zone of Azerbaijan (Figure 5.). The profile extends along the Ayrichay-Aletsh deep fault in the pan-Caucasus direction. The density of earthquakes is observed in the Zagatala-Balakan area in

the north-west direction of the intersection. 2 earthquakes with magnitude ml≤4.2 were registered in Zagatala territory. On April 15, at 17:02 local time, an earthquake with a magnitude of ml-3.9 was recorded in the Zagatala area, 7 km southeast of the Zagatala station. The earthquake was felt up to 4 in the epicenter and 3 in nearby residential areas. An imperceptible earthquake with a magnitude of 3.2 was recorded in the Balaken area. In the north-west direction of the fault, earthquakes are mainly distributed at a depth of 3-23 km. The shock with magnitude ml=4.2 occurred within 9 km of the subsidence layer, earthquakes with ml≤3.9 occurred at a depth of 18 km. The earthquake foci are located in the impact zone of the Alazan-Eyrichay fault.

An increase in seismicity is observed in the Sheki-Gabala plains. Against the background of weak seismicity, an earthquake with a magnitude of ml=3.0 was recorded in Sheki region. The earthquake was felt up to 3 points in the epicenter. The earthquake occurred within a 7 km depth subsidence layer. The epicenters of the earthquake are located in the impact zone of the Alazan-Eyrichay fault. In the Sheki-Gabala plains, earthquakes are mainly spread at a depth of 2-30 km. Earthquakes with depths of up to 40 km were recorded in these areas. Seismicity in Shamakhi-Ismayilli zone in 2022 compared to 2021 was higher than the background level. When moving to the Shamakhi-Ismayilli zone, one observes the migration of the hearths in the NE and NE direction. The northern part of the Shamakhi-Ismayilli zone is more active. A density of hypocenters is observed at a depth of 4-12 km up to the Dashgil-Mudrasa and Alazan-Ayrichay-Alat faults. Here, reflective boundaries are located at a depth of 10-12 km. Earthquakes with magnitude ml≤1.9 were distributed at a depth of 10 km.

On September 1, at 22:21 local time, an earthquake with a magnitude of ml=3.4 was recorded in Agsu district, 10 km southwest of Pirgulu station. The earthquake was felt up to 3 points. As can be seen from the section, earthquakes with great depths also occur in Shamakhi-Ismayilli area. In the Ismayilli district, an earthquake with an imperceptible magnitude of ml=3.0 occurred at a depth of 44 km. 2 earthquakes with magnitude ml≥3.0 were recorded in Gobustan territory. On October 29, at 17:50 local time, an earthquake with a magnitude of ml=3.6 was registered in Gobustan region, 42 km south of Pirgulu station. The earthquake was felt up to 3 points. After the earthquake, an imperceptible earthquake with a magnitude of ml=3.1 was recorded on October 30. The earthquakes occurred within the 4 km deep subsidence layer.

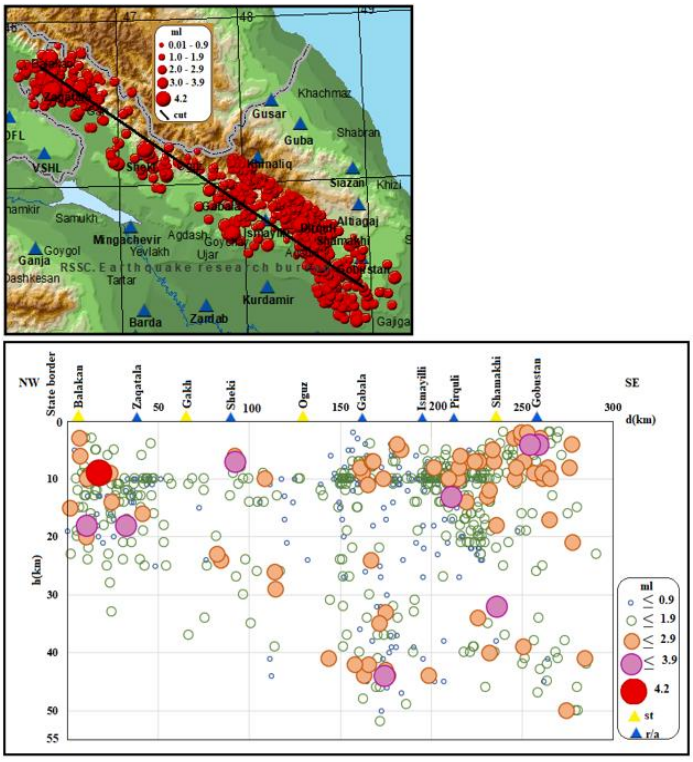


Figure 5. Seismological cross-section at depth in the NW-SW direction in the Greater Caucasus

The territory of the Lesser Caucasus. In order to study the seismicity of the Karabakh territory in 2022, a map of epicenters of explosions and earthquakes was created (Figure 6). In contrast to 2021, a decrease in the number of explosions due to road construction in the territory of Karabakh is observed. Industrial explosions were registered in Kalbajar area in 2022 as it happens every year. This leads to an increase in the seismic activity of the area.

The reason for the increase in the number of explosions in the territory of Karabakh is the construction of roads. In connection with the construction of roads, mountains and tunnels are blown up in the areas. I would like to mention that the waveform of road construction explosions differs from that of industrial explosions. Activation is observed in Agdam and Zangilan areas in 2022. On January 16, at 07:25 local time, an earthquake with a magnitude of ml=4.9 was recorded in Zangilan district, 53 km northeast of Ordubad station. The earthquake was felt up to 5 in the epicenter and 4-3 in the surrounding regions. 1 foreshock and 7 aftershocks were recorded before the mainshock. A spatial distribution map of the seismic intensity of the earthquake that occurred in Zangilan region was drawn up based on the ELER program (Figure 6).

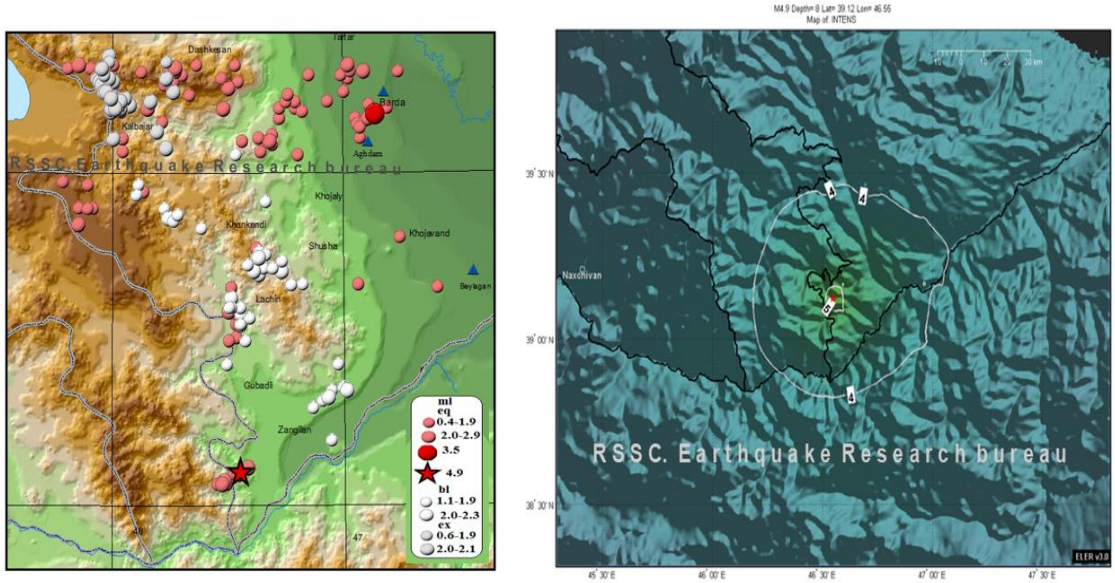


Figure 6. Map of epicenters of earthquakes in the territory of Karabakh and spatial distribution map of seismic intensity

On October 4, at 05:41 local time, an earthquake of magnitude ml=3.5 was recorded in Agdam region, 9 km southwest of Barda station. The earthquake was not felt.

Caspian water area. In 2022, compared to 2021, the seismicity of the Caspian Sea was lower than the background level. The analysis of the distribution of the number of earthquakes and the released seismic energy shows that the number of earthquakes and the released seismic energy have decreased. The occurrence of earthquakes with magnitude ml≤4.2 in the Central Caspian water area is related to the activation of the Makhachkala-Krasnavodsk fault. The concentration of earthquakes in the center is observed at the intersection of the Agrakhan-Krasnavodsk and transverse Karabogaz Safidrud faults. The foci are spread at a depth of 3-62 km. Towards the center, the increase of earthquakes with magnitude ml≥3 is registered. Earthquakes with magnitude ml≥3 are observed to be distributed at a depth of 23-62 km. The highest earthquake magnitude in the Caspian water area was ml=4.3. The earthquake occurred at a depth of 62 km.

Erupting mud volcano. The Lokbatan mud volcano is one of the world-famous volcanoes located on the Absheron Peninsula of Azerbaijan, near the Lokbatan settlement. This volcano is recognized in both local and international scientific circles as an important natural phenomenon for researchers interested in mud volcanism. The Lokbatan mud volcano first erupted in 1810 and has been active many times since then. During volcanic eruptions, mud, oil, gas and water come to the surface and cover large areas. In 2001, a large mudflow

occurred during the activity of the Lokbatan volcano, and this event attracted the attention of local and international media [1, 6]. On 11.08.2022 at 09:36 local time, another eruption of the mud volcano was observed in Lokbatan. Based on the arrival times of the waves from the stations for the event, the activation period of the eruption of mud volcanoes, the depth of the crater, the continuity of the eruption and the energy released during the eruption were determined.

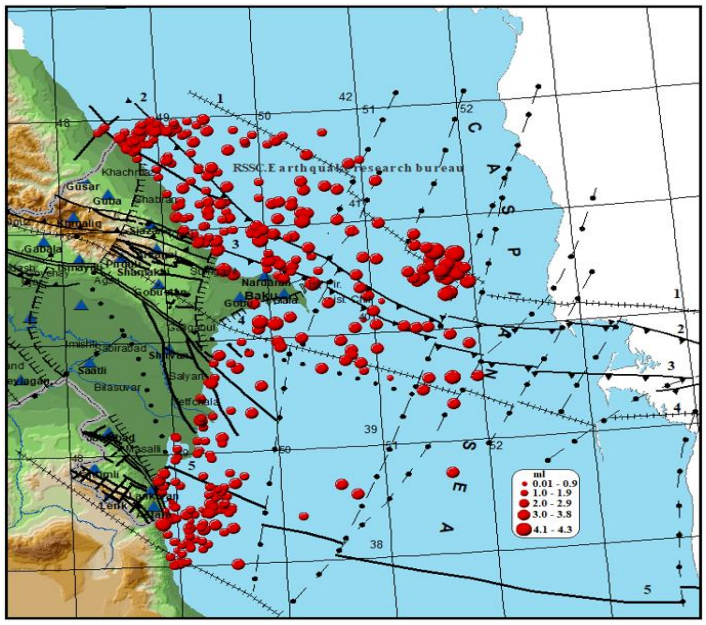


Figure 7. Earthquakes ruptures and epicenters map that occurred in the Caspian water area during 2022. Fractures: 1- Agrakhan-Krasnavodsk; 2 – Makhachkala-Krasnavodsk; 3- Absheron-Pribalkhan; 4 – Sangachal-Ogurchu; 5- Mil-Khishishlar 6 - Garabogaz-Safidrud; 7 – Laxiridjan [11, 13]

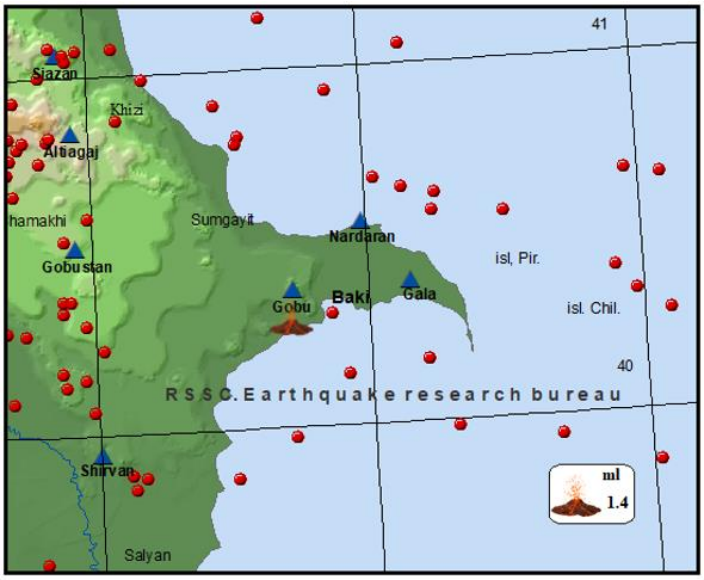


Figure 8. Map of epicenters of earthquakes and volcanoes that occurred on 01.05.2022-11.08.2022 Based on the arrival time of the waves from the stations of the volcano, the activation period of the mud volcano eruption is 05:36, the depth is h-3, and the duration of the eruption is 5 minutes. 12 sec., the seismic energy released during the eruption was determined to be E=0.6·107.

№	Date	Time UTC	Coordination		h, Δ km	ml	Duration
			φ	λ			
1	11.08.2022	05:36:47.06	40.30	49.71	3	1.4	5 m.12h

The volcano was recorded by telemetric seismic stations at Gobu, Nardaran, Gala, Gobustan, Shirvan, Gusar stations.

Mechanisms of earthquake foci.

In 2022, an analysis of the focal mechanisms of 9 earthquakes in the territory of the Greater Caucasus was carried out (Fig. 9) [8]. On March 1 at 14:34:34 local time, an earthquake with magnitude ml=4.2 and depth H=9 km was recorded in Zagatala region. The directions of both compression (P) and tension (T) axes of the earthquake are oriented in the plane close to the horizon (PL=9-28). A sharp angle of incidence (DP=77-64) was determined for both nodal planes. Displacement values at the hearth show that left-lateral displacement is dominantly uplift-type movement, and is consistent with the Kakheti transverse fault. It should be noted that On April 15 at 17:02:35 local time, another earthquake was registered in Zagatala region (magnitude ml=3.9 and depth H=23 km). The direction of the compressive (P) stress axes of the earthquake are oriented in the plane close to the horizon (PL=8). A sharp angle of incidence (DP=57-41) was determined for both nodal planes. The value of the displacement in the hearth shows that the fault-uplift type of movement is dominant, and is consistent with the longitudinal Shambul-Ismailli fault.

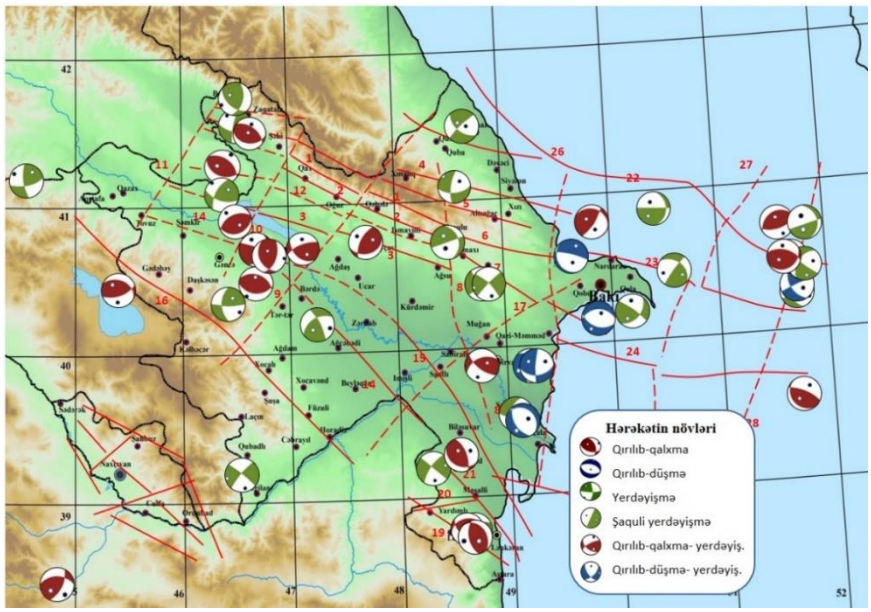


Figure 9. Focal mechanisms of earthquakes with ml≥3.0 that occurred in the first half of 2022 (Map of ruptures was compiled by:[12-13])

Ruptures: 1-Dashgil-Madrasa, 2-Vendam, 3 - Gokchay, 4-Siyazan, 5-Zangi-Kozluchay, 6-Germian, 7-Acichay-Alat, 8-Western-Caspian, 9-Arpu-Samur, 10-Ganjachay-Alazan, 11-Kazakh-Signakh, 12-Northern -Acinour, 13-Iori, 14-Kur, 15-Mingachevir-Saatli, 16-Bashlibel, 17-Palmir-Apsheron, 18-Akhti-Nügedi-Kiliziali, 19-Talish, 20-Yardimli, 21-Öntalish, 22-Center - Khazar, 23 - Apsheron-Pribalkhan, 24 - Sangachal-Ogurchi, 25 - Chikishes, 26 - Yashma flexure, 26a - Gyzilagac, 27 - Shakhov-Azizbeyov, 28 - Garabogaz-Safidra

On July 23, at 12:09:11 local time, an earthquake with a magnitude of ml=3.1 and a depth of H=7 km was registered in Balakan region. The direction of the compression axis (P) of the earthquake is horizontal (PL=0), and the direction of the tension stress axis (T) is oriented in the plane close to vertical (PL=53). A sharp angle of incidence (DP=56-56) was determined for both nodal planes. The value of the displacement in the furnace shows that the fault-uplift-displacement type of movement prevails, and it is consistent with the Vandam Sharur-zakatala faults.

In 2020, the increase in seismicity, which began at the collision of the Shamakhi and Hajigabul seismogenic zones, continues in 2022. On February 7, at 17:56:11 local time, an earthquake with a magnitude of ml=3.4 and a depth of H=6 km was recorded in Hajigabul region. The value of the displacement in the furnace indicates the predominance of fault-uplift type movement and is consistent with the Kura fault.

The strongest earthquake of the year occurred on January 16 at 07:25:04 local time in Zangilan region (magnitude ml=4.9 and depth H=6 km) was registered. Both compression (P) and tension (T) axes of the earthquake are oriented in the plane close to the horizon (PL=8-1). A sharp dip angle (DP=85-83) has been determined for both nodal planes, and the value of the displacement in the focus indicates that the movement of the left side displacement type prevails [8].

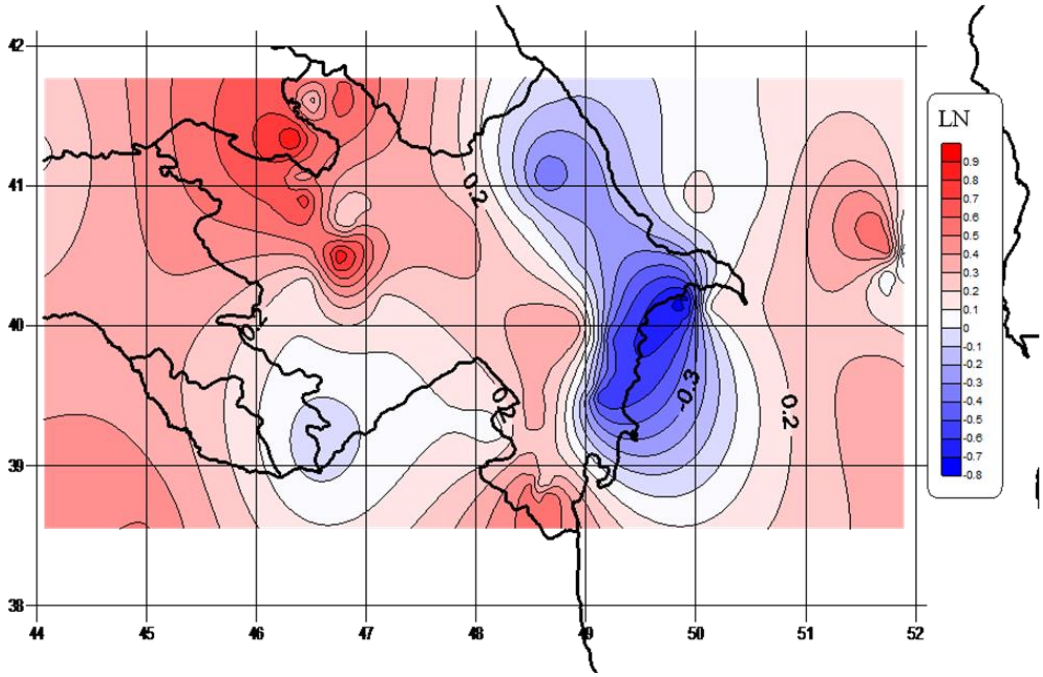


Figure 10. Distribution map of the Lode-Nadai coefficient calculated on the basis of the mechanisms of the earthquakes that occurred in 2022

On March 9, at 22:24:54 local time, an earthquake with a magnitude of ml=3.0 and a depth of H=13 km was recorded in Goranboy region. After that earthquake, another earthquake with a depth of H=17 km was recorded at 22:22:22 local time on April 28. Earthquakes occurred as a result of compressional stress. Displacement values at the hearth indicate a dominant fault-uplift type movement, and are consistent with the Jamubi Kura fault. On October 28 at 11:09:16 local time, another earthquake with magnitude ml=3.0 and depth H=10 km was recorded in Goranboy region. Both compression (P) and tension (T) axes of the earthquake are oriented in the plane close to the horizon (PL=11-23). A sharp angle of incidence (DP=82-66) was determined for both nodal planes. The value of the displacement in the furnace shows that the movement of the left-side displacement type prevails, and is compatible with the Arpa-Samur fault.

On July 31 at 18:35:12 local time, the magnitude ml=3.3 and the depth H=10 km in Jalilabad region. Both the compression (P) and tension (T) axes of the earthquake were oriented in the plane close to the horizon (PL=11-15) and right-lateral displacement-type movements were determined in the center and were consistent

with the Burovar fault. However, on September 6, at 08:05:52 local time, another earthquake with magnitude ml=3.0 and depth H=41 km was recorded in Jalilabad region. A flat incidence angle (DP=24) was determined for the second nodal plane of the earthquake. The value of the displacement in the hearth shows that the overthrust-type movement is dominant, and is consistent with the Bilasuvar fault.

In addition, it should be noted that several strong earthquakes with magnitude ml=5.5-5.7 and depth H=15-28 km were recorded on the territory of Iran from September 21 to October 5. The value of the displacement in the crater shows that the fault-uplift type of left-lateral displacement type of movement prevails, and is consistent with the Başkale Khoy and Tabriz faults.

The Caspian Sea water area in 2022 is characterized by high seismicity, as in previous years. The mechanism of a total of 14 earthquakes with magnitude ml≥3.0 in 2022 in the Caspian Sea region was worked out. The analysis showed that the earthquakes occurred mainly in the intersection zones of the Agrakhan-Krasnovodsk, Sangachal-Ogurchu (Krasnopolyansk), Shakhovo-Azizbeyov and Garabogaz-Safidrud faults.

Thus, as a result of the orientation of the compression and tension axes, a distribution map of the Lode-Nadayi coefficient was constructed. As can be seen from the picture, the central, southern and western part of the territory of the republic is mainly characterized by compressive stress. Tensile stress is observed in the Gobustan-Absheron area and the middle parts of the Caspian Sea, and in the Guba-Gusar region (Fig. 10).

Conclusion

During 2022, 62 seismicity analyzes were conducted based on digital data. 12,284 earthquakes were recorded during the year. Of them, 19 perceptible earthquakes were recorded. In the territory of Azerbaijan, the strongest earthquake with a magnitude of ml-4.9 occurred in the Zangilan area.

In 2022, the explosions that occurred during road construction in the Karabakh area decreased, and activation was observed in the Agdam and Zangilan areas in 2022. Activity was high in Shamakhi-Ismayilli, Gusar-Guba, Gabala-Khinalig and Talish zones. On the southeastern slope of the Greater Caucasus, Zagatala-Balakane (A10=1.0-1.6), Small Caucasus, Gazakh-Aghstafa (A10=1.0-1.6) values are characterized. In 2022, an increase in seismicity was recorded in the Samukh area. At the same time, weak seismicity is observed in the Caspian Sea. Seismicity was high on the Georgia-Armenia border (A10=1.6-2.0). An increase in activity compared to 2021 (A10=1.6-2.0) is observed in the Iranian region

On 11.08.2022 at 09:36 local time, a mud volcano erupted in Lokbatan, and based on the arrival times of the waves from the stations for the event, the activation period of the mud volcano eruption, the depth of the crater, the duration of the eruption, and the energy released during the eruption were determined.

2022 An increase in seismicity is observed in Göranboy and Neftchala regions. Two earthquakes with magnitude ml=3.0 were recorded in Neftchala region on January 14 at 17:45:36 local time and on April 20 at 20:09:08 local time. Earthquakes occurred as a result of tensile stress. The value of the displacement in the furnace shows that the fault-fall type of movement prevails, and it is compatible with the Pirsaat-Salyan-Neftchala fault.

On March 09 at 22:24:54 local time, an earthquake with a magnitude of ml=3.0 was recorded in Goranboy region. After that earthquake, another earthquake was registered on April 28 at 22:22:22 local time. Earthquakes occurred as a result of compressional stress. The value of the displacement in the hearth indicates a dominant fault-uplift type of movement, and is consistent with Kura faulting. The mechanism of 14 earthquakes with magnitude ml≥3.0 in 2022 in the Caspian water area has been worked out. The analysis showed that the earthquakes occurred mainly in the intersection zones of the Agrakhan-Krasnovodsk, Sangachal-Ogurchu (Krasnopolyansk), Shakhovo-Azizbeyov and Garabogaz-Safidrud faults. The values of the displacement in the hearth show that the movements of the broken and falling type prevail.

The analysis of compression and tension axes based on the data of the earthquake source mechanisms showed that the central and western part of the territory of the republic is mainly characterized by compression stress. Tension is observed in the Gobustan-Absheron area and the middle parts of the Caspian Sea, and in the Guba-Gusar region.

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REFLECTION OF THE DYNAMICS OF THE FOCAL MECHANISM OF SHAMKIR AND ISMAYILLI EARTHQUAKES ON THE NATURE OF THE SEISMOMAGNETIC EFFECT (SME)

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Annotation

The article studies information about anomalous changes in the geomagnetic field voltage. The nature of the seismomagnetic effect is determined by the geomagnetic regime in the source. The analysis of the data of the area magnetic surveys allowed to study the stress deformation state of the geological environment in the Sheki-Shamakhi polygon and to evaluate the north-west migration of excess stresses in the earth's crust.

Key word: *SME – seismomagnetic effect, nTl – nanotesla. mechanism of the earthquake center, geodynamic mode, geomagnetic field stress, ml - in magnitude*

ŞƏMKIR VƏ İSMAYILLI ZƏLZƏLƏRININ OCAQ MEXANIZMI DINAMIKASININ SEYSMOMAQNIT EFEKTININ (SME) XARAKTERINDƏ ƏKS OLUNMASI

A.Q. Rzayev, M.K. Məmmədova, Ş.A. İsmayılova

Annotasiya

Məqalədə geomaqnit sahə gərginliyinin anomal dəyişmələri haqqında məlumatları öyrənir. Seysmomaqnit effektin yaranma xarakteri ocaqdakı geomaqnit rejimlə təyin olunur. Ərazi maqnit tədqiqatlarının məlumatlarının təhlili Şəki – Şamaxı poliqonunda geoloji mühitin gərginlik deformasiya vəziyyətini öyrənməyə və yer qabığında izafi gərginliklərin şimal – qərb istiqamətində miqrasiyanı qiymətləndirməyə imkan vermişdir.

Açar sözlər: *SME – seysmomaqnit effekt, nTl – nanotesla . zəlzələ ocağının mexanizmi, geodinamik rejim, geomaqnit sahə gərginliyi , ml – maqnituda*

ОТРАЖЕНИЕ ДИНАМИКИ ОЧАГОВОГО МЕХАНИЗМА ЗЕМЛЕТРЯСЕНИЙ В ШАМКИРЕ И ИСМАИЛЛЫ НА ХАРАКТЕРЕ СЕЙСМОМАГНИТНОГО ЭФФЕКТА (SME)

А.К. Рзаев, М.К. Мамедова, Ш.А. Исмаилова

Аннотация

В статье рассматриваются аномальные изменения напряженности геомагнитного поля перед Шамкирским и Исмаиллинским (ml=4.1, ml=4.2, 24.03.2023 года). Установлено что характер сейсмомагнитного эффекта определяется геодинамическим режимом в очаге. Анализ данных площадных сьемок позволил оценить напряженно-деформированное состояние геологической среды на Шеки-Шамахинском полигоне и миграцию избыточных напряжений в земной коре в северо-западном направлении.

Ключевые слова: *SME – сейсмомагнитный эффект, nTl – нанотесла, механизм источника землетрясения, геодинамический режим, напряжение геомагнитного поля,* ml- *в магнитуда*

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

The magnetometric method is successfully applied not only to geologic mapping, tectonics, the state of fault lines, and the determination of boundaries of geological complexes, but also in seismoprognostic studies and in the study of geodynamic regimes in the epicenters of earthquakes.

This is due to the unique property of the geomagnetic field to record and remember the entire transformation process of the earth's crust. This explains the cause-and-effect relationships of many

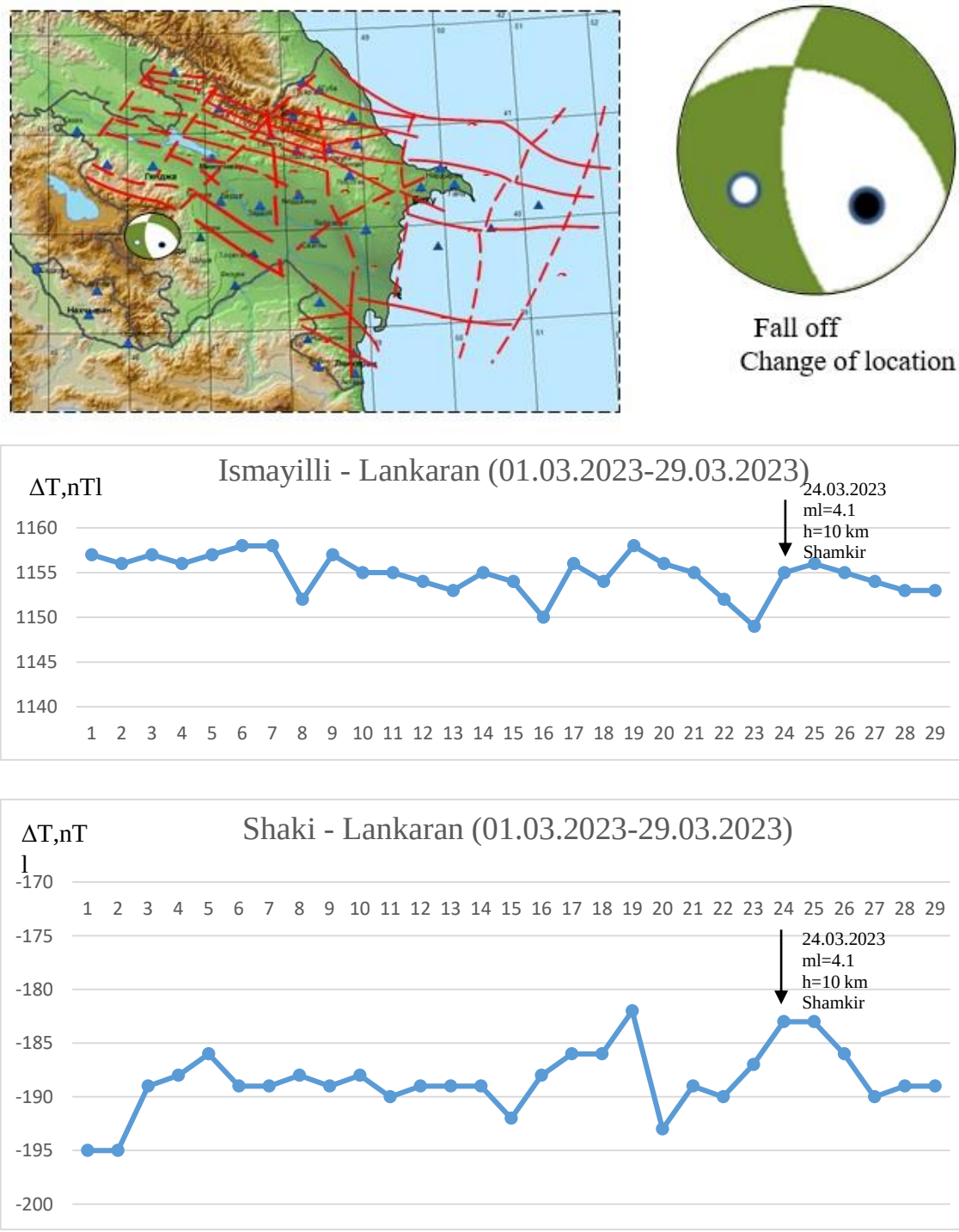


Figure 1. Reflection of the dynamics of the focal mechanism of the Shamkir earthquake (24.03.2023, ml=4.1, h= 10 km) in the nature of the Seismomagnetic effect (SME 10-12 nTl)

24.03.2023 Lat=40.85 Lon=48.20 H=9 Ml=4.2

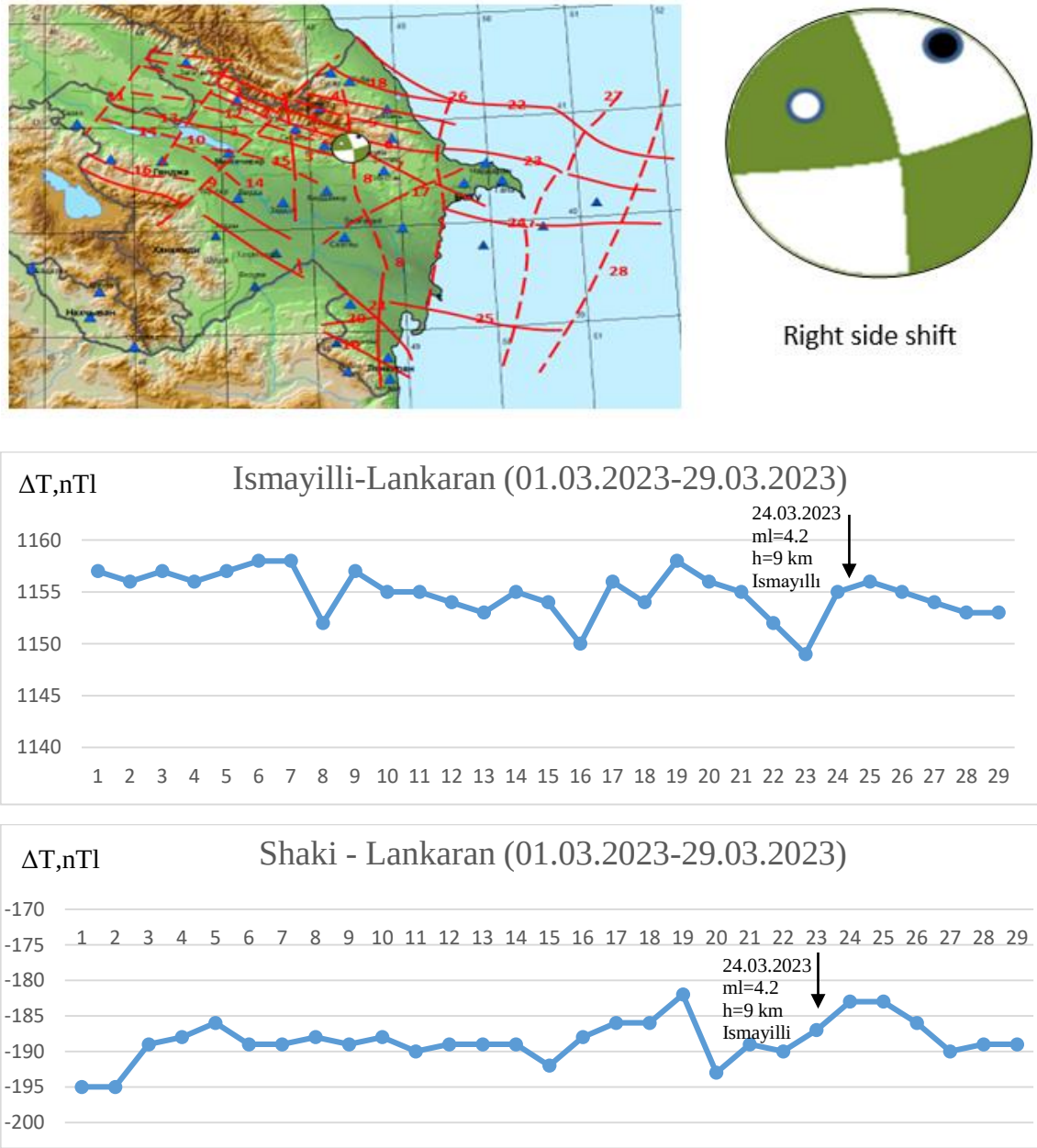


Figure 2. Ismailli earthquake (24.03.2023 ml=4.2, h=9 km) is reflected in the nature of the seismomagnetic effect (SME 10-12 nTl) of the dynamics of the furnace mechanism

geophysical processes that occur under conditions of accumulation of excess elastic stresses. The seismogenic zone is reflected in the formation of the seismomagnetic effect (SME) due to the fact that it is a zone of excess accumulation of elastic energy and frequent changes in the stress state. That is, SME can be considered as an indicator of the seismotectonic process consisting of horizontal and vertical movements of the earth's crust in seismogenic zones as components of the general geodynamic regime. The results of many years of research conducted in Azerbaijan's polygons made it possible to determine a number of characteristic features of the seismomagnetic effect and its dependence on the mechanism of the earthquake source.

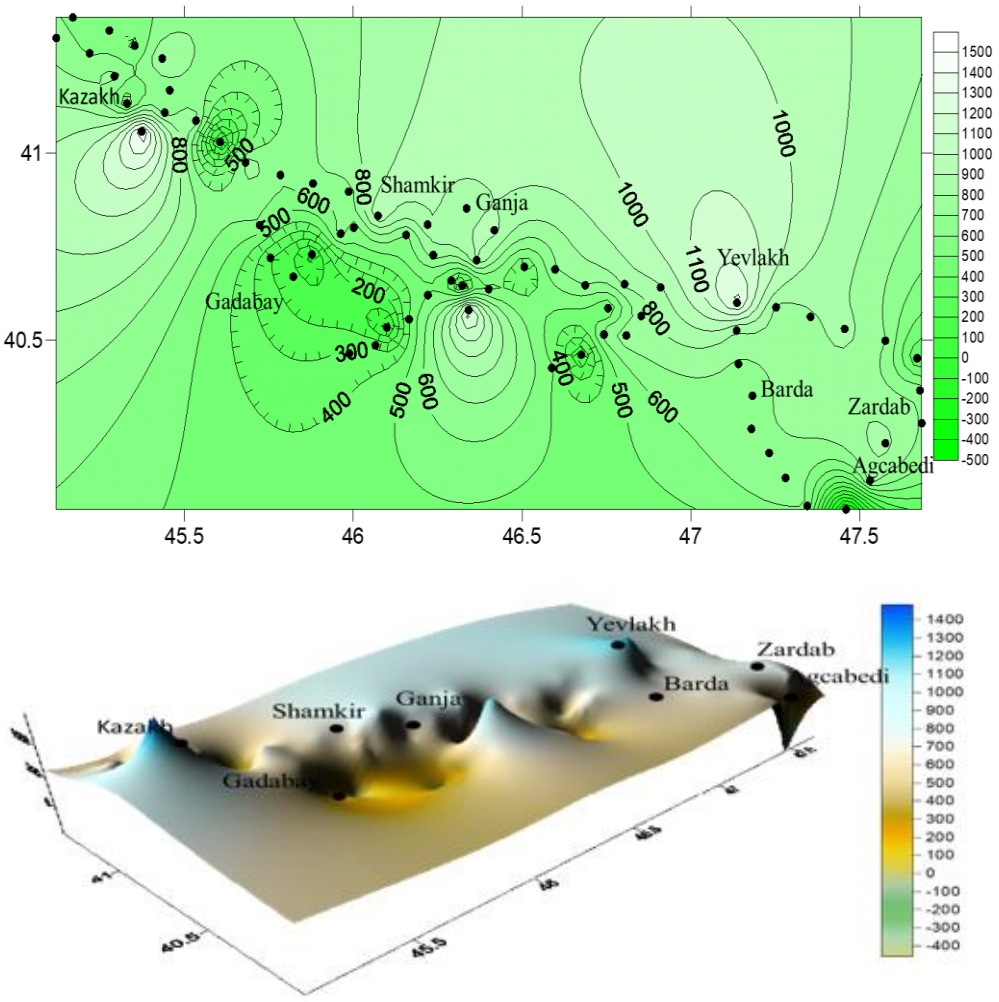


Figure 3. In 2023, the stress-strain state of the earth's crust in the Ganja-Gazakh geodynamic range in 3D format

Thus, in the case of compression of the earthquake center and the formation of reverse fault deformation, the seismomagnetic effect mainly manifests itself with a positive sign. When the tension mechanism is formed in the earthquake center and as a result of this, the fall-sliding deformation occurs, the Seismomagnetic effect is manifested with a negative sign before this seismotectonic process. [Rzayev, 2016]. In order to evaluate the energetic state of any seismogenic zone, the time-spatial growth method of the geomagnetic field voltage gradient was applied. [Rzayev, 2011].

On March 24, 2023, at 08.27.19, an earthquake of magnitude ml= 4.1 occurred in Shamkir region at a depth of h= 10 km. The earthquake occurred in the area where the Pan-Caucasus-oriented Kura and orthogonal Ganjachay-Alazan faults intersect. The earthquake occurred as a result of compressive stress and is characterized by faulting and uplift movements. Angle of incidence 54o-37o, Azimuth angle 88o-290o. The earthquake coincides with the Kura fault. The mechanism of the earthquake source is broken-up type. On the 24th of that date, at 07.09.57, an earthquake of magnitude h= 9 km, ml= 4.2 occurred in Ismayilli district. The earthquake is characterized by right-sided displacement, faulting elements. Dip angle Dip= 83o-81o. Azimuth angle (AZ=350o -82o).

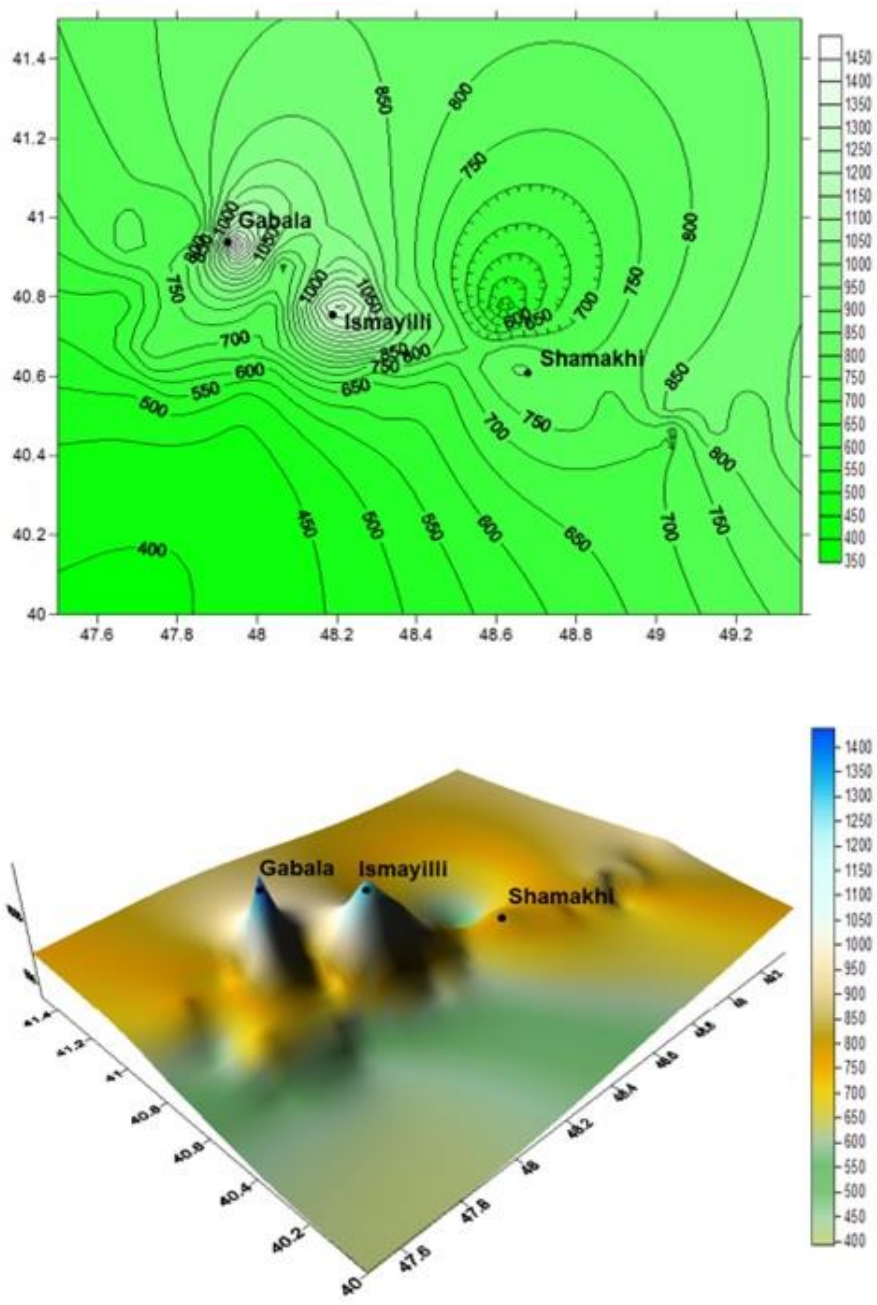


Figure 4. In 2023, the stress-strain state of the earth's crust in the area of the Northern geodynamic range in 3D form

At this time, it is noted that the Seismomagnetic effect (SME) felt at Ismayilli and Sheki stations was formed due to increases. [Figure 1], [Figure 2]. As can be seen from the pictures, the mechanism of the earthquake source, "Break-up" is completely reflected in the time formation of the SME and is confirmed by the nature of the transformations of the geomagnetic field stress.

Depending on the mechanism of the earthquake source, the tension-crisis state of the geomagnetic field $\Delta T \sim f(t)$ of the geological environment is reflected in the pre-earthquake formation of local anomalies with a positive or negative increase in the voltage ΔT

24.03.2023 Lat=40.97 Lon=46.08 H=10 Ml=4.1

As can be seen from Figures 3 and 4, stress-deformation zones against the background of normal distribution of geomagnetic field stress are characterized by a high (positive) gradient of geomagnetic field stress increase of more than -100 nTl km shows that earthquakes occurring within the zones on this background cause uplift faults to rupture in the foci.

Conclusion

Analysis of the time evolution of the voltage gradient of the geomagnetic field allows detection of the seismomagnetic effect (SME) up to 25 nTl. The nature of the SME formation reflects the geodynamic processes during its implementation and during the formation of the earthquake source.

The analysis of the data of the field magnetic surveys made it possible to study the stress-deformation state of the geological environment in the Sheki-Shamakhi landfill and to assess the migration of excess stresses in the earth's crust in the northwest direction.

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ANALYSIS OF ENGINEERING-GEOLOGICAL AND SEISMIC EXPLORATION DATA CARRIED OUT IN ALIJANCHAY AND VILASHCHAY RESERVOIR AREAS

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Summary

The Republic of Azerbaijan is located in an active seismic zone. The seismic hazard of the construction sites should be taken into account during the design of the buildings and facilities built in this area, including water reservoirs. In order to improve the water supply, promote the creation of modern farms on arable land and support the employment of the population, it is planned to build a new dam on the old dam in order to increase the useful volume of the Alijanchay reservoir in the Oguz and Sheki regions, and the Vilashchay reservoir in the Masalli region. Before the construction of water reservoirs on the Alijanchay and Vilashchay rivers, complex seismological, geological and geophysical studies were conducted in the area and the seismic hazard level of the area was assessed.

Key words: *seismic-stiffness method, engineering-seismic exploration, physical-mechanical properties of soils, geological environment, reservoir.*

ƏLİCANÇAY VƏ VİLƏŞÇAY SU ANBARI SAHƏLƏRİNDƏ APARILMIŞ MÜHƏNDİSİ-GEOLOJİ VƏ SEYSMİK KƏŞFİYYAT MƏLUMATLARININ ANALİZİ

E.S.Qaravəliyev, L.T.Fəttahova, İ.N.Cəlilova, A.B.Quliyeva

Xülasə

Azərbaycan Respublikası aktiv seysmik zonada yerləşir. Bu ərazidə tikilən bina və qurğuların, o cümlədən su anbarlarının layihələndirilməsi zamanı tikinti sahələrinin seysmik təhlükəliliyi nəzərə alınmalıdır. Su təminatının yaxşılaşdırılması, əkinə yararlı torpaqlarda müasir təsərrüfatlar yaradılmasının təşviqi və əhalinin məşğulluğunun dəstəklənməsi məqsədilə Oğuz və Şəki rayonları ərazisində Əlicançay su anbarının, Masallı rayonu ərazisində isə Viləşçay su anbarının faydalı həcminin artırılması məqsədilə II növbəsinin, yəni köhnə bənd üzərində yeni bəndin tikilməsi nəzərdə tutulub. Əlicançay və Viləşçay çayları üzərində su anbarlarının tikintisindən əvvəl ərazidə kompleks seysmoloji, geoloji və geofiziki üsullarla tədqiqatlar aparılmış və ərazinin seysmik təhlükə səviyyəsi qiymətləndirilmişdir.

Açar çözlər: *seysmik-sərtlik üsulu, mühəndisi-seysmik kəşfiyyat, qruntların fiziki-mexaniki xüsusiyyətləri, geoloji mühit, su anbarı.*

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

АНАЛИЗ ИНЖЕНЕРНО-ГЕОЛОГИЧЕСКИХ И СЕЙСМИЧЕСКИХ ИССЛЕДОВАТЕЛЬСКИХ ДАННЫХ, ПОЛУЧЕННЫХ В РАЙОНАХ ВОДОХРАНИЛИЩ АЛИДЖАНЧАЙ И ВИЛАШЧАЙ

Э.С. Гаравелиев, Л.Т. Фаттахова, И.Н. Джалилова, А.Б. Гулиева

Аннотация

Азербайджанская Республика расположена в активной сейсмической зоне. При проектировании зданий и сооружений в этом регионе, в том числе водохранилищ, необходимо учитывать сейсмическую опасность строительных участков. Для улучшения водоснабжения, развития современных хозяйств на пахотных землях и поддержки занятости населения в районах Огуз и Шеки предусмотрено увеличение полезного объема водохранилища на реке Алиджанчай, а в районе Масаллы — на реке Вилашчай путем строительства новой плотины на старой дамбе в рамках второго этапа. До строительства водохранилищ на реках Алиджанчай и Вилашчай были проведены комплексные сейсмологические, геологические и геофизические исследования, а также оценена степень сейсмической опасности региона.

Ключевые слова: *сейсмическая жесткость, инженерно-сейсмическая разведка, физико-механические свойства грунтов, геологическая среда, водохранилище.*

Taking into account the huge demand for irrigation and drinking water in the republic, one of the most urgent problems is the efficient use of water resources and the creation of new reservoirs. It should also be noted that the creation of water reservoirs is of great importance in the socio-economic development of the regions. Reservoirs to be built on Alijanchay and Vilashchay rivers will supply thousands of hectares of land with water.

During the engineering activity carried out in the geological environment, taking into account the fact that the engineering assessment of the area is initially determined by the geological conditions and geological structure, the study of the seismic resistance of the reservoirs, the study and evaluation of the geological conditions to ensure their normal operating conditions, the selection of a suitable area for construction and environmental risk management expresses the relevance of research.

The first research area, the projected area on Alijanchay river, is located 10 km southwest of Oguz city.

The second research area is a reservoir located on the Vilashchay river, near the village of Garibler, in the Masalli district. The volume of this reservoir is 46.0 mln. m³, the height of the earth embankment is 37 m. With the construction of the 2nd turn of the reservoir, the height of the dam will be increased by 15 m and the volume of the reservoir will increase to 130 mln. m³.

During the construction of water reservoirs, it is planned to assess the seismic risk in the area, conduct complex seismological-geophysical research, identify areas that may create risk and take preventive measures.

Since the creation of water, human life has been as an integral part, access to water, efficient use of water has been an urgent issue in all ages of history 6.

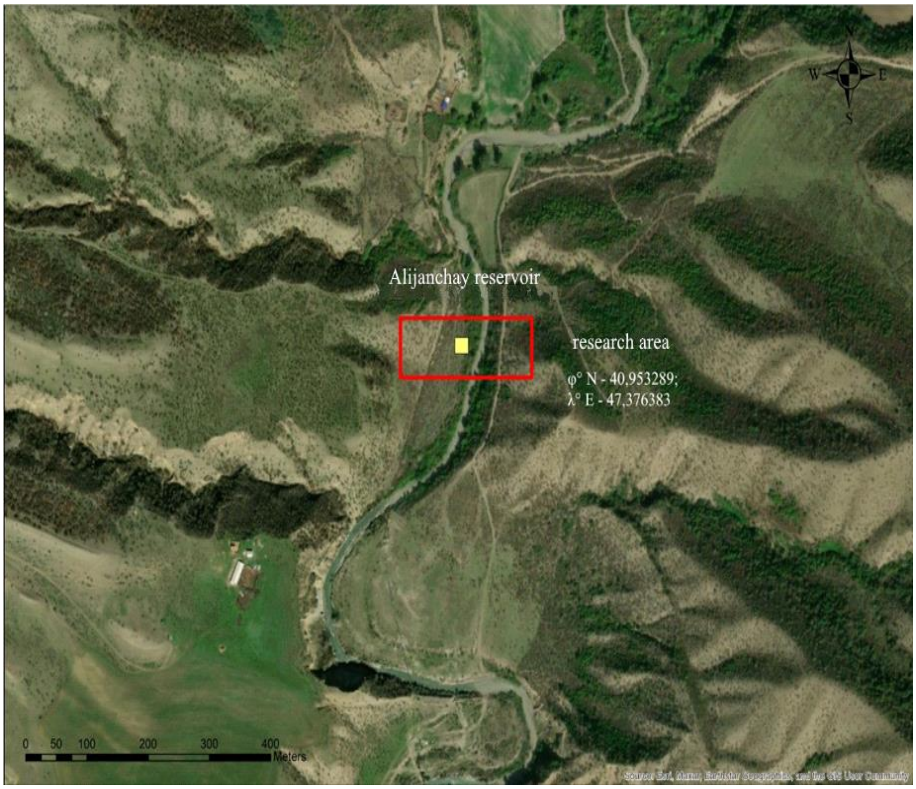


Figure 1. Research area in Alijanchay reservoir (M 1:5000)

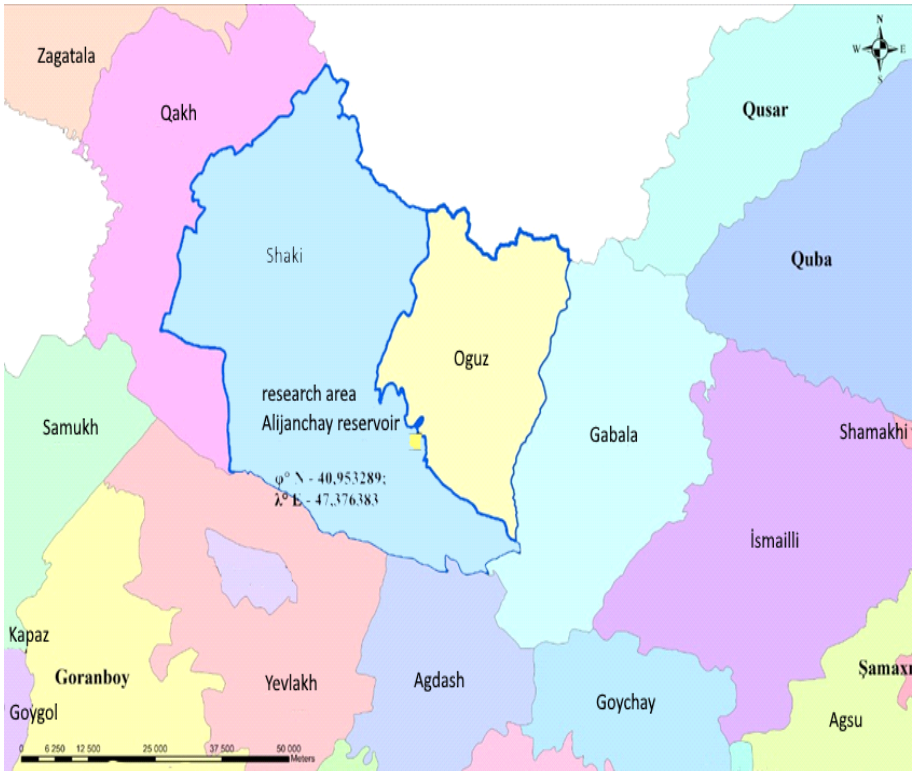


Figure 2. The area where the Alijanchay reservoir (M 1:570000)

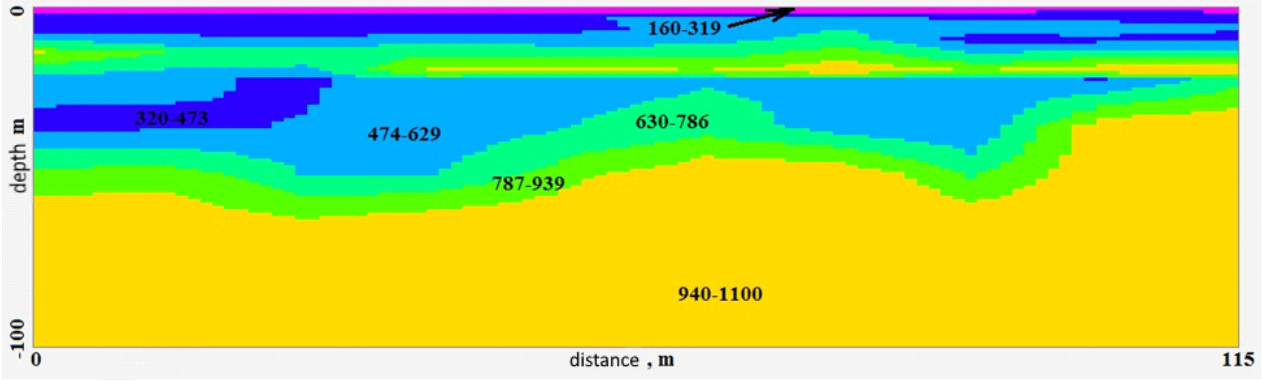


Figure 3. Velocity cut of transverse waves on profile No.1 in Alijanchay reservoir area (in m/s)

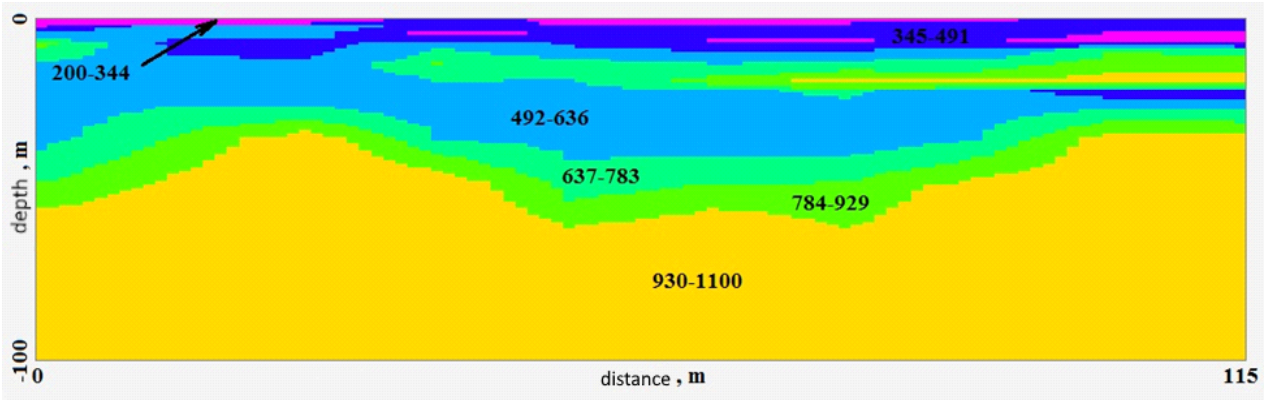


Figure 4. Velocity cut of transverse waves (in m/s) on profile No.2 in Alijanchay reservoir area

Alijanchay reservoir

Alijanchay River is the left branch of Kura River and is formed by the union of Oguz, Dashağıl, and Khalkhal rivers. It flows through the territory of Oguz, Sheki, Yevlakh regions and the city of Mingachevir (pictures 1, 2).

Alijanchay reservoir will contribute to the irrigation of thousands of hectares of land, improve the water supply of the population, and will also play an important role in preventing fires.

In order to study the seismo-geological structure of the reservoir area to be built on the Alijanchay river, research works were carried out using the "Refraction Microtremor (REMI)" method of engineering-seismic exploration. During the research work, seismic profiles were connected to geological exploration wells dug in the area, and the heterogeneity of the environment was monitored in the space between the wells, and characteristic sections were established by calculating the bedding, thicknesses and corresponding transverse wave velocities of the layers 2].

Geophysical measurements, processing and interpretation of received data were performed using high-quality devices, equipment and software that meet modern requirements.

By carrying out geophysical prospecting in geologically risky areas, the seismo-geological structure of the area up to 100 m depth was studied, the stratigraphic and lithological dividing boundaries of the layers were determined, seismic cross-sections were established at depth, and the seismic characteristics of the layered environment were studied.

Using the seismic-stiffness method, the change (increase-decrease) in the intensity of earthquake vibrations of the construction site was calculated based on the physical mechanical and seismic characteristics of the rocks (clay, clay, sand, sandstone, sandstone, gravel) involved in the lithological sections of the research area 1].

Table 1.

Wells №	**Soil Composition**	**Plasticity (I_p)**	**Consistency ($İ_L$)**	**Soil density $_d$ (q/sm^3)**	**Wave speed V_S (m/san)**	**Water level (m)**	**Well deoth h(m)**
The main axis of the dam							
1, 2, 3,4	Clay (solid and semi-solid)	0,16	<0	1,75	500	-	50,0-60,0 -75,0
	Pebbles	0,18	<0	2,18	800		
Upper control bed							
4,5, 6,7,8	Gravels, the composition is gravel	0,14	<0	1,63	500	4,45	30,0-55,0
	Clays, gravel composition	0,20	<0	1,70	600		
	Sandstone, weathered		<0	1,90	850		
Lower control bed							
9,10, 11,12	Sandstone, weathered			1,80	900	3,25	30,0-60,0
	Clay (solid and semi-solid)	0,15	<0	1,73	400		
	Sand		<0	1,67	350		
	Clay, poorly moist	0,21	<0	1,85	580		
The route of the construction-operation tunnel							
1, 4	Clay (solid and semi-solid)	0,11	<0	1,58	470	4,0-4,80	30,0
	Clay, solid and poorly moist	0,21	<0	1,68	500		

Engineer-geological and geophysical data of Alijanchay reservoir area in Oguz region are shown in table 1

Based on the conducted research, the seismic hazard of the area was assessed with 9 intensity points on the 12-point CEC-64 table.

Vilashchay Reservoir

The second research area is the construction of the second phase of the Vilashchay Reservoir located in Masalli district, one of the ancient settlements of Azerbaijan 3].

Masalli district is located 232 km from Baku and its area is 720 km^2. Masalli district located in the south of the republic borders Lankaran, Lerik, Yardimli, Jalilabad, Neftchala districts. It is surrounded by the Caspian Sea (Little Kizilagach Bay) from the east, and the Talysh range of mountains from the west. Vilashchay, Shina-Parada, Godmanchay, Goytepechay, Metalchay, etc. rivers flow. Vilashchay Reservoir was created in a very picturesque place where Vilashchay River exits the sloping plain.

The main hydrographic element of the studied area is the Vilashchay River, its length is 115 km, and the catchment area is 344.6 km^2. The upper part of the river is located in the mountainous zone (picture 5). The water of Vilashchay and its tributaries is sweet (mineralization up to 1.0 g/l).

The studied area is part of the Yardimli synclinorium, which is one of the main geological structures of the Talysh region, and the geological structure of the region includes tufogenic-sedimentary, sedimentary continental sediments of different genesis of the Paleogene, Neogene and Quaternary systems.

Clay and gravel soils of alluvial (aQIV) origin are spread in the research area. The researched reservoir area on the Vilashchay River is shown in Figure 4.



Figure 5. Vilashchay reservoir area (M 1:17 000)

By conducting research, the normative values of the physical and mechanical indicators of the soil in the area were determined (Table 2).

Geological engineering activity carried out in the environment has an impact on the geological environment and creates relevant changes in this environment. Therefore, it has become necessary to study the changes in the geological environment, to effectively use the geological environment and to solve problems related to its preservation. 7].

On the basis of laboratory studies, 4 engineering-geological elements with a depth of 10.0-40.0 m have been separated in the research area.

M 1:220 000

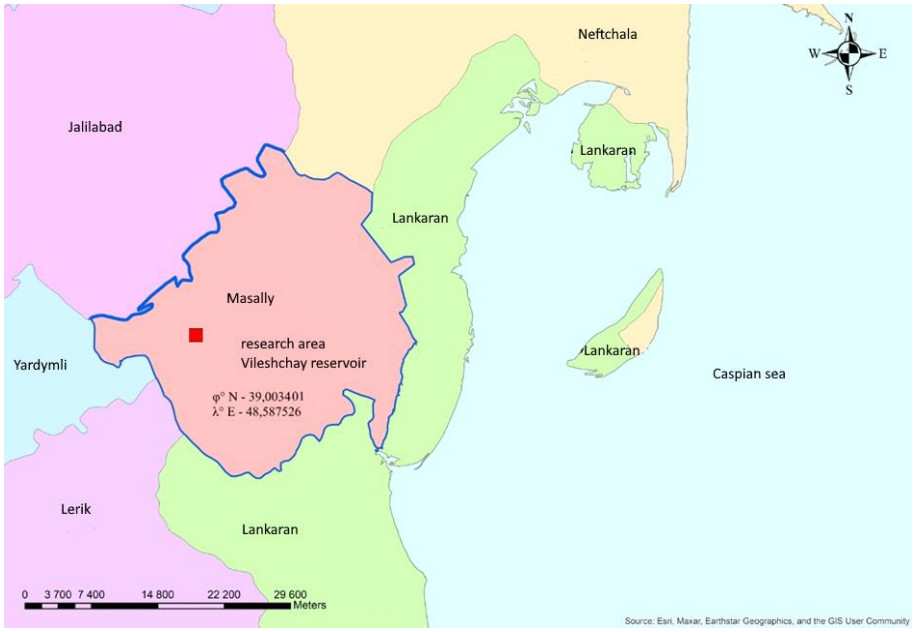


Figure 6. The area of Vilashcay reservoir

Table 2.

Wells №	**Soil composition**	**Soil density, $_d$ (q/sm^3)**	**Transverse wave speed, V_S (m/sec)**	**Well Depth h(m)**
1-23	Pebbles, interspersed with sand and clay	1,71	620	10,0-40,0
	Clay, semi-solid consistency, containing small pebbles	1,58	450	

Based on the conducted seismic studies, the seismic hazard of the area where the Vilashchay reservoir is located was assessed with an intensity of 8 points on the 12-point CEC-64 table, and the importance of considering the engineering-geological and geophysical conditions during construction was assessed.

Studying the characteristic regime of water reservoirs, their hydrodynamics, protection and efficient use of water resources is one of the important issues in our republic 5].

Conclusion

- Based on the conducted geophysical and seismological studies, the seismic hazard of the Alijanchay reservoir area was assessed as 9 points on the 12-point CEC-64 table, and the seismic danger of the area where the Vilashchay reservoir is located was assessed as 8 points.
- Based on the conducted engineering-seismic exploration studies, it was determined that the soils of Alijanchay and Vilashchay reservoir areas are class II (according to Az.DTN 2.3.-1).

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MULTIFACTOR MODEL FOR SEISMOLOGICAL RESEARCH

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Annotation: The study of risks in seismology or problems of earthquake forecasting are important tasks in modern earth science. The difficulty of solving these problems is that this task is multifactorial, because when assessing risk, many factors that affect the seismicity of an area should be considered. At the same time, to increase the credibility of the assessment, the degree of correlation between factors should be taken into account. Risk assessment depends on various geodynamic factors, which are determined individually for each area of the earth's surface. This paper discusses a multifactor method for implementing the task of assessing the risk of seismicity in an area.

Key words: *risk, seismology, multifactor method, earthquake, model.*

SEYSMOLOJİ TƏDQİQATLAR ÜÇÜN MULTİFAKTOR MODELİ

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Xülasə: Seysmologiyada risklərin öyrənilməsi və ya zəlzələnin proqnozlaşdırılması məsələləri müasir Yer haqqında elmin mühüm vəzifələrdir. Bu problemlərin həllinin çətinliyi bu vəzifənin çoxfaktorlu olmasıdır, çünki riskin qiymətləndirilməsi zamanı ərazinin seysmikliyinə təsir edən bir çox amillər nəzərə alınmalıdır. Eyni zamanda, qiymətləndirmənin etibarlılığını artırmaq üçün amillər arasında korrelyasiya dərəcəsi nəzərə alınmalıdır. Riskin qiymətləndirilməsi yer səthinin hər bir sahəsi üçün fərdi olaraq təyin olunan müxtəlif geodinamik amillərdən asılıdır. Bu məqalə bir ərazidə seysmiklik riskinin qiymətləndirilməsi tapşırığını həyata keçirmək üçün çoxfaktorlu metod nəzərdən keçirilir.

Açar sözlər: *risk, seysmologiya, çoxlufaktorlu metodu, zəlzələ, model*

МНОГОФАКТОРНАЯ МОДЕЛЬ ДЛЯ СЕЙСМОЛОГИЧЕСКИХ ИССЛЕДОВАНИЙ

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Аннотация: изучение рисков в сейсмологии или вопросы прогнозирования землетрясений являются важными задачами в современной науке о Земле. Сложность решения этих проблем состоит в том, что эта задача является многофакторной, т.к. при оценках риска следует рассматривать очень много факторов, которые воздействуют на сейсмичность района. При этом, для увеличения правдоподобности оценки, следует учесть степень корреляции между факторами. Оценка риска

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[2] *Strategic Scientific Research Center*

зависит от различных геодинамических факторов, которые определяются в частном порядке для каждого района земной поверхности. В данной статье рассматривается многофакторный метод, для реализации задачи оценки риска сейсмичности района.

Ключевые слова: *риск, сейсмология, многофакторный метод, землетрясение, модель*

Introduction

Seismology is largely an empirical science, since seismological models are based on experimental facts. The goal of empirical sciences is to capture an abstract model of the results of real observations. In order to draw conclusions about the real connection in the set of observations with the highest probability, probability theory methods are used, since no model can cover the entire set of observations. The goal of probabilistic (stochastic) modelling is to recognize the true structure of the system based on observed data.

Modern theories of the structure of the Earth, explaining the occurrence of earthquakes, are based on seismic observations. The main goal of geophysical research is to determine the structure of the environment based on observations of the characteristics of physical fields. The quality of seismic hazard analysis is determined by the attenuation factor of the intensity of seismic impacts.

The characteristics of the seismic impact of an earthquake are determined by the tectonic structure of the region, the depth of the source, the geometry of the source, the direction and course of the process of destruction of rocks, and other parameters. In addition, local geological features play an important role in the manifestation of the seismic effect at points on the surface.

The seismicity model of the earthquake zone determines the quality of the analysis. The seismicity of the region is characterized by:

1. The frequency of earthquakes;
2. The statistical distribution of the strength of tremors by magnitude;
3. The spatial distribution of sources,
4. Macroseismic observation of seismic events, seismic intensity, and the nature of damage.

Many tasks of seismology are associated with the possibility of calculating the probabilities of some events associated with the seismic process. The main task of seismology is to learn to predict the strength, time and place of earthquakes.

Seismic processes occur and develop in time and space under the influence of the internal determinism of global tectonics. Uncertainties associated with the interplay of the Earth's internal physical fields and the gravitational force of celestial bodies, as well as their influence on global tectonics, introduce an element of randomness into seismicity models [Burtiyev, 2017].

Multifactor analysis in seismology

Seismic processes are diverse, since their formation is caused by various geological and geophysical processes occurring in the depths of the Earth. These processes are characterized by many different parameters, which are characterized by multifactor random variables. In the study of such multiparameter processes, multivariate analysis is used [Tarasov, 2011].

Multifactor analysis is based on determining the minimum number of factors that make up the largest share of data variance. In studying the complex nature of seismicity, factor analysis helps to better understand the essence of seismic processes. Factor analysis allows us to study the structure of the relationship of variables, where each group of variables will be determined by the factor for which these variables have maximum loads.

The result of factor analysis is the transition from a set of initial variables to a smaller number of new variable factors. Factor analysis solves the problem of reducing the number of variables with minimal loss of initial information. If we assume that the correlations between variables are explained by the influence of hidden factors, then the main task of factor analysis is to analyze the correlations of a set of parameters.

Most factor analysis methods are based on principal component analysis, which transforms a group of correlated original variables into another group of uncorrelated variables. Principal component analysis solves

the problem of reducing the number of variables while maintaining the maximum proportion of variance in observations by selecting only the main components that explain the majority of variance.

To improve the efficiency of the seismicity risk assessment process in a given area, it is necessary to be able to conduct forecasting based on multifactor models.

The main stages of forecasting in a multifactor model are:

1) selection of factors that are not correlated with each other;

2) determination of the parameter values of the multifactor forecasting model;

3) verification of the adequacy of the resulting multifactor forecasting model;

4) application of the multifactor forecasting model.

The main stages of factor analysis: calculation of the correlation matrix; extraction of factors; selection and rotation factors; interpretation of factors; calculation of coefficient values; assessment of the quality of the model. For example, in [Ioane, 2021], an array of seismic data is analyzed, consisting of parameter values characterizing the mechanism and geometry of the Vrancea seismic zone in Romania. It is assumed that the values of these parameters are due to hidden factors that cannot be observed directly. Identification of these factors is the task of factor analysis.

The task of factor analysis is to determine the minimum number of factors that contribute most to data dispersion. The use of factor analysis begins with the calculation of descriptive statistics of the array of observed values for 16-dimensional random variables characterizing the seismicity mechanism and geometry of the Vrancea source. Factor analysis allows us to identify the relationships that determine the correlation interdependence between seismic parameters. It is assumed that the cause of a significant correlation between the parameters are the sought-after factors. The task of factor analysis is to determine the minimum number of factors that contribute most to data dispersion. The values of the statistical characteristics of the parameters in this work have a large spread, that is, their values are measured in different units that are incompatible with each other, so they are scaled using standardization (1):

$$X_{ij}^{s} = \frac{X_{ij} - \bar{X}_j}{\sigma_j} \qquad (1)$$

where: *Xij* is the value of the *j* parameter in the *i* observation, *Xi* is the value and *σi* is the standard deviation of the *j* parameter.

The values of the statistical characteristics of the parameters in the experiment [Ioane, 2021] have a large scatter, and their values are measured in different units that are incomparable with each other, so they should be brought to a single scale using standardization. The first idea of the presence of dependent parameters can be obtained from the correlation matrix, which characterizes the degree of correlation between the parameters of the original array. The higher the proportion of high correlations, the better the data are suitable for factor analysis. For example, the value of the correlation coefficient between the parameters np_{1stk} (direction of nodal plane 1) and np_{2stk} (direction of nodal plane 2) is 0.726 [Burtiyev, 2017]. The value of the correlation coefficient between the parameter p_{az} (azimuth of the compression axis) and np_{1dp} (angle of incidence of the nodal plane - plane of zero displacements 1) is 0.884 [Burtiyev, 2017], which indicates a sufficiently high degree of dependence between the parameters and is the basis for including them in one group. In factor analysis, the correlation matrix is transformed, after which all non-diagonal elements of the correlation matrix become zero, and the diagonal elements change their values. This means that the parameters become independent of each other. Most factor analysis methods are based on principal component analysis, which transforms a set of correlated input parameters into a set of uncorrelated factors. In this method, after calculating the correlation matrix, it is orthogonally transformed. The factor loadings are determined by the values of the matrix elements. Recall that the factor loading is the value of the correlation coefficient of each of the original features with each identified factor. The closer the connection of a given feature with the factor in question, the higher the value of the factor loading. The most common rotation method is Varimax [Athar,

2023] (uncorrelated factors). The method is based on finding the eigenvalues and eigenvectors of the correlation matrix from the solution of the equation:

$$R = AA' \qquad (2)$$

where: R is the original correlation matrix; A is the matrix whose elements are the loading factors a_{ij} of the parameter i by the component j; A' is the transposed matrix.

The development of a more complex and adequate attenuation model is the subject of study by many seismologists. Thus, the analysis of macroseismic and instrumental data of the Vrancea mid-depth earthquakes revealed some features of the earthquake impact:

- impact on large areas with a predominant North-East and South-West orientation;
- a high degree of dependence of the amplitude of seismic ground displacements on local and regional geological conditions compared to the magnitude and distance from the source;
- high variability of the parameters of strong ground movements; reflection of the earth's surface relief by isolines [Ismail-zade, 2007].

In the near zone, where $r \sim h$ (r is the distance to the earthquake epicenter, h is the depth of the earthquake source), the geometry of the earthquake source has a decisive influence on the configuration of the macroseismic field [Shebalin, 1961].

From the values of descriptive statistics it is evident that the values of statistical characteristics of seismic parameters have a large spread, and their values are initially measured in different units that are incompatible with each other, so they should be brought to a single scale. using standardization (1).

The values of the regression coefficients are estimated by the least squares method, and for consistency, biaslessness and efficiency of estimates, the Gauss-Markov conditions must be met:

$$E(\varepsilon_i) = 0, \ (i=1,n) \qquad (3)$$

The variance of the random component in all observations must be constant (homoscedasticity), equal to zero, i.e.

$$D(\varepsilon_i) = \sigma^2, \ (i=1,n) \qquad (4)$$

Recall that homoscedasticity is a property that denotes the constancy of the conditional variance of a vector or sequence of random variables. It is assumed that the random component has a normal distribution, i.e.

$$E(\varepsilon_i \varepsilon_j) = 0, \ \varepsilon_i \sim N(0; \ \sigma^2), \ (i \neq j) \qquad (5)$$

The multivariate linear regression model is expressed by the following expression:

$$y_i = \alpha + \beta x_1 + \beta x_2 + \ldots + \beta x_{18} + \varepsilon_i \quad (i=1,n) \qquad (6)$$

where: y is a dependent random variable, $x_1 \ldots, x_j$ are regression variables; β_1, $\beta_2, \ldots, \beta_j$ are regression coefficients; ε is a random variable. The appearance of a random component:

$$\varepsilon_i = y_i - y^{\wedge} \qquad (7)$$

where: y_i is the real value, $y^{\wedge}$ are the values of the dependent variable calculated using the regression equation. They are associated with the influence of unaccounted factors on the dependent variable y, the inadequacy of the selected model and observation errors.

To explain 100% of the variance in seismic data from the experiment [Ioane, 2021], 16 components are required. However, using the factor extraction procedure, it was possible to extract only 4 factors out of 16,

which explains 84,996% of the variance in the data set. That is, a factor model consisting of 4 factors preserves 84.996% of the original information.

When grouping the original array of parameters, information loss is inevitable. Saving information by only 60% is considered a fairly good indicator. Typically, when conducting factor analysis, the first principal components are used, the total share of variance of which exceeds 60%. Considering that during factor analysis the number of parameters is reduced several times, even with a large loss of information, for example, by 40%, it is possible to use a factor model.

The graph of eigenvalues is informative in determining the number of factors that begin to decline sharply. After a given number of factors, the dependence under study is close to the horizontal line, that is, the decrease in eigenvalues slows down. The inflection point is on the 4th factor, i.e. no more than 4 factors are identified. This method is used to determine the number of factors before rotation, the purpose of which is to determine a simple model. In this model, each parameter corresponds to a large value of factor loading for one factor and a small value for all the others.

The factor load is determined by the correlation coefficient of each parameter with each of the identified factors. The sum of the squares of the column loads is the dispersion of the coefficient and serves as a measure of its informativeness. In the principal component method, the dispersion of the principal components is equal to the eigenvalues of the correlation matrix of the original variables. When implementing the stage of selecting factors that do not correlate with each other, the sample values of the paired correlation coefficient (r_{ij}) between the factors x_i and x_j are used. If the condition is met [Tikhomirov, 2003]

$$|r_{ij}| > (0{,}7–0{,}8), \quad (1)$$

then there is a significant connection between these factors. In this case, one of the factors should be excluded so that the same factor is not taken into account twice. Let us denote the risk as R, and $x_1,\ldots,x_n$ as geodynamic factors influencing the risk of seismicity, and the values of the pair correlation coefficient (r_{ij}) between factors xi and x

$$|r_{ij}| < 0{,}6 \quad (2)$$

A multiple linear regression model is proposed as a predictive multifactorial model.

$$y = a_0 + a_1 \cdot x_1 + a_2 \cdot x_2 + a_4 \cdot x_4 + a_9 \cdot x_9 + a_{10} \cdot x_{10} \quad (3)$$

To estimate the parameters of this model (3), the least squares method was chosen.

$$A = (E^T E)^{-1}(E^T Y), \quad (4)$$

where E is the matrix of factor values, Y is the vector of statistical data (time series), T is the transposition operation, (–1) is the operation of finding the inverse matrix. When checking the adequacy of the obtained models, it is recommended to conduct an additional statistical analysis, namely: to check the significance of the coefficients of the forecast models.

$$H0: bj = 0, H1: bj \neq 0, j=1, 2, 4, 9, 10.$$

The *t*-statistic is recommended as a criterion [Lemeshko, 2008]

$$t_j = \frac{a_j}{s(a_j)} \rightarrow t(\nu_0) \quad (5)$$

where: a_j – estimates of the coefficients b_j obtained by the least squares method; $s(a_j)$ – estimates of the standard deviation of the coefficients a_j; the value (5) under known restrictions [Lemeshko, 2008] has a *t*-distribution with the number of degrees of freedom v_0, in our case $v_0 = 7$.

The following were chosen as adequacy criteria: Fisher's F-criterion, the Durbin-Watson criterion, the criterion of "ascending" and "descending" series, and the criterion of peaks. The Durbin-Watson criterion checks the most important premise of regression analysis – the absence of autocorrelation in the sequence of residuals e_t.

The value of the criterion is calculated using the formula

$$d = \frac{\sum_{t=2}^{m}(e_t - e_{t-1})^2}{\sum_{t=1}^{m} e_t^2}$$

This value is compared with two table levels: the lower d_1 and the upper d_2. If the obtained value d is greater than two, then before comparison it must be transformed:

$$d' = 4 - d.$$

If d (or d □) is in the interval from zero to 1 d, then the residual values are strongly autocorrelated. If the value of the d -criterion falls in the interval from d_2 to 2, then there is no autocorrelation. If d_1□□d□□d_2, an unambiguous conclusion about the absence or presence of autocorrelation cannot be made and it is necessary to use another criterion, for example, the first-order autocorrelation coefficient.

Conclusion

The study of risks in seismology or earthquake forecasting issues are important tasks in modern Earth science. The complexity of solving these problems is that this task is multifactorial, since when assessing risk, it is necessary to consider many factors that affect the seismicity of the area. At the same time, to increase the credibility of the assessment, it is necessary to take into account the degree of correlation between the factors. And in some cases, it is also necessary to study the synergy of processes, when the simultaneous impact of several factors has more than the total impact. Risk assessment depends on various geodynamic factors, which are determined individually for each area of the earth's surface. This article discusses a multifactor method for implementing the task of assessing the risk of seismicity of the area.

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CLASSIFICATION OF NON-ANTICLINAL TRAP TYPES IN THE BINAGADI AND SULUTEPE OIL AND GAS FIELDS IN AZERBAIJAN

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Annotation

The main condition is the precise classification of stratigraphic-lithological traps of non-anticlinal type with the allocation of horizons on the compiled map. Providing accurate and complete information on each perspective horizon of the Binagadi and Sulutepe fields, it is possible to indicate their differences. One of the elements of the forecast of non-anticlinal traps is the study of horizons, interpretation and detection of the zone of stratigraphic and lithological wedging. Thus, on the basis of the constructed maps and the definition of oil contours on the Binagadi and Sulutepe areas, it is possible to estimate the location of oil and gas wells.

Keywords: *productive strata, oil and gas contour, sedimentation process, transgression, regression, consedimentation and postsedimentation, diagenesis, catagenesis, hypergenesis and tectogenesis.*

AZƏRBAYCANIN BİNƏQƏDİ VƏ SULUTƏPƏ NEFT-QAZ YATAĞINDA QEYRİ-ANTİKLİNAL TƏLƏLƏRİN TƏSNİFATI

Qədirov Z.S., Huseynova M.A, Ələkbərova S.A., İbrahimova L.A.

Xülasə

Əsas şərt tərtib olunmuş xəritəyə əsasən horizontların müəyyən edilməsi ilə qeyri-antiklinal tipli stratiqrafik-litoloji tələlərin dəqiq təsnifatıdır. Binəqədi və Sulutəpə yataqlarının hər bir perspektivli horizontu haqqında dəqiq və dolğun məlumat verməklə onların fərqlərini qeyd etmək olar. Qeyri-antiklinal tələlərin proqnozunun elementlərindən biri horizontların tədqiqi, stratiqrafik və litoloji sıxışdırma zonasının təsfiri və aşkarlanmasıdır. Beləliklə, qurulmuş xəritələr əsasında Binəqədi və Sulutəpə ərazilərində neft konturlarının müəyyən edilməsilə neft və qaz quyularının yerini qiymətləndirmək olar.

Açar sözlər: *Məhsuldar silsilələr, neft və qaz konturu, çöküntülərin yığılması prosesi, transqressiya, reqressiya, konsedimentasiya və postsedimentasiya, diagenez, katagenez, gipergenez və tektogenez*

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КЛАССИФИКАЦИЯ НЕАНТИКЛИНАЛЬНЫХ ТИПОВ ЛОВУШЕК НА НЕФТЕГАЗОНОСНЫХ МЕСТОРОЖДЕНИЯХ БИНАГАДИ И СУЛУТЕПЕ В АЗЕРБАЙДЖАНЕ

Гадиров З.С., Гусейнова, М. А., Алекперова С.А., Ибрагимова Л.А.

Аннотация

Главным условием является прецизионная классификация стратиграфо-литологических ловушек неантиклинального типа с выделением горизонтов по составленной карте. Давая точную и полную информацию по каждому перспективному горизонту месторождений Бинагади и Сулутепе, можно указать на их различие. Одним из элементов прогноза неантиклинальных ловушек является изучение горизонтов, интерпретация и обнаружение зоны стратиграфического и литологического выклинивания. Таким образом, на основе построенных карт и определения контуров нефти по площадям Бинакади и Сулутепе можно оценить расположение нефтегазовых скважин.

Ключевые слова: *продуктивная толща, нефтегазовый контур, процесс седиментакопления, трансгрессия, регрессия, конседиментация и постседиментация, диагенез, катагенез, гипергенез и тектогенез.*

Introduction

Due to the fact that the onshore anticlinal oil and gas fields of Azerbaijan are at a late stage of development, it is necessary to expand the exploration and prospecting work in more promising areas associated with promising non-anticlinal traps [1].

It should be noted that the problems identified during the exploration of non-anticlinal traps, such as stratigraphic, lithological wedging, erosional rupture, disproportionate angles, reef formation, etc., are associated with the heterogeneity of trap types, their sizes, bedding elements, accumulation conditions, etc. [1-5].

Taking into account the above, at an early stage of the research, various types of the most common non-anticlinal traps in Azerbaijan were selected [2, 3]. For this purpose, 6 types of non-anticlinal traps were studied - pinching out, surface washouts, tectonic ruptures, consedimentation and postsedimentation, repeated changes, and the process of sedimentation. The studies were carried out according to the specified block diagram of Figure 1 of the sequence. As a result of the studies, the diagram shows the breakdown of the stages of the corresponding fragments of the trap. As a result, the type of identified non-anticlinal traps, stratigraphic affiliation, reservoir properties and their productivity are predicted. At the same time, one can encounter unique non-anticlinal traps that differ sharply from each other.

As shown in the figure, to determine the existence of non-anticlinal traps, the initial geological conditions are first investigated. In the process, the conditions for the formation of traps, paleogeography, transgression and regression of the sea basin, and the location of the coastline were investigated. The effects of sedimentation, the accumulation of terrigenous and carbonate deposits, which play the role of seals, are also analyzed. During the research, tectonic disturbances, their geomorphological results and the relationship between sedimentation processes, the tectonic-sedimentary period, factors of the appearance of modern coastal and coastal zones and other geological processes are widely studied. To carry out these research works, a comparative analysis of the Binagadi and Sulutepe oil and gas fields was carried out.

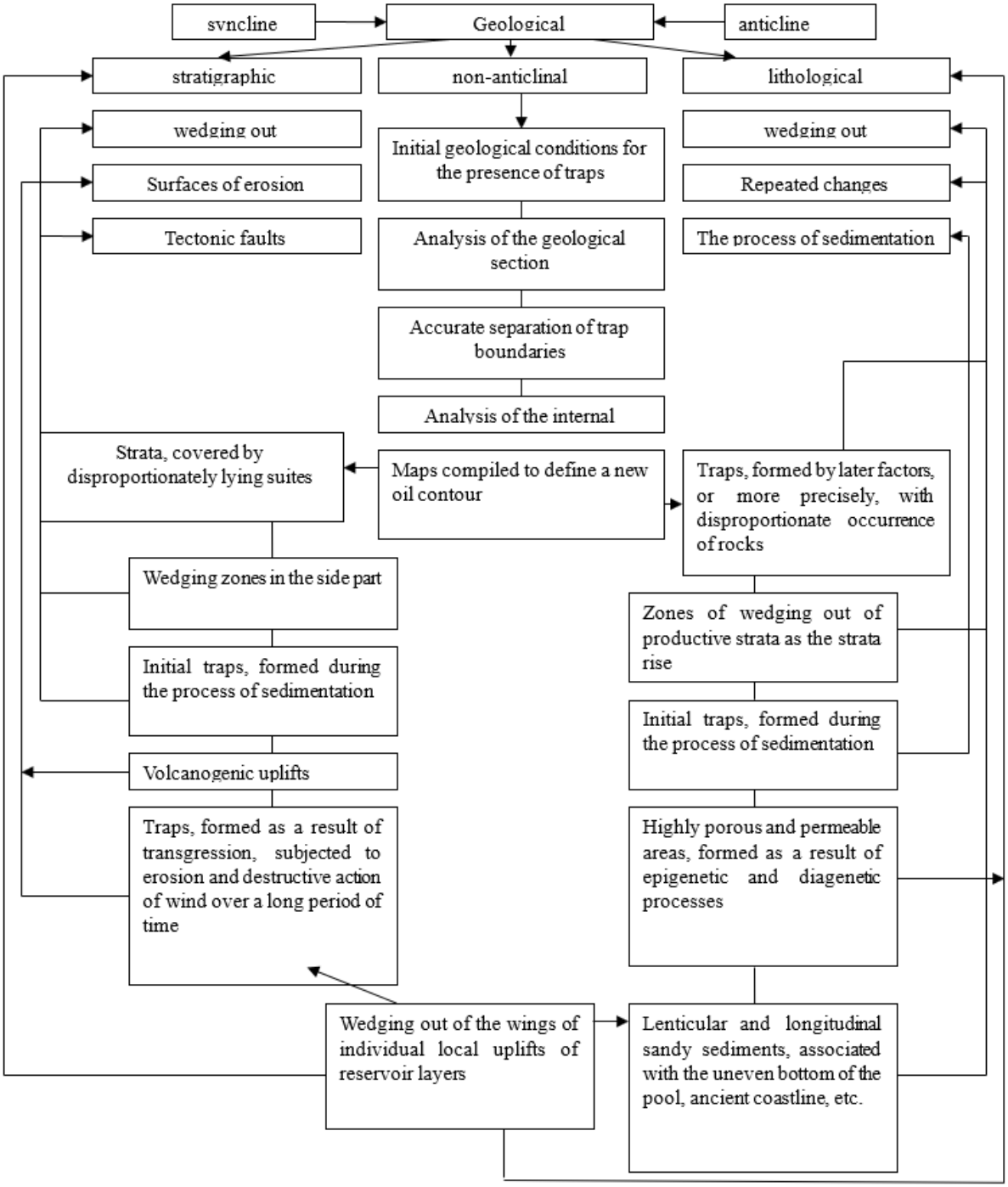


Figure 1. Block diagram of the non-anticlinal trap system approach

At the second stage, according to the studied areas, according to the division of stratigraphic and lithological traps into stages, the causes and time of formation of non-anticlinal types of traps are determined. The concave fold of oil and gas traps of the stratigraphic and lithologic type, reflecting such stages as diagenesis, catagenesis, hypergenesis and tectogenesis, is formed in the process of the evolution of the earth's crust. Therefore, it is necessary to clearly distinguish between stratigraphic and lithologic wedging [1].

Thus, in the second stage, the growth of productive layers is associated with traps with stratigraphic and lithologic wedging or facies replacement.

The formation of lithologic oil and gas traps is associated with the presence of lithologic screening, which has a different structure and genesis. Many horizons associated with wedging are classified as lithologic type traps [1-3]. In our opinion, this is due to the different meanings of the term "wedging". As for wedging associated with the replacement of permeable sediments with impermeable ones, it would be more correct to single out the concept of "lithologic wedging". The basis for identifying lithologic type oil and gas fields is a change in the lithologic composition of rocks. This is genetically associated with a change in the sedimentation process, and at a later stage of development with diagenesis and epigenesis

As shown above, this type of wedging is characterized by an unchanged or slight change in the thickness of the formation, and individual productive layers are wedged out here [2]. Traps with lithological wedging or facies replacement (consedimentation) are formed in the crest part on the bottom of the sedimentation basin as a result of changes in sea level (sand layers are covered with impermeable rocks in a wedge-shaped manner). Stratigraphic and lithological traps were shown on the Binagadi area on the geological section lV-lV (Fig. 2a). Stratigraphic traps are formed here as a result of wedging out of the PKS, KS6, KS_{5c+d} and KS_{5a+b} suites. The noted suites, resting on the roof of the Pontic suite, wedge out from the southeast to the northwest. The wedging area, starting from a depth of 340-350 meters, continues up to 40-50 meters. The dip angles of the layers are 45-50º [4].

. The lithologic trap is located within the KS_4 suite. The trap pinches out at a depth of 120-130 m and has a dip depth of 300 meters. The angle of dip of the trap is 35-40º. These types of traps are formed within the same formation as a result of facies pinching out of porous or low-porosity productive rocks. They are directly related to the sedimentation process, especially the movement of the sea line and the deep part of the sedimentation basin. Therefore, the formation of KS_4 is assumed under the conditions of synsedimentary accumulation. The same horizons that lithologically pinched out as a result of uplifts and regressions, coming to the surface of the earth, were subjected to erosion and were washed out in the crest part. As a result of the subsequent fall and transgression, they are covered with a transgressive layer of sediment at a disproportionate angle. As a result, horizons with lithologic pinching out withdisproportionate surfaces are formed. It would be more correct to relate them to the lithological-stratigraphic group of traps.

Along profile VI-VI (south-west-north-east), penetrable rocks, being replaced by impenetrable ones, form a successive stratification of the observed layers (Fig. 2g). The traps formed as a result of this are associated with the anticlinal folds of the sedimentation basin. Here, on the wings and periclines of the basin, lithological wedging is also observed as a result of the action of sea waves. From the bottom up, within the various suites, the depth of wedging changes significantly. This proves that the bottom of the basin was in intensive movement during the sedimentation period.

At the third stage, eroded surfaces, exposed to erosion and wind action for a long time, are associated with traps formed as a result of consedimentation and postsedimentation.

Due to various inconsistencies, stratigraphic traps formed as a result of oscillatory movements make it possible to substantiate this type from a genetic point of view. Another group of stratigraphic traps is associated with transgression and disproportionate occurrence of reservoir layers (Fig. 2a, b, c, d, e). This disproportionate form is formed slightly further from the coastline. Here, as a result of the continuous approach of the coastline, reservoir layers are formed, which are directly related to the process of pinching out of the consedimentary transgression and disproportionate tilt. Within the redistribution of layers, a disproportionate tilt is also observed. Wedge-shaped layers are also formed during consedimentary regression (Fig. 2a). The noted groups of traps can also be taken as traps associated with stratigraphic pinching out [4].

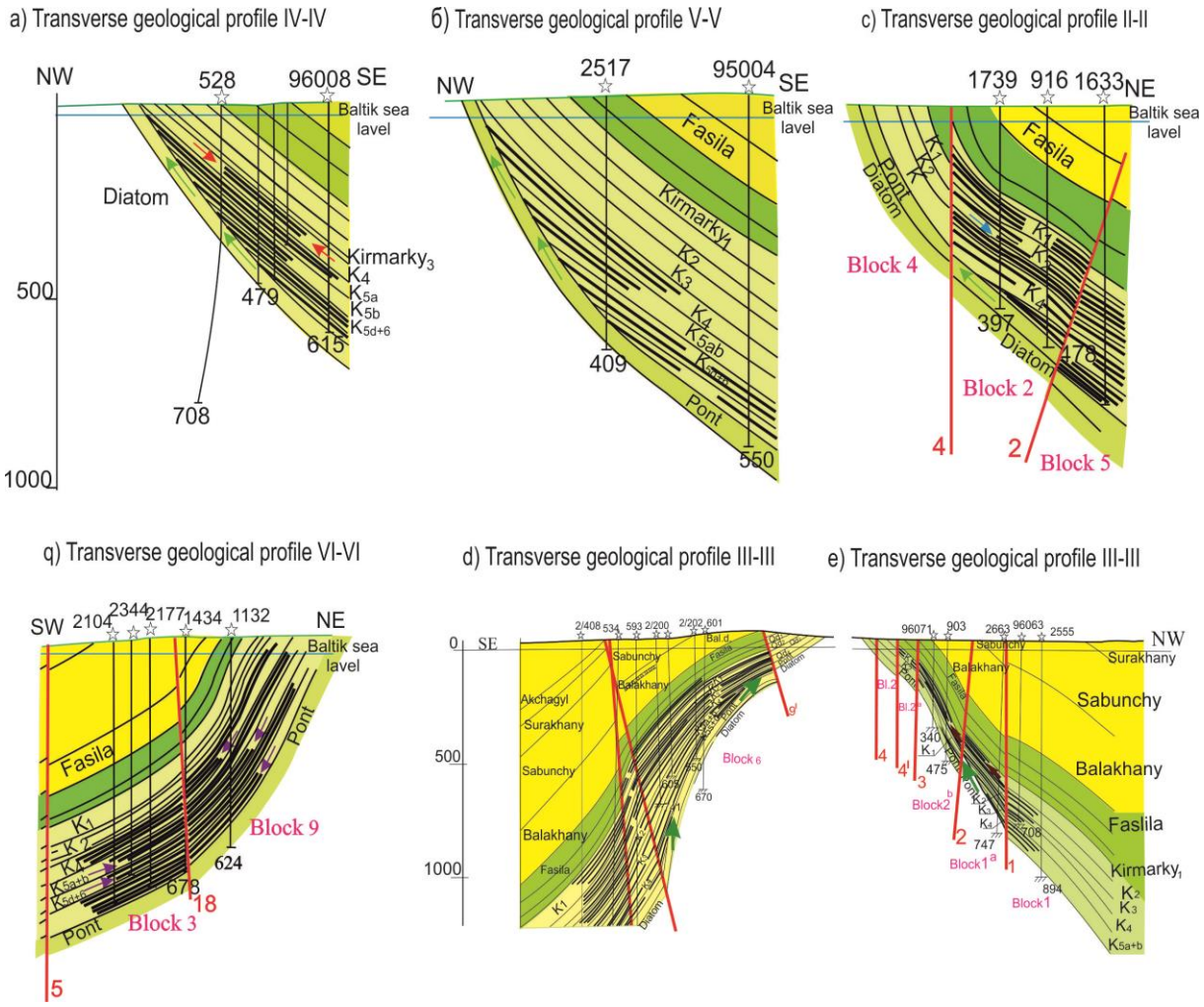


Figure 2. Binagadi oil field. Stratigraphic and lithological oil and gas traps by geological traps.

- *Reservoirs bounded on all sides by impenetrable rocks or lithologically bounded traps;*
- *Stratigraphically wedging horizons (regression and transgression);*
- *Traps associated with sand formations formed as a result of diagenetic and epigenetic features of sedimentation;*
- *Lithological wedging of horizons uplifts of productive strata or lithological wedging as a result of sea level change on the slopes of the basin due to secondary movements occurring on the floor of the sedimentation basin or traps formed by wedge-shaped replacement of sand beds by impenetrable rocks with the formation of synsedimentary traps of facies replacement;*
- *Lithologically wedging traps associated with the replacement of penetrable rocks by impenetrable ones.*

Studies of the stratigraphic traps found at the Binagadi field, as well as the conditions of formation of oil and gas fields show that they are associated with both transgressive cover and regressive bedding forms. To determine the oil contour of the KS_4, KS_{5a+b}, KS_6 and PKS horizons, structural maps were compiled and the difference in the structural structure of the PKS and KS_6 horizons (Fig. 3) from that of the KS_{5c+d}, KS_{5a+b} and KS_4 horizons (Fig. 4) was determined. This shows that during the accumulation of the PKS and KS_6 horizons, as a result of the uplift of the earth's crust in the area of the Boyuk-dag mud volcano, the withdrawal

of sea waters is the cause of regression (stage I) (Fig. 3). And during the accumulation of the horizons KS_{5c+d}, KS_{5a+b} and KS_4 as a result of the expansion of the sea boundary (stage II) a transgression occurred, as a result of which the river boundary shifted 5.8 km to the west.

The sedimentation zones of the horizons KS_6 and PKS do not differ much. Therefore, they can be attributed to stage I. And the sedimentation zones of the horizons KS_{5a+b}, KS_{5c+d} and KS_4 for the same reasons can be attributed to stage II.

In the marginal parts of the sedimentation basin, a transgressive cover is observed in the horizons KS_{5c+d}, KS_{5a+b} and KS_4. Here, the transgressive cover successively covers previously eroded monoclinal layers with a stratigraphic wedge in the direction of the coastline (Fig. 2b). The disproportionately covered transgressive layer consists of impermeable rocks. In its formation during breaks in sedimentation, the main role is played by erosion and washing out of reservoir layers (post-sedimentation processes).

Thus, they are associated with traps formed in the fourth stage as a result of tectonic disturbances.

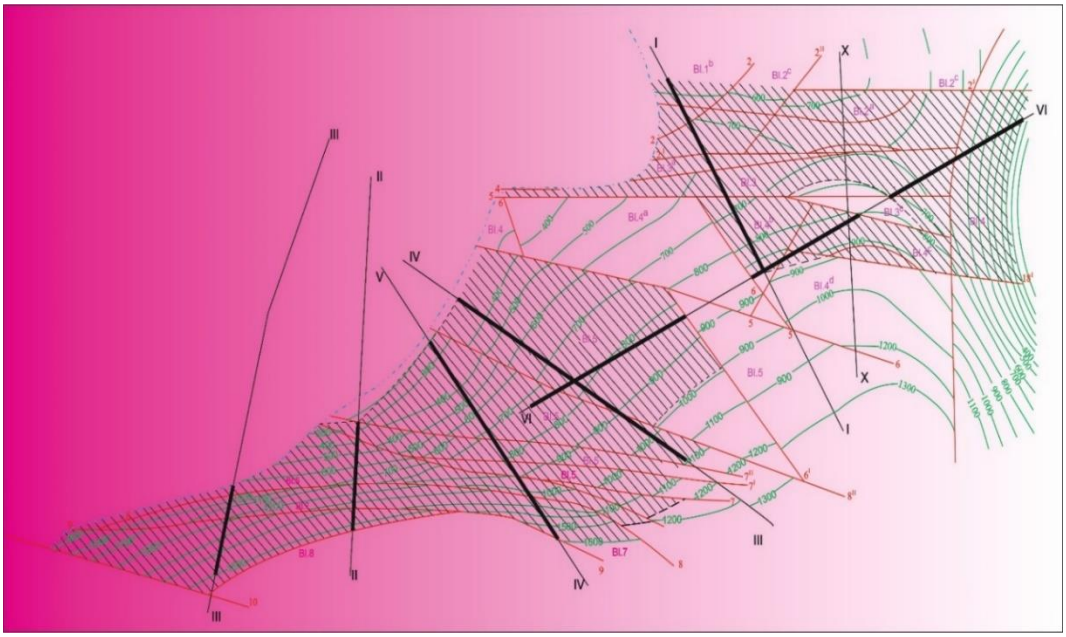
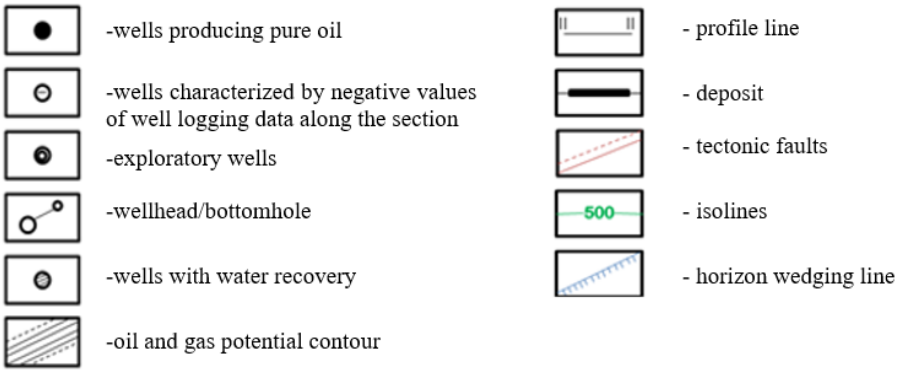


Figure 3. Map of the oil-bearing contour definition along the KS_6 horizon at the Binagady field



Geological profile II-II of the Binagadi area cuts the southwestern and northeastern wings of the structure. Stratigraphic and lithologic traps rich in hydrocarbons are involved here. Lithologic traps are distinguished in the upper part of the NKS suite, as well as the KS_{5c+d} and KS_{5a+b} suites. And stratigraphic traps are associated with the pinching out of the PKS, KS_6, KS_4, KS_2, KS_1 suites (Fig. 2 c, e). Each wing of the structure is complicated by numerous vertical tectonic faults. As a result, traps of a mixed structural-

stratigraphic type are also involved here. As a result of tectonic shift, individual reservoir layers are covered with impermeable layers. It should be noted that these types of traps refer to local uplifts that are eroded in the crest part and covered with impermeable rocks (with an inappropriate angle).

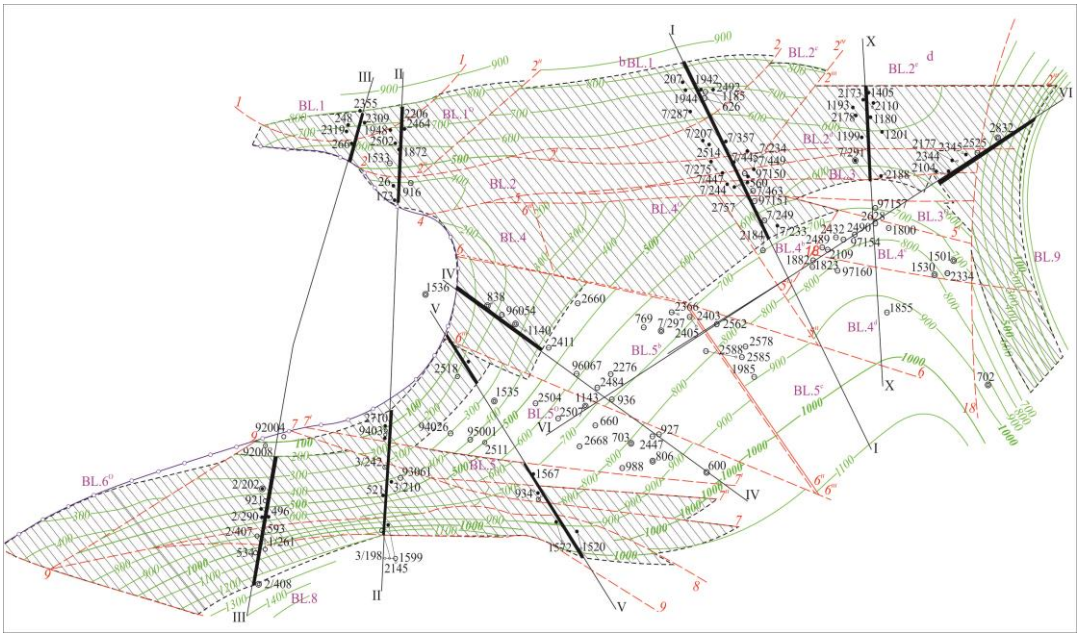


Figure 4. Map of the oil-bearing contour definition by the horizon KS_{5a+b} at the Binagadi field

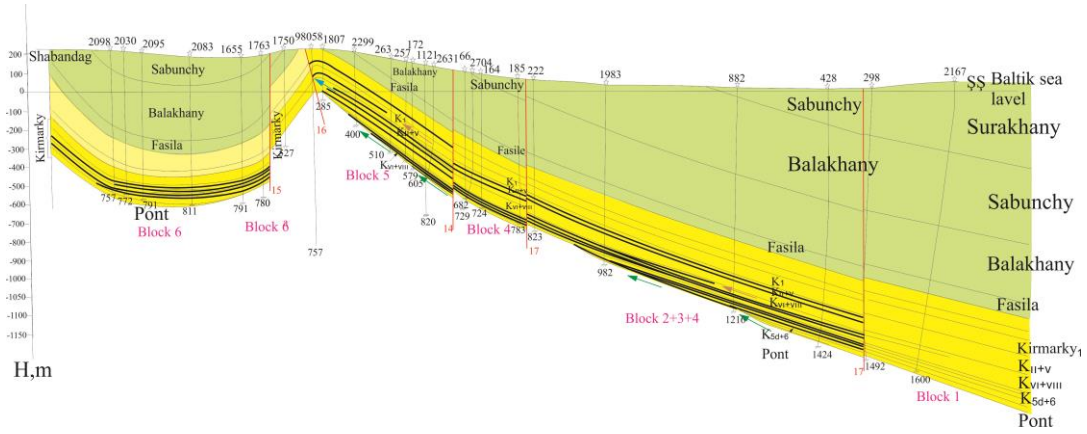


Figure 5. Transverse geological profile VIII-VIII at the Sulutepe field

On the northwestern wing, the angle of dip of the suite is 45-50˚. Here, the presence of tectonic faults is the reason for the development of a large number of structural-stratigraphic traps. But in many suites (KS_{5a+b}, KS_2) as a result of the replacement of sandy rocks with clayey ones, the formation of lithological traps is observed. The stratigraphic trap is associated with the KS_{5c+d} suite.

Repeated change of lithological traps at the fifth stage, refer to lenticular and cord sandy deposits associated with the bottom of the basin, the ancient coastline, etc.

Lithological traps in the Sulutepe oil and gas field are located only along the line of the geological profile VIII-VIII within the horizon KS_{II+V} (Fig. 5).

As the productive strata rise, the lithological traps of the KS_{II+V} horizon are associated with traps of wedging out or facies replacement. This type of wedging out, as shown above, is characterized by an unchanged or slightly changed thickness of the layer, and here individual productive strata are wedged out.

Due to repeated movements occurring on the bottom of the basin, traps with lithological wedging out or synsedimentary facies replacement are formed in the crest as a result of changes in sea level, and sand layers are replaced by impermeable rocks.

Thus, at the sixth stage, the results of the conducted studies are analyzed, the locations of non-anticlinal traps are determined, the allocation of the corresponding fragments of the sections is studied, and the definition of the oil-water boundary is more accurately and widely specified to determine a new oil contour based on the compiled maps.

Maps have been compiled to determine the oil contours of the horizons KS_{II+V}, $KS_{VI+VIII}$, KS_{5d+6}, PKS of the Sulutepe field.

From the map compiled for the horizons KS_{5d+6} and PKS (Fig. 6, 7), it is evident that only stratigraphic traps are open on the geological profiles IX^a-IX^a and IX-IX.

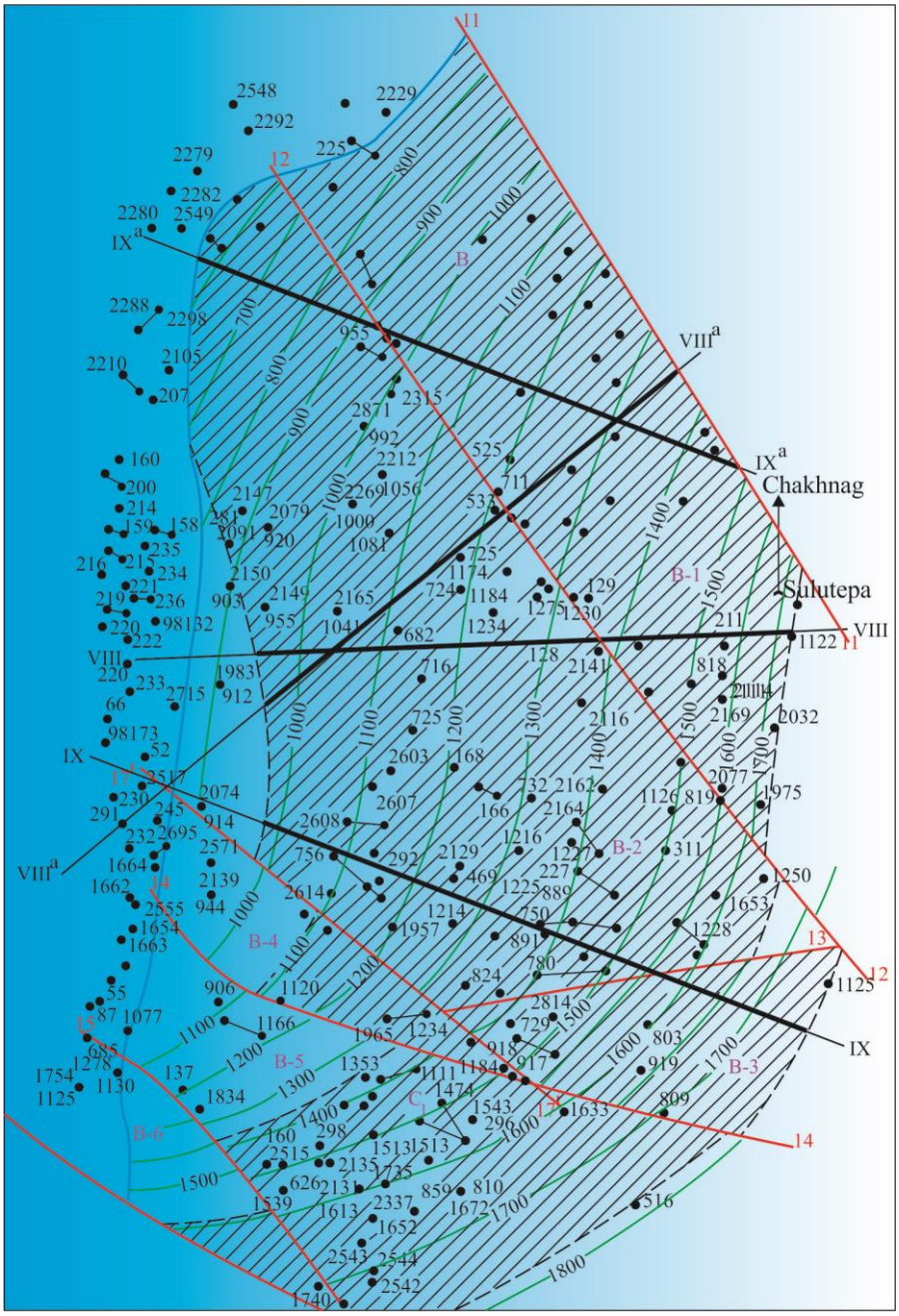


Figure 6. Map of the oil-bearing contour definition for the KS_{5d+6} horizon at the Sulutepe field

It is evident from the section that the $KS_{VI+VIII}$, KS_{5d+6} and PKS suites, starting from a depth of 1600-1750 m, were completely saturated with hydrocarbons. Starting from a depth of 500 m, the KS_{II+V} suites are also saturated with gas and oil. And this group includes the KS_{II+V}, $KS_{VI+VIII}$, KS_{5d+6} and PKS horizons, which are disproportionately based on volcanic uplifts.

The maps take into account the oil and gas, water and various contacts along the sections corresponding to each suite. At this time, it is necessary to make a more accurate choice of petrophysical parameters and lithofacies composition. The correct choice of parameters is a prerequisite for the existence of traps and its productivity. For the first time at the modern level, we have constructed a 3D model to clarify the boundaries of non-anticlinal traps along the KS_{5d+6} horizon of the Sulutepe oil and gas field (Fig. 8).

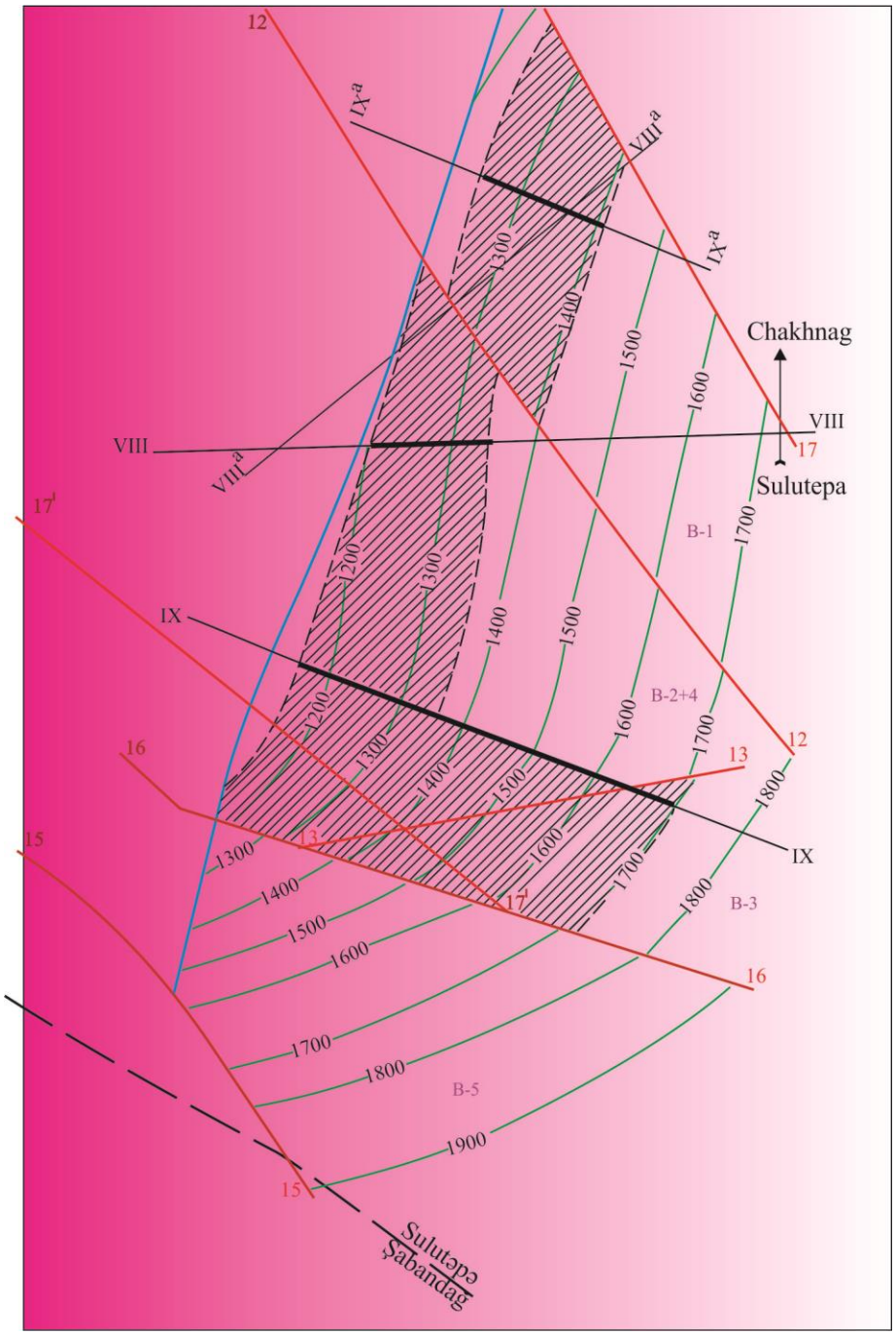


Figure 7. Map of the oil-bearing contour definition along the PK horizon at the Sulutepe field

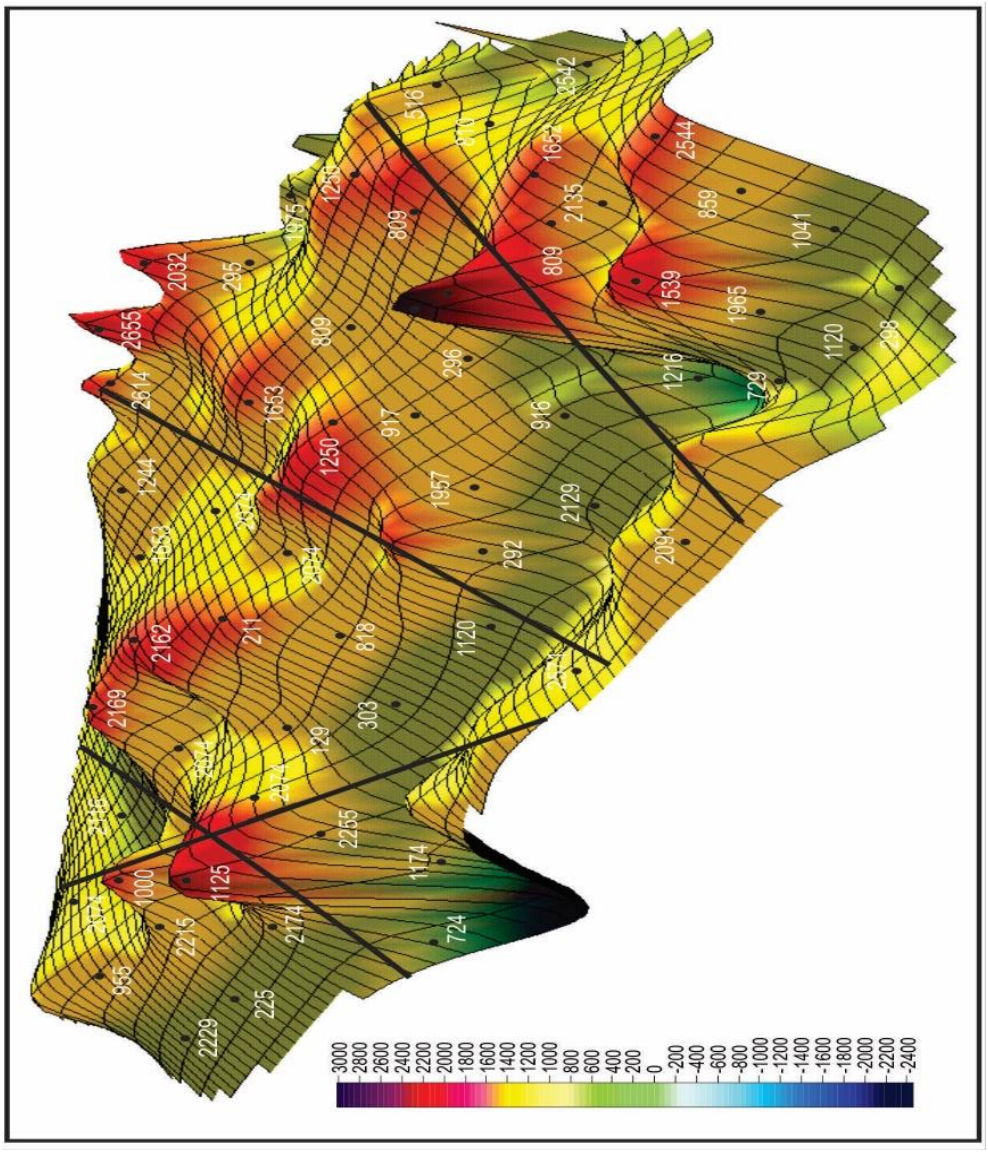


Figure 8. 3D model for horizon KS_{5d+6} of the Sulutepe oil and gas field to clarify the boundaries of non-anticlinal traps.

Almost all types of non-anticlinal traps shown below can be found in the northwestern and southwestern parts of the Binagadi and Sulutepe fields.

- Lithological areas formed as a result of diagenetic and epigenetic processes;
- Zone of lithological wedging out of productive horizons as layers rise;
- Primary traps formed during sedimentation.
- Lenticular and longitudinal sandy sediments associated with an uneven basin bottom, ancient coastline, etc.

Stratigraphic

- disproportionately covered layers in the flank parts of depressions;
- zones of stratigraphic wedging out in the flank parts of depressions;
- Buried uplifts of paleorelief;
- Volcanogenic uplifts;

Stratigraphic-lithological

- Wedging out of reservoir layers on individual local wings of uplifts

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