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The Earthquake Occurred in the West of Kazakhstan, Buzachy Peninsula on April 25, 2023

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Abstract

Until recently, Western Kazakhstan was considered a non-seismic region of Kazakhstan, particularly in the southern and northern parts of the Caspian Sea. Earthquake catalogues of Kazakhstan had almost no data on earthquakes in this region, which is likely to be a consequence of the lack of systematic seismic observations in this area. During the Soviet and post-Soviet periods, no permanent seismic stations were installed in this region. However, the region has recently attracted increased scientific interest due to the presence of extensive oil and gas fields, the active development of which has been accompanied by the rapid urbanisation of the cities of Aktau and Atyrau. The seismic hazard assessment and the construction of general seismic zoning (GSZ) maps of the Republic of Kazakhstan, as well as detailed seismic zoning of individual administrative regions of Western Kazakhstan, require the availability of reliable data on seismic events occurred in the past. The identification of seismic generating zones in the GSZ-2017 map, currently in force in Kazakhstan, is mainly based on a set of geological, tectonic and geophysical data; however, there has been no confirmation of their connection with modern seismic activity. Over the past 15 years, the stations of the network of the National Nuclear Centre of the Republic of Kazakhstan, which are located approximately 1000 km away from the area of the earthquake under study, have recorded a number of earthquakes with magnitude mb = 3 - 4 in the areas of hydrocarbon deposits. The nature of these deposits was considered to be induced, associated with oil and gas production. A station closer to the study area was installed only in 2022 in the north of the Caspian Sea within the framework of the international project SNECCA [1]. It is located about 400 km away from the studied event area. The earthquake occurred on 25 April 2023, magnitude of mb = 4.6, is noteworthy as the first event of this nature to be instrumentally recorded by stations in Kazakhstan and by significant number of seismic stations of various networks in other states. It was felt in numerous settlements across Kazakhstan. A detailed analysis of this earthquake has confirmed the presence of natural seismic activity in the region that was previously considered as aseismic. In this paper, much attention is given to the determination of the instrumental characteristics of this earthquake. A large amount of available data from different processing Centers is involved, data from both individual three-component stations and seismic arrays are used in combination, and different processing methods are applied to locate the hypocentre. The position of the hypocentre in relation to the seismic generation zones identified on the existing General Seismic Zoning Maps (2016) was considered. The obtained data demonstrated the relevance of establishing seismic stations in the considered region for permanent monitoring of seismicity, including weak natural and anthropogenic events. Information about such events will serve to solve important tasks of seismic hazard assessment in Western Kazakhstan.

Keywords

Earthquake, Seismic Station, Hypocenter, Magnitude, Seismic Hazard

1. Introduction

The earthquake of magnitude mb = 4.6 occurred on 25 April 2023 on the territory of the Mangistau area of the Republic of Kazakhstan on the Buzachi peninsula. Shocks with intensity of 4 (MSK-64) were felt by the inhabitants of Kyzan settlement (23 km from the epicentre), Tuzshykol settlement (37 km from the epicentre) and 2 - 3 (MSK-64) in Aktau city. This earthquake is unique for this region, the first perceptible instrumentally registered event is the subject of this paper.

The issue of seismic hazard of the territory of Western Kazakhstan has become very topical in recent decades. This is mainly due to two factors. First, the need for a reasonable assessment of the occurrence of possible natural large earthquakes in this region, which is reflected in maps of seismic zoning of the territory of Kazakhstan as a whole and maps of detailed seismic zoning of its individual regions. Now the question of carrying out work on detailed seismic zoning of the Mangistayu region is being raised. GZS maps are the basis for planning the development of territories, are used in construction codes and regulations for the correct consideration of information on the parameters of large earthquakes and their probability of occurrence in calculations of earthquake-resistant buildings and structures. The accuracy of the estimates affects the seismic safety of the region. Secondly, Western Kazakhstan is an area where large hydrocarbon deposits are located and actively developed. Researchers associate these with the possibility of strong man-made earthquakes, which can also contribute to the assessment of seismic hazard and seismic risk.

Secondly, Western Kazakhstan is an area where large hydrocarbon deposits are located and actively developed. Researchers have identified the potential for strong induced earthquakes, which could also contribute to the seismic hazard and seismic risk assessment.

To study these two factors, it is essential to have a detailed understanding of the historical and current seismic activity of the territory, as well as accurate data on the parameters of detected earthquakes. This information is crucial for conducting a reliable hazard assessment.

However, a significant limitation of the current study is the absence of instrumental data on earthquakes that have occurred in the region under investigation. In the past, the creation of zoning maps was based on hazard assessment data pertaining to seismic generating zones, which were identified through a set of geological, tectonic and geophysical data. This was due to the unavailability of seismic data and the reliance on data on the seismicity of zones situated in other regions, such as the Balkan-Kopetdag seismic generating zone, which is located to the south of Western Kazakhstan and crossing the Caspian Sea from Kopetdag to the Caucasus.

In this regard, a detailed study of the felt seismic event occurred in 2023 in the Western Kazakhstan region on Buzachi Peninsula, initially recorded by all Kazakhstani seismic stations and by the stations of other countries, subsequently processed by numerous international data centers, provides insights into the seismic activity in this region. The data obtained from this analysis can be used for research if the field of seismic impact forecasting.

2. Review of Available Literature on Region Seismicity and Seismic Observation Networks

In the 1990s, the first publications on strong earthquakes on the territory of Western Kazakhstan appeared. However, this information was quite contradictory and unreliable. Thus, the article by Nikonov A.A. [2] describes a strong earthquake of the XIII century probably occurred on the Mangyshlak peninsula. The author provides an approximate location and magnitude based on the limited historical evidence available. The principal characteristics of the South Mangyshlak earthquake are as follows: the time of occurrence is estimated to be 1280 ± 30 years, the latitude is 43.2˚N, the longitude is 51.6˚E, the magnitude is 7.3 ± 0.5, and the intensity at the epicentre is estimated to be between 9 and 10 ± 1.0 points.

The paper by Nurmagambetov A.N. [3], states that according to the map of seismic zoning of Kazakhstan (SNiP P7-81) in force at the time, the Caspian Sea region was considered to be aseismic, with the exception of 5-point oscillations from earthquakes which sources were located in other regions. Nurmagambetov A.A. expresses reservations about the assertion made by Nikonov A.A. regarding the historical occurrence of an earthquake with magnitude M = 7.3 in Mangyshlak. The evidence presented to support the assertion that the XIII-century earthquake occurred in this region is deemed insufficient. The author analyses the Soviet catalogues of earthquakes published in the yearbooks "Earthquakes in the USSR" for the period 1962-1988. A review of the Soviet catalogues of earthquakes published in the yearbooks "Earthquakes in the USSR" for 1962-1988 revealed three events with epicenters on the territory of Mangistau region with magnitude M = 3. However, the location of these events was determined with low accuracy, and the parameters of the events could not be considered convincing.

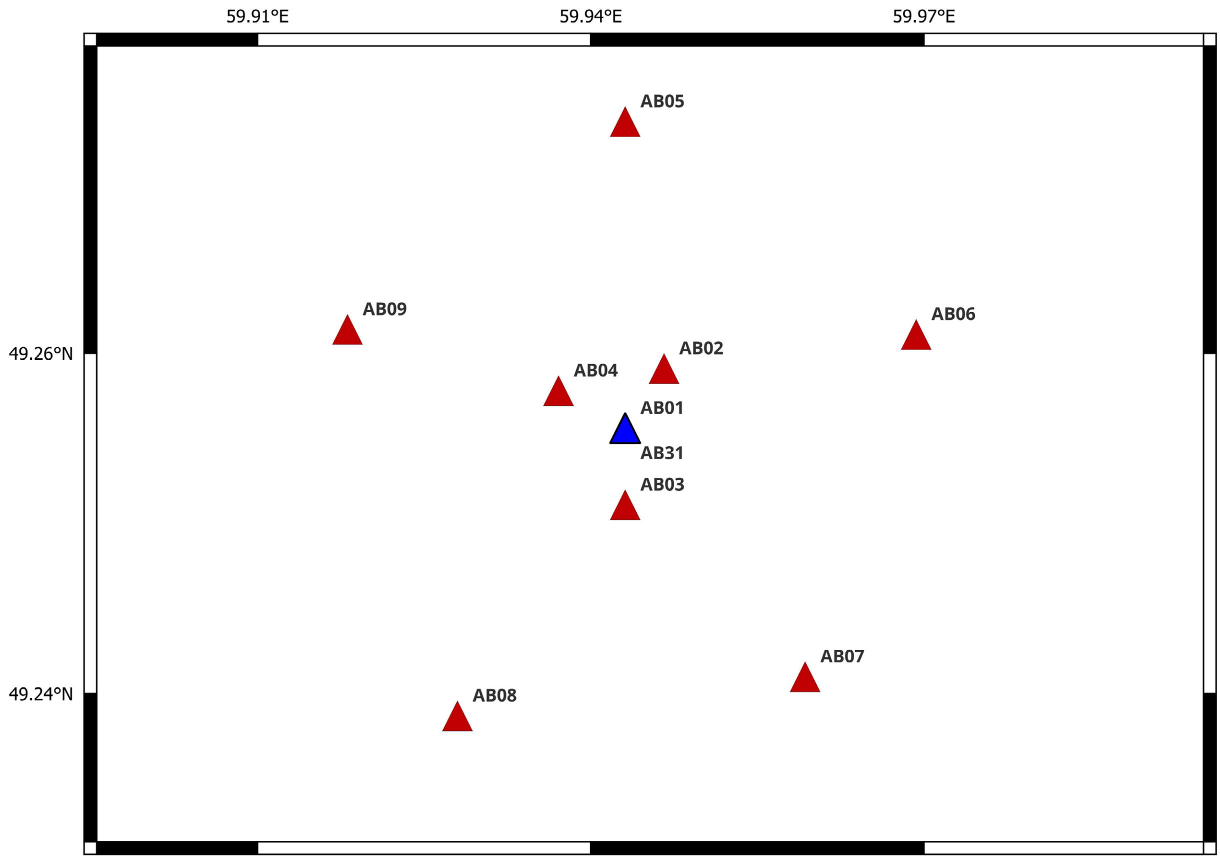
The most reliable data can be obtained by instrumental recording of the event by seismic stations (sometimes also by detailed macroseismic data). However, there were no fixed seismic observation stations in the extensive territory of Western Kazakhstan during the Soviet era. In the planning of seismic observation networks, the selection of station installation sites was always prioritised in areas with a high seismic activity. In other words, new seismic stations were installed in areas where previous seismic activity had already been documented, and no stations were installed in areas where no seismic events had been observed, or where they occurred rarely. These areas were considered to be aseismic by the researchers, despite the lack of empirical evidence regarding their seismic activity.

From time to time, temporary stations belonging to the Complex Seismological Expedition (CSE) of the Schmidt Institute of Physics of the Earth of the USSR Academy of Sciences were installed in Western Kazakhstan. The stations were deployed for a period of up to one year to record nuclear tests. The stations were equipped with short-period devices, namely RVZT and CSE, which had their own periods of seismometers, namely 1.5 seconds and 1.25 seconds, respectively. The stations operated in a restricted area in the vicinity of the Mugodzhary ridge. For example, the stations Bugitsay, Leninskaya, Novotroitskoye and Novogodnaya were operational in 1974-1975 and 1979-1980. Later, the Novotroitskoye station commenced operations as the Aktyubinsk station of the Special Control Service of the Ministry of Defence of the USSR in the late 1980s and early 1990s. Its function was to monitor nuclear explosions.

The situation began to change in 2004, when the seismic monitoring network of the National Nuclear Centre of the Republic of Kazakhstan (NNC RK) underwent significant changes for the study of seismicity in Western Kazakhstan. A new seismic array, Akbulak [4], was opened as part of the AFTAC international network for monitoring nuclear tests and verification of the Comprehensive Nuclear Test Ban Treaty (CTBT) [5], signed and ratified by the Republic of Kazakhstan in 1996 and 2002, respectively. This seismic array is located 200 km south-east of Aktobe. It consists of 9 one-component stations and one three-component station. The array aperture is 4 km. All recording equipment is located in boreholes ranging in depth from 30 to 80 m. Careful selection of the location of the stations, the use of borehole seismometers and special processing methods have made it possible to achieve extremely high sensitivity of this array (**Figure 1**).

It should be noted that recording of events by even one array makes it possible to locate the epicenter of the event, which is difficult if not impossible for one or even two separate three-component stations.

The three-component station in Aktobe continued its operation in a new capacity. Its equipment was modernized and installed in a borehole at a depth of 65



Brown triangles are one-component vertical stations, blue triangles are a three-component station.

Figure 1. Location scheme of seismic observation elements of the Akbulak array.

meters. This station was included in the International Monitoring System of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO IMS) [5].

In 2022-2023, 11 seismic stations were installed and upgraded in Kazakhstan as part of the International Science and Technology Centre (ISTC) SNECCA project [1]. Data from these stations are available for analysis through the IRIS/DMC Center, three of which were opened in the northern part of Western Kazakhstan—the Inder, Fedorovka and Alga stations. The operator of this network is the National Scientific Center for Seismological Observations and Research (NSCSOR) of the Ministry of Emergency Situations of Kazakhstan. However, no stations have yet been installed in the study area of Mangistayu region, where the earthquake occurred.

Since 2004, it has been possible to assess the seismicity of Western Kazakhstan using the instrumental records of two stations of the NNC RK, as well as data from various international data centers with which the Data Centre of the Institute of Geophysical Research of the NNC RK cooperates. These centers are ISC, NEIC, IDC, GSRAS, IRIS/DMC [6]-[9]. Since 2004, on the territory of Western Kazakhstan a large number of quarry explosions, induced earthquakes related to mining, and only some natural earthquakes have been recorded and processed at the Data Centre of the Institute of Geophysical Research of NNC RK. The strongest natural earthquake recorded is the Shalkar earthquake of 26 April 2008 [10]. Its magnitude was 4.3 to 5.3, Ms = 4.6, intensity at the epicenter 7 according to different sources. The origin of this earthquake was located in the north of western Kazakhstan near Lake Shalkar. One aftershock was recorded after the Shalkar earthquake. Near the epicenter of this 2008 earthquake, there are two epicenters of earlier earthquakes—1976 (mb = 3.8) and 1989 (mb = 4.5), found in the data of International Centers [11]. All three events had close parameters of focal mechanisms, indicating their close nature.

In the region of Mangistau, close to the earthquake occurred in 2023, the retrospective analysis of data recorded by the stations of NNC RK allowed us to find records of a natural event. This earthquake occurred on 16 April 2006 at t0 = 12.24.45 with coordinates 44.34N, 53.48E, energy class K = 6.2. To check the reliability of this fact, we have reprocessed the data of the Akbulak seismic array. **Figure 2** shows the records of this earthquake. F-k analysis was then performed [12], and the azimuths to the epicentre were determined to be 221˚ and 224˚ by P- and S-waves (**Figure 3**). The location of the epicentre from the Akbulak and Aktobe stations confirmed its position close to the origin of this 2023 earthquake. **Figure 4** shows the map of seismic stations network operating in Kazakhstan at the time

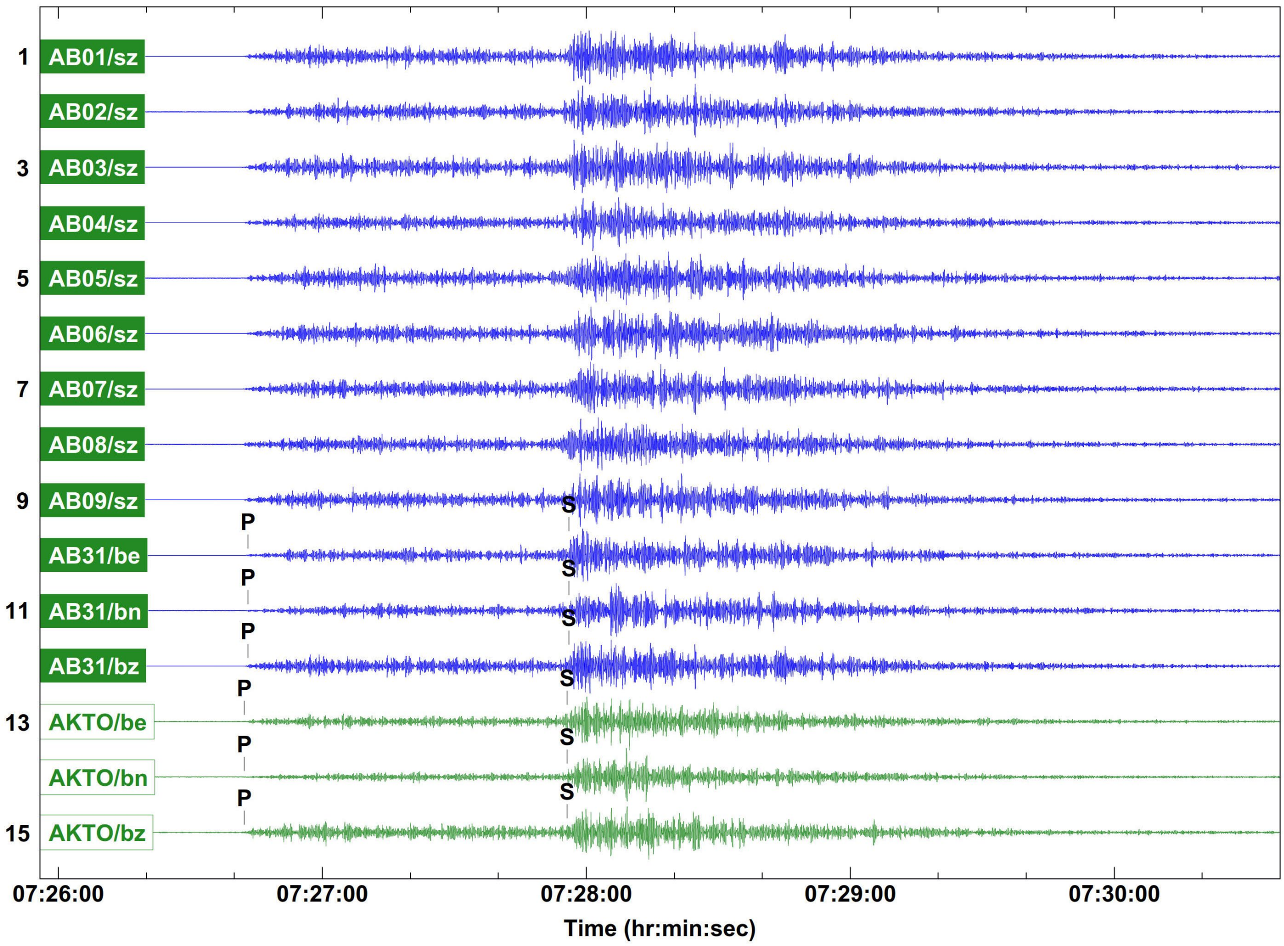


Figure 2. Records of 16 April 2006 earthquake from Akbulak and Aktyubinsk stations.

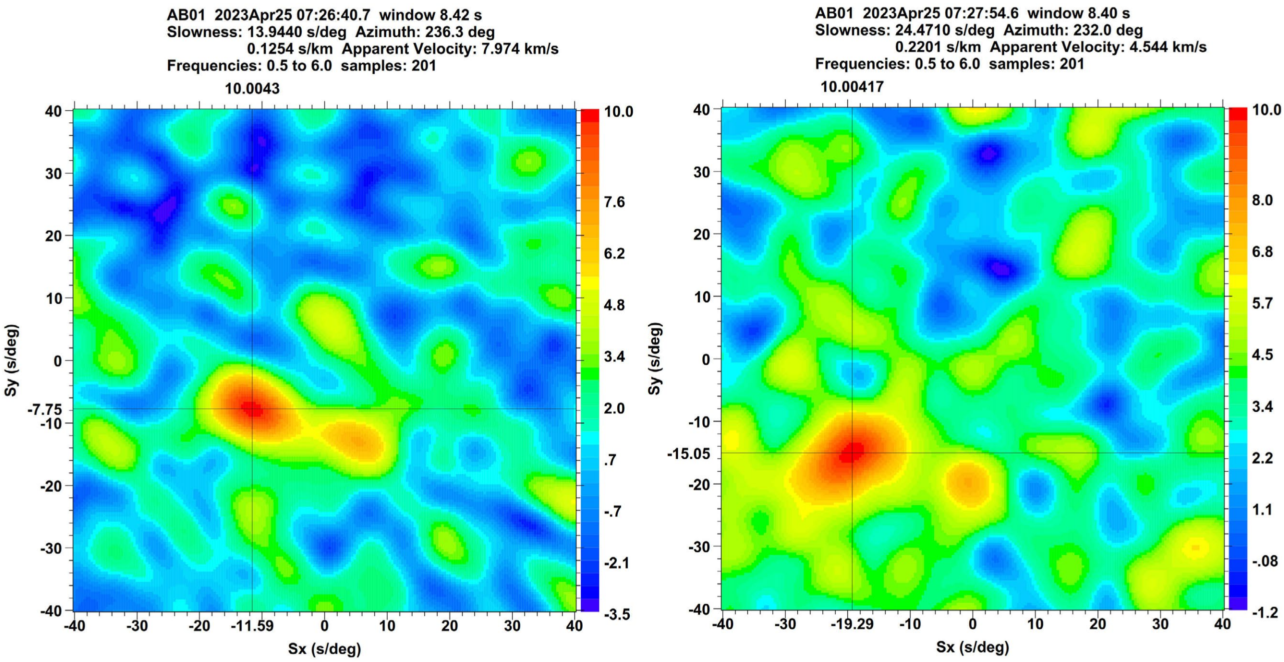


Figure 3. Results of F-k-analysis by P-wave (left) and S-wave (right) from Akbulak seismic array.

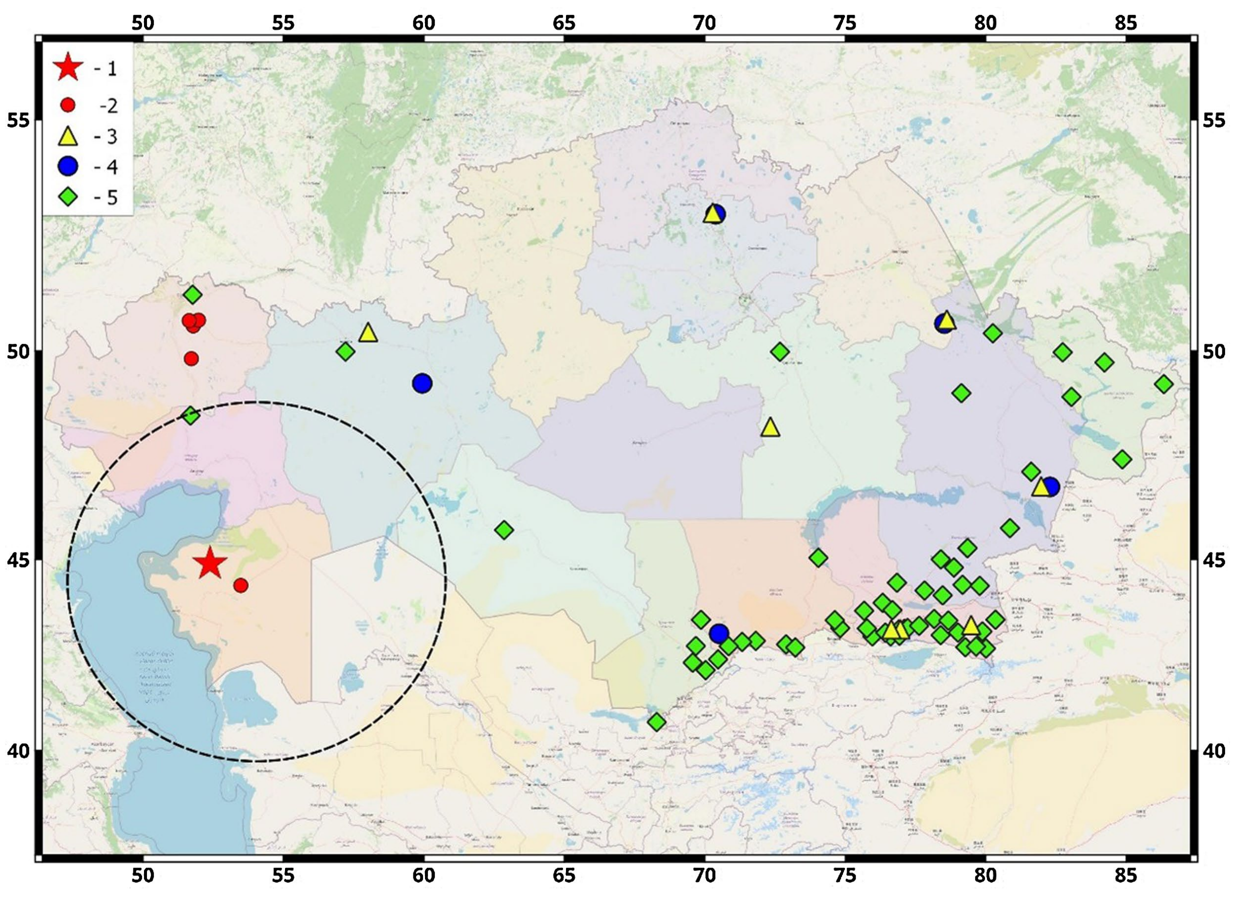


Figure 4. The map of seismic stations location on the territory of the Republic of Kazakhstan for 2023: 1—epicenter of the earthquake on April 25, 2023, 2—epicenters of earlier recorded earthquakes in the region; 3—three-component stations of NNC RK; 4—seismic arrays of the NNC RK; 3—three-component stations of NSCSOR. The circle shows the area where seismic stations are absent.

of the 2023 earthquake and the epicenters of the instrumentally confirmed earthquakes in western Kazakhstan (5 earthquakes).

3. Methodology and Data Used to Determine Instrumental Characteristics of Earthquake of April 25, 2023

The earthquake that occurred on 25 April 2023 was recorded by a considerable number of seismic stations worldwide (223), located at both regional and teleseismic distances from the epicentre (see Figure 5 and Figure 6). The INDER station of the SNECCA network [1], located at a distance of 420 km to the north of the

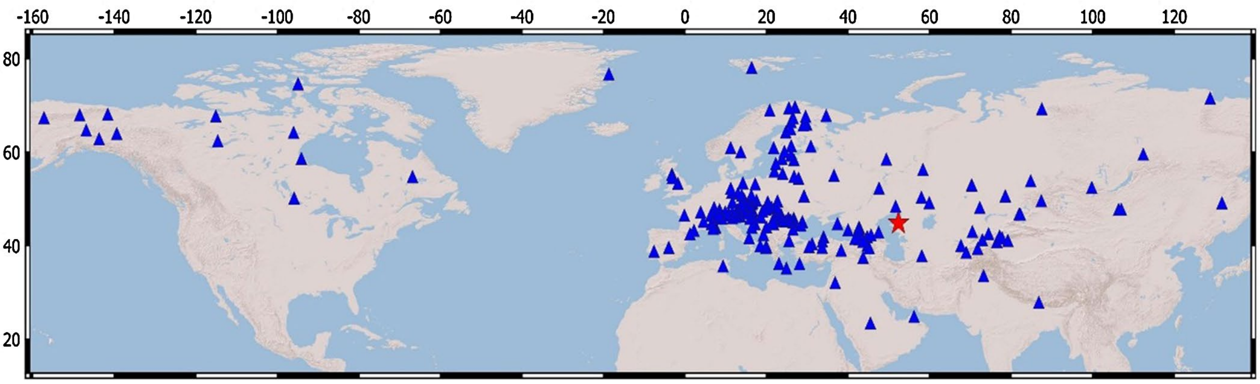


Figure 5. The map of the 25.04.2023 earthquake epicenter and permanent seismic stations worldwide that recorded the event.

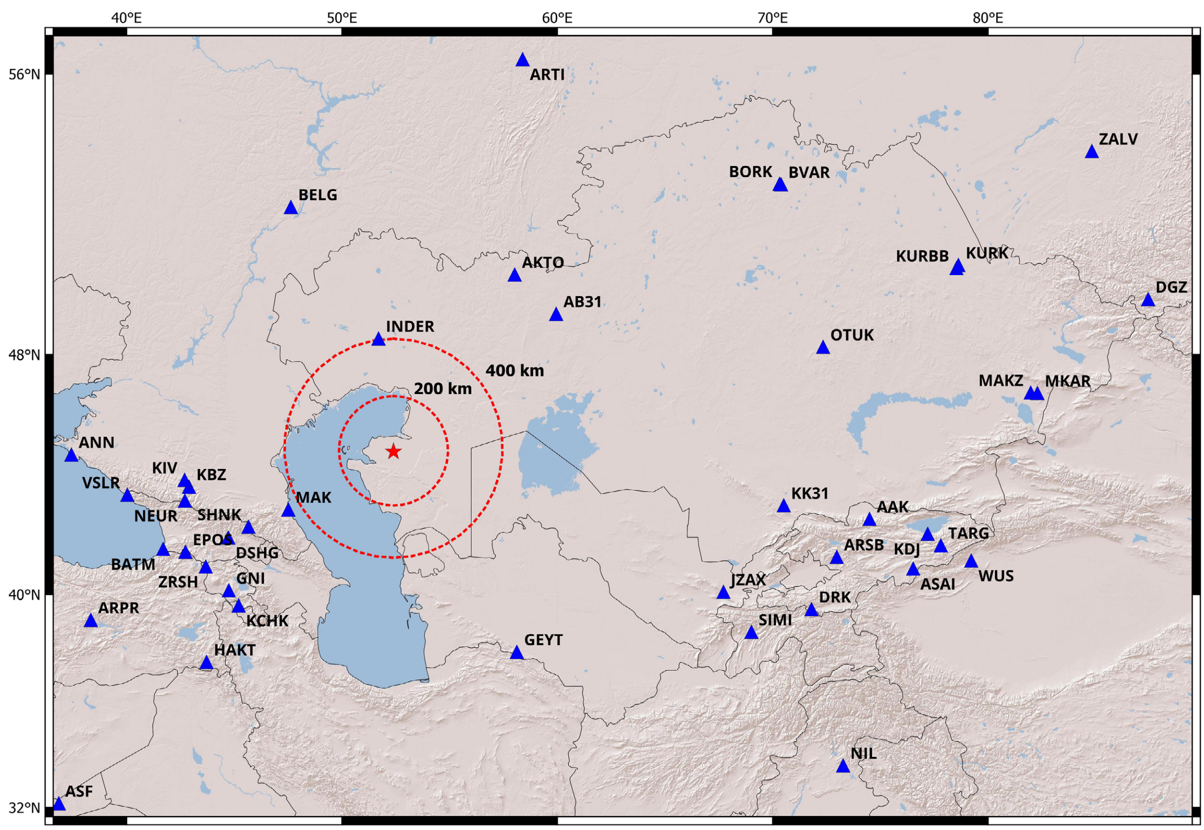


Figure 6. The map of earthquake epicenter and location of seismic stations the recorded the event at regional distance.

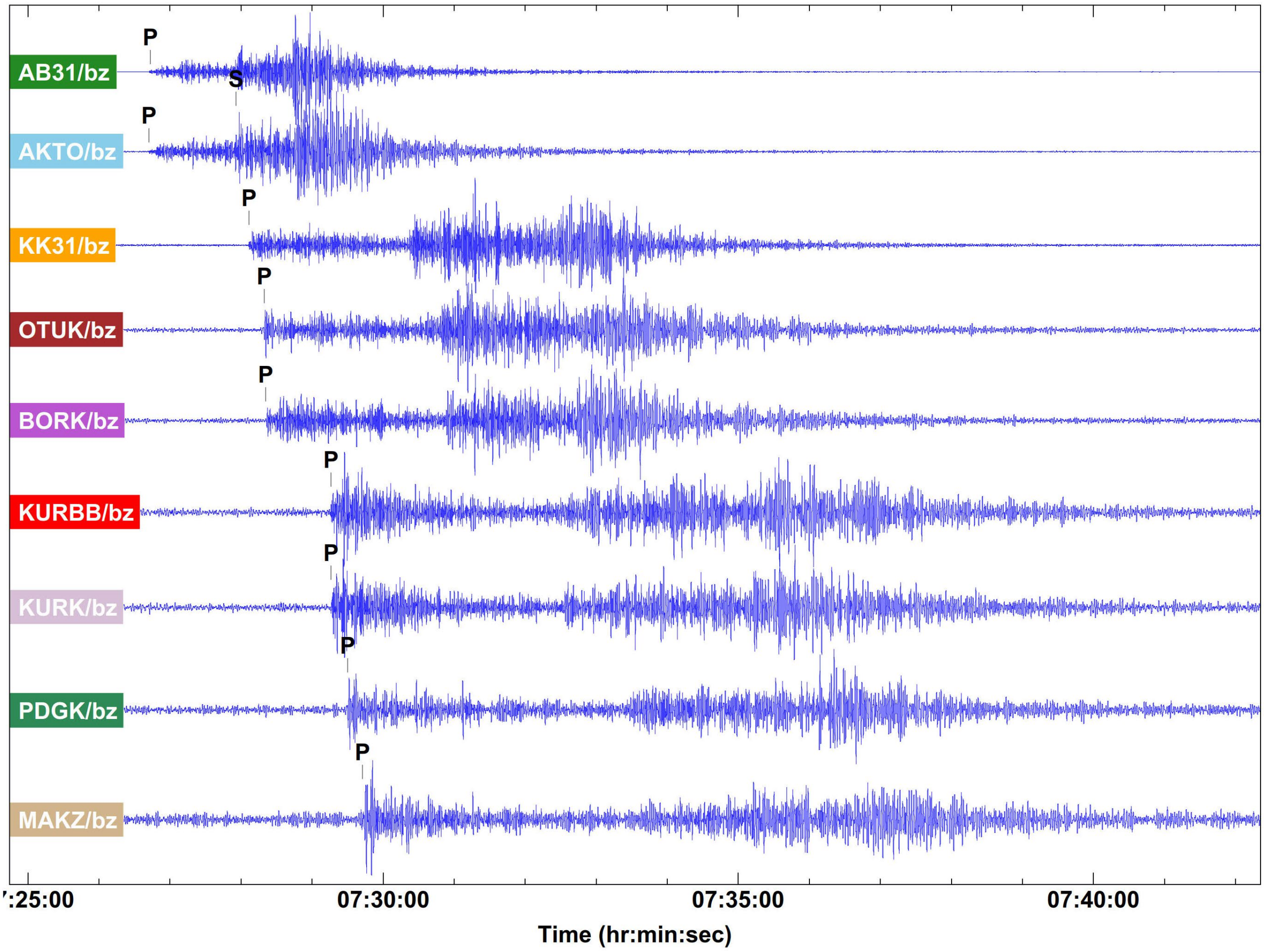


Figure 7. Seismograms of April 25, 2023 earthquake by data of NNC RK stations (vertical channels of three-component stations).

epicentre (**Figure 2**), is the closest station to the earthquake's epicentre. As indicated by the International Seismological Centre (ISC) [6], the processing of Kazakhstani stations primarily used data from the seismic stations of the National Nuclear Center of the Republic of Kazakhstan (NNC RK) network. **Figure 7** shows the records of the NNC RK network stations.

In the NNC RK IGR Data Center (KNDC) [13], an immediate solution (**Table 1**) on the source parameters was derived from the records of the NNC RK network stations immediately following the event (**Table 1**). However, due to the fact that all NNC RK stations are located no closer than 620 km and in a limited azimuth segment, it is not possible to obtain a high-precision solution. We were interested in getting an answer to the question—what seismic generating zone is associated with the occurrence of this earthquake? Where can we expect such and stronger sources in the future?

To this end, with the permission of the operator of one of the oil fields, data from the local seismic monitoring network, which is responsible for tracking anthropogenic seismicity in the field, were employed.

In order to accurately localise the source, the Data Center (KNDC) employed the ILoc epicentre determination algorithm [14] [15], utilising seismic wave travel time predictions derived from the three-dimensional RSTT velocity model [16]-[18] and the AK135 model [19]. The data available (seismic bulletins) from all stations that recorded the earthquake worldwide, including data from the field network operator, were employed in this analysis (**Table 1**). The results of the Data Centre's location were compared with the parameters obtained by different international and regional seismological centres (see **Table 1** and **Figure 8**).

Table 1. Instrumental parameters of April 25, 2023 earthquake by data of the international and regional seismological centers.

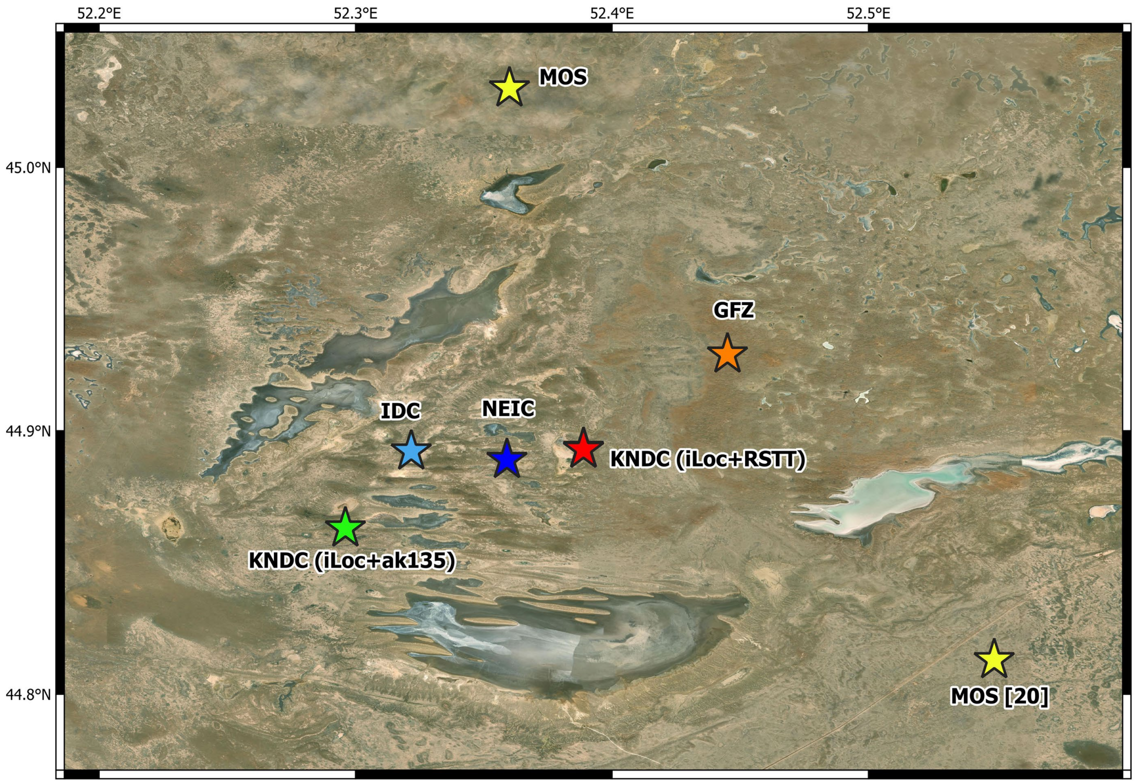
No.	Agency	Time	Lat	Lon	Depth	Smaj	Smin	Nsta	Magnitude	Source
1	IDC	07:25:00.7	44.892	52.322	0 f	9.0	6.0	35	mb = 4.2 ML = 4.7	ISC
2	GFZ	07:25:02.7	44.929	52.445	10 f	6.2	4.5	102	mb = 4.6, ML = 5.3	ISC
3	NEIC	07:25:02.2	44.889	52.359	10	10.3	9.3	94	mb = 4.5	ISC
4	MOS	07:25:02.4	45.030	52.360	10			8	mb = 4.5	ISC
5	MOS	07:25:04.1	44.813	52.549	10	9.8		52	mb = 4.5	[20]
6	KNDC (urgent)	07:25:07.7	44.949	53.463	0	55	32	13	mb = 5.0 mpv = 4.2 K = 10.5	ISC
7	KNDC iLoc+ ak135	07:25:01.6	44.863	52.296	10.9	4.3	2.9	122	mb = 4.6 ML = 4.8 mB = 1.7	KNDC
8	KNDC iLoc+ RSTT	07:25:01.9	44.893	52.389	10	5.8	3.7	122	mb = 4.6 ML = 4.8 mB = 1.6	KNDC

The solution obtained by the NNC RK data centre using the oil field operator stations and other stations worldwide (a total of 122 stations) via the optimal location method, Iloc+RSTT (KNDC Iloc + RSTT), is deemed to be the most accurate. Namely this solution will be employed in the subsequent analysis. The KNDC solution is close to the NEIC solution of the US Geological Survey, which utilises data from 94 global stations.

The focal mechanism of the earthquake that occurred on 25 April 2023 has oblique-fault type mechanism, with two rupture planes of equal probability in the meridional and latitudinal directions [20].

4. Analysis Results of Origin Location of the Earthquake 25.04.2023 in Relation to Geological-Tectonic, Geomorphological Characteristics and Location of Seismic Generating Zones

The earthquake area is located in western Kazakhstan within the Mangistau region on the Buzachy peninsula. Most of the territory of Mangistau region, including



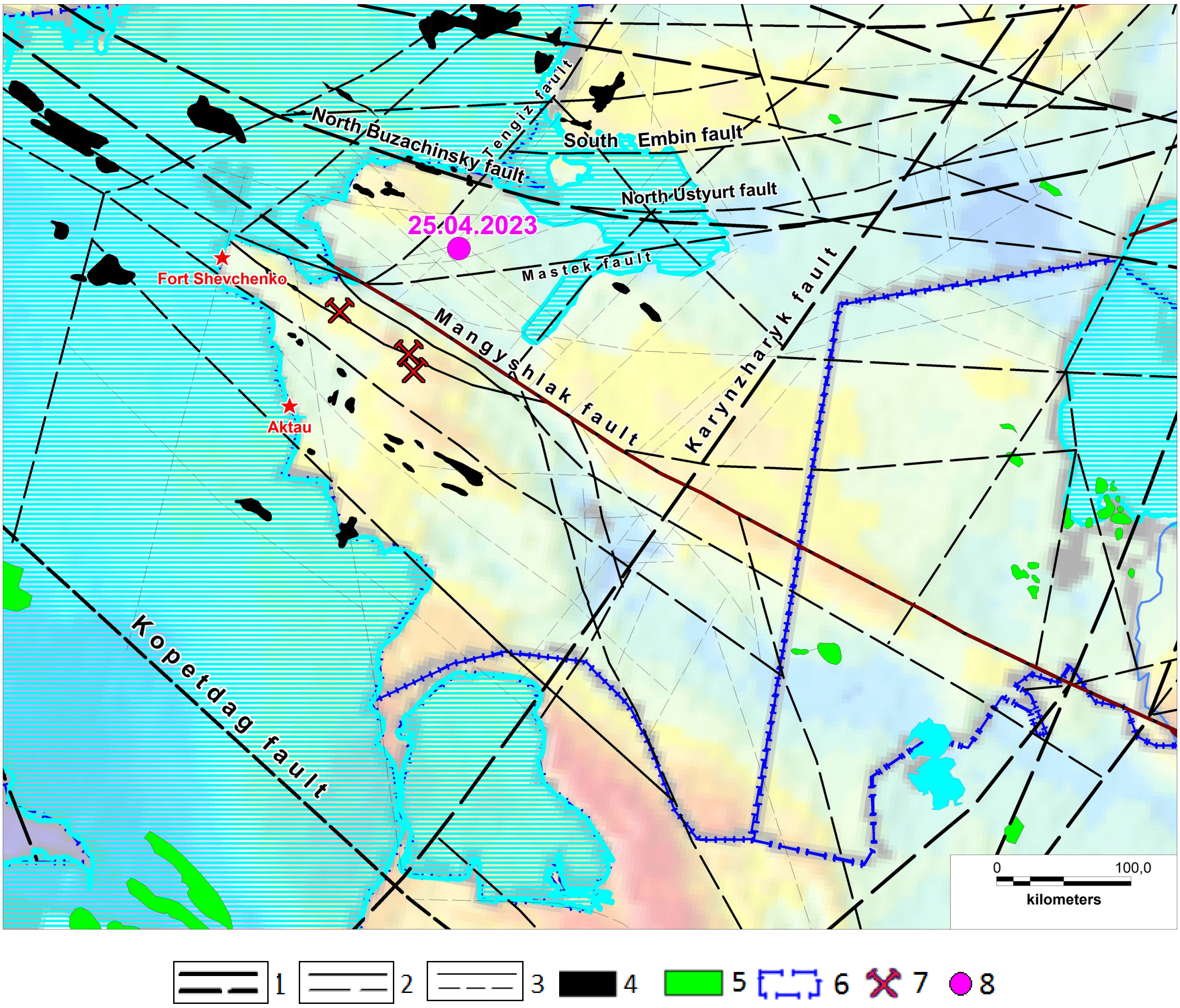
IDC—International Data Center (Vienna); NEIC—National Earthquake Information Center of the Geological Survey of the USA; MOS—Geophysical Survey of RAS; GFZ—Center for Earth Investigation, Germany; KNDC—Data Center of the IGR NNC RK.

Figure 8. The map of 25.04.2023 earthquake epicenters by data of the international and regional seismological centers.

the study area, is covered by a thin layer of loose Quaternary sediments (sands, clays, loams), under which there is a layer of Cenozoic sedimentary rocks of Neogene and Paleogene age. Only in the western part of the territory, on the Buzachy and Mangyshlak peninsulas there are outcrops of Mesozoic sedimentary deposits of Jurassic and Cretaceous age, as well as a continuous series of Permo-Triassic sediments. Cenozoic and Mesozoic sedimentary deposits and undivided Permo-Triassic sediments with a total thickness of up to 5 and more km are represented by interbedded layers of mudstones, siltstones, sandstones, conglomerates, marls, limestones and dolomites. At the bottom of the section, layers of siderite, anhydrite, salt and gypsum are added [21]-[24]. The complex of Lower Palaeozoic to Triassic volcanogenic-sedimentary rocks, 3 - 5 km thick, extends deep into the subsurface to the crystalline basement. The Mesozoic and Palaeozoic sedimentary formations of the study area are associated with hydrocarbon reservoirs, some of which are quite large oil and oil and gas condensate fields where commercial production of hydrocarbons takes place. Gas and oil and gas fields predominate on the southern and south-western sides.

The tectonic setting of the study area is characterized by the intersection of tectonic faults of different orders, mainly from the north-west and north-east. For example, the Buzachy peninsula itself is bounded from the northeast and south-west by large first-order North-Buzachy and Mangyshlak faults (**Figure 9**). And the area of the epicenter of the Buzachy earthquake is bounded by wedge-shaped tectonic faults of the second order from the north-eastern direction converging towards the south-west (from the north-west-Tengiz and from the south-east-Mastek). Directly in the area of the epicenter of the Buzachy earthquake there are intersecting faults of the third order of the same extensions with the addition of faults of the north-west extension.

A thorough analysis of various cartographic materials and data on the investigated territory was conducted, encompassing geological, oil and gas bearing, topographic maps, and maps of geophysical (magnetic and gravimetric) fields, as well as satellite images. This analysis, conducted by the KNDC and USGS, revealed



1 - 3—First, second and third order faults in the bedrock overlain by loose sediments (dotted line); 4 and 5—Contours of oil and gas deposits; 6—State boundaries; 7—Active quarries; 8—Epicenter of the Buzachy earthquake. The map of gravity anomalies in free air was used as a back.

Figure 9. Tectonic scheme of the investigated territory with the area of epicenter location of Buzachy earthquake 25.04.2023.

that the epicenter of the earthquake is located within a semicircular structure represented by the gentle Kyzan depression, measuring 20 × 40 km in dimensions, extending in a NE direction, and encompassing an area of 740 sq. km. The Kyzan settlement (see **Figure 10**) is located a short distance to the east. In Kyzan settlement the earthquake was felt with intensity 4 (MSK-64). The entire Kyzan depression, from the south-east and south directions is situated on a geomorphological scarp of 20 meters height.

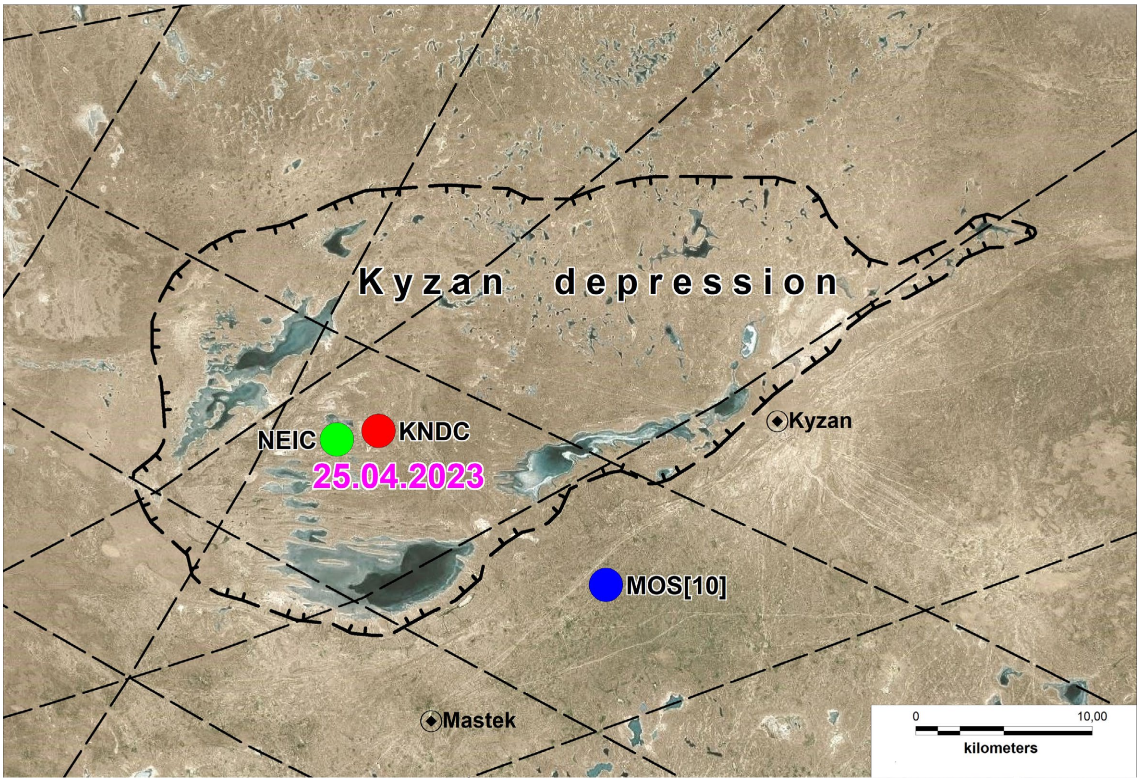
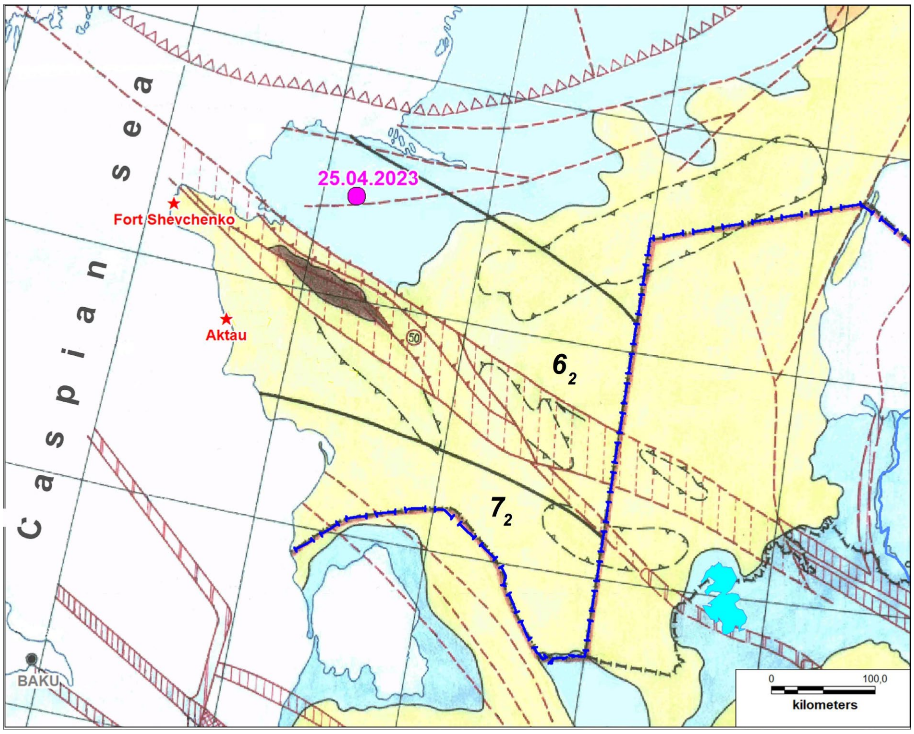


Figure 10. BingMap image Buzachy Peninsula with the area of the epicentre of this earthquake, determined from data of different agencies, in a semicircular structure within the Kyzan depression and the location of tectonic faults.

Let us consider the position of the epicentral zone of the Buzachy earthquake on the seismic zoning maps of the territory of Kazakhstan for 2003 and 2016 (**Figure 11** and **Figure 12**), approved by law and updated in the Construction Norms and Rules of the Republic of Kazakhstan for 2006 and 2017 [25] [26]. These maps show the location of seismisity generating zones and the maximum magnitude of possible earthquakes in them, as well as isolines of their seismic intensity in points on the MSK-64 scale [27].

The location of the Central-Mangyshlak-Ustyurt seismic generating zone with $M_{max} \leq 5$ is shown on both maps, but the 2016 seismic zoning map for this zone in its eastern part already shows an increase of the maximum magnitude to $M_{max} \leq 5.5$. The configuration of the points isolines for the seismic intensity of earthquakes on the MSK-64 scale and their values are different on the two maps. On the 2003 zoning map, the points isolines and their values for the area of the



Legend on seismicity generating zones is shown in **Figure 13**.

Figure 11. Fragment of the general seismic zoning map of the Republic of Kazakhstan of 2003 [28] for the Mangistau region and adjacent areas with the area of the earthquake epicenter.

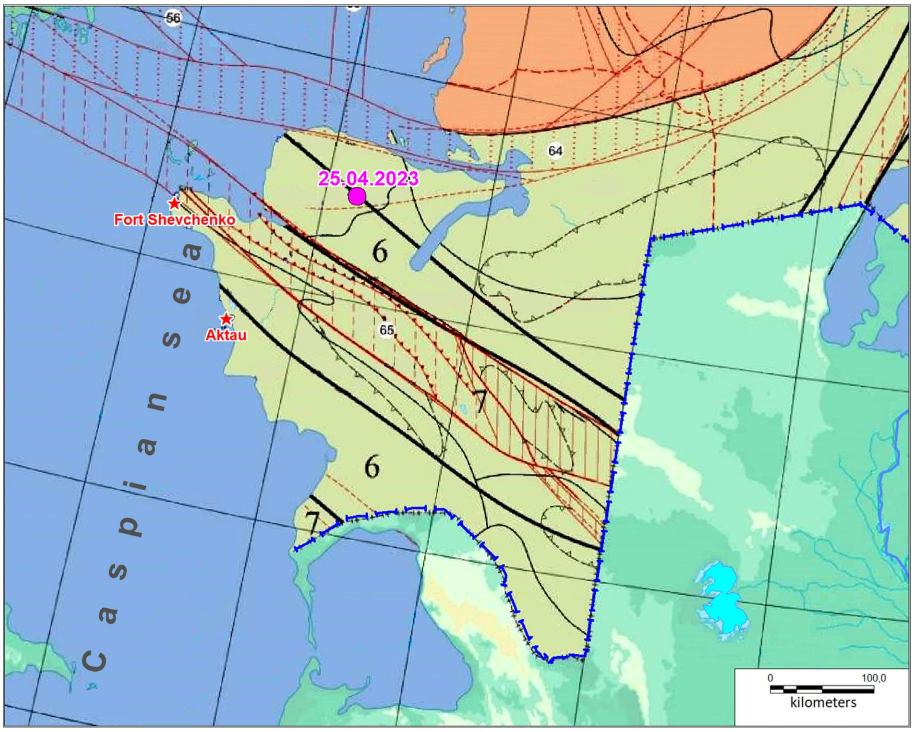


Figure 12. A fragment of general seismic zoning map for the period of recurrence 2475 years in MSK-64 intensity points (isolines in black colour) of the Republic of Kazakhstan of 2016 [26] for Mangistau region with the area showing the earthquake epicenter location.

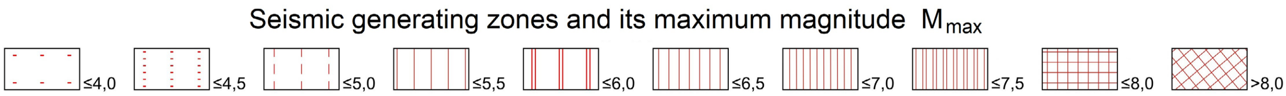


Figure 13. Legend of seismic generating zones and its maximum magnitude.

Central-Mangyshlak-Ustyurt seismic generating zone are calculated mainly under the condition of the influence of only the neighbouring Balkan-Kopetdag seismic generating zone located to the south outside the study area and having a high seismic potential $M_{max} > 8$. The Central-Mangyshlak-Ustyurt seismic generating zone itself and the epicenter of the Buzachy earthquake fall within the area of seismic intensity 6 MSK-64 (**Figure 11**).

On the map of general seismic zoning of 2016 (**Figure 12**) [26], the points isolines and their values are plotted, taking into account the possible influence of the Central-Mangyshlak-Ustyurt seismic generating zone itself, within which only the zone of seismic intensity 7 on the MSK-64 scale is identified. In addition, in the northern part of the study area, the later assigned South-Emba-Mugodzhar seismic generating zone with $M_{max} \le 4.5$ is shown. The epicenter of this earthquake is located on the point 6 isoline.

The description of these two seismisity generating zones is given below.

The Central-Mangyshlak-Ustyurt seismicity generating zone (# 65 in the map) is spatially defined by the homonymous dislocation system, which is a WNW-trending uplift zone separating the North Ustyurt synclise together with the South Buzachi trough from the South Mangyshlak-Ustyurt trough system of the Turan plate. The northern boundary of the described zone is the Central Mangyshlak-Ustyurt deep fault. The southern boundary of the described zone runs along the Beke-Bashkuduk and Shakhpakhta faults, which extend to the surface of the basalt layer of the Earth's crust. A characteristic feature of the internal structure of the described zone is a high degree of dislocation of platform sediments, including the Upper Permian-Triassic (Karatayu) complex, which folded structure is visible in the exposed cores of the Karatayu anticlinorium. In the central Mangyshlak-Ustyurt zone, folding and thrusting structures are widely developed and cover both Mesozoic and Cenozoic strata. The direct reflection of these structures in the relief, as well as cases of overthrusting of Palaeogene deposits on Quaternary formations, indicate that the considered tectonic zone is still under the influence of submeridional horizontal compressional forces. Intense folding and thrusting dislocations of the platform cover in this case represent a manifestation of suture folding, resulting in the formation of an Early Cimmerian linear inversion zone that is active to the present day. Foci of M = 5.0 - 5.5 earthquakes are limited to, and can occur in, zones of listral-type decompaction in the lower horizons of the Sialic crustal complex [29].

The South-Emba-Myugodzhar seismicity generating zone (#64 on the map) is identified as an inferred zone between the South-Emba and North Ustyurt faults, which converge to the northeast. The zone is highlighted by all researchers as the boundary zone between the old Russian and the young Turanian platforms, and within its boundaries there is a significant reorganization of the Earth's crust. The considered zone is well defined by geomorphological, geophysical and space photo interpretation methods [29].

To the north of the named zone, the thickness of the sialic crustal complex decreases to 2 - 5 km, while the thickness of the lower basite complex increases to 25 - 30 km. Southward of the Embene zone, the thickness of the Palaeozoic complex decreases rapidly. Finally, the structure of the platform cover is different on the different sides of the South Embene Zone: in the Caspian Basin the salt tectonic structures dominate, while in the North Ustyurt the folds of the cover acquire linear features, with their orientation subparallel to the zone of juxtaposition of platforms of different ages. The above data allow us to consider the South Emba zone as a mobile element of the Earth's crust at the latest stage, which played an important role in the geological development of the region throughout the Neogene. Apparently, along this zone, the North Ustyurt block is thrusting over the North Pre-Caspian block, or the latter is being pushed under the edge of the Turan platform. Cluster analysis of the set of parameters led to the conclusion that the maximum magnitude of earthquakes should not exceed M = 4.5 [30]. According to the map of the general seismic zoning of 2016, the epicenter of the Buzachy earthquake is not connected with the above-mentioned seismicity generating zones, but for the reoccurrence period of 2475 years it also falls within the area of the seismic intensity of 6 MSK-64 (**Figure 10**), and for the reoccurrence period of 475 years—the origin is located in the area of the seismic intensity of 5 [31].

5. Conclusions

1) The instrumental records of the earthquake that occurred on the Buzachy peninsula in western Kazakhstan have made it possible to locate the epicentre quite accurately and to estimate the depth and energy characteristics of the source. The accuracy of the epicenter determination is ±4 km, focal depth 10 km, magnitude mb = 4.6, ML = 4.8, energy class K = 10.5. This is the first event in this region to be detected and processed with high accuracy.

2) According to the contemporary map of seismic zoning of the territory of Kazakhstan, the epicenter area is located between two seismisity generating zones—Central-Mangyshlak-Ustyurt and South-Emben-Mugodzhar.

3) The earthquake was felt in a number of settlements in the Mangystau region with a maximum intensity of 4. The estimated intensity at the epicenter of this earthquake is 5. If a larger earthquake of Mw = 5.0 - 5.5 occurs in the same area, the shaking intensity may exceed 6.

4) The very fact that an earthquake occurred at this location indicates that the area is seismically active.

5) Seismic stations or, better still, a seismic array should be installed in this region of western Kazakhstan to allow continuous monitoring of weak seismicity, quarry explosions and induced events throughout western Kazakhstan and beyond.

6) When the paper was ready, another earthquake occurred in the study area, approximately 100 km south-west of the initial event. According to the available

operational data, the magnitude of this earthquake was mb = 4.2 [32]. This fact also confirms the findings of paragraphs 4 and 5 of this conclusion.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Chiang, A., Gok, R., Godoladze, T., Berezina, A., Aguiar, A., Aderhold, K., Hafner, K., Woodward, R., Mackey, K., Stachnik, J., Babayan, H., Yetirmishli, G., Mikhailova, N., Ashirov, B. and Negmatullaev, S. (2023) Seismic Network Expansion in the Caucasus and Central Asia (SNECCA). https://conferences.ctbto.org/event/23/contributions/4684/

[2] Nikonov, A.A. (1994) Destructive Earthquake in Mangyshlak. *Physics of Earth*, **5**, 71-74.

[3] Nyurmagambetov, A. (1996) To Seismicity and Seismic Hazard of Mangystayu Region. Reports of the Ministry of Science, Academy of Science of RK, 47-53.

[4] Teynor, L., Kemerait, R., Adair, K., Belyashova, N., Marchenko, V., Nedelkov, A., Komarov, I. and Kunakov, A. (2004) A New Seismic Array Akbulak: Selection of Site, Instruments, Communication System. Geophysics and Non-Proliferation Problems/NNC RK Bulletin, 7-14.

[5] Comprehensive Nuclear-Test-Ban Treaty. https://www-beta.ctbto.org/sites/default/files/2023-10/2022_treaty_booklet_E.pdf

[6] International Seismological Centre (2023) Online Bulletin.

[7] Gerhard, G. and Bras, R.L. (2021) Twenty Years of IDC Reviewed Event Bulletin (REB) Statistics Using Data from a Sparse IMS Network to One Reaching Near Completion. https://conferences.ctbto.org/event/7/contributions/1185/attachments/136/335/P4.1-446_MDA_analysts.pdf

[8] Federal State Budget Enterprise of Science, Federal Research Center: United Geophysical Survey of Russian Academy of Science (FRC UGS RAS). http://www.gsras.ru/

[9] Consortium EarthScope/Data Management Center. https://ds.iris.edu/ds/nodes/dmc

[10] Mikhailova, N.N. and Velikanov, A.Y. (2014) Shalkar Earthquake of April 26, 2008, K=11.1, Mw=5.1, I0=7 (West Kazakhstan). *Earthquakes of Northern Eurasia*, No. 17, 304-312.

[11] Mikhailova, N.N., Sokolova, I.N., Velikanov, A.Y. and Poleshko, N.N. (201) Seismicity of Western Kazakhstan by Data of the NNC RK Network. Seismic Forecasting Observations on the Territory of Azerbaijan/NASA, 336-348.

[12] Capon, J. (1969) High-Resolution Frequency-Wavenumber Spectrum Analysis. *Proceedings of the IEEE*, **57**, 1408-1418. https://doi.org/10.1109/proc.1969.7278

[13] Center for Acquisition and Processing of the Special Seismic Information of the Institute of Geophysical Research, Branch of the RSE National Nuclear Center of the Republic of Kazakhstan. https://www.nnc.kz

[14] Bondar, I. and McLaughlin, K. (2009) Seismic Location Bias and Uncertainty in the Presence of Correlated and Non-Gaussian Travel-Time Errors. *Bulletin of the Seismological Society of America*, **99**, 172-193. https://doi.org/10.1785/0120080922

[15] Bondár, I. and Storchak, D. (2011) Improved Location Procedures at the International Seismological Centre. *Geophysical Journal International*, **186**, 1220-1244. https://doi.org/10.1111/j.1365-246x.2011.05107.x

[16] Myers, S.C., Begnaud, M.L., Ballard, S., Pasyanos, M.E., Phillips, W.S., Ramirez, A.L., *et al.* (2010) A Crust and Upper-Mantle Model of Eurasia and North Africa for Pn Travel-Time Calculation. *Bulletin of the Seismological Society of America*, **100**, 640-656. https://doi.org/10.1785/0120090198

[17] Begnaud, M.L., Myers, S.C., Young, B., Hipp, J.R., Dodge, D. and Phillips, W.S. (2020) Updates to the Regional Seismic Travel Time (RSTT) Model: 1. Tomography. *Pure and Applied Geophysics*, **178**, 2475-2498. https://doi.org/10.1007/s00024-020-02619-5

[18] Begnaud, M.L., Anderson, D.N., Myers, S.C., Young, B., Hipp, J.R. and Phillips, W.S. (2021) Updates to the Regional Seismic Travel Time (RSTT) Model: 2. Path-Dependent Travel-Time Uncertainty. *Pure and Applied Geophysics*, **178**, 313-339. https://doi.org/10.1007/s00024-021-02657-7

[19] Kennett, B.L.N., Engdahl, E.R. and Buland, R. (1995) Constraints on Seismic Velocities in the Earth from Traveltimes. *Geophysical Journal International*, **122**, 108-124. https://doi.org/10.1111/j.1365-246x.1995.tb03540.x

[20] Sokolova, I.N., Gabsatarova, I.P. and Babkova, Y.A. (2023) Earthquake on April 25, 2023 in the Northeastern Caspian Region (Western Kazakhstan)/Sovremennye metody obrabotki i interpretatsii seismologicheskikh dannykh. Tezisy XVII Mezhdunarodnoi seismologicheskoi shkoly [Modern Methods of Processing and Interpretation of Seismological Data. Abstracts of the XVII International Seismological Workshop]. GS RAS Publisher, 156 p.

[21] (1975) Geological Map of the USSR. Scale 1: 10 000 000. RGI.

[22] Bekzhanov, G.R., Koshkin ,V.Y., Nikitchenko, I.I., *et al.* (2000) Geological Structure of Kazakhstan. Academy of Mineral Resources of RK, 396.

[23] (1970) Geology of the USSR. V.21. Western Kazakhstan. Nedra, 800 p.

[24] (1980) Geological Map of Kazakhstan. Scale 1:500 000. Western Kazakhstan Series. Explanatory Note. Moscow, 211 p.

[25] (2006) SNiP RK 2.03-30-2006. Construction in Seismic Regions. Almaty, 80 p.

[26] (2017) Construction Rules of RK 2.03-30-2017. Construction in Seismic Zones. Astana, 111 p.

[27] (2004) MSK-64 Scale for Earthquakes Intensity Estimation. Construction Rules of RK 2.03-28-2004. Almaty, 8 p.

[28] (2003) The Map of General Seismic Zoning of the Republic of Kazakhstan and Adjacent Territories of Kyrgyzstan, Uzbekistan, Turkmenistan, and China. Scale 1: 2 500 000. Institute of Seismology, MES RK.

[29] Kurskeyev, A.K., *et al.* (2000) Seismic Zoning of the Republic of Kazakhstan. 200.

[30] Timush, A.V., *et al.* (2012) Seismicity Generating Zones in Kazakhstan. "High Technology" Publication, 80.

[31] (2015) Development of the General Seismic Zoning Maps for Kazakhstan Territory. Report on Research Work. Institute of Seismology MES RK.

[32] USGS National Earthquake Information Center (2024). https://earthquake.usgs.gov/earthquakes/eventpage/us7000nven/technical