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TECTONIC AND TECHNOGENIC EARTHQUAKES IN CENTRAL KAZAKHSTAN

Abstract. In the article seismic events of tectonic and technogenic nature in Central Kazakhstan are considered. The characteristic of seismic monitoring of the territory of this region by the seismic network of the Institute of Geophysical Investigations of the Ministry of Energy of the Republic of Kazakhstan is given.

The new instrumental level of monitoring made it possible to obtain and study preliminary statistics on tectonic earthquakes, explosions in quarries, mines, and other technogenic events in Central Kazakhstan, as well as data on the stress-strain state of the deepest parts of the earth's crust.

A retrospective analysis of the features of the manifestation of foci of tectonic and technogenic seismicity on the platform structures of Central Kazakhstan is presented. The parameters of earthquakes in this region, the judgments about the nature of the mechanism of earthquake foci and the types of tectonic movements, maps of isoseism are constructed.

At the same time, it is shown that, in spite of tangible progress in the study of seismic events in Central Kazakhstan, some technical and methodological issues have not been developed in the long run, and work on this continues.

Key words: earthquake, focal mechanism, seismic stations, aftershock, magnitude, epicenter, isoseist.

Introduction. Central Kazakhstan has traditionally been considered aseismic, where seismic events with an intensity on the MSK-64 scale of more than 5 are not expected [1].

Based on these representations, a network of seismological stations was located in the South, South-East and East Kazakhstan, for which catalogs of earthquakes were compiled in the current regime.

According to Central Kazakhstan, earthquake catalogs were not compiled, since special seismological observations were not conducted here.

Based on these representations, the network of seismological stations was concentrated over the territories of the Northern Tien-Shan and Dzungaria, and also in part of Eastern Kazakhstan [2], for which catalogs of earthquakes were compiled in the current regime.

However, in connection with the creation of a new modern high-tech system for monitoring earthquakes and industrial explosions, the view of the seismicity of Central Kazakhstan has changed.

The use of these seismic stations, characterized by high sensitivity, made it possible to identify a number of focal zones in areas that had not previously attracted the attention of seismologists and to change the point of view on the geodynamics of this region of Kazakhstan.

All this can be considered as a leitmotif for the study of earthquake foci in Central Kazakhstan, which relevance is obvious, because in themselves they carry the potential threat to the industrial and civil facilities located nearby to these people [3].

At the same time, it should be noted that the study of natural seismicity in this region is difficult due to its low level. Approximately at the same energy level, seismic events occur regularly, generated by numerous explosions in quarries, industrial facilities and landfills.

In addition to "industrial explosions," the study of natural geodynamic and seismotectonic processes in Central Kazakhstan also complicates technogenic seismicity, sources of which arise in the Earth's crust when human engineering activities affect it, particularly in the extraction of oil and gas, extraction of ore, coal and other mineral resources, in the construction of roads, hydraulic structures, etc.

In order to identify the nature of various seismic events, special scientific research is being carried out to identify the class of sources of disturbance in the geological environment. For this purpose, various features are used - features of the wave pattern of records of earthquakes and career explosions, correlation and spectral analysis, attract independent data from space photographs, etc.

This article analyzes strong earthquakes recorded by the stations of the IGR ME RK in the territory of Central Kazakhstan and is included in seismic bulletins of national and global services. In addition, the technogenic seismicity in this region, related to the intensive development of deposits of solid minerals, is considered.

Characteristics of the system of seismic monitoring of the territory of Central and South-Eastern Kazakhstan. Over the past 20 years, Kazakhstan has created a new modern network of high-tech seismic stations integrated into the International Global Monitoring Networks.

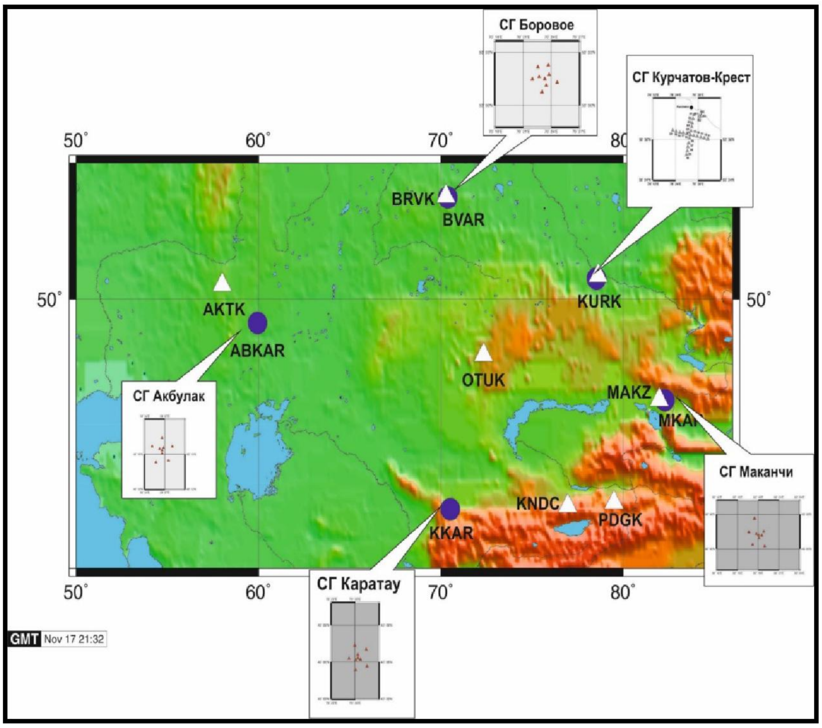

Figure 1 – Location of stations on the territory of Kazakhstan, data from which are received by KNDC.
Legend: mugs - seismic groups, triangles - three-component stations.
Separate footnotes show the configuration of seismic groups.

This system, first of all, was created to control the implementation of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) in Kazakhstan, which signed the treaty in 1996 and ratified in 2001.

During the period from 1994 to 2006, a number of international agreements have built and commissioned new seismic groups and three-component stations, located mainly along the perimeter of weakly seismic territories of Kazakhstan [4, 5].

Figure 1 shows the scheme of the location of IGI ME RK stations, the data from which are received in real time by the KNDC (Kazakh National Data Center) in Almaty. Such a network allows monitoring of seismic events, both in Kazakhstan and abroad.

Information on strong earthquakes in Central Kazakhstan.

Shalginsky earthquake in 2001. Shalgin earthquake was registered by the stations of the IGI ME RK and studied by a special expedition operating in the epicentral zone.

The main parameters of the earthquake. The epicenter of the Shalgin earthquake was located on the western border of the Central Kazakhstan arch, near the intersection of the Jalair-Naiman shift with a transverse regional fault, with which epicenters of aftershocks are associated [6].

On the map of epicenters of earthquakes constructed according to the catalog of the ISC - International Seismological Center (1964-2006), epicenters of other earthquakes were not directly located near the epicenter of the Shalgin earthquake (figure 2).

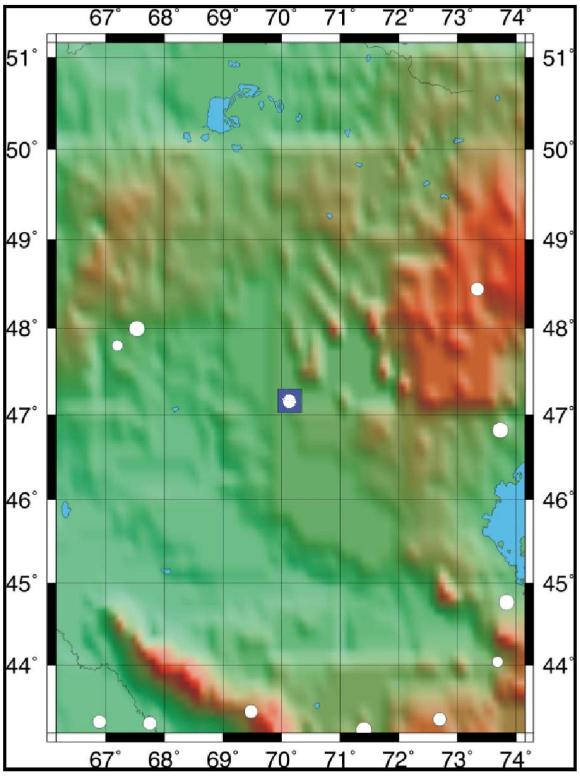

Figure 2 – Map of earthquake epicenters of Central Kazakhstan in the catalog of the International Seismic Center ISC.
The square on the map is the epicentral zone of the Shalgin earthquake.

The intensity of concussions in the epicentral region was 6 points on the MSK-64 scale.

The definitions of the hypocenter of the Shalgin earthquake for different services lie in the region with an aperture of 30 km (±15 km from the true epicenter) and, apparently, have real accuracy for this region (figure 3).

The final parameters of the main shock of this earthquake, taking into account the data of different International Centers are presented in table 1.

Macroseismic research. They were started 6 days after the main shock of the earthquake. Expedition from Almaty examined more than 10 settlements. A small number of the latter is due to the fact that the epicenter of the event is located in a sparsely populated region of Central Kazakhstan.

The closest to the epicenter is Shalginsky village - 43 km, where the earthquake was felt and observed by the majority of residents who were both inside and outside of the premises. In a number of settlements (Agadyr, Kyzyltau, Karazhal), the earthquake caused 5 point fluctuations.

As a result of macroseismic survey, the approximate position of the macroseismic epicenter can be described by the following coordinates: 47.17 ° N and 70.30 ° E (figure 3).

Based on the results of the survey, an isoseismal map of this earthquake was constructed [6], where the isoseism is clearly stretched in the northeasterly direction, consistent with a fault in the same direction orthogonal to the main northwest direction (figure 4).

According to the stereogram of the mechanism of the source for this earthquake in two variants, the following conclusions can be drawn in figure 5: 1. Shalgin earthquake is realized under conditions of compression in the northeastern direction and stretching under the sublatitudinal one. 2. In the focus, there

Legend: 1 - automatic detection (KNDC);
2 - definition by the operator (KNDC) on the data received in real time;
3 - through the network of IGI stations (KNDC); 4 - through the network of IGI stations and KNET (Kyrgyzstan).

Obn1 - urgent processing in the "Obninsk" ITC; Obn2 - the final definition of the Obninsk;
REB - definition of the International Seismological Center (IDC); NEIC - definition of the US Geological Survey.
Cross - macroseismic epicenter; an asterisk - an instrumental epicenter, non-filled circles - aftershocks of the Shalgin earthquake.

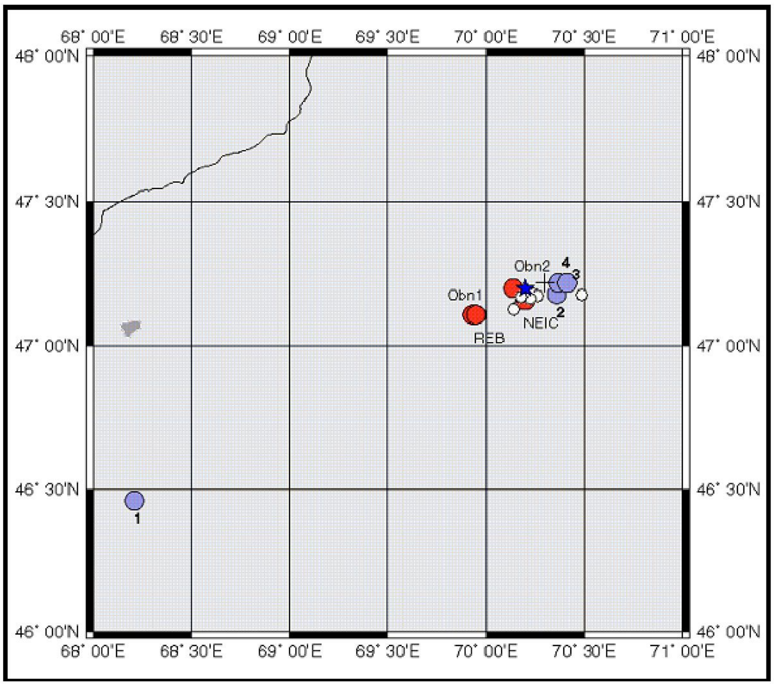

Figure 3 – Results of determining the epicenters of the main shock and aftershocks.

Table 1 – The final instrumental parameters of the Shalgin earthquake

Date	Time	Latitude, N	Longitude, E	Depth, km	M_s	MPV	K
22.08.01	15.57.57,7	47,20	70,20	19	5,0	5,4	13,2

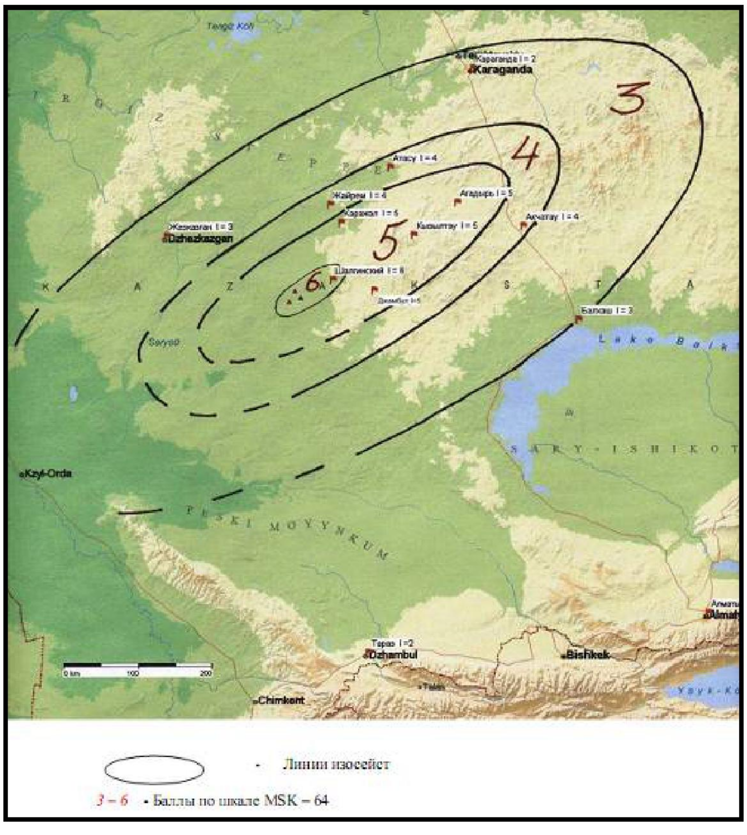

Figure 4 – Map isoseism of Shalgin earthquake on August 22, 2001 (according to A. I. Nedelkov)

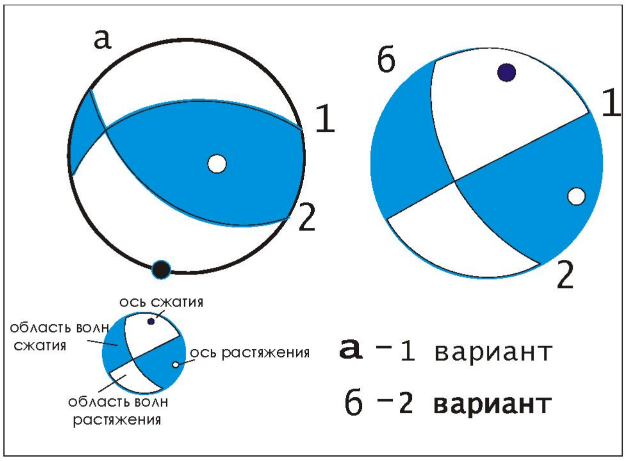

Figure 5 –
Stereograms of the mechanism of the source
of the Shalgin earthquake 22.08.01

was a displacement of the blocks in the form of a right-sided shift along the strike of the plane of the northeasterly direction, which agrees with the orientation of the fault to which the focus is confined [7].

In the epicentral area, on August 25, 2001, temporary field seismic stations were exhibited.

It was possible to register six weak aftershocks at depths of 5-15 km, the parameters of which are presented in table 2.

Table 2 – Basic parameters of aftershocks of the Shalgin earthquake

#	Date	Time, T_0	Latitude, φ°, N	Longitude, λ°, E	Depth, km	Mpva	K
1	8/22/2001	18-37-01.0	47.18	70.24	15	3.0	6.8
2	8/31/2001	05-18-21.4	47.1754	70.2631	11.5		
3	8/31/2001	22-53-59.8	47.1648	70.2264	5		
4	9/01/2001	19-53-47.6	47.1782	70.4873	15		
5	9/04/2001	22-35-56.4	47.1711	70.1780	7		
6	9/07/2001	08-53-24.8	47.1273	70.1393	10		

The strongest aftershock was recorded about three hours after the main shock. His energy class was 6.8. The rest of the aftershocks are much weaker than the first. It was not possible to determine their energy characteristics. Aftershock activation occurred along the fault plane of the northeast strike.

The Shalgin earthquake showed that the existing map of general seismic zoning does not give a complete picture of the seismic hazard in Central Kazakhstan.

On this map, a source with a development power of 6 points was not predicted, seismic generating zones with such a seismic potential were not shown. This information served as a material for recording in the new developed map the general seismic zoning of the territory of Kazakhstan.

The Karaganda earthquake on June 21, 2014.

The main parameters of the earthquake. The Karaganda earthquake was registered by all seismic stations of the IGI ME RK network. It should be noted that a strong earthquake in Central Kazakhstan with an epicenter to the north of Almaty is a rare event. Here, as well as in Northern Kazakhstan, industrial quarry explosions associated with the development of minerals are recorded.

The nearest station to the epicenter was the IGI Ortau station about 160 km away. The records were also received at Borovoye stations (432 km), Kurchatov (426 km) and other farther stations that are part of the global network of stations. Their data are automatically transmitted to international centers - the European EMSC in Paris, the American NEIC, the International Seismological Center in England ISC (figure 6).

The earthquake was processed in KNDC and in other international data centers. The solutions of different centers for determining the epicenter of earthquakes practically coincide. The coordinates of the epicenter vary within a few hundredths of a degree with a magnitude of mb = 4.8-5.2 and a depth of h = 9-20 km (table 3).

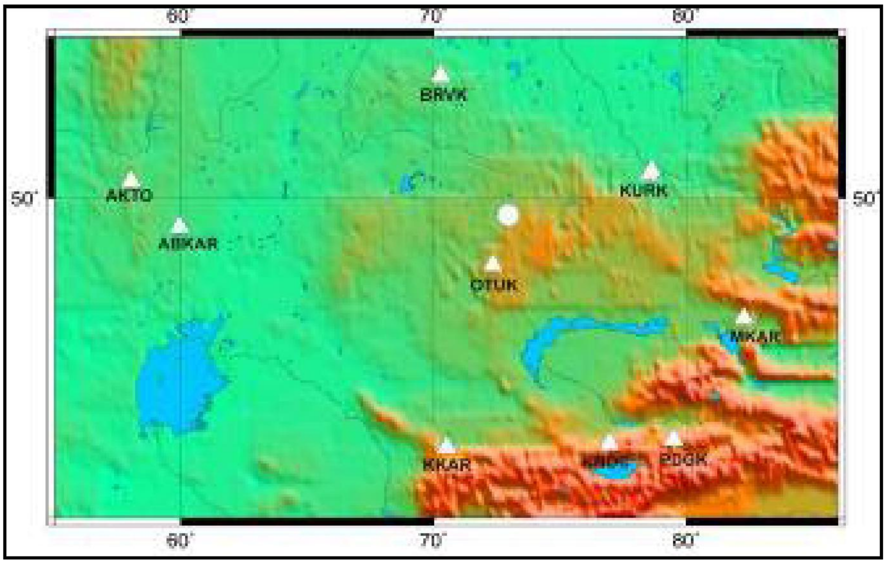

Figure 6 – Location of seismic stations IGI (triangles) relative to the epicenter of the earthquake on June 21, 2014 (circle)

Table 3 – Basic parameters of the earthquake near the city of Karaganda

Data	Latitude, N	Longitude, E	Time, t_0	mb	K	H, km
EMSC(France)	49.57	72.9	6:30:04.3	4.8		17
ГС РАН (Russia)	49,53	72,98	6:30:02.8	5.0	12	20
РК (KNDC+СОМЭ)	49,56	72,97	6:30:03.4	5.2	11,7	9

Immediately after the event, information began to be received that the Karaganda earthquake was felt in a number of settlements. The nearest to the epicenter, according to preliminary data, was Abay, located 10 km to the north-west of the epicenter. The city of Karaganda was 33 km from the epicenter with an estimated intensity of 4-5 points. The earthquake was felt in Astana with a force of 2 points.

The epicenter of the earthquake was located on the northern border of the Kazakh shield, near the southern boundary of the Karaganda coal basin. In tectonic terms, it is confined to the northern boundary of the Uspenskoye zone of the crushing of the northeastern strike with a width of up to 90 km, bounded by subparallel tectonic faults.

The question arose about the nature of this real event. Is it tectonic or man-made? Is it not associated with intensive work in the area in the coal mines?

Macroseismic survey. The epicentral territory of the earthquake was conducted in a week, from June 28 to July 3 (IGI ME RK; Velikanov AE and Uzbekov AN).

Surveys were conducted by detour of 34 settlements within a radius of just over 100 km around the epicenter of the earthquake that occurred and compiling questionnaires to establish the actual scores at the visited points on the MSK-64 seismic intensity scale. Routes of detour of settlements have coincided with the main directions of road routes diverging in different directions from the regional center of Karaganda.

For this earthquake, the focal mechanism of the source was determined from the first P-wave shifts recorded by 15 seismic stations. The reliability of the solution of the focal mechanism is indicated by the consistency of the signs, which is 100%, and also the range of the scatter of the parameters to be determined, not exceeding 10^0.

Based on the results of the earthquake source mechanism, it was realized under conditions of the submeridional orientation of the compressive stress axis and the sublatitudinal, hollow, submerging tensile stress axis. Under the conditions of a regional stress field, under the influence of which a discontinuity occurred in the focus, consistent with the dynamics and orientation of the main lineaments in the region, it can be concluded that this is a tectonic earthquake.

The type of tectonic movement in the focal zone is characterized by a horizontal shift with a small toklift component. The orientation of one of the planes is consistent with the regional fault of the north-eastern direction, marked in the scheme to the south of the epicenter [8].

Another possible plane of discontinuity agrees with the orientation of local faults that cut structures in the northwestern direction. Note that a similar type of focal mechanism is characteristic of the foci of earthquakes of the Kazakh shield (Shalginsky, Zhezkazgan and Semipalatinsk test site).

At the same time, it should be said that the possibility of provoking such an earthquake with active explosive activity in a nearby located career is not ruled out. The class of such induced earthquakes is also called natural-technogenic [8].

Summarizing the above, it is necessary to add that the seismic processes in Central Kazakhstan are continuing. Note that recently on September 20, 2017, seismic stations of the IGI ME RK recorded an earthquake that occurred at 08.44 minutes in Astana time (02:44 GMT), the epicenter of which is located 190 km east of the city of Karaganda. Coordinates of the epicenter: 50.180 degrees N, 75.700 degrees E. The magnitude mb = 3.8. The energy class is K = 8.7. The depth h = 13 km (figure 7). The elucidation of the genesis and mechanism of this earthquake is under study. The nearest town of Koyandy is 40 km away. Koyandy earthquake.

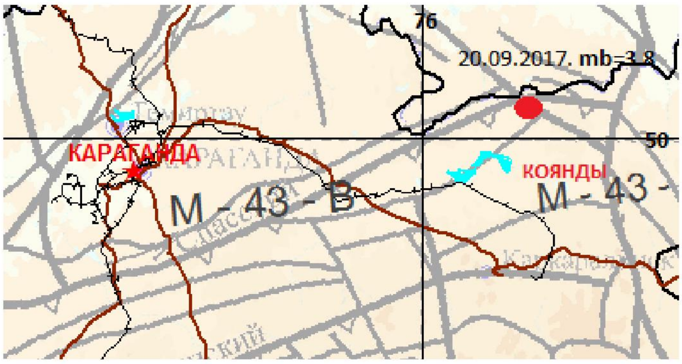

Figure 7 – Epicenter of the earthquake on September 20, 2017

Technogenic earthquakes in Central Kazakhstan. They are associated with the intensive development of deposits of solid minerals. An example of such seismic events can be considered earthquakes at the copper deposit of Zhezkazgan.

Long-term development of this field (more than 60 years) led to significant geodynamic changes in the geological environment, which were manifested by powerful technogenic earthquakes. The strongest of them, with mb = 4.8, Ms = 4.5, occurred on August 1, 1994, on the territory of the Zlatoust-Belovsky quarry, near the city of Zhezkazgan (figure 8).

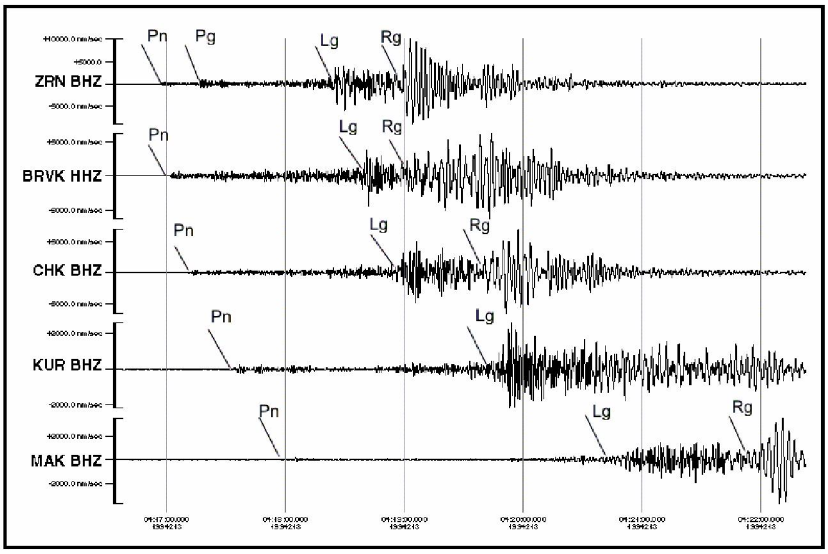

Figure 8 – Seismically records of the event 1st August, 1994.
Zhezkazgan region. t_0=4-15-39.7, φ=47.833°, λ=67.451°, mb=4.8, K=12.2. Stations of IGR. Z-component

This large-scale collapse took the lives of 6 people and caused the destruction of many operating underground excavations and buildings on the surface. The consequences of the earthquake almost led to a complete stoppage of work at one of the mines, the closure of a number of mines and the transfer of surface structures from the danger zone. Railroad tracks were destroyed, the cars were overturned [10, 11].

Figure 9 shows a diagram of the collapse of the overlaying strata with access to the surface of the day [10].

Another seismic event of technogenic nature that occurred on June 23, 1996 in the Zhezkazgan field (Ms = 3.7), was felt at considerable distances; in the village of Karazhal (epicentral distance Δ=243 км), the village of Agadyr (Δ=398 км) with an intensity of 3 points and etc.

Stations of the IGI ME RK also recorded seismic events of technogenic nature 09.09.2002 (Ms = 4.4) and 23.06.2005 (Ms = 4.0) near Zhezkazgan. Figure 10 shows the epicenters, and Table 4 shows the parameters of strong earthquakes with the energy class 9.4-12.2 occurring in this region.

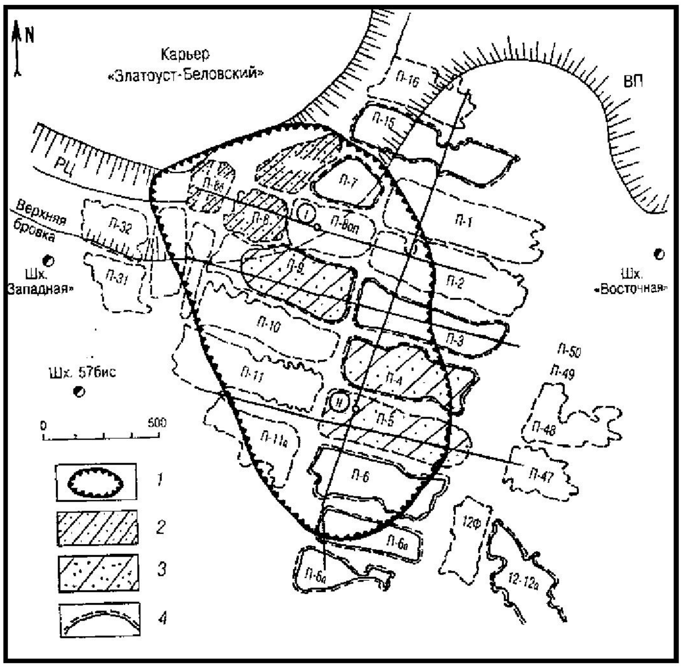

Figure 9 – Zlatoust-Belovsky quarry of the Zhezkazgan deposit.
Scheme for the implementation of the collapse process that occurred on August 1, 1994.
Legend: 1 - contour of collapse, 2-4 - panels respectively laid, partially embedded and weakened [9].

Table 4 – Parameters of technogenic seismic events near Zhezkazgan

Date	t_0	φ°,N	λ°,E	h	mpva	Ms	K
01.08.1994	04:15:39.7	47.833	67.451	0	4.8	4.5	12.2
17.07.1995	19:08:30.9	47.973	67.699	0	3.9		10.4
23.06.1996	18:28:25.8	47.8643	67.618	0	4.3		10.9
01.08.1996	00:06:04.5	47.9284	67.6856	0	4		10.4
09.09.2002	22:27:01.3	47.873	67.573	0	4.6	3.8	11.0
23.06.2005	18:00:07.6	47.9059	67.4092	0	4.1	3.5	10.4
16.01.2009	22:18:29.8	47.8672	67.4203	0	3.7		9.4
19.03.2009	19:08:46.6	47.934	67.6777	0	4.3		10.4
11.06.2009	06:05:49.9	47.8672	67.5424	0	3.9		10.3

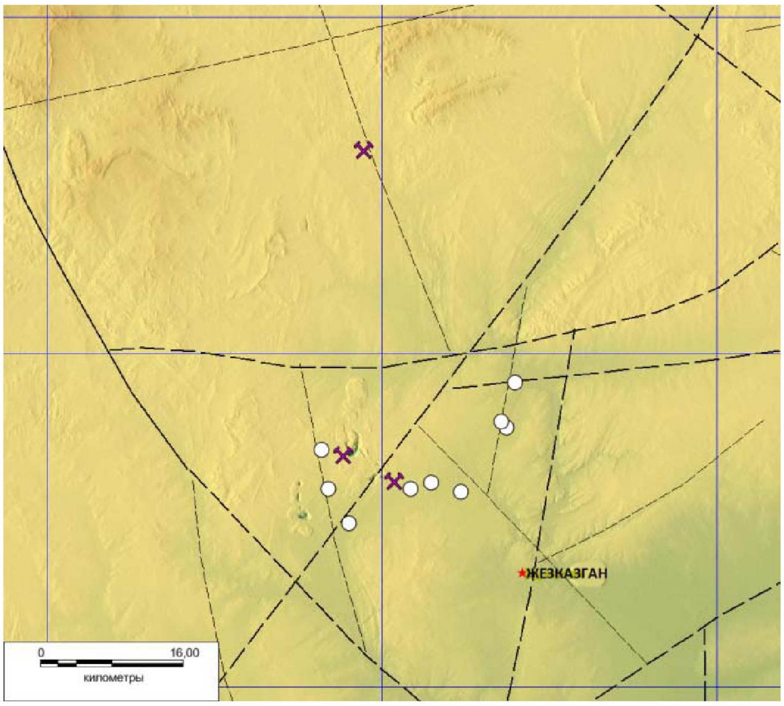

Figure 10 – Map of the location of the epicenters of seismic events in the Zhezkazgan field.
Legend: dotted line - discontinuous violations; circle - the epicenter of the event according to KNDC, crossed hammers - quarry.

In connection with the foregoing, for detailed analysis of the seismic processes taking place in Central Kazakhstan, it is not enough to attract only regional seismic stations. It is necessary to carry out special monitoring at the developed useful deposits in order to observe the patterns of preparation of strong man-made earthquakes, as well as to register the mine and mine explosions occurring here.

The **conclusion**. Based on the research:

- A new instrumental level of monitoring made it possible to obtain representative statistics on tectonic earthquakes, explosions in quarries and mines, technogenic events in Central Kazakhstan.

- The peculiarities of the manifestation of earthquake foci in platform structures are revealed and the question of the nature of seismic events in Central Kazakhstan is covered.

- It is shown that, in spite of tangible progress in the study of seismic events in Central Kazakhstan, some technical and methodological issues have still not been properly developed, and work on them continues.

For example, the generalization of all seismological data on earthquakes that have occurred, the comparison of this information with geological and tectonic data will make it possible to establish the relationship of specific foci with tectonic processes in each seismogenic zone, and also to determine the nature of the stresses acting in the region.

The identification of such links is very important for the study of previously considered aseismic regions of Central Kazakhstan.

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ОРТАЛЫҚ ҚАЗАҚСТАНДАҒЫ ТЕХНИКАЛЫҚ ЖӘНЕ ТЕХНОГЕНЦИЯЛЫҚ ЕРЕЖЕЛЕР

Аннотация. Мақалада Орталық Қазақстанда тектоникалық және техногендік сипаттағы сейсмикалық оқиғалар қарастырылған. Қазақстан Республикасы Энергетика министрлігінің Геофизикалық зерттеулер институтының сейсмикалық желісі бойынша осы аймақтың аумағын сейсмикалық бақылау сипаттамасы келтірілген.

Мониторингтің жаңа аспаптық деңгейлері Орталық Қазақстанда тектоникалық жер сілкінісі, карьерлерде, кеніштерде және басқа да техногендік оқиғалардағы жарылыстар туралы статистикалық мәліметтерді және жер қыртысының ең терең бөліктерінің стресс-күйі туралы мәліметтерді алуға мүмкіндік берді.

Орталық Қазақстанның платформалық құрылымдарында тектоникалық және техногендік сейсмикалық факторлар көріністерінің ерекшеліктерін ретроспективті талдау ұсынылды. Осы аймақтағы жер сілкінісінің параметрлері зерттелді, жер сілкінісі ошақтарының механизмі және тектоникалық ауысулардың түрлері туралы пікірлер жасалды, изосейлік карталар жасалды.

Сонымен қатар, Орталық Қазақстанда сейсмикалық оқиғаларды зерттеуде елеулі прогреске қарамастан кейбір техникалық және әдістемелік мәселелер әлі күнге дейін тиісті түрде дамымаған және олар бойынша жұмыс жалғасуда.

Түйін сөздер: жерсілкіну, фокал механизмі, сейсмичкалық станциялар, афтершок, магнитуда, эпицентр, изосейста сызығы.

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Алматы, Казахстан

ТЕКТОНИЧЕСКИЕ И ТЕХНОГЕННЫЕ ЗЕМЛЕТРЯСЕНИЯ В ЦЕНТРАЛЬНОМ КАЗАХСТАНЕ

Аннотация. В статье рассмотрены сейсмические события тектонической и техногенной природы в Центральном Казахстане. Приводится характеристика сейсмического мониторинга территории этого региона сейсмической сетью Института Геофизических Исследований Министерства Энергетики Республики Казахстан.

Новый инструментальный уровень мониторинга дал возможность получить и изучить по Центральному Казахстану представительную статистику по тектоническим землетрясениям, взрывам в карьерах, шахтах и др. техногенным событиям, а также данные о напряженно-деформированном состоянии глубоких частей земной коры.

Представлен ретроспективный анализ особенностей проявления очагов тектонической и техногенной сейсмичности на платформенных структурах Центрального Казахстана. Изучены параметры землетрясений в этом регионе, высказаны суждения о природе механизма очагов землетрясений и типах тектонических подвижек, построены карты изосейст.

Вместе с тем, показано, что, несмотря на ощутимый прогресс в изучении сейсмических событий в Центральном Казахстане, все еще не получили должного развития некоторые вопросы технического и методического характера, работа над которыми продолжается.

Ключевые слова: землетрясения, фокальный механизм, сейсмические станции, афтершок, магнитуда, эпицентр, изосейста.