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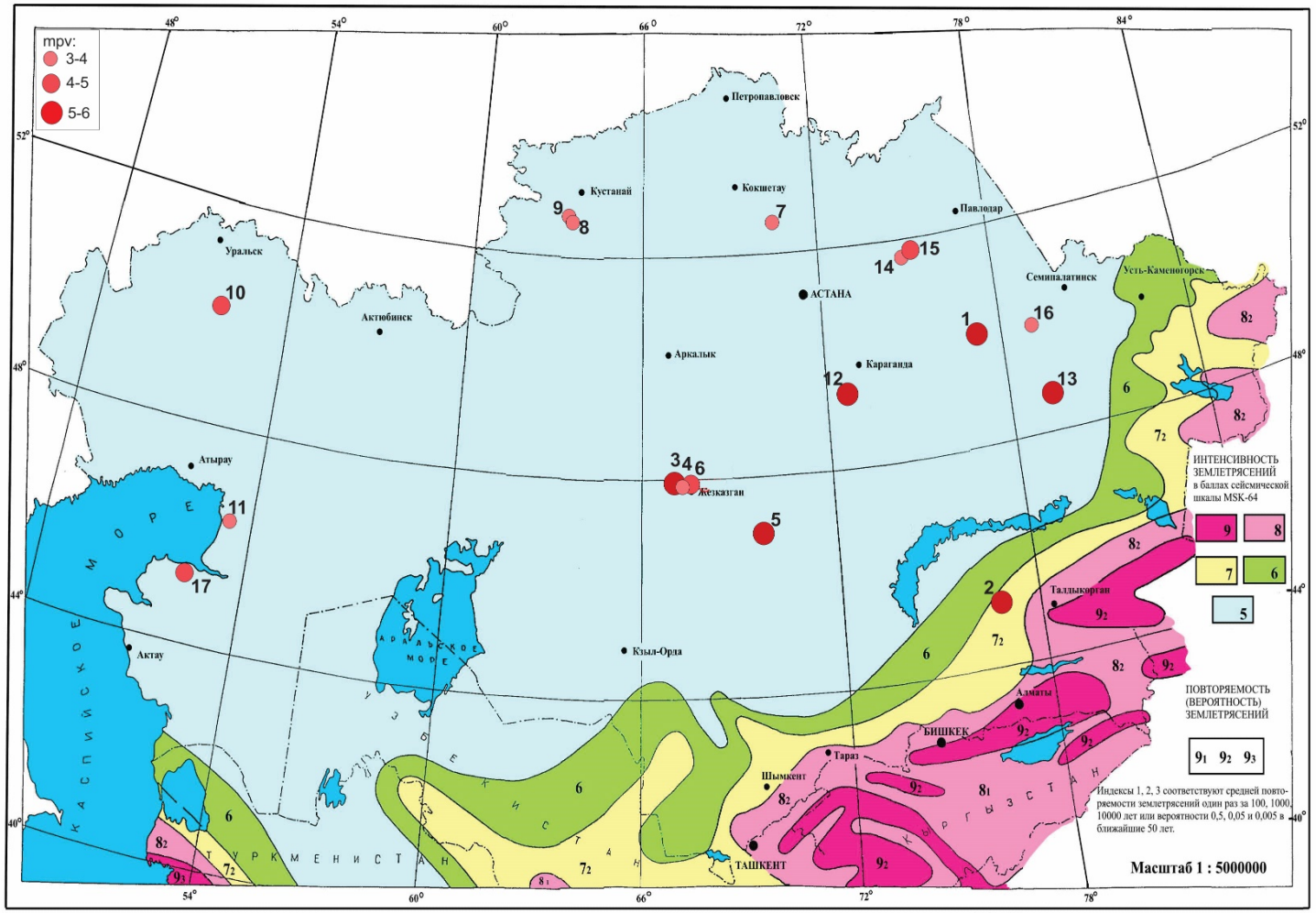
Seismic monitoring and the results of its application in Kazakhstan to study seismic events of various nature.

Mongolia, Ulaanbaatar 2026

Content

- General information on seismic hazard and seismic observation networks in Kazakhstan up to year 2000;
- New network of stations - new data on natural, anthropogenic and environmental hazards on the territory of Kazakhstan;
- Seismic events of different nature and associated seismic risks;
- Problems in studying and predicting risk in 'weak seismic' areas of Kazakhstan.

General seismic zoning map of Kazakhstan, 1998

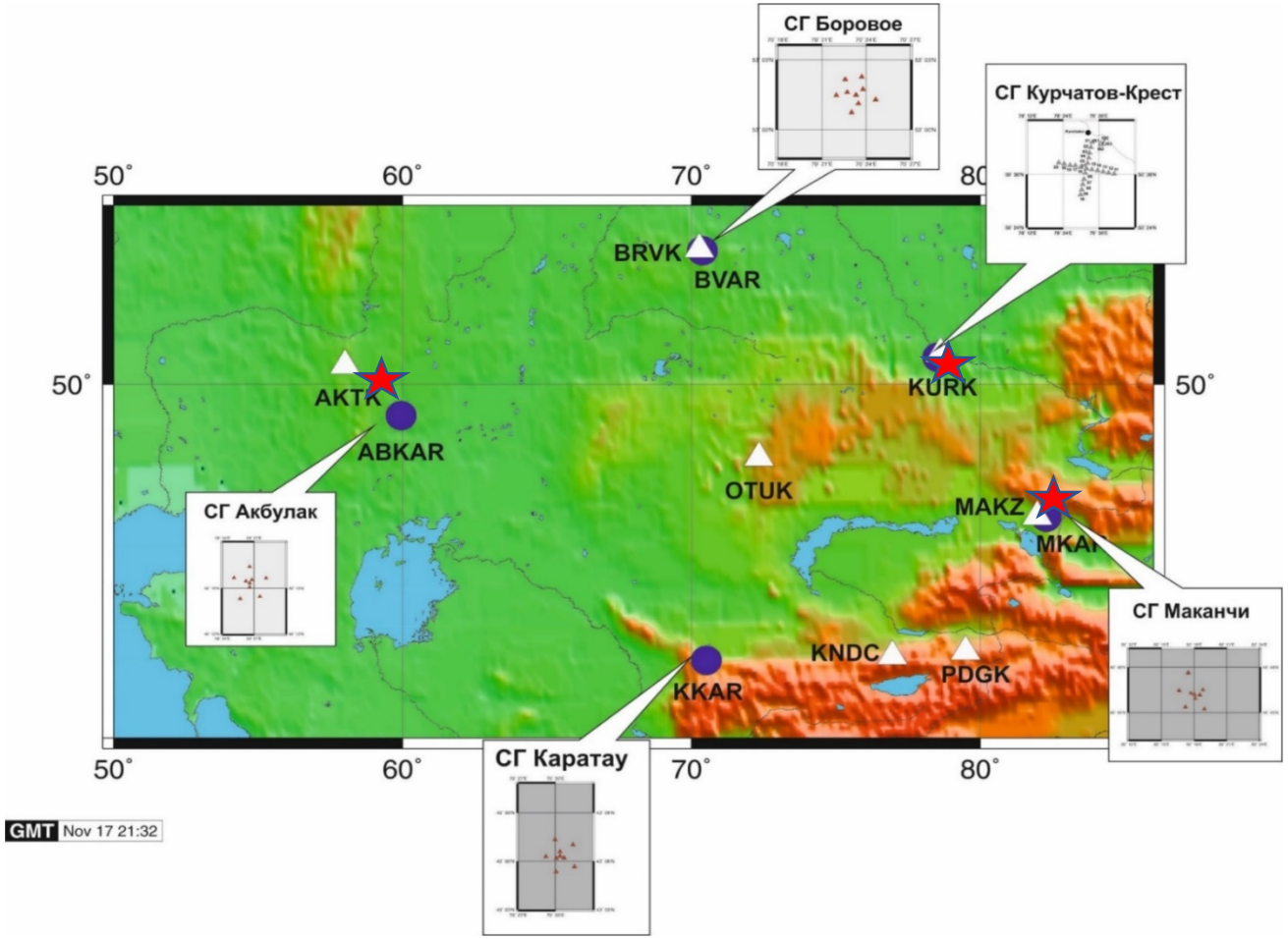


Red circles are strongest events in the «aseismic zone» since 2000.

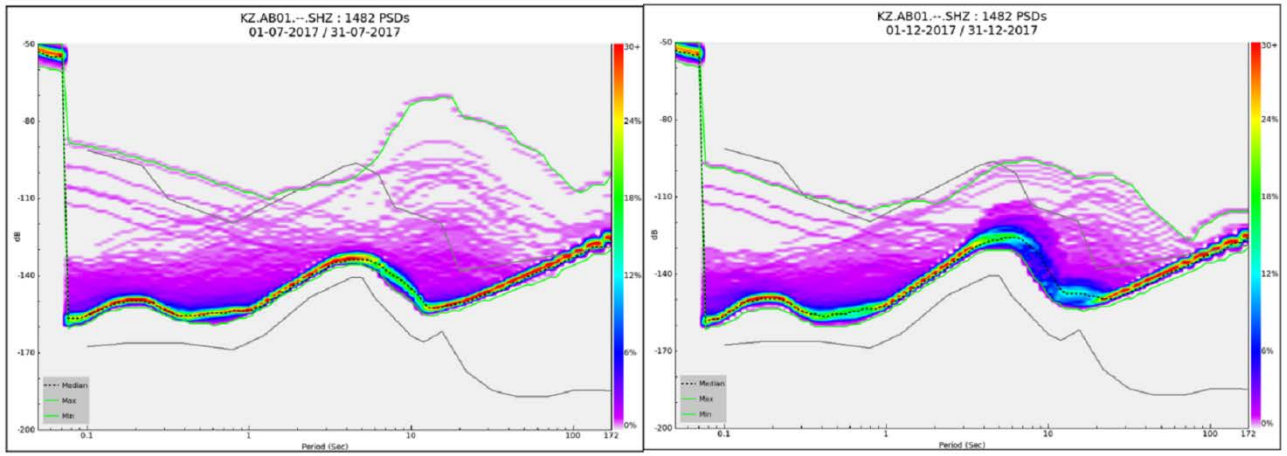
In Kazakhstan, for many decades, it was traditionally believed that the south, south-east and partly east of the country's territory is seismically active. Consequently, all seismic stations were located on this territory. The general seismic zoning maps of 1998 and 2003 reflected this idea.

The development of the observation network has taken place in the high-seismic areas. Each new large earthquake in places unexpected for seismologists led to changes in the maps and installation of stations in this area. This was the case after the Dzhambul earthquake in 1971, Bakanas earthquake in 1979, Zaisan earthquakes in 1990.

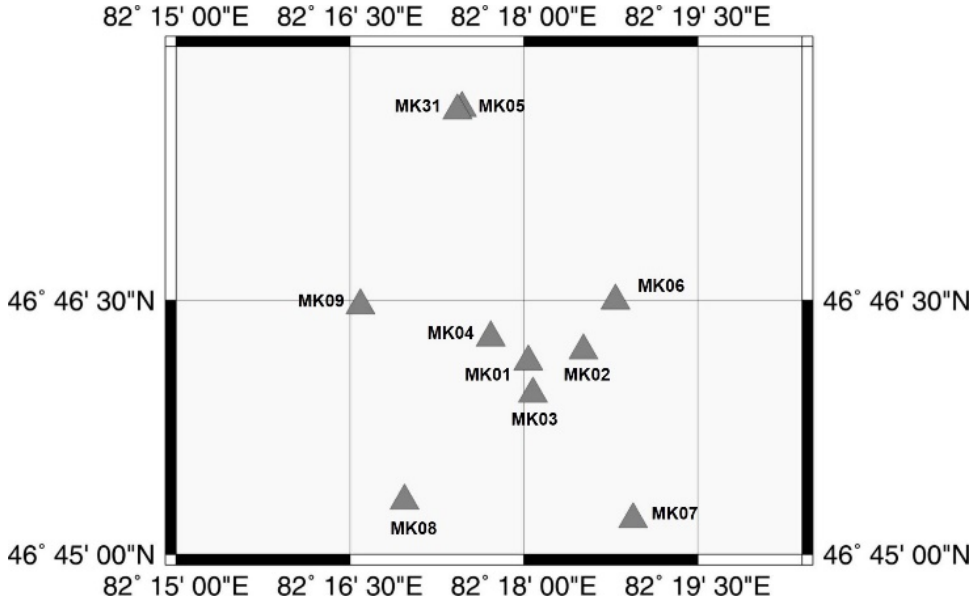
1. New network of stations –new data in Kazakhstan's seismicity

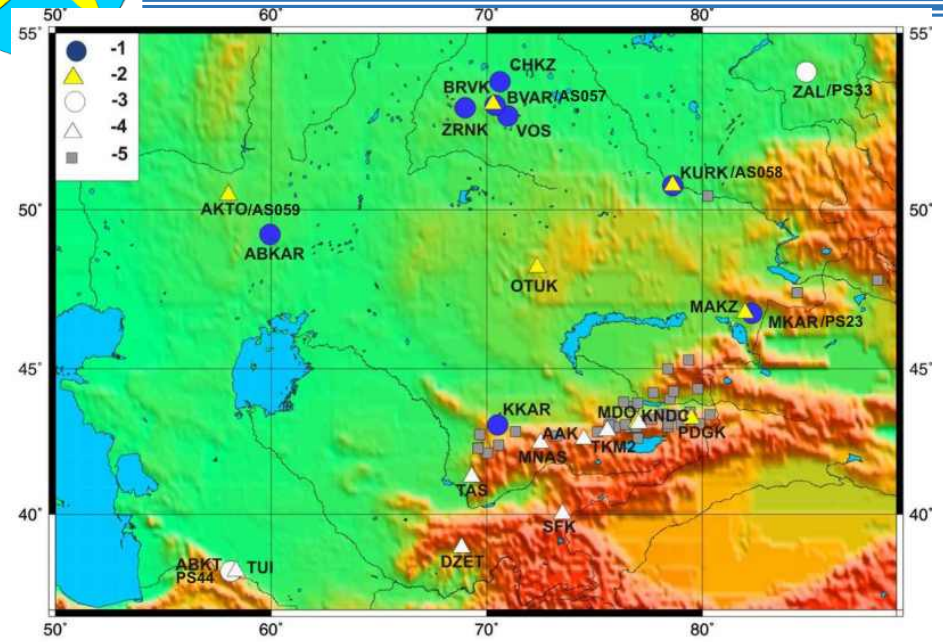


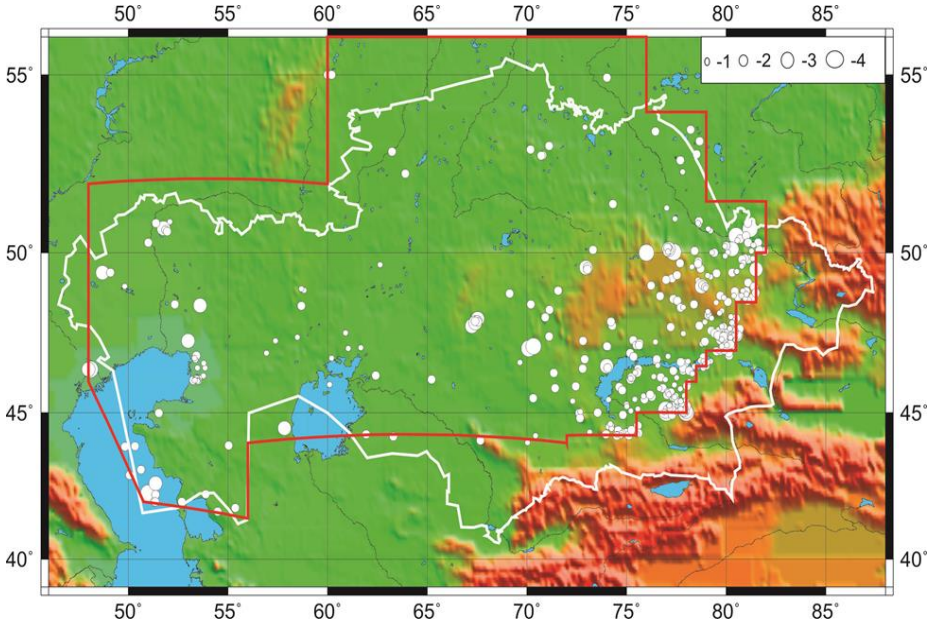
A significant shift in the issue of seismic monitoring of the entire territory of Kazakhstan occurred after 1996, the year when Kazakhstan signed the CTBT (Comprehensive Nuclear Test Ban Treaty). According to this Agreement, facilities of the International Monitoring System (IMS) were to be built in the country, and their location was not related to a priori ideas about the seismicity of the area. The task of the IMS network is to monitor the implementation of the CTBT in relation to nuclear tests.



The main criteria for creating a new monitoring network are the successful location of the station in the configuration of the entire system, a quiet location in terms of the level of "seismic noise", and the placement of equipment in wells in the bedrock. In 2000-2006, five new seismic groups (10-21 elements in each group) and one three-component station were built and put into operation, which are part of the CTBTO and AFTAC IMS systems.







In the Data Center in Almaty, established in 1999 (KNDC) regional bulletins have begun to be compiled for the entire territory of Kazakhstan and adjacent territories of neighboring Central Asian countries. In this case, the data of the SOME stations is used. Kazakhstan and some stations of Kyrgyzstan , Russia , etc..

1- seismic groups and 3-component stations of the IGI of the National Research Nuclear Center of the Republic of Kazakhstan; 2 – foreign seismic groups; 3 – foreign 3-component stations; 4 – SOME stations (only tables of seismic phases were used).

At the same time, work began with the available data from the world centers for collecting information on events in the "aseismic" territory of Kazakhstan.

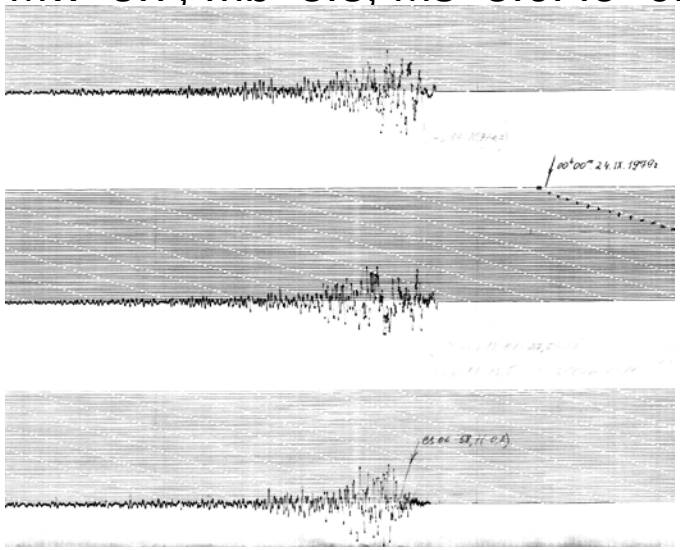
Map of earthquake epicenters in low-activity areas from historical times to 2020.

1 - Ms<2; 2- 2 ≤ Ms < 4; 3- 4 ≤ Ms < 5; 4- 5 ≤ Ms

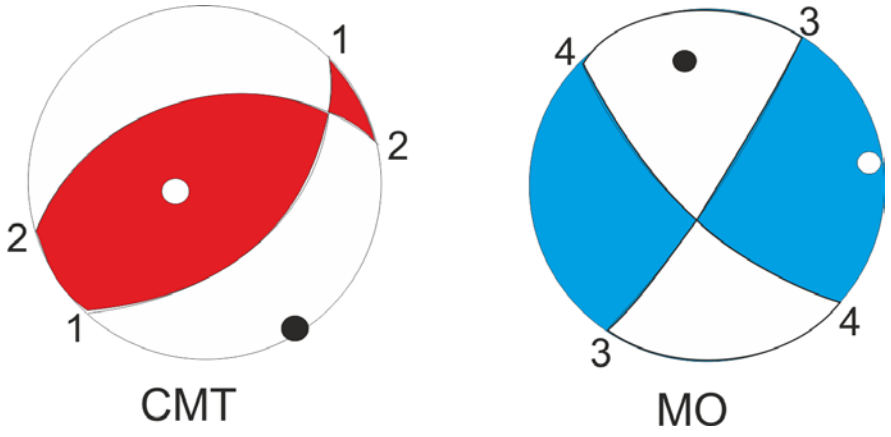
Second type is the diversity of earthquake nature in the weakly seismic territory of Kazakhstan

Natural tectonic earthquakes. The Bakanasi earthquake of 1979 was the first of the previously recorded unusual events in the platform area. (south-east of Kazakhstan). It has been studied in detail due to a number of unique features. The hearth depth of 40 km is confirmed by the presence of deep phases on recordings of distant stations at teleseismic distances. These are the phases sP, sS, pP. These phases have been recorded at more than 200 stations. A day later, a group of seismic stations was installed in the epicentral zone to register aftershocks, but not a single event was recorded.

Mw=5.7; mb=5.8; Ms=5.6. Io=6. On 12.09.2010, another earthquake with (energetic class) K=12 occurred in the



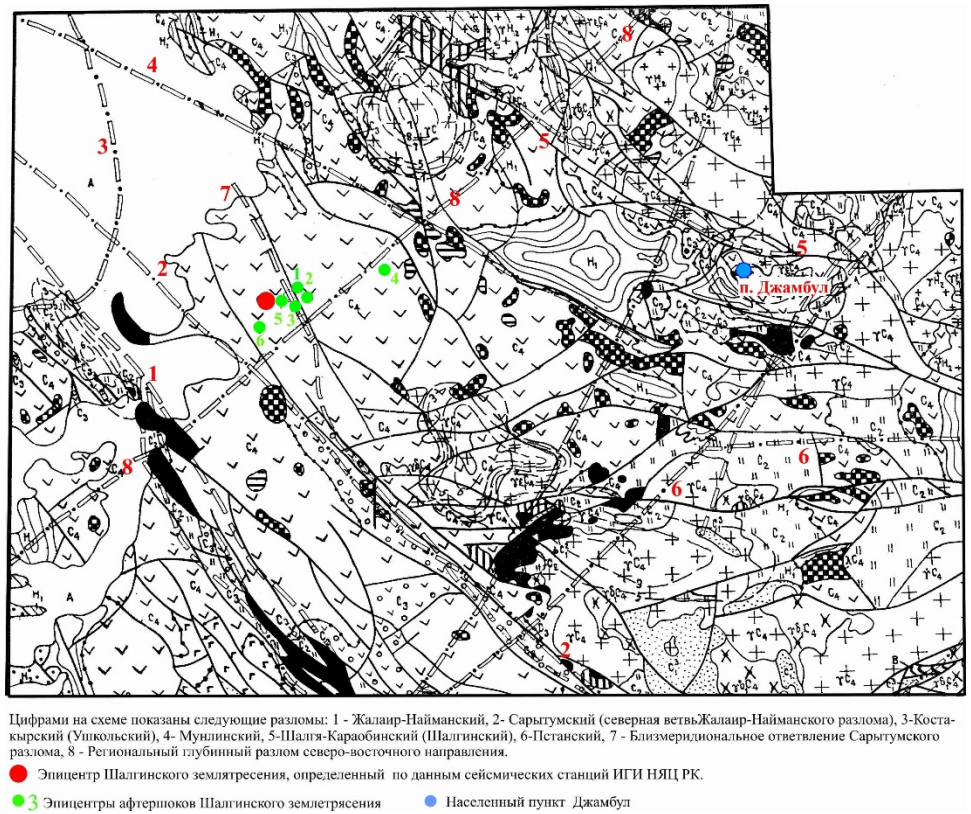
Seismogram of Almat-Ata station, SKD, V=50



CMT and mechanism of the earthquake source 1979.

According to the data of the focal mechanisms, a similarity of processes has been established in the foci of two strong earthquakes in the Bakanasi zone (1979 and 2010). Both earthquakes occurred under conditions of near-horizontal compression in the north and northwesterly direction. along planes falling to the northwest and extending in a northeasterly direction.

Shalgyn earthquake 22.08.2001 (Central Kazakhstan) Ms = 5.4, mb=5.8, K=13.6, Io=6. Depth 8 km.



Цифрами на схеме показаны следующие разломы: 1 - Жалаир-Найманский, 2- Сарыгумский (северная ветвьЖалаир-Найманского разлома), 3-Коста-кырский (Ушкольский), 4- Мулинский, 5-Шалгя-Караобинский (Шалгинский), 6-Пстанский, 7 - Близмеридиональное ответвление Сарыгумского разлома, 8 - Региональный глубинный разлом северо-восточного направления.

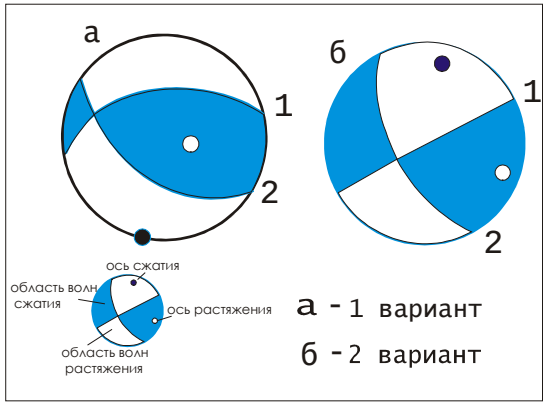
Эпицентр Шалгинского землятресения, определенный по данным сейсмических станций ИГИ НЯЦ РК.

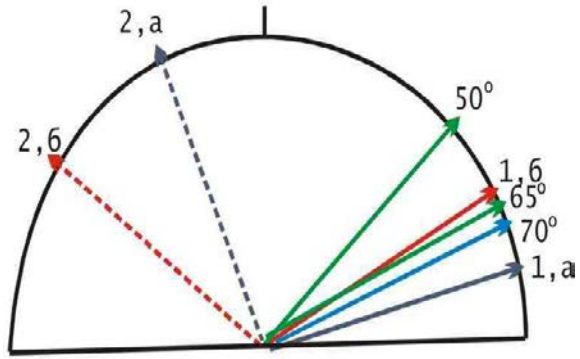
3 Эпицентры афтершоков Шалгинского землетрясения

Населенный пункт Джамбул

Линии изосейст

3 – 6 - Баллы по шкале MSK – 64

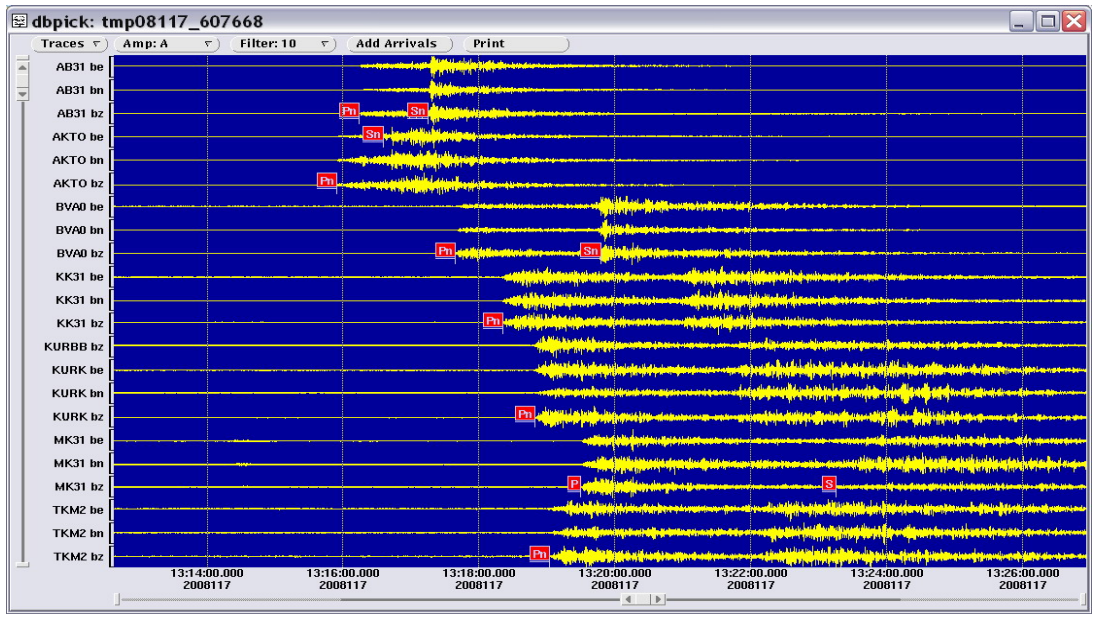


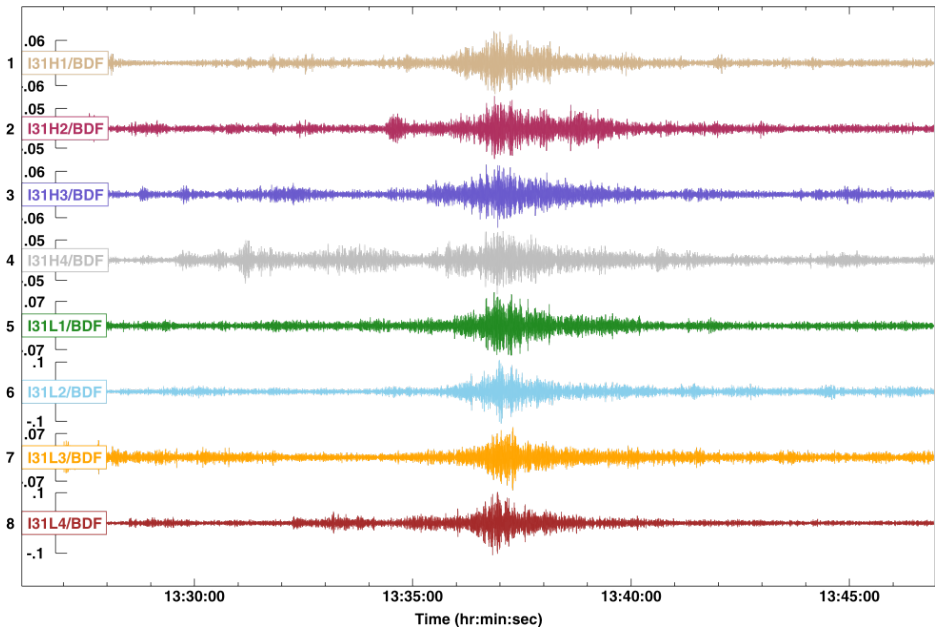


For the first time, reliable materials on the activity of this region of Kazakhstan were obtained. For the first time, data on the stress state of the Earth's crust has been obtained. This earthquake served as an incentive to study the seismicity of other regions of Kazakhstan, previously considered aseismic. The issue of creating a seismic observation system in Kazakhstan has been raised in a new way.

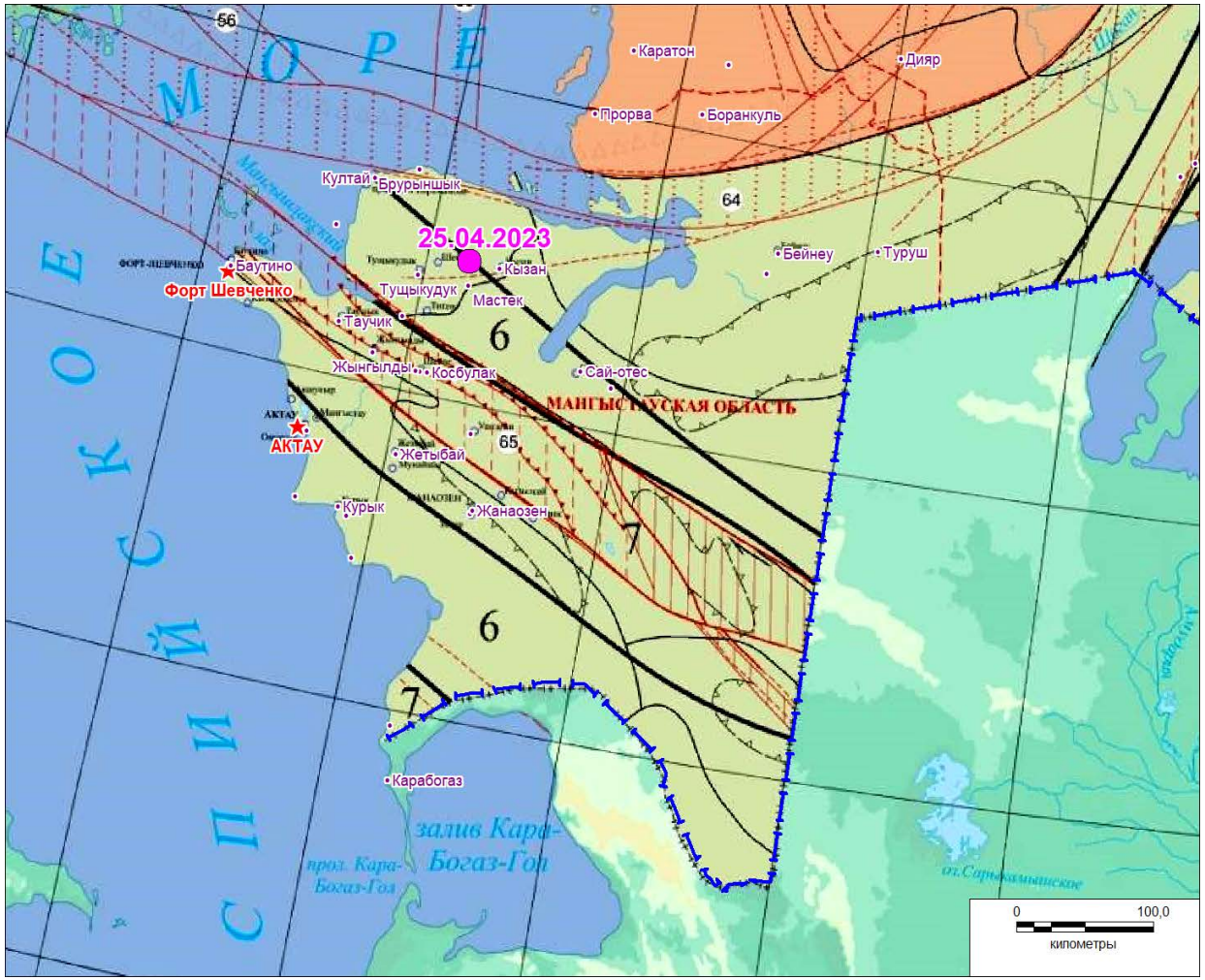
Shalkar earthquake in the West of Kazakhstan 26.04.2008. mb = 5.0, Ms = 4.6, Io = 7-8.

The area of the Shalkar earthquake is located in the northern part of the Caspian basin, where the sedimentary rock cover reaches 15-18 km to the crystalline basement. An important feature of the section of the cover is the presence of a powerful (up to 3-4 km in the primary occurrence) salt–bearing stratum of the Kungurian age (P1k), dividing the cover into subsalt and suprasalt structural and formation complexes. In accordance with the studied conditions in the epicentral zone, geological and tectonic characteristics, it is believed that this is a natural tectonic phenomenon associated with the karst process and active salt diapirism. The earthquake is shallow, and strong infrasound waves have been recorded by the infrasound station of the National Research Center of the Republic of Kazakhstan. The local stress system according to the data on the mechanism of the hearth indicates the prevailing tensile stresses, since the type of movement in the hearth is defined as shear-discharge.



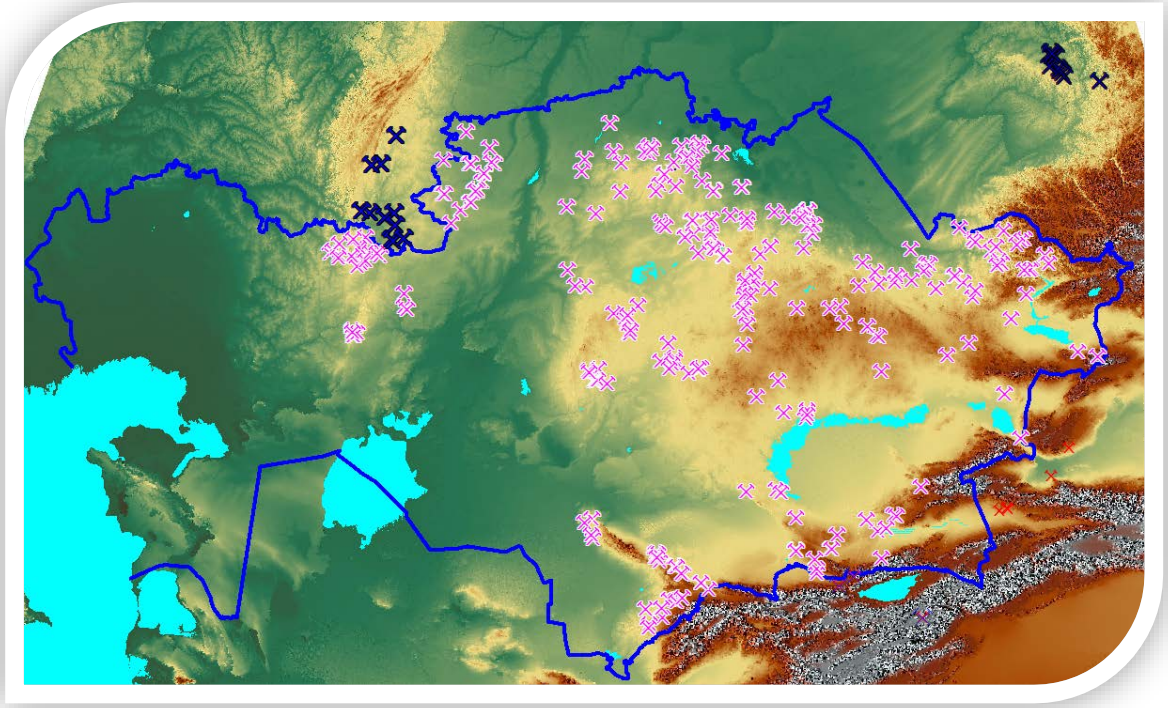


In Western Kazakhstan, in 2023, earthquakes were recorded on the Buzachi Peninsula, recognized as natural tectonic earthquakes. On May 23, 2023, an earthquake occurred with a magnitude of mb=4.6, ML=4.8, energy class K=10.5.



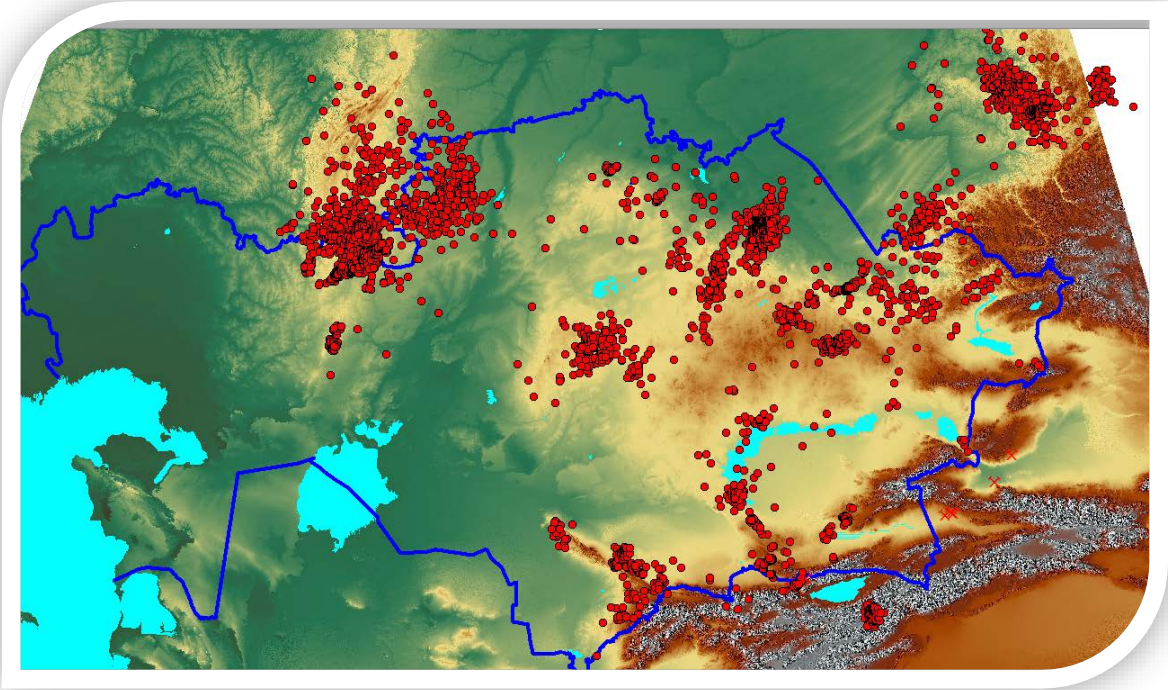
Tremors with an intensity of 4 points were felt by residents of the village of Kyzan (23 km from the epicenter), the village of Tuzshykol (37 km from the epicenter) and 2-ф3 points in Aktau, the work is devoted to this earthquake, unique for this region, the first tangible and instrumentally recorded event here [5]. According to the modern 2017 map of the general seismic zoning of the territory of Kazakhstan, the epicenter area is located between two seismic generating zones - Central Mangyshlak-Ustyurt and South Embensko-Mugodzhar.

Man-made events

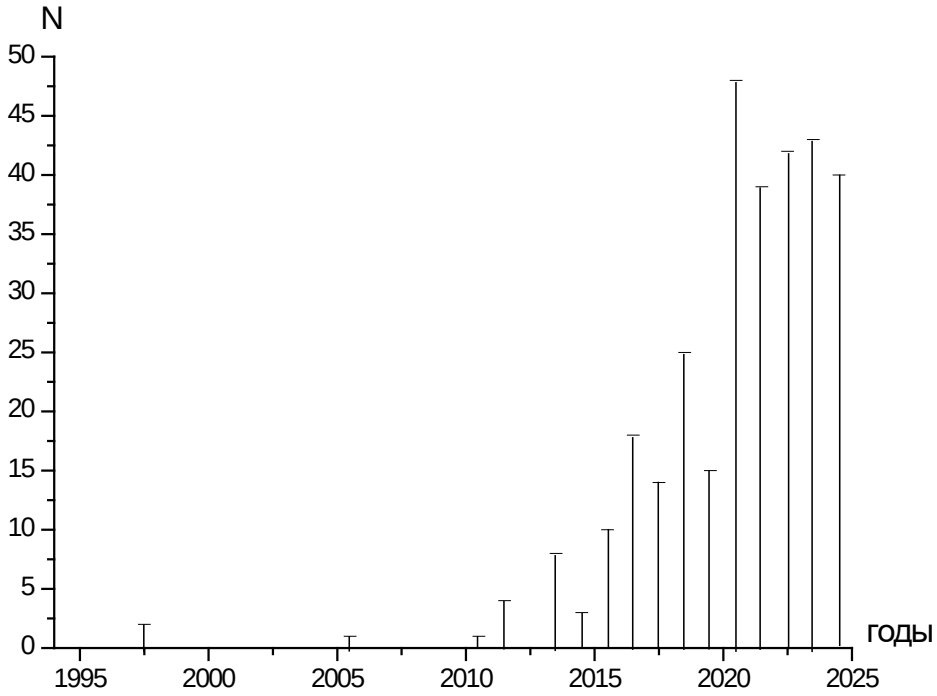


A large number of man-made events and earthquakes are registered on the territory of Kazakhstan. Most of the recorded seismic events of a technogenic nature of the first type, of course, are industrial explosions carried out during the development of minerals.

About 5000-6000 of them are registered per year. Explosive seismicity is a separate aspect in seismic monitoring and requires recognition of their nature, unlike earthquakes, for the correctness of catalogues used in assessing seismic hazards.



Man-made earthquakes. Kazakhstan is rich in minerals, and their development is very active. This includes the extraction of liquid hydrocarbons and solid minerals. Man-made earthquakes occur as a result of active and prolonged production activities in the extraction of minerals, their foci are noted directly within the developed deposits. The network of seismic stations of the National Research Nuclear Center of the Republic of Kazakhstan registers man–made earthquakes at hydrocarbon deposits - Tengiz, Karachaganak, Zhanazhol, and at deposits of solid minerals The fossils of Zhezkazgan, Zhomart, Ekibastuz, Karazhyra. Subsurface users have created special geodynamic and seismic monitoring networks only in some of these fields . However, as a rule, the data of such networks is confidential and inaccessible to researchers.



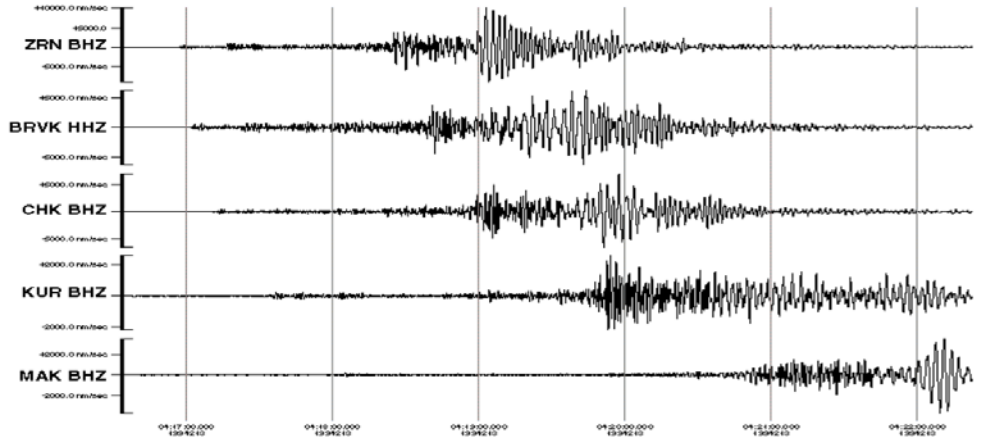
The sources of man-made earthquakes have mostly shallow depths. This increases their danger to buildings and structures: small earthquake magnitudes are compensated by the proximity of the source to the surface, so that relatively weak man-made earthquakes can cause strong seismic effects.

The annual number of seismic events from the area of the Tengiz deposit in Western Kazakhstan, recorded by the seismic network of the IGI of the National Research Center of the Republic of Kazakhstan and global monitoring networks. The maximum magnitude was recorded in 2022. mb = 4.0-4.4

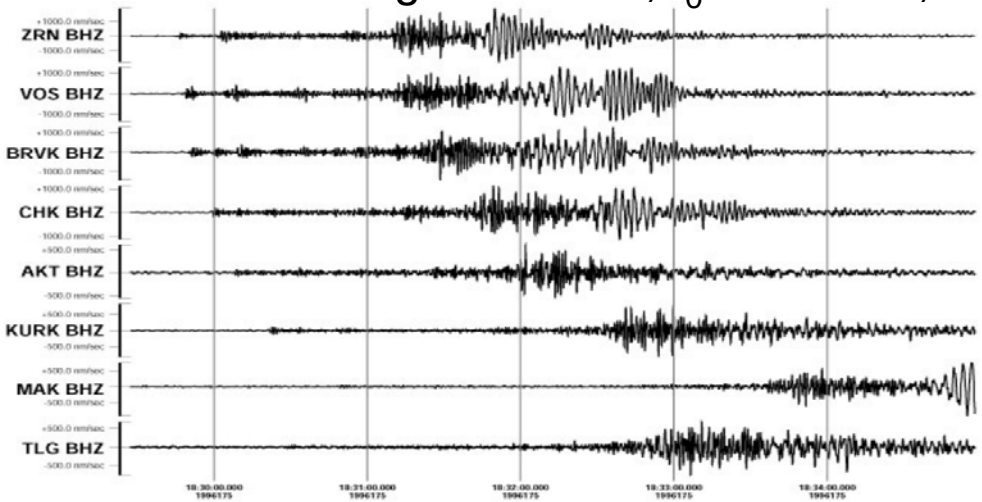
The third type of man-made earthquakes is trigger (naturally man-made or induced) seismicity.

There are quite strong earthquakes registered in the platform region of Kazakhstan near deposits where man-made impacts (mining, quarry and underground explosions) have been carried out for a long time. The difference between the considered seismic events and natural tectonic ones is that they most likely would not have occurred on the territory of this region if there had not been the influence and indirect participation of man-made factors that trigger such crustal earthquakes. Such earthquakes are classified as man-made-tectonic or natural-man-made. V.V.Adushkin noted: "The focal zones of such earthquakes are formed both near production and at a considerable distance, which are determined by the features of the tectonic structure and the changed flows of energy and fluid. The earthquake itself can occur at any time, without any connection with the schedule of man-made impacts. The main contribution to the energy of these earthquakes is made by tectonic stresses." Such earthquakes usually form in the upper layers of the Earth's crust and are accompanied by high intensity impacts. Such natural and man-made earthquakes include the Zhezkazgan series of strong earthquakes, the Karaganda earthquakes, and the earthquakes near Rudny in Northern Kazakhstan.

Strong man-made earthquakes have occurred in the mining fields of solid minerals in Central Kazakhstan. Examples are the Zhezkazgan earthquakes of 1994 and 1996. Magnitudes mpv =3.9–4.6.



Record August 1 1994, t_0=04:15:39,7



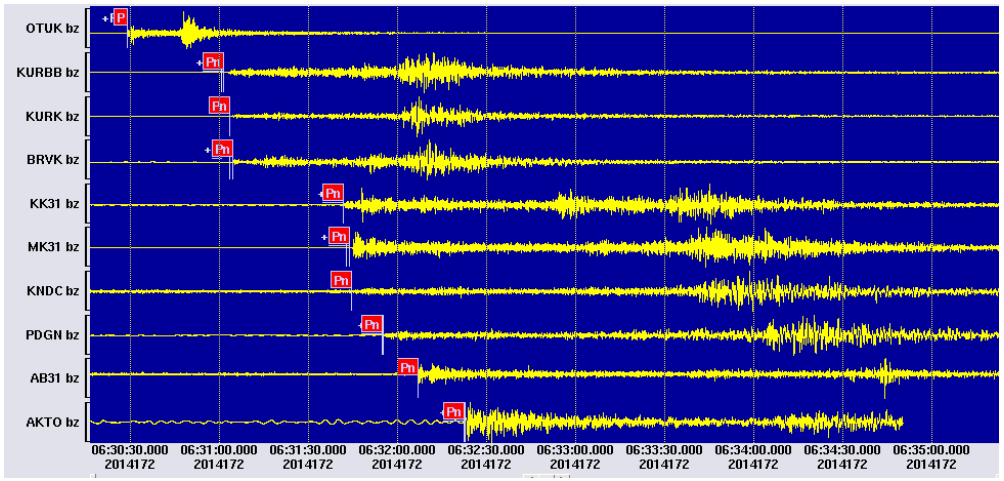
Record June 23 1996, t_0=18:28:26,7

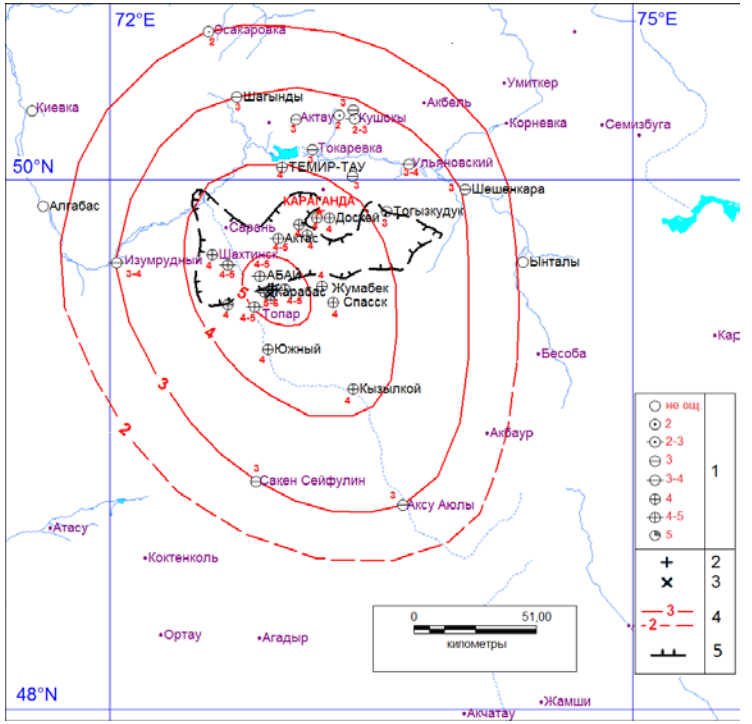
ground rupture

deformation of the rail track

The Karaganda earthquake June 21 2014. mb=5.2, depth h=10км. Io=5-6.

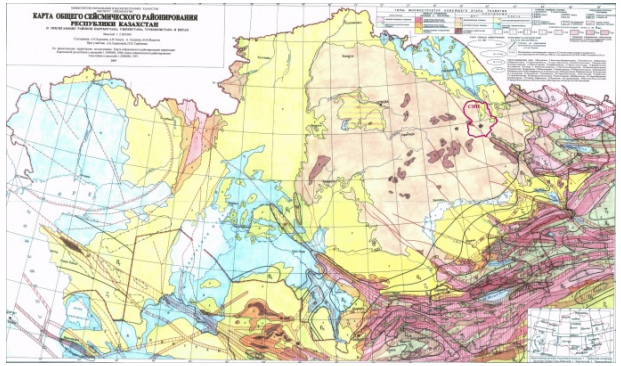
The epicenter of the earthquake is located on the northern border of the Kazakhstan shield near the southern border of the Karaganda coal basin.

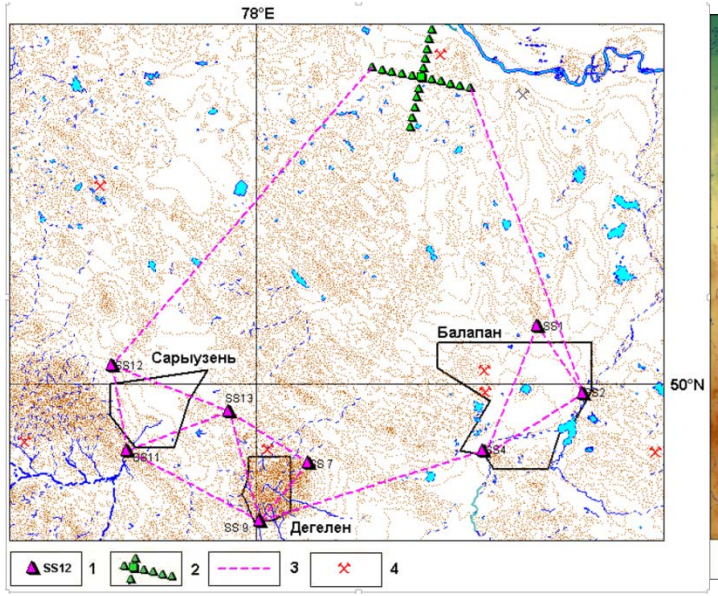


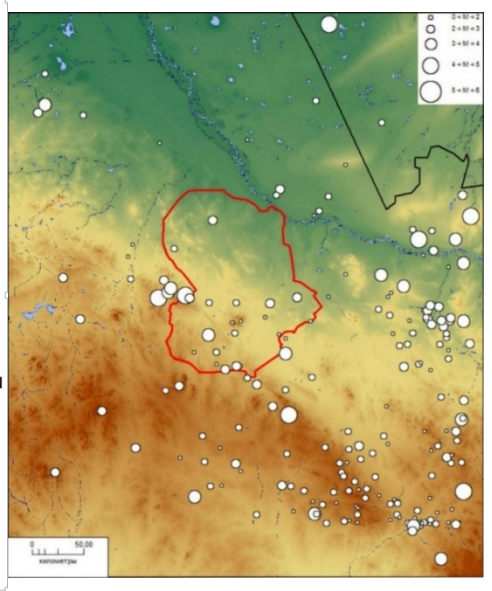


The earthquake is not the result of an explosion or a simple rock collapse, but was realized in the conditions of a regional stress field, under the influence of which a rupture occurred in the hearth, consistent with the dynamics and orientation of the main lineaments of the region. Most likely, this earthquake was triggered by active explosive activity in a nearby quarry, where quarry explosions have been carried out for many years.

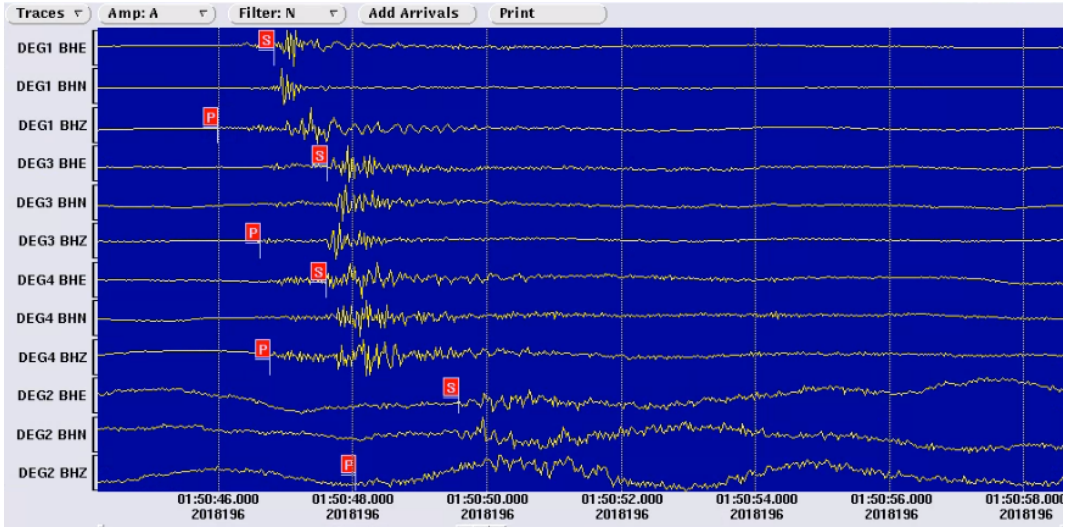
Seismicity of the territory of the former Semipalatinsk test site



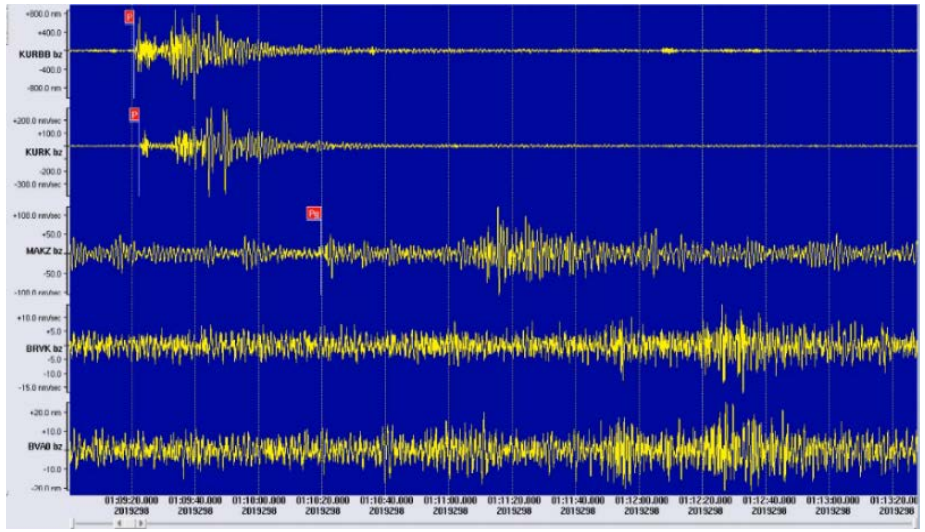




On the territory of the former Semipalatinsk test site and its Surroundings there is natural Tectonic seismicity, man-made
Seismicity near places previously
Conducted nuclear tests,
Technogenically induced seismicity.



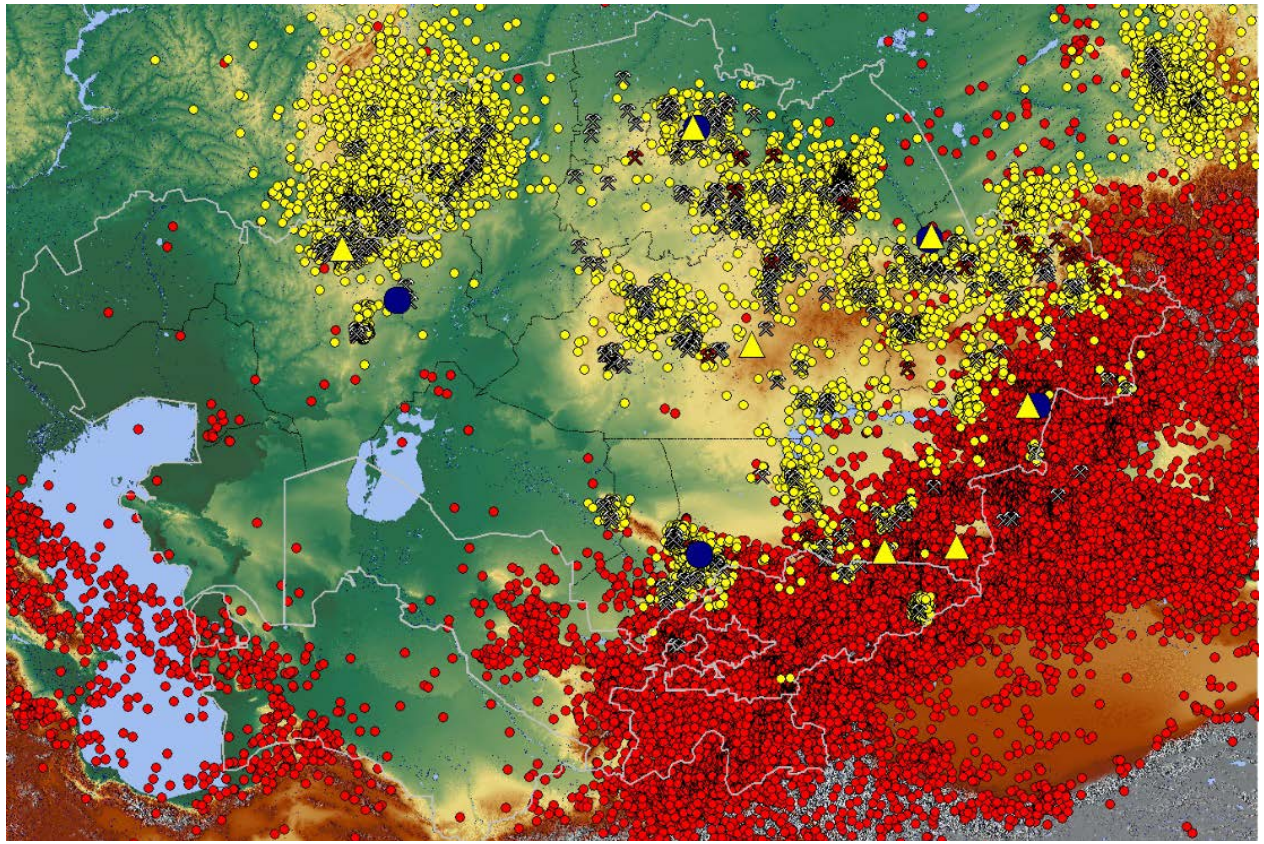
Recordings of man-made events at Degelen (left) with mpv=1.4 and at Karazhyra quarry (right) with mpv=3,2



Problems in studying the seismicity of weakly seismic territories of Kazakhstan

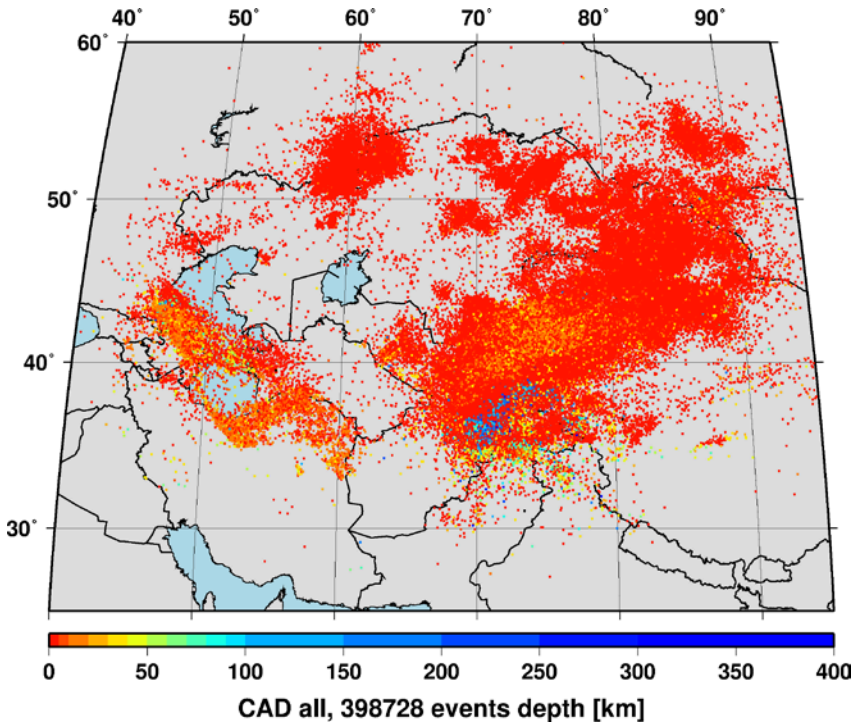
1. The problem in getting a complete picture of the events taking place in the "aseismic" territory is the lack of a sufficient number of seismic stations in this part of the country. Currently, the existing network of stations provides representative registration of earthquakes with a magnitude mb ≥3.5 (4.0). We do not have a complete picture of the seismic areas in this area. But we know from our experience in the fields that a large number of events occur, starting with negative magnitudes. I think that in the platform territories the number of stations will never satisfy the tasks of representative registration of weak events. It is promising to create new seismic groups that have a higher effective sensitivity than three-component stations, and it is also possible to locate events in one group. Only recently, work has been completed to study the registration conditions and select locations for a new seismic group in the south of Western Kazakhstan as part of a two-stage experiment using a network of field stations. A total of 16 stations and three small-aperture groups were installed. The network has been operating for 1 year.

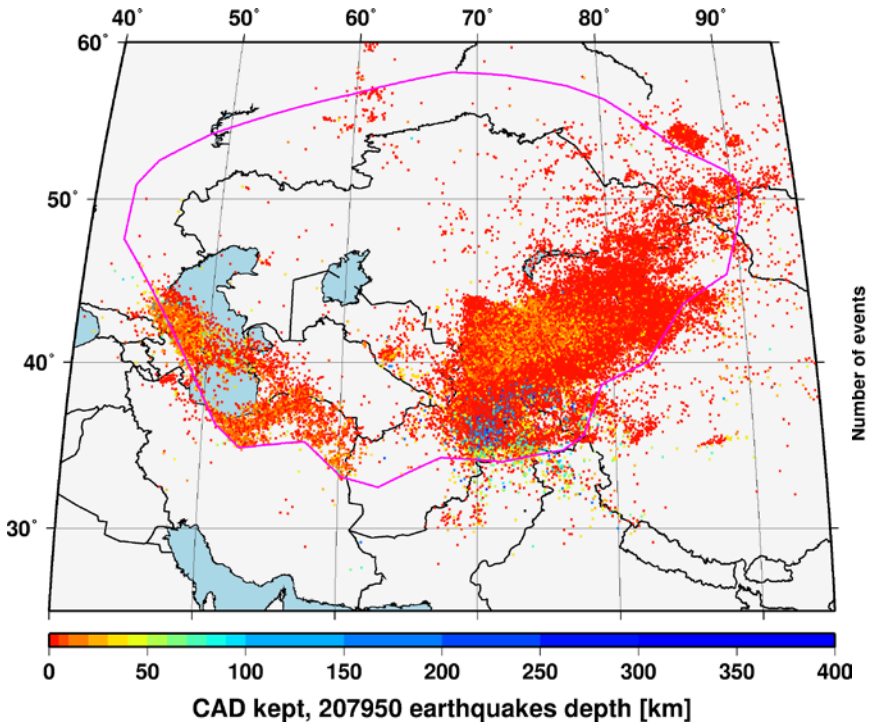
Quarry explosions and the problem of studying platform seismicity.

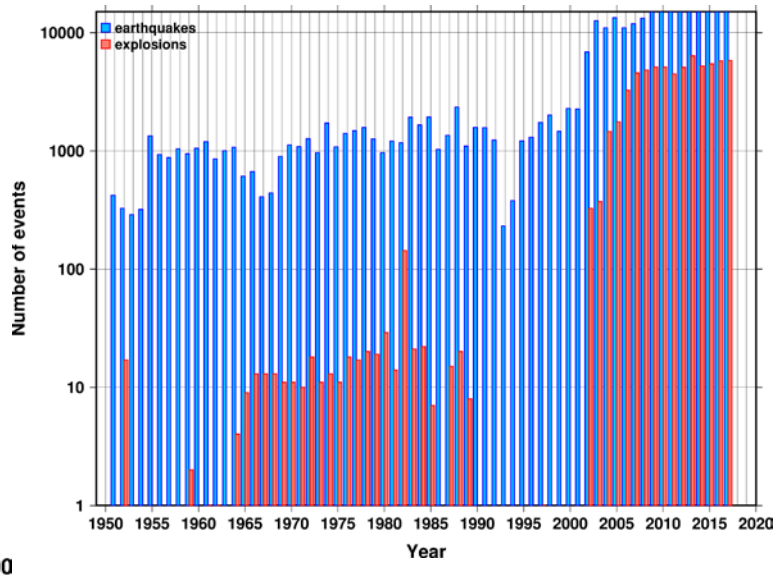


For Kazakhstan, the problem is the recognition of explosions and earthquakes due to the huge number of quarry explosions recorded by the network of the National Research Center of the Republic of Kazakhstan. Over the past 10 years, the KNDC seismic bulletin has included 194,000 events, 64,000 of which are explosions. It is known that a number of man-made and natural-man-made earthquakes occur almost in the same place where explosions are carried out. Identifying the nature of events in newsletters and catalogs is a difficult and time–consuming task in routine data processing. Recognition methods are being developed and technologies are being improved. But we must understand that this is a necessary and important stage of work in the preparation of catalogs for studying seismic hazards.

Here is an example from the results of the ISTC “CASHA-BU” international project to create a catalog of earthquakes in Central Asia for subsequent seismic hazard assessment.

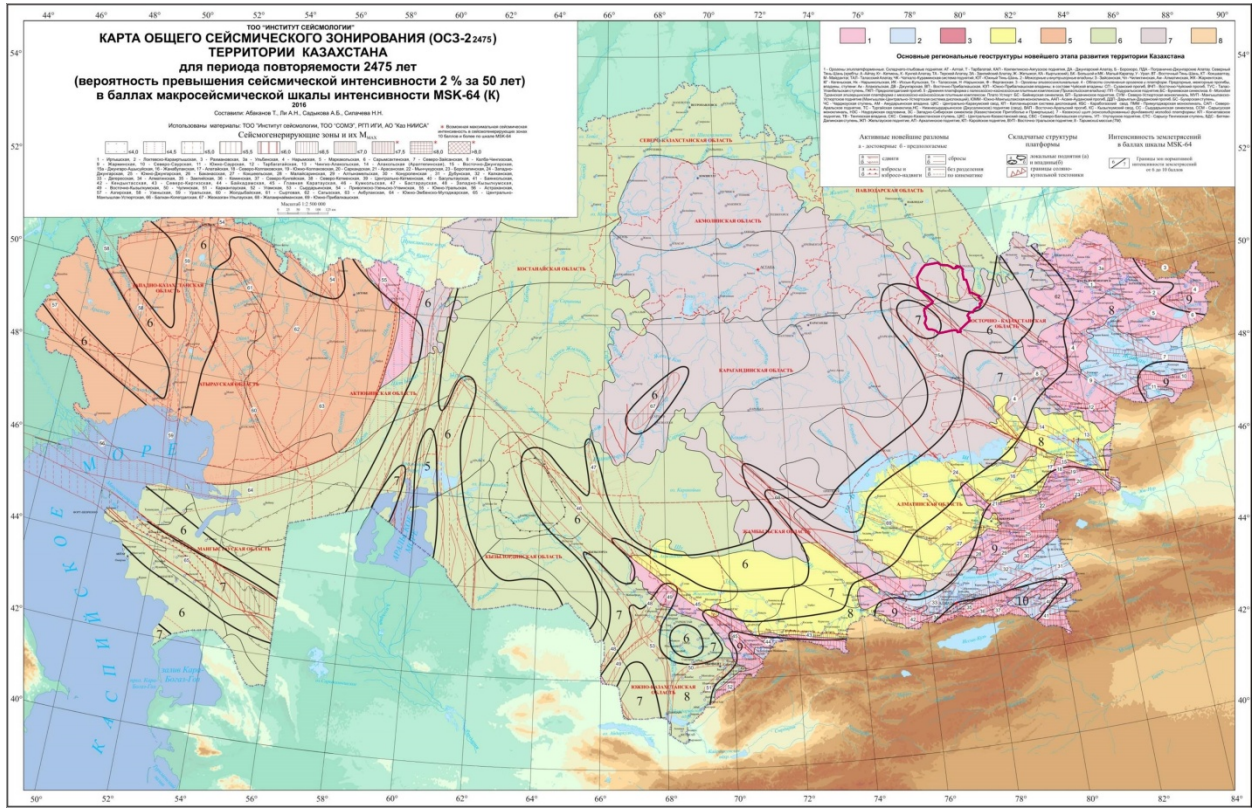


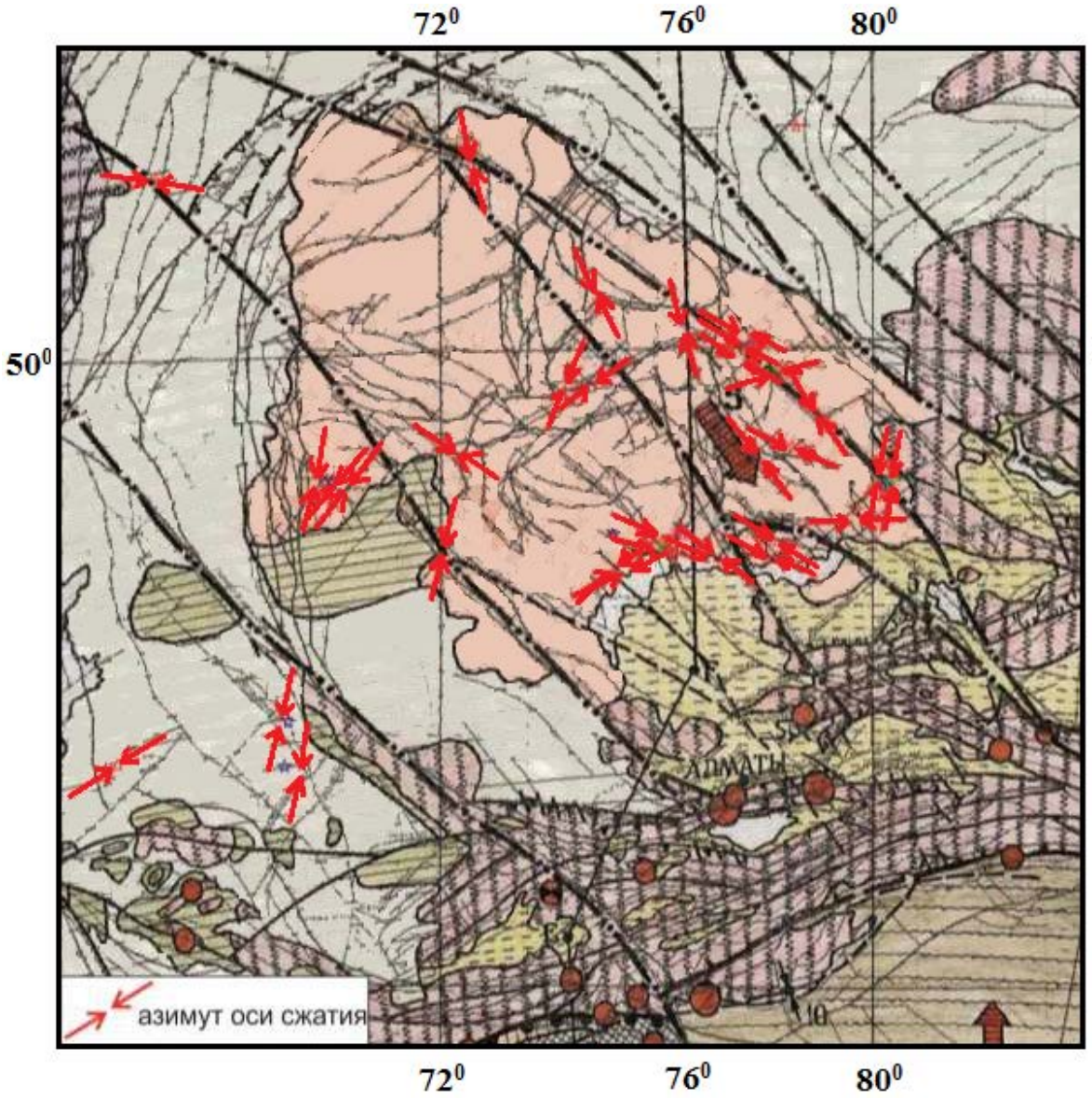


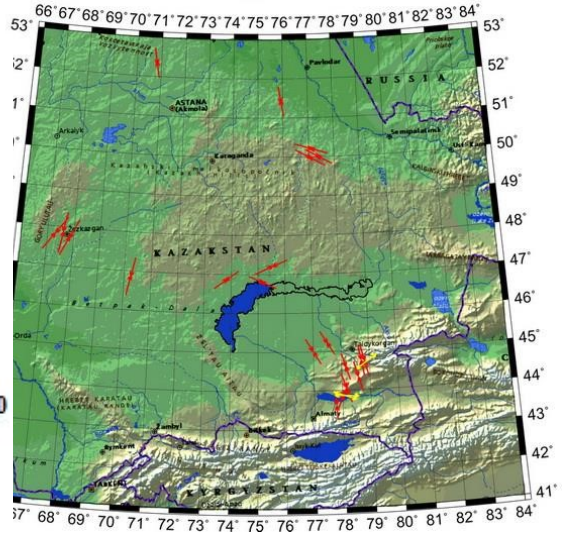


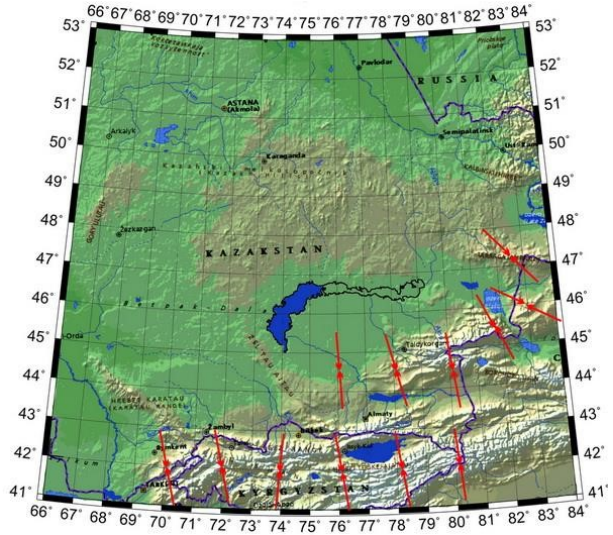
On the left is a map of epicenters based on the data compiled from all seismic bulletins and catalogs of Central Asia. In the middle, after removing the explosions as a result of the KNDC operation. On the right is a diagram of the number of earthquakes and explosions in the CASHA-BU catalog. The beginning of KNDC's work on explosions is clearly visible (2002).

The information obtained in recent years on the registration and study of events on the platform part of Kazakhstan has allowed us to gain important knowledge and identify some new patterns. They can be summarized as follows: 1. The view on the seismicity and seismic hazard of the territory of Kazakhstan has changed. Some of these data were used in the compilation of new maps of the seismic zoning of Kazakhstan in 2006 and 2017.





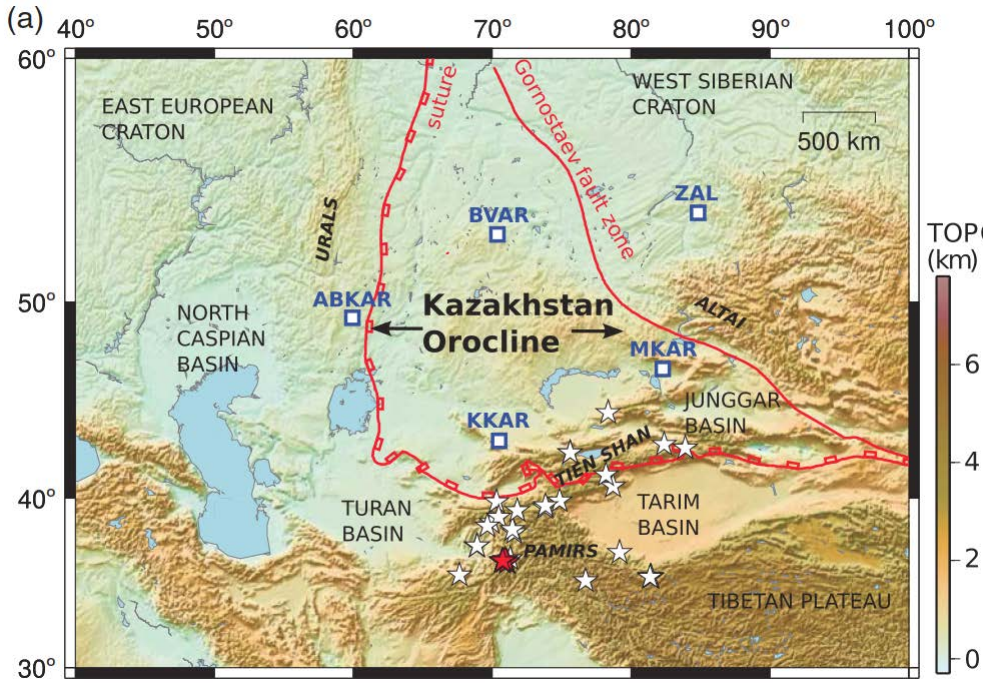


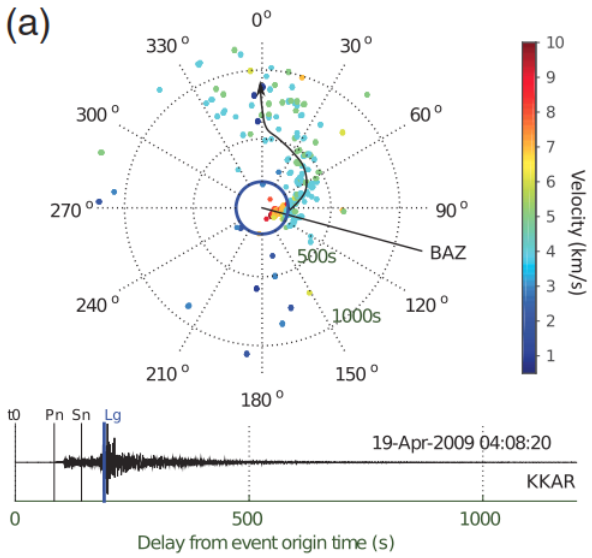


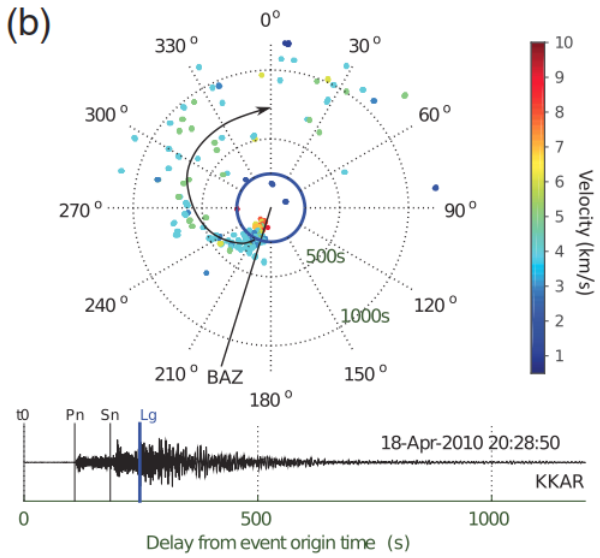
2. For the first time, interesting results have been obtained on the study of the stress-strain state of the Kazakh shield based on the data of the mechanisms of foci registered by the network of the National Research Center of the Republic of Kazakhstan. It is shown that the stress system on the territory of the Kazakh Shield differs significantly from that observed in the well-studied seismically active parts of the Northern and Southern Tien Shan. The stress system of the Kazakh Shield is characterized by conditions of near-horizontal compression and directions consistent with the directions of movement of Alpine geomorphostructures.

3. Patterns in earthquake aftershock activity have been identified in highly active and weakly seismic zones. Natural earthquakes on the platform have either produced no aftershock or only isolated ones, while active regions of the Northern Tien Shan and Dzungaria have recorded a large number of aftershocks.

4. Platform regions are generally characterized by weaker seismic wave absorption. However, there are areas where the quality factor of the medium is lower than in the highly active Northern Tien Shan. For example, areas of high absorption have been identified near the Balapan site of the Semipalatinsk Test Site. Powerful nuclear explosions were conducted there, and major fault zones are located there. The constant vibration facilitated the migration of deep processes.







Detailed Analysis of the Far-Regional Seismic Coda in Kazakhstan Using Array Processing

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Bulletin of the Seismological Society of America, Vol. 107, No. 2, pp. –, April 2017, doi: 10.1785/0120160015

THANK YOU
FOR YOUR ATTENTION!