CTBT: SCIENCE AND TECHNOLOGY 2017 CONFERENCE

T1.5-P15

SEISMICITY OF SEMIPALATINSK TEST SITE TERRITORY BY DATA OF KAZAKHSTAN MONITORING NETWORK

Mikhailova N.N., Sokolova I.N., Velikanov A.Ye., Poleshko N.N.

Institute of Geophysical Research ME RK, Almaty, Kazakhstan

Currently, there are several critical facilities at the Semipalatinsk Test Site region: 3 research nuclear assemblies, adits and boreholes at which nuclear tests were conducted earlier, etc. In addition, Kurchatov town is considered as one of optional places for construction a nuclear power plant in Kazakhstan. Thus, assessment of seismic hazard of the region is very important.

According to the current map of general seismic zoning of the Republic of Kazakhstan (2003), Semipalatinsk Test Site territory is located on the territory that is not considered as seismically active. In this part of the East Kazakhstan, there are no seismic generating zones, and earthquakes with intensity more than 5 are not predicted (Figure 1). However, the special field observations and seismic monitoring investigations conducted in recent years, as well as analysis of archive data showed that the Test Site territory and its vicinity experienced earthquakes in the past and some seismicity is observed in present. Maximum magnitude of the recorded earthquakes is 5 – 5.9[1-4].

In its geological structure the Test Site territory is located in central part of junction of two large geotectonic structures – Caledonian Chingiz-Tarbagatay and Hercynian Zharma-Sayurskiy geotectonogens structurally related to Altay-Chingiz folded region (Fig.2). On the basis of geological and geophysical data there were revealed 1 - subcrustal (mantle) faults dipping to 200-250 km depth and demarcating the earth crust blocks. These are main Chingiz, Chingiz-Sayurskiy (Kalba-Chingiz), Charsko-Gornostayevskiy faults (Fig.2, 3). The distance between the faults is 30-50 km; the faults extend on hundreds kilometers.

Tectonic elements location was précised on base of decoding of Landsat satellite images, materials of geological and topographical surveys of Kazakhstan, results if the IGR RK works (Fig. 4). Two orthogonal fault systems are marked out – longitudinal-traverse (north-west and north-east) and NS – EW.

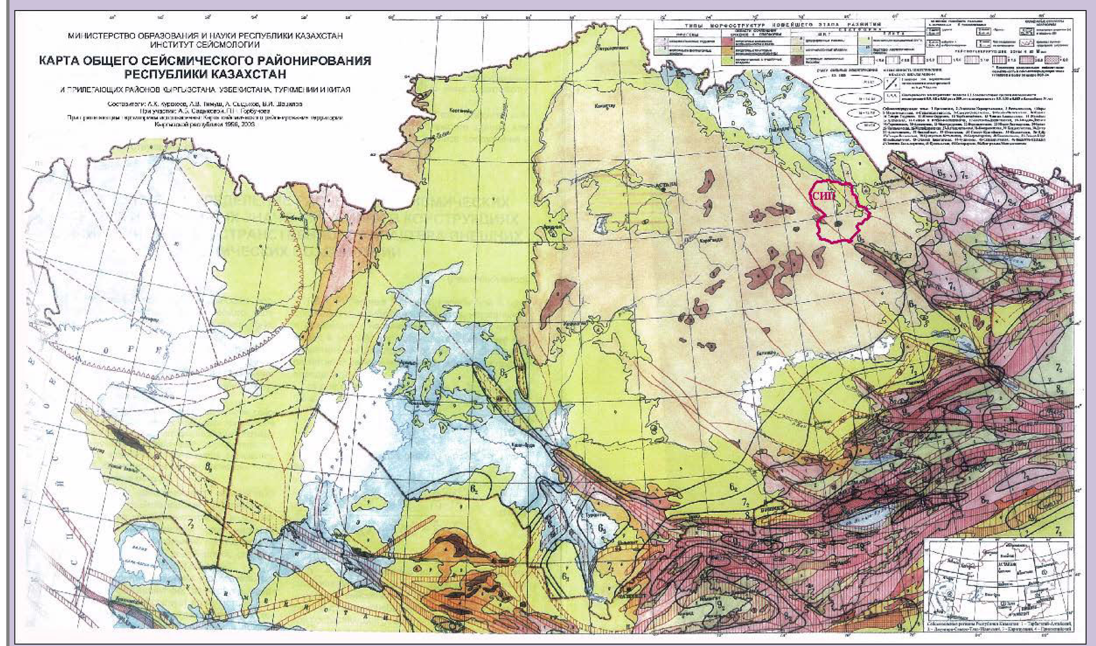


Figure 1. The map of general seismic zoning of RK (2003).

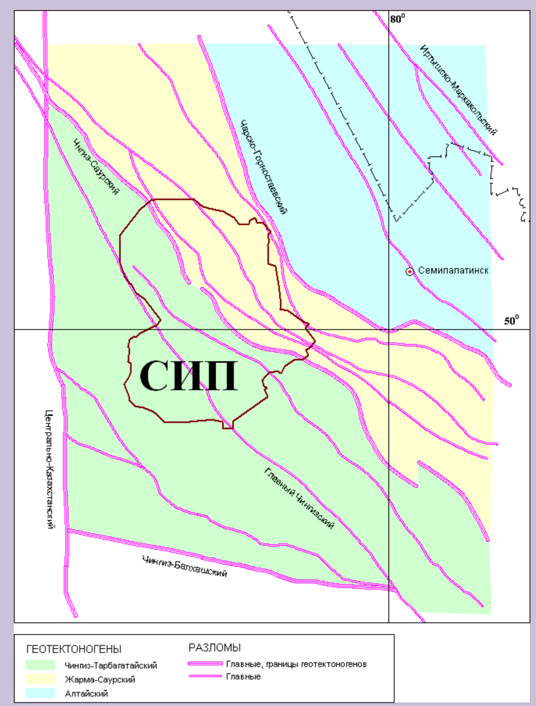
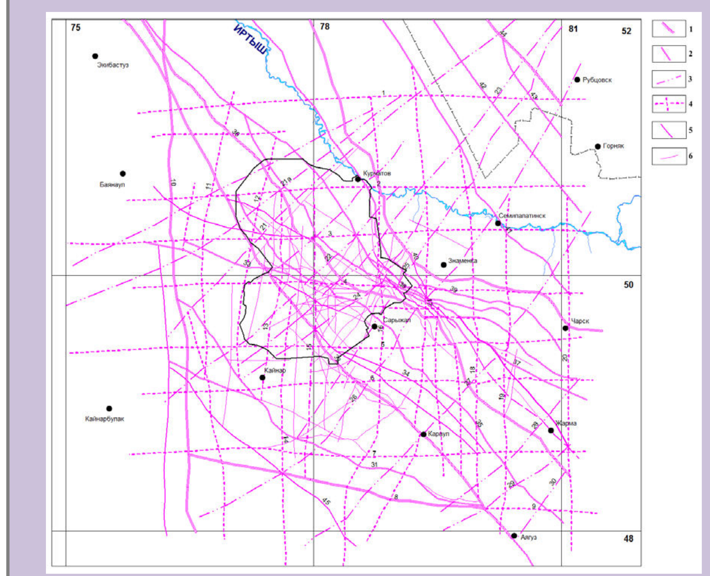
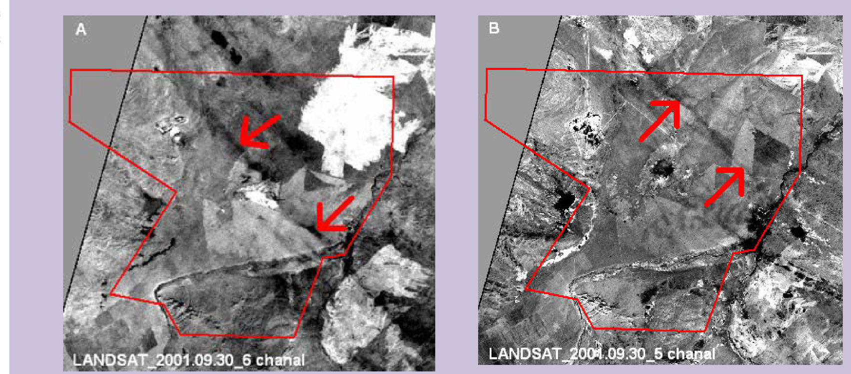


Figure 2 The scheme of geological-tectonic structure placement at Altay-Chingiz region (Large Altay)



Tectonic elements location was précised on base of decoding of Landsat satellite images, materials of geological and topographical surveys of Kazakhstan, results if the IGR RK works (Fig. 4). Two orthogonal fault systems are marked out – longitudinal-traverse (north-west and north-east) and NS – EW.



Balapan site.

Fig. 4. A view of linear holes filled with underground water above Chinrayuss (A) and Zhanan (B) faults on space images of LANDSAT for 2001.09.03 in infrared ranges of electromagnetic spectrum (6 chanal - thermal, 5 chanal - middle zone).

The following activities were undertaken to solve the issue on natural seismicity at the STS region:

- world seismological bulletins [5, 6], and information on historical seismicity from literature were analyzed [1-4, 7-9].
- Historical analogue earthquake seismograms beginning from 1950 were collected, earthquake parameters were précised (Fig.5a, b).
- All modern instrumental seismic data from regional Kazakhstan network beginning from 1994 were processed [10] (Figure 5c)

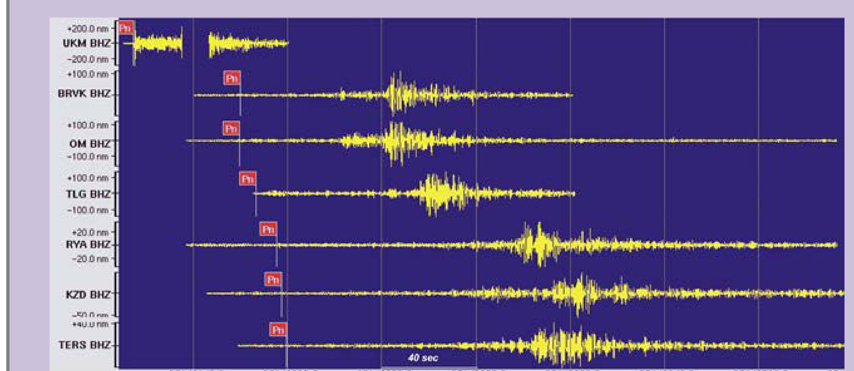


Figure 5a. Digitized seismograms of the earthquake of December 26, 1966, t0=17:39:38.5. φ=49.52°. λ=78.71°. mpv =4,3 by archive data of CSE JIPE RAS and SEME MES RK.

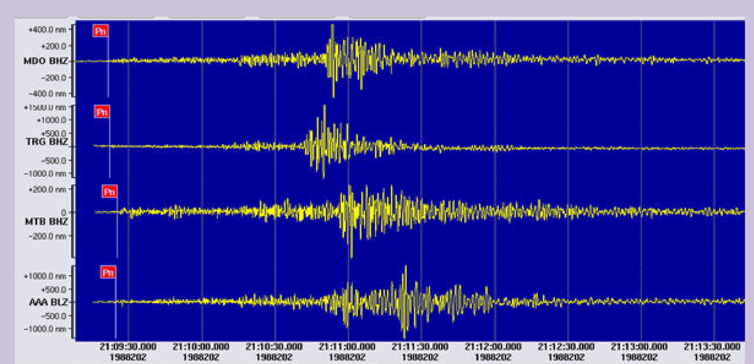


Figure 5b. Digitized seismograms of the earthquake of July 20, 1988. φ=48.3°, λ=81.1°, Ms=5.1. By archive data of SEME MES RK.

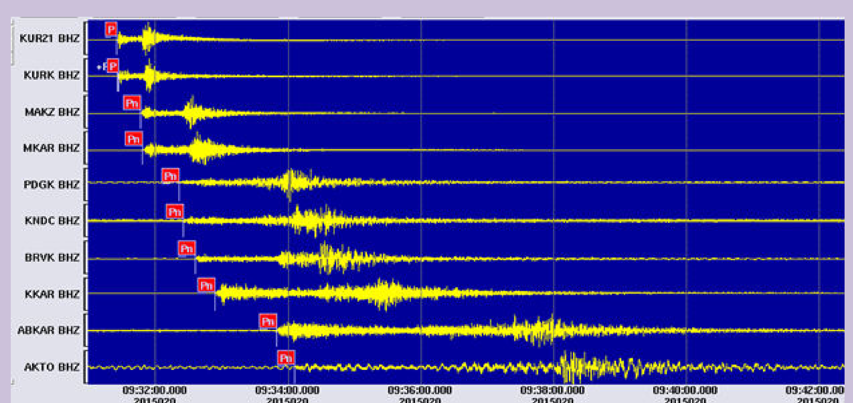


Figure 5c Seismograms of earthquake of January 20, 2015, φ=48.982°, λ=78.759°, mpva=5.3, K=12.2 by the IGR RK stations, Z-components.

Temporary seismic stations networks were installed on the Test Site territory during 2005-2010 to record small seismic events at the sites Sary-Uzen (2007, 2008, 2010 yy), Balapan (2005, 2006, 2010 yy) and Degelen (2006, 2007, 2010 yy) (Fig.6) where strong nuclear tests were conducted formerly.

During seismic monitoring of the STS territory and adjacent territories by a temporary network of field seismic stations installed at Balapan, Degelen and Sary-Uzen sites in field seasons 2005-2008 and 2010, 1613 seismic events were recorded from the STS region and adjacent territories for 546 days of continuous observations, most of the events were identified as mining explosions and only 36 events were the earthquakes (Table 1). Major part of the earthquakes was recorded by the field network stations only, and less than 30% of the events are recorded by the permanent observation network of the IGR.

Figure 7 shows the number of earthquakes recorded by the temporary network by years.

The most of earthquakes happened in 2007 and 2010, however in 2007 the field observations had been conducted by 8 seismic stations during 5 months, and in 2010 duration of field observations was 3 months only. Analyzing the results of seismic monitoring by years it can be concluded that currently the geodynamic processes are activating at the STS region, and taking into account availability of large number of critical facilities at this territory, the activation process can lead to undesirable consequences, for instance, increase of tunnels collapse at Degelen region etc. (Figure 8a).

Figure 8b shows the seismograms of induced earthquake occurred at Degelen site on July 24, 2010, 20:12:55.8, coordinates φ=49.6978º, λ=78.0440 º, magnitude mpva<1.

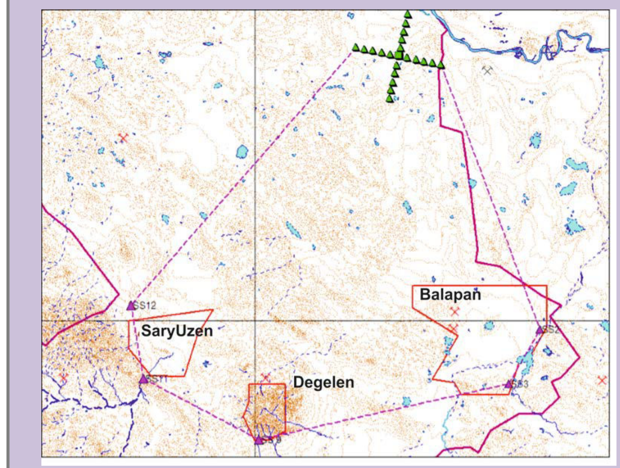


Figure - 6. Location of the field seismic stations at the STS in 2010.

Table 1. The results of seismic monitoring of the STS territory and its vicinity by temporary field stations network

Years of monitoring	Sites monitoring	Number of field stations	Duration, days	Recorded seismic events		
				Total	among them: Industrial blasts	among them: Earthquakes
27.08 – 9.11.2005	Balapan	5	75	165	160	5
29.06 – 10.11.2006	Degelen, Balapan	10	135	259	256	3
6.06 – 11.11.2007	Saryozen, Degelen, Balapan	8	158	456	444	12
10.08 – 5.11.2008	Saryozen, Balapan	6	87	376	371	5
08.05-07.08.2010	Saryozen, Degelen, Balapan	5	91	357	346	11
TOTAL			546	1613	1577	36

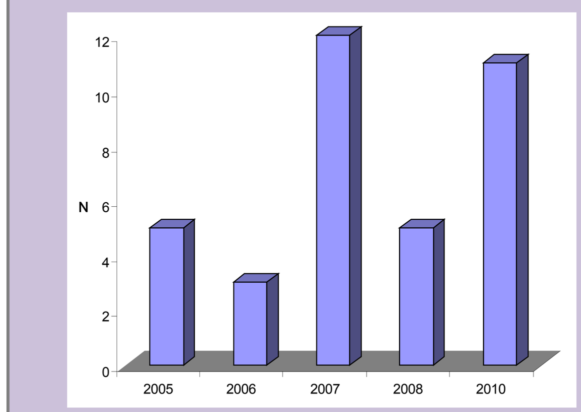


Figure 7. Number of the recorded events by years.

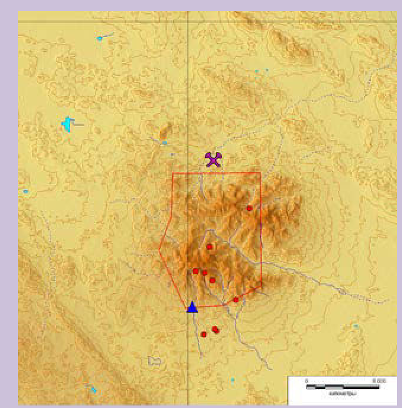


Figure 8a. The map of seismic events epicenters location at the region of Degelen test site of the STS. Circles – epicenters, triangle –seismic station DEG1, cross – quarry.

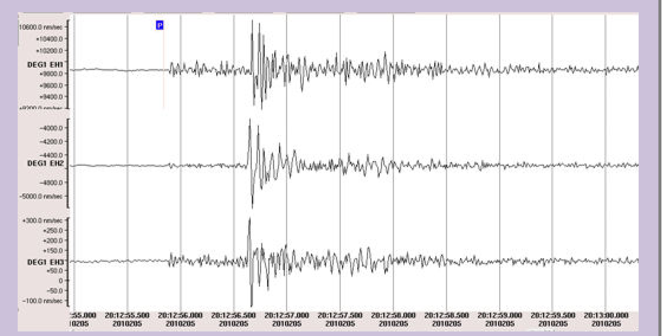


Figure 8b. Seismograms of induced earthquake at Degelen site, July 24, 2010, 20:12:55.8, coordinates φ=49.6978º, λ=78.0440 º.

Currently, there is large number of active quarries at the STS territory (Figure 9): Karazhyra (coal), Naymanzhol (gold), Yesymzhal (marganese), Karazhal (fluorite), Shorskoye (molybdenum), Zhanan (gold), Syuzdal (gold), Central Myukyur (gold), Zherek (gold), Novotyubinskoye (limestone for cement), Abyz (gold, polymetals) etc. The catalogue of active quarries was created, ground-truth explosions records necessary to discriminate the nature of seismic events recorded during seismic monitoring were collected from each quarry [11].

For seismic events identification using records of seismic stations the following parameters are studied: 1 – event coordinates and proximity to known quarries; 2 – event depth; 3 – peculiarities of wave pattern records; 4 – event time; 5 – availability of signal recorded by the infrasound station; 6 – energy class range; 7 – spectral ratio of amplitudes in different wave groups; 8 – spectrum parameters of different wave groups [11].

Each of the listed parameters can not be taken individually for precise division of seismic events into explosions and earthquakes. Joint analysis of several parameters, for example, proximity of the epicenter to known quarry, shallow depth, specific record by the infrasound station and specific time enhance the possibility identify the seismic event as quarry blast. The most effective method for identification is analysis of spectral ratio of shear and longitudinal waves, and specific features of wave pattern of the recorded event. In addition, the energy class ranges specific for each site are also considered. Note that definite quantitative criteria of discrimination can be different depending on Kazakhstan region, and recording station; this fact leads to necessity of its detailed study.

Below is an example of such analysis for Kara-Zhyra coal quarry located in the east of Kazakhstan. The quarry coordinates are φ = 50.0183º and λ = 78.7266º, it is located near Kurchatov seismic station (78 km) and Kurchatov-Cross seismic array (69 km to the central facility).

Most explosions conducted at Kara-Zhyra quarry have explosive mass of 5-15 tones, and there are some explosions having explosive mass of 50 tones. Most explosions have energy class 5-7, several explosions have K=9 that corresponds to magnitude mb=3.8; such explosions are recorded by large number of global seismic network stations and are included into the world seismic catalogues. Most of explosions at this quarry are conducted at 7 – 8 h GMT (13 – 14 h local time) and at 13 – 14 h GMT (19 – 20 h local time).

Figure 10 shows a wave pattern of explosion conducted at Kara-Zhyra quarry on 6.29.2008, and earthquake of 4.18.2004 by Kurchatov seismic station. The explosion record differs significantly from the earthquake record. The explosion record has clear onset of P-wave, relatively small amplitude of S-wave and prevailing low-frequency surface waves, and the earthquake record has different wave pattern, there are no surface waves, and S-wave amplitude is larger.

While analyzing the event much attention was paid to method of amplitude ratio of S and P waves as the most effective and universal method for identification of chemical explosions and earthquakes [11]. Processing method included measuring of decimal logarithms of S/P amplitudes ratio on vertical component at narrow-band filtering. The filters with central frequencies of 1.25, 2.5, 5 Hz and bandwidth of 2/3 octaves at -3 Db level from maximum were used. Figure 11 shows and example of such analysis for Kara-Zhyra quarry and earthquakes close to it. It is clearly seen that the event nature can be quite confidently identified by spectral ratio of S- and P-wave amplitudes by Kurchatov station.

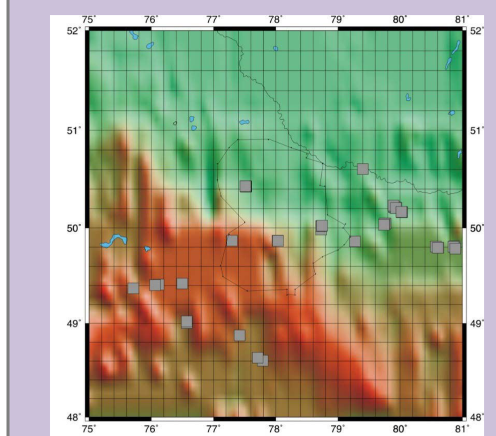


Figure 9. Quarry location map on the STS territory.

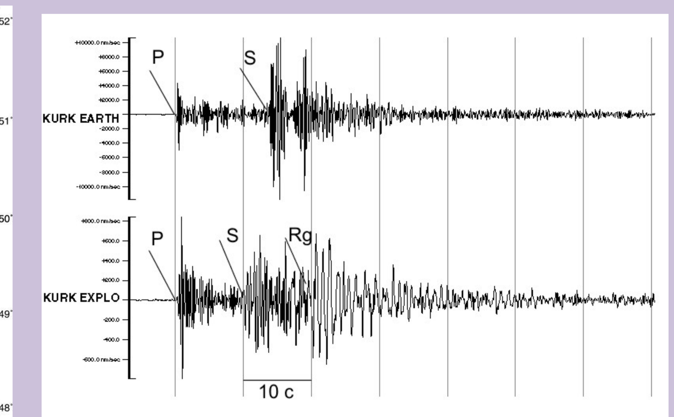


Figure 10. – Upper seismogram – the earthquake of 4.18.2004, φ=49.99°, λ=77.42°, mb=3.8,
Lower seismogram – the explosion at Kara-Zhyra quarry of 6.29.2008, φ=50.00°, λ=78.63°, mb=3.3

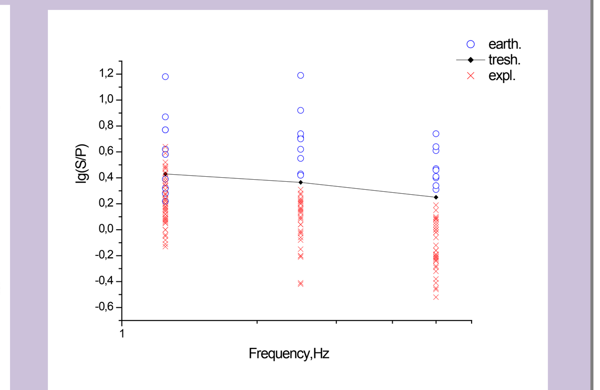


Figure 11. – Distribution of spectral ratio of maximal amplitudes of S/P.

Data on macro seismicity were collected for historical and contemporary felt earthquakes [3, 7]. The records of strong motions recorded by Kurchatov station were analyzed for small number of earthquakes. At Kurchatov station the accelerograph of strong motions was installed in 1996 in addition to FBA23, DAS Q330. Data are processed using ViewWave software developed by T. Kashima [12, 13]. In total, 17 records of strong motions (Table 2) were found. Figure 12 shows the records and response spectra of earthquake occurred on January 20, 2015 at 09-30-56.5, mpv=5.3 [14], epicentral distance 79 km (KURK station). Maximum recorded acceleration is 0.9 cm/s^2 corresponds to the earthquake of January 29 at 20:02:28.3, in the east of Kazakhstan, φ=49.72°, λ=83.47°, mpv=5.4, at epicentral distance 366 km; in Kurchatov the earthquake was felt with intensity 3-4.

Table 2. Characteristic of strong motion records by Kurchatov stations.

Station	Number of strong motions records	Distance, km	Magnitude range	Амах, cm/s^2
KURK	17	17-963	3.2-6.3	0.9

Earthquakes focal mechanism at STS.

Focal mechanisms for 7 earthquakes origins occurred from 1976 to 2016 were determined (stereograms are shown in Figure 13). In most origins, the shifts occurred under the conditions of near-horizontal stress compression in west-north-west direction; orientation of dilatation axis is more variable by dipping angles values and by extension azimuths.

Comparison of rupture planes parameters in the origins of investigated earthquakes with the region tectonics shows that structural explanation could be found for both nodal planes. The strike-slips with minor reverse component along planes of the north-west extension steeply dipping to the south-west can reflect seismic activity of regional Chingiz-Alakol strike-slip. At the same time, more gentle planes of the north-east extension dipping to the south-west coincide with orientation of faults crossing the structures of Kazakh Shield.

Using the set of data, a united catalogue of earthquakes for the STS territory and its vicinity was created for the period from 1783 to 2016 (Figure 14); the most active seismic zones were revealed. The calculations show that the Test Site territory can experience events with intensity 6-7 by MSK-64 scale (Figure 15).

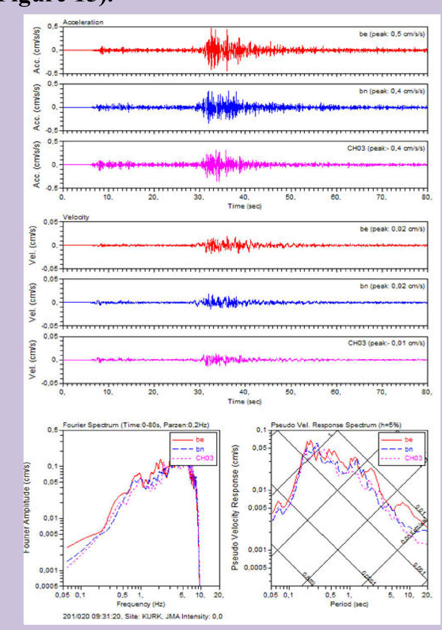


Figure 12 – Records and earthquake response spectra 01.20.2015 at 09-30-56.5, mpv=5.3 (KURK station).

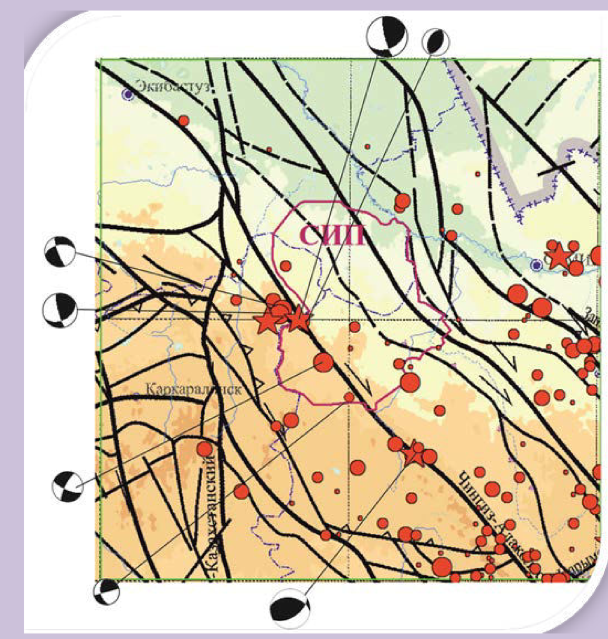


Figure 13. Stereograms of focal mechanisms of earthquakes on the territory of Semipalatinsk Test Site

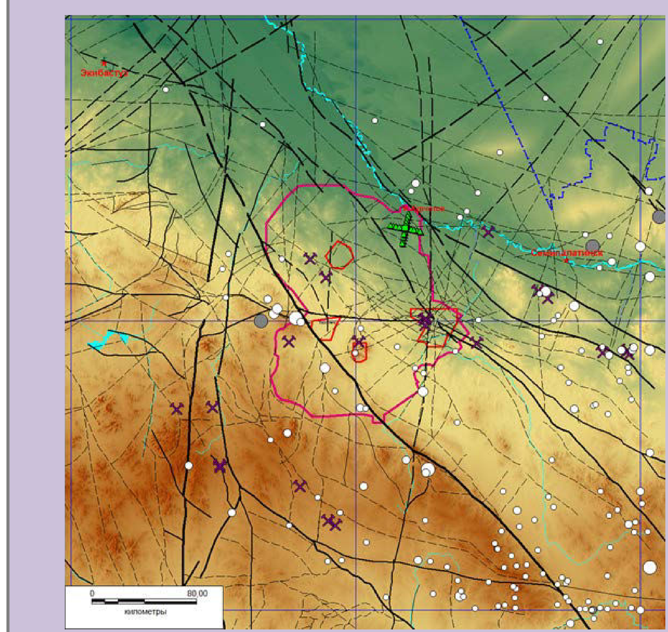


Figure 14. The map of earthquakes epicenters occurred at the STS and its vicinity; size of circle correspond to magnitude value: 1- mb<3, 2- 3≤mb<4, 3- 4≤mb<, 4- mb≥5. Grey circles – epicenters of earthquakes happened before 1961, white circles – after 1961. Crosses show active quarries.

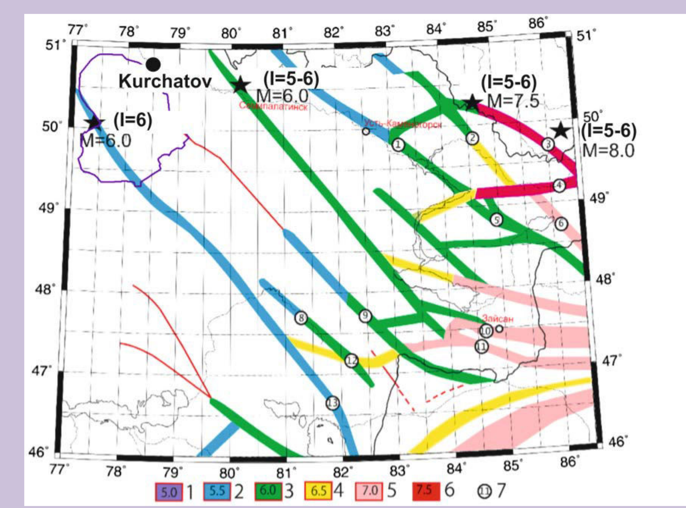


Figure 15. Assessment of seismic hazard from potentially possible earthquakes

Conclusion

1. It was revealed that earthquakes connected with active tectonic processes were recorded at the STS territory and its vicinity in historical past and have been recorded during past years.
2. Current map of general seismic zoning of RK does not show actual seismic hazard of the territory and should be revised.
3. For adequate assessment of quantitative seismic hazard at the investigated area it is necessary to establish permanent system of seismic observations. To assess possible appearance of seismic influence, special seismic and tectonic works on investigating tectonic faults activity should be conducted.
4. Availability of small seismic shocks testify geodynamic processes at the region where nuclear explosions were conducted.
5. Calculations show that the Test Site territory may experience shocks with intensity 6.

References

1. Pooley C.I., Douglas A., Pearce R.G. 1983. The seismic disturbance of 1976 March 20, 08.01.1994 t_0= 04^h 15^m 39.659 φ=47.833 λ=67.451 h=20 км east Kazakhstan: earthquake or explosions? // Geophys.J.R. Soc. 74. P.621-631.
2. V. Khalturin, T. Rautian, P.Richards A Study of Small Magnitude Seismic Events During 1961-1989 on and near the Semipalatinsk Test Site, Kazakhstan // Pure appl.geophys. 158 (2001) 143-171.
3. Seismic zoning of Kazakhstan. Almaty. Science. 1979. P. 140.
4. New catalogue of large earthquakes on the USSR territory. Moscow. 1977.
5. Internet-resource http://www.isc.ac.uk.
6. Internet-resource http://earthquake.usgs.gov/earthquakes/eqarchives/epic.
7. Mikhailova N.N., Nedelkov A.I., Sokolova I.N., Poleshko N.N. Investigation of seismicity of the former Semipalatinsk Test Site territory and its vicinity//Geophysics of XXI century: Proceedings of eighth geophysical readings from Fedynskiy V.V. Moscow (March, 2-4, 2006) – Tver. 2007. P. 179-190.
8. Earthquakes in the USSR. Moscow. Science. Annual collections for 1962-1991.
9. Earthquakes of Northern Eurasia. Obninsk: GS RAS. Annual collections for 1992-1998.
10. Internet-resource http://www.kndc.kz.
11. Velikanov A.Ye., Sultanova G.S., Aristova I.L., Sokolova I.N., Myukambayev A.S. Identification of industrial explosions while estimating seismic hazard of Kazakhstan regions of low seismicity. Vestnik NNC RK. 2012. Issue 1. P.68-73.
12. Sokolov A.N., Mikhailova N.N. Recording and data base of strong motions by Kazakhstan stations of nuclear monitoring to assess impact on critical industrial facilities // Vestnik NNC RK. 2013. Issue 3.
13. Kashima T. 2002. ViewWave Help, IISEE, BRI.
14. Myukambayev A.S., Mikhailova N.N. Seismic hazard of the main Chingiz fault for the territory of Semipalatinsk Test Site // Vestnik NNC RK. – 2015. – Issue 3. P.82-86.