Operational Procedures of Agencies Contributing to the ISC

Monitoring System of the Institute of Geophysical Research of the Ministry of Energy of the Republic of Kazakhstan

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Operational Procedures of Contributing Agencies

5.1 Monitoring System of the Institute of Geophysical Research of the Ministry of Energy of the Republic of Kazakhstan

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The seismic monitoring network of the Institute of Geophysical Research of the Ministry of Energy of the Republic of Kazakhstan (IGR ME RK) was created with the support provided by international organisations over the past two decades. This article describes the history of station installations, parameters and opportunities of the system as well as the functions and results of the Kazakhstan National Data Centre (KNDC) of IGR ME RK.

5.1.1 Regional Seismicity and Station Network

The territory of Kazakhstan and adjacent countries is seismically active especially its south-east part. The mountain ranges of the south Tien Shan, north Tien Shan and Dzhyungariya have experienced earthquakes with magnitudes greater than 8. The largest earthquakes in the territory of Kazakhstan were the 1889 Chilik earthquake with M_W=8.3, and 1911 Kemin earthquake with M_W=8.2. Figure 5.1 shows a map of large earthquake epicentres that occurred in the territory of Central Asia with magnitudes greater than 5; the map was constructed by data of the EMCA (Earthquake Model Central Asia) catalogue (*Mikhailova et al.*, 2015).

In the past, the seismic stations network was created mainly at the seismically active south-east part of Kazakhstan. And only some individual stations operated in the south and east. The other regions of Kazakhstan (west, north, and centre) had almost no stations. The first station, Alma-Ata, was opened in 1927 in Alma-Ata. After that seismic stations were installed in Chimkent (1932) and Semipalatinsk

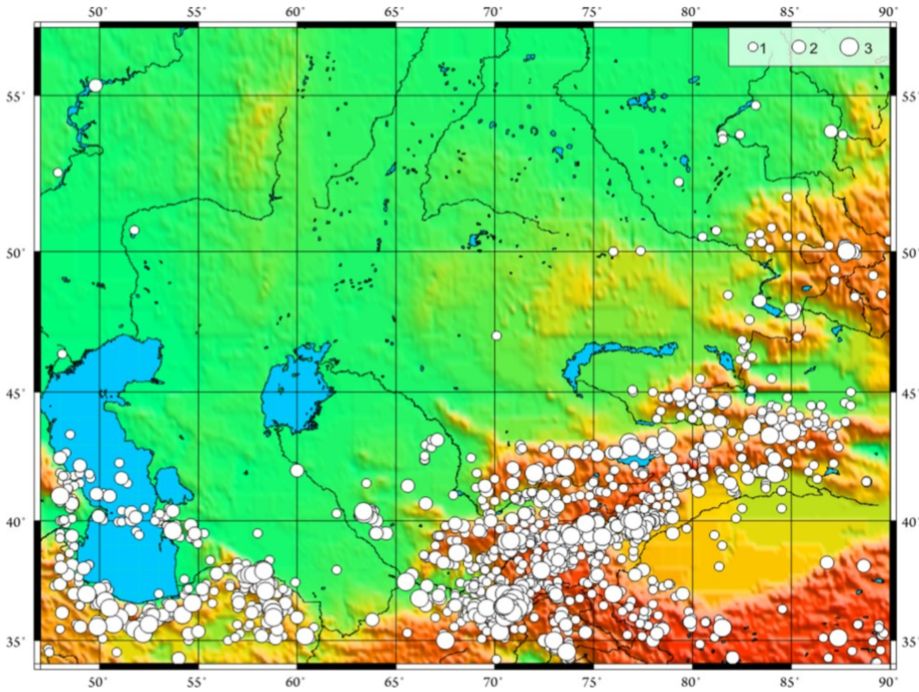
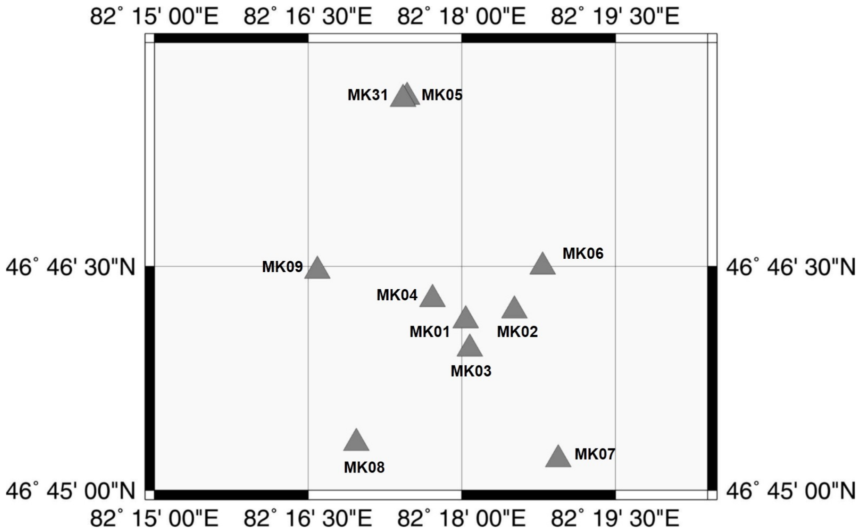


Figure 5.1: *Map of large earthquake epicentres on the territory of Central Asia, $M \geq 5$ (from the ancient time to 2009). 1: $5 \leq M \leq 6$, 2: $6 < M \leq 7$, 3: $M > 7$. (Mikhailova et al., 2015)*

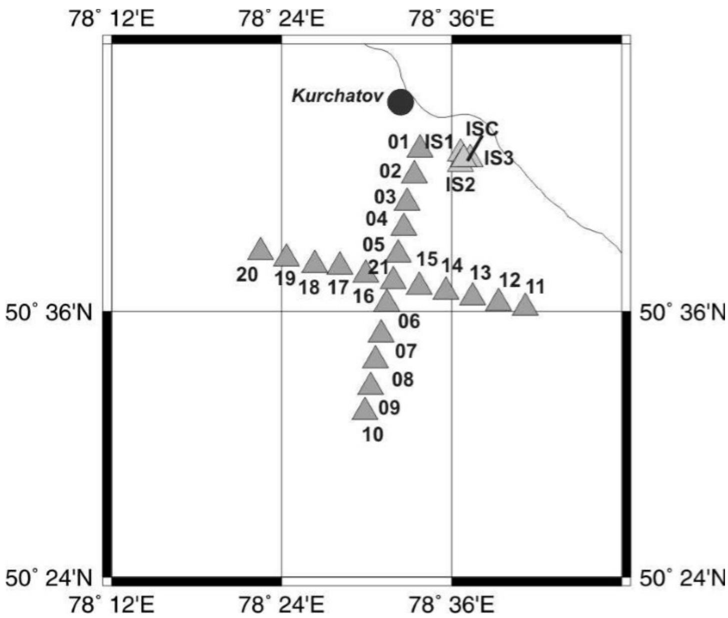
(1934). In the 1950s, after beginning to work on detailed investigations of the seismic regime, several stations were opened at the same time and formed a seismic monitoring network. The network was operated by the Institute of Physics of the Earth (IPE) of the Academy of Science (AS) of USSR until 1969. The data were processed in Talgar town by the Complex Seismological Expedition (CSE) of IPE AS USSR. In 1969 the CSE stations were transferred to the Institute of Geological Science (IGS), of AS of Kazakh SSR, and after that to the newly created Institute of Seismology (IS) of AS Kazakh SSR (1976) where the network had been developed due to the opening of new stations and observatories, and due to modernisation. From 1969, station data were processed by the processing group of the IGS, and then since 1976 by the IS AS Kazakh SSR. In 1979, the Seismological Experience-Methodical Expedition (SEME, ISC agency code SOME) was formed and operated all stations in the network. It had a group for seismic data processing and this structure still exists (*Mikhailova and Kurskeyev*, 1995).

The period from 1999 to 2009 was a unique stage in the seismological observations development in Kazakhstan: during this short period new seismic arrays and stations were put into operation one by one. The seismic arrays network and some other stations are operated by the Institute of Geophysical Research which was part of the National Nuclear Centre (NNC) of RK (*Mikhailova*, 2009). The main designation of the created seismic arrays is monitoring nuclear tests and earthquakes as part of the global monitoring networks. Three seismic arrays – Makanchi, Borovoye, and Kurchatov-Cross – are included in the International Monitoring System (IMS) created under the Comprehensive Test-Ban Treaty (CTBT) (*Mikhailova*, 2016). Makanchi is a primary station of the IMS, Borovoye and Kurchatov-Cross are included in the IMS network of auxiliary stations (*Mikhailova*, 2016). Two seismic arrays - Karatayu and Akbulak - were created together with the Air Force Technical Application Centre (AFTAC, USA) and were integrated into the network of nuclear tests monitoring of AFTAC (*Mikhailova*, 2016).

The seismic arrays have different configurations and apertures (*Mikhailova*, 2016). The configuration of



(a) MK01–MK09: elements with one-component vertical seismometers, MK31 – three-component seismometer



(b) 01–20: elements with one-component vertical seismometers; 21: three-component seismometer. IS1, IS2, IS3, IS4 are elements of the infrasound array KURIS.

Figure 5.2: *Configuration of seismic arrays. a: Makanchi (same configuration as seismic arrays Borovoye, Karatayu, Akbulak); b: Kurchatov-Cross*

four arrays (Makanchi, Borovoye, Karatayu, Akbulak) approximately represents a circle with nine elements installed in lines (vertical seismometers) and one central element (three-component seismometer). Their aperture is 3–4 km. These are so-called small-aperture arrays (Figure 5.2(a)). Kurchatov-Cross seismic array (*Mikhailova*, 2016) is configured in the form of orthogonal profiles with 21 installed elements (20 vertical seismometers, 1 central three-component seismometer, Figure 5.2(a)). The array aperture is 22.5 km. Figure 5.3 shows the site of Makanchi seismic array and Figure 5.4 of Kurchatov-Cross seismic array.

(a)

(b)

Figure 5.3: *Makanchi seismic array. Left: The Central receiving Facility (CRF) for stations PS23 (MKAR), MAKZ(IRIS) and infra sound station. Inside the balls are satellite antennas. Right: Another view of CRF.*

(a)

(b)

Figure 5.4: *Views of Kurchatov-Cross seismic array. On the left is CRF of station AS058, on the right is an instrument vault of one of the elements.*

The seismometers at all arrays are located in wells of 25 m – 60 m depth. More detailed information on seismic arrays and its aperture can be found on the web site of the Kazakhstan National Data Centre `www.kndc.kz`.

Data from all seismic arrays arrive at the Kazakhstan National Data Centre (KNDC), Almaty, and are transmitted or submitted after processing to international data centres (IDC, IRIS/DMC, NEIC, ISC, EMSC, GSRAS), where they are successfully used for global seismic monitoring. The data from the Kazakhstan seismic arrays are always used for processing of the largest earthquakes of the world; researchers from different countries apply this data to solve tasks in different fields of geophysics including investigation of the Earth's structure and creation of its more complete models (*Mikhailova*, 2016).

In addition to seismic arrays, the IGR network contains three-component stations among which there are two stations of the IRIS IDA network, one IRIS GSN station, one station of the IMS auxiliary network and two stations were earlier included into the network under the CAREMON project (*Mikhailova et al.*, 2010).

The main dates of the IGR ME RK observation system installation are:

1994	The stations of the special control service of the former USSR – Borovoye, (BRVK) Kurchatov (KURK), Aktyubinsk (AKTK/AKTO), Makanchi (MAKZ) were transferred to the NNC RK.
1994	Installation of 8 broadband digital stations on the territory of Kazakhstan together with LDEO (AKTK, BRVK, CHKZ, KURK, MAKZ, TLG, VOS/VOSK, ZRNK).
1994 – 1996	Installation of 3 stations of IRIS/IDA and IRIS/GSN system (Borovoye, Kurchatov, Makanchi) in Kazakhstan.
1996	Kazakhstan signed the Comprehensive Test-Ban Treaty according to which the installation of 5 IMS facilities on the territory of Kazakhstan is planned.
1997	Installation of three-component seismic stations Podgornoye (PDGK/PDGN), northern Tien Shan.
1999	Opening of the Centre for acquisition and processing of data (KNDC) in Almaty.
1999 – 2000	Construction and launching of the primary IMS Makanchi station PS23 (MKAR). The station was certified in January 2002.
2000 – 2001	Construction and launching of Karatau (KKAR) station (AFTAC).
2001 – 2002	Construction and launching of the auxiliary IMS Borovoye AS057 (BVAR) station. The station was certified in December 2002.
2001	Construction and launching of Aktyubinsk infrasound station (IS31). The station was certified in November 2004.
2002 – 2003	Construction and launching of Akbulak station (AFTAC).
2005	Modernisation and launching of auxiliary IMS station, Aktyubinsk AS059 (AKTO). The station was certified in November 2005.
2006	Launching of three-component KNDC station located in Almaty.

2006	Launching of auxiliary IMS station, Kurchatov-Cross AS058 (KUR01-KUR21). The station was certified in 2007.
2010	Launching of three-component Ortau station (OTUK) located in the territory of Central Kazakhstan, and modernisation of three-component Podgornoye station (PDGK/PDGN), Northern Tien Shan.
2016	Launching of three-component seismic station Kaskelen (KASK) westward of Almaty city.

Figure 5.5 shows a map of the IGR ME RK network stations location.

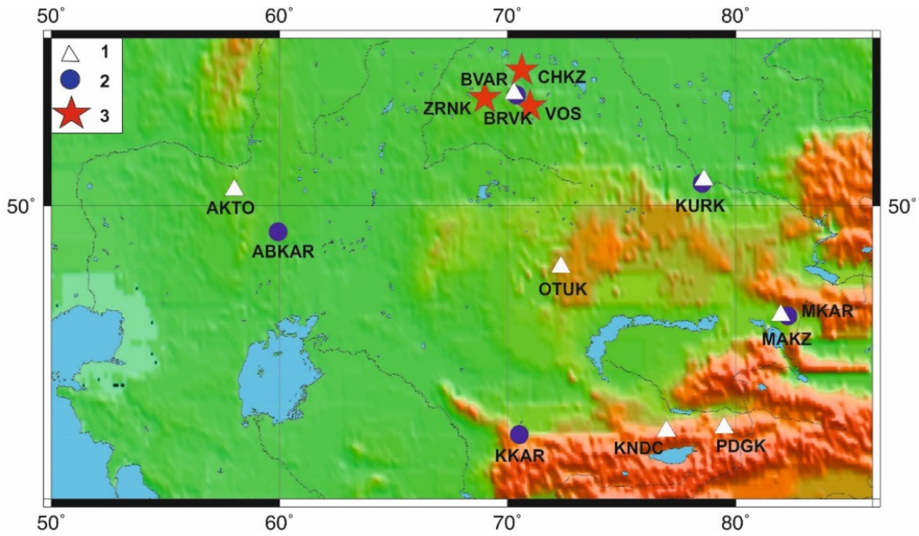


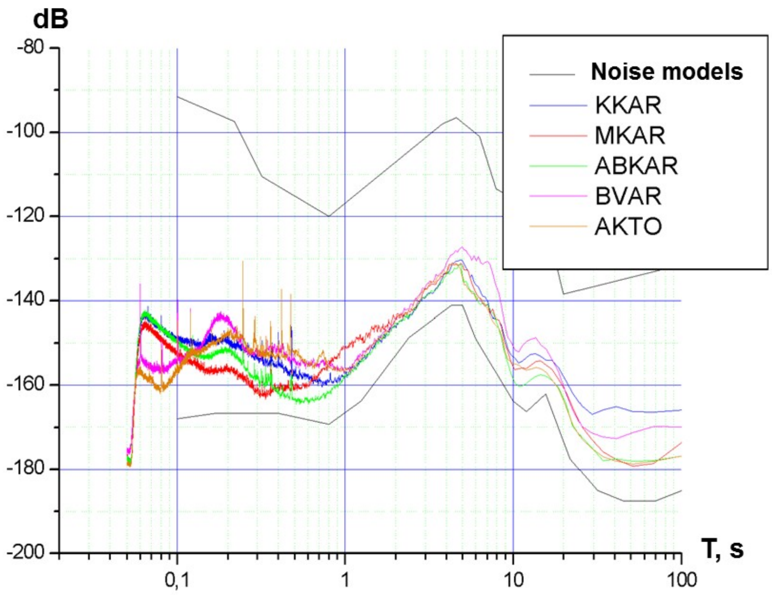
Figure 5.5: *IGR seismic stations. 1: three-component seismic station, 2: seismic array, 3: seismic arrays Zerenda, Chkalovo, Vostochnaya of the large-aperture Borovoye system that are being upgraded.*

Most of the seismic stations of Kazakhstan have excellent conditions for seismic signals recording. Owing to the detailed selection of sites for the stations in respect to geology and seismic noise characteristics, successful configuration of arrays, integration of broadband and short-period instruments, all stations in the system are highly sensitive to regional and teleseismic events. This allows for using the system successfully within the national and international monitoring.

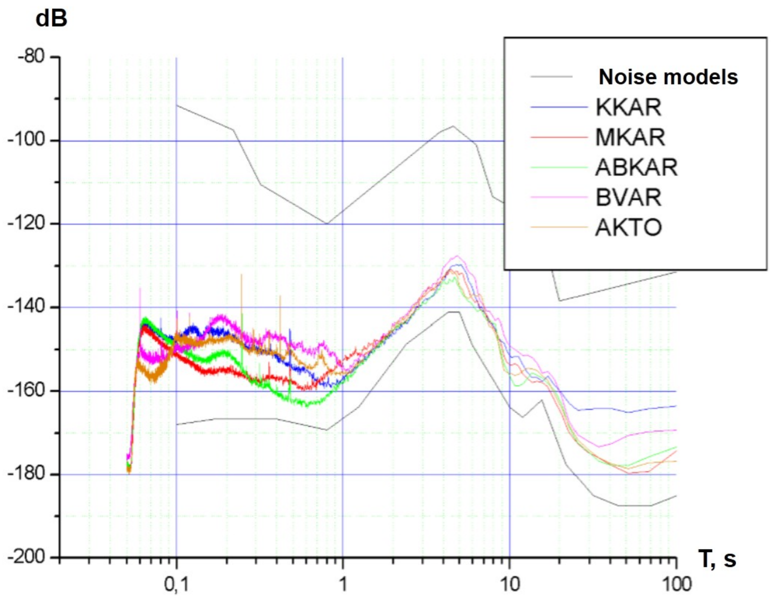
Figure 5.6 shows the seismic noise spectral density for Makanchi, Karatayu, Akbulak, Borovoye and Aktyubinsk stations for day and night time as well as the global models of seismic noise by *Peterson* (1993). It is clearly seen that curves for all stations are close to the low-level noise model (*Sinyova et al.*, 2000; *Mikhailova and Komarov*, 2006a).

5.1.2 Data Processing and Data Availability

Data from all stations arrive in real time to the Data Centre (KNDC). The KNDC tasks are acquisition and transmission of data of the network stations, processing of arriving seismic and infrasound data, storage and exchange of data with other national and international centres and research investigations in support of monitoring. Since 2009 with support from the Norwegian Centre NORSAR and Norway MFA, KNDC regularly conducts training courses on processing and interpreting seismograms in support of the CTBT for the specialists from Central Asian countries of the former USSR.



(a) Night time



(b) Day time

Figure 5.6: *Spectral density of seismic noise for stations Makanchi, Karatayu, Akbulak, Borovoye, and Aktyubinsk (vertical component).*

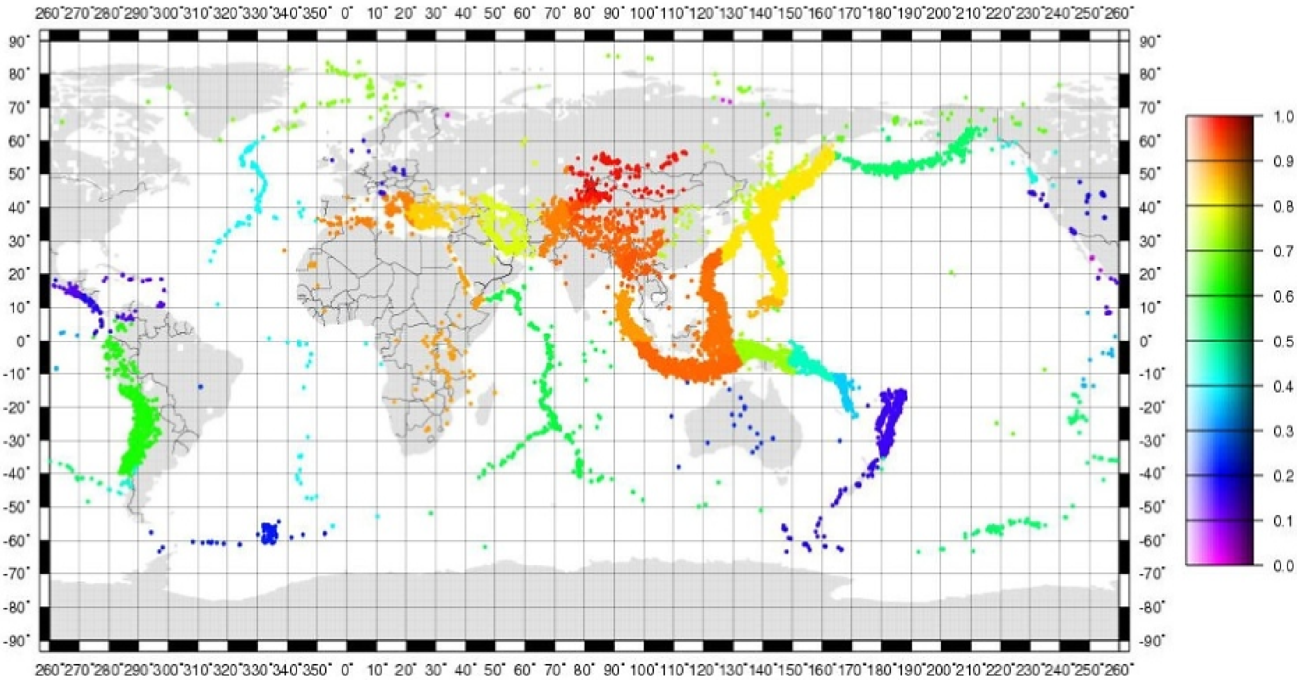


Figure 5.7: *Map of Makanchi station participation in REB bulletin created by the International Data Centre. The Figure shows the part of REB with Makanchi station participation.*

The Centre actively exchanges data with many research organisations in Kazakhstan and the world. Figure 5.7 shows data from Makanchi station participation in the Reviewed Event Bulletin (REB) seismological bulletin created by the International Data Centre (IDC) of the CTBTO.

Data processing in the Centre is conducted 24 hours a day, 7 days per week. The processing of seismic events is made for local and regional distances (Central Asia), we determine the arrival time, amplitudes, and periods of regional seismic phases Pn, Pg, P, Sn, S, Lg, Rg. The following types of seismic bulletins are created:

- Automated bulletin, the delay is from 40 minutes to one hour.
- Interactive regional bulletin, 1 day delay.
- Joint interactive regional bulletin (with SEME Ministry of Education and Science (MES) RK and other Central Asia stations), 2 days delay (Figure 5.8).
- Catalogue of seismic events indicating its nature, several months delay.

Note that for the creation of interactive seismic bulletins, KNDC uses data from stations belonging to several other organisations. The data arrive in real time from seismic arrays Zalesovo (Russia), Alibek (Turkmenistan), several stations in Kyrgyzstan and one SEME station. In addition, KNDC receives arrival times, amplitudes and periods in tabular form from SEME stations that are inaccessible in real time.

For the bulletin creation, 'Seatools' software (NDC USA) is used. This software is applicable for data processing from three-component stations and from seismic arrays (*Mikhailova and Sinyova*, 2002b).

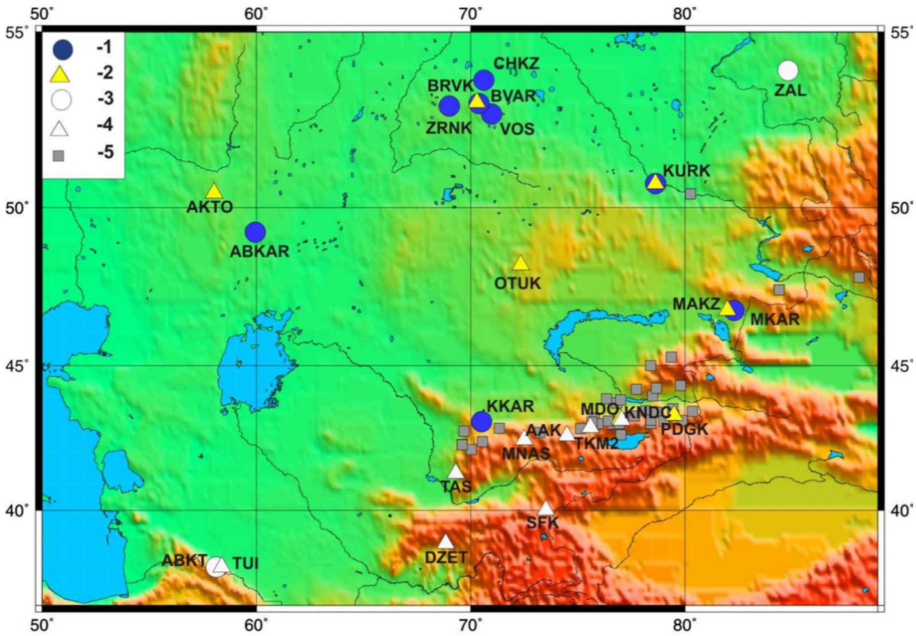


Figure 5.8: Stations used by KNDC for seismic bulletin creation. 1: seismic arrays of the IGR, 2: three-component stations of the IGR, 3: seismic arrays of neighbouring countries, 4: CAREMON stations, 5: stations of SEME MES RK which data arrive in tabular form.

The software has tools for calculating the regional mpv magnitude and energy class K (*Rayutian*, 1964; *Mikhailova and Neverova*, 1986). All processing results can be found in KNDC web-site `www.kndc.kz`.

The data of the IGR ME RK stations network are used for special tasks of nuclear monitoring, such as location, estimation of parameters and discrimination. In addition, the network records large amounts of earthquakes occurring on the territory of Central and South Asia. The data analysis of the IGR monitoring network allowed the revealing of earthquake sources in regions that were traditionally considered as aseismic or of low seismic activity in the territory of Kazakhstan (Figure 5.9) (*Mikhailova and Sokolova*, 2003a; *Mikhailova et al.*, 2003b; *Belyashova et al.*, 2002; *Mikhailova et al.*, 2002a; *Mikhailova et al.*, 2006b; *Chekaninskiy*, 1928; *Urazayev*, 1979; *Kondorskaya and Shebalin*, 1977; *Mikhailova et al.*, 2003c; *Mikhailova et al.*, 2012). Its discovery is an interesting fact which should be taken into account for seismic hazard assessment. In addition, the staff of the Data Center of the IGR ME RK has analysed retrospective historical and new data from digital stations. The availability of a huge archive of historical seismograms in the Republic containing records from the 1960s allowed us to determine the parameters of some historical earthquakes that occurred in different regions of Kazakhstan. The judgement on Kazakhstan's seismicity has been changed significantly.

New data on seismicity should effect the assessment of seismic hazard in Kazakhstan and be taken into account while compiling a new map of general seismic zoning.

The Institute of Geophysical Research supports the open data exchange policy for researchers all over the world. The waveforms of the IGR RK station network are sent to the IRIS DMC in SEED format. They contain data from three-component seismic stations, seismic arrays and KURIS infrasound station. The network code is KZ, DOI: 10.7914. This archive contains data from July 1994 onward. Some stations ABKAR, KKAR, MKAR, KURK, BRVK and MAKZ transmit data to IRIS DMC in real time mode, the rest are presented with half a year delay.

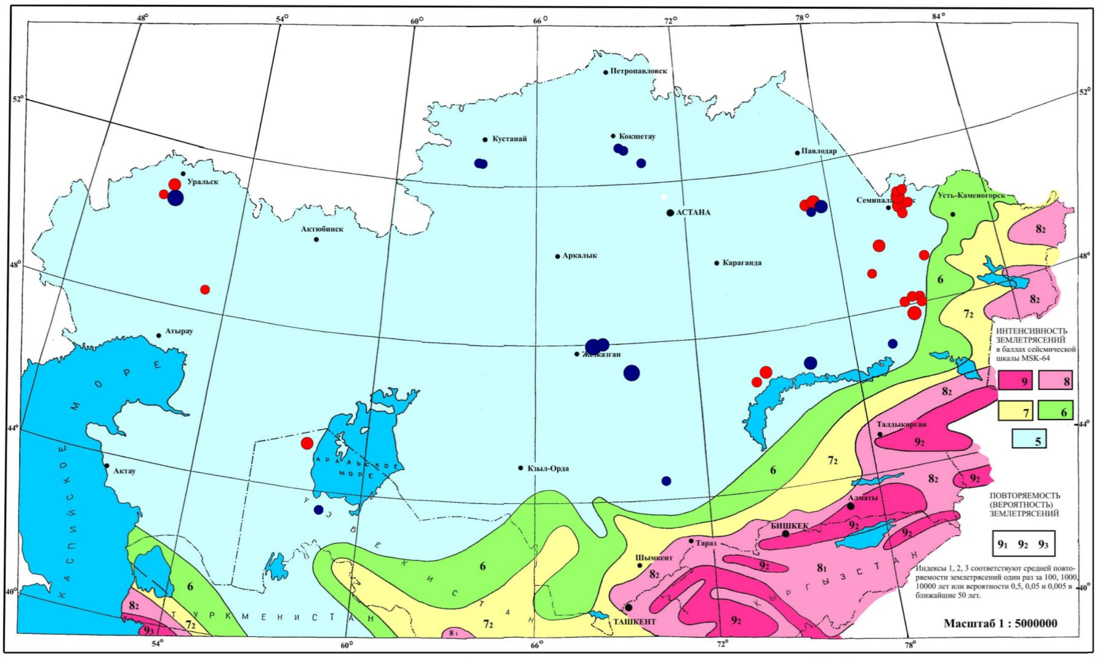


Figure 5.9: *Map of seismic zoning of Kazakhstan territory (2006) with earthquake epicentres (mPV $\geq$ 3) at new regions. Red circles: historical earthquakes from 19th century to 1994, blue circles: earthquakes recorded by the IGR network. Colours are earthquake intensity by MSK-64 scale.* $9_1, 9_2, 9_3$ *correspond to earthquake recurrence or probability period, where 1,2,3 are the average recurrence of earthquakes: once per 100, 1000, 10000 years; or probability 0.5, 0.05 and 0.005 in the nearest 50 years. Scale 1:5.000.000. (Construction in Seismic Regions, Construction Codes and Rules, 2.03.-30-2006, Committee on Construction Affairs of the Ministry of Industry and Trade of the Republic of Kazakhstan, Almaty 2006, 80 pages).*

In addition, the IGR ME RK, starting from July 2002, regularly submits the seismic bulletins to the ISC. The agency code is NNC (soon to be changed to KNDC).

5.1.3 References

Belyashova N.N., N.N. Mikhailova and I.N. Sokolova (2002), Central and Eastern Kazakhstan, *Earthquakes of Northern Eurasia in 1996*, GS RAS, Obninsk, 71 – 75 (in Russian).

Chekaninskiy I.V. (1928), Report on seismic phenomena at Semipalatinsk province from 1760 to 1927 (from Semipalatinsk historical archive) (in Russian).

Kondorskaya N.V. and N.V. Shebalin (eds.) (1977), A new catalogue of large earthquakes on the territory of the USSR, *Nauka*, Moscow, (in Russian).

Mikhailova N.N. and N.P Neverova (1986), Calibration function to determine MPVA magnitude of Northern Tien Shan earthquakes, *Integrated investigations at Alma-Ata prognosis site*, Nauka, Moscow, 41 – 47 (in Russian).

Mikhailova N.N. and A.K Kurskeyev (1995), Present Status of the Network for Seismic Observations in Kazakhstan, *Journal of Earthquake Prediction Research*, *4*(4), 497 – 506.

Mikhailova N.N., A.I. Nedelkov A.I., I.N. Sokolova, Ye.N. Kazakov and A.V. Belyashov A.V (2002a), Shalgin earthquake in Central Kazakhstan of 22.08.2001, *Geophysics and problems of non-proliferation*, *Vestnik NNC RK*, *2*, 78 – 87 (in Russian).

Mikhailova N.N. and Z.I. Sinyova (2002b), Processing of the NNC RK seismic stations data, *Geophysics and problems of non-proliferation*, *Vestnik NNC RK*, *2*(10), 64– 68 (in Russian).

Mikhailova N.N. and I.N. Sokolova (2003a), Central and East Kazakhstan, *Earthquakes of Northern Eurasia in 1997*, GS RAS, Obninsk, 89 – 91 (in Russian).

Mikhailova N.N., I.N. Sokolova and A.I. Nedelkov A.I (2003b), New data on earthquakes at aseismic regions of Kazakhstan, *Geophysics of XXI century: year 2002*, Collection of proceedings of the Fourth Geophysical Readings after V.V. Fedynskiy, 28 February – 2 March, 2002, Moscow, 251 – 255 (in Russian).

Mikhailova N.N., N.A. Volf and Z.I Sinyova (2003c), Seismicity of areas surrounding new seismic arrays makanchi and Karatayu, *Geophysics and problems of non-proliferation*, *Vestnik NNC RK*, *2*, 94–100 (in Russian).

Mikhailova N.N. and I.I. Komarov (2006a), Spectral parameters of seismic noise by data of Kazakhstan monitoring stations, *Vestnik NNC RK*, *2*, 19 – 26 (in Russian).

Mikhailova N.N., A.I Nedelkov, I.N. Sokolova and N.N. Poleshko (2006b), Investigation of seismicity of the former Semipalatinsk Test Site territory and its vicinity, *Geophysics of XX century: year 2006. Collection of proceedings of the Eighth Geophysical Readings after V.V. Fedynskiy*, 179 – 191 (in Russian).

Mikhailova N.N. (2009), Kazakhstan seismic observations system of the Institute of Geophysical Research of the National Nuclear Centre and its information capabilities, *Seismic safety of Almaty: Proceedings of Scientific and Technical Conference*, ES Department. MES RK., Almaty (in Russian).

Mikhailova N.N., A. Strollo, D. Bindi, A.Ye. Velikanov, V.G. Kunakov, I.I. Komarov and Z.I. Sinyova (2010), New Kazakhstan stations installed within CAREMON Project, *Monitoring of Nuclear Tests and Their Consequences: Reports thesis*, VI International Conference, Kurchatov, 9 – 13 August 2010, 23 – 24.

Mikhailova N.N., I.N. Sokolova, A.Ye. Velikanov and N.N. Poleshko (2012), Seismicity of the western Kazakhstan by data of the NNC RK network, *Seismic prediction observations on the territory of Azerbaijan*, RCSS NASA, 336 – 348 (in Russian).

Mikhailova N.N., I.L Aristova and A.S. Mukambayev (2015), Unified earthquakes catalogue for Kazakhstan territory and adjacent regions (from ancient times to 2009), *Vestnik NNC RK*, *4*, 132–143 (in Russian).

Mikhailova N.N. (2016), Important results obtained owing to seismic arrays opening in Kazakhstan, *Vestnik NNC RK*, *2*, 23–32 (in Russian).

Peterson, J. (1993), Observation and Modeling of Seismic Background Noise, *Open-File Report 93-322*, Albuquerque, New Mexico.

Rayutian T.G. (1964), To calculation of earthquake energy at 3000 km distance, *Proceedings of the IPE AS USSR*, *32*(199), 72 – 98.

Sinyova Z.I., N.N. Mikhailova and I.I. Komarov (2000), Investigation of dynamic parameters of seismic noise by data of Kazakhstan network digital stations, *Vestnik NNC RK*, *2*, 24 – 30 (in Russian).

Urazayev B.M (1979), Seismic zoning of Kazakhstan, *Nauka* (in Russian).