

# 70-years contribution of “Borovoye” Geophysical Observatory into nuclear explosions monitoring

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**2021 is 70-years from the day when nuclear explosion of 38 Kt yield was conducted at STS and recorded at Borovoye area. Following first successful experiment and field works, the Special Division of IPE USSR decided to establish “Borovoye” geophysical observatory. In 1961, it recorded UNE of 2.6 Kt from Nevada Test Site at ~10 thousand km distance.**

**“Borovoye” Observatory is one of the most known global stations for nuclear explosions monitoring. Its uniqueness is determined by good seismological-geological settings for seismic signals recording, the most continuous history of digital recording started in 1966.**

**In 1974, Vostochnoye, Chkalovo, and Zerenda seismic stations were installed near the Observatory, and formed a so-called large-aperture “Triangle” array with the central station on the Observatory territory. In different years, the magnetotelluric and infrasound stations were used here for monitoring.**

**In the post-Soviet period, BVAR seismic array of the IMS was constructed at the Observatory area and certified in 2002; in addition, BORK seismic station of IRIS IDA was installed here.**

**The report presents the history of Borovoye Observatory, shows the examples of recorded nuclear explosions conducted at different world Test Sites, and investigates the spectral density of seismic noise in different periods of time.**

## *Year 1951*

The official date of “Borovoye” station opening is 1961. However, the first seismic instruments were installed at the contemporary stations region in 1951. That year, by pure accident, the second air nuclear explosion of 38 kT yield conducted at Semipalatinsk Test Site was recorded. The explosion record was destroyed, but marked the beginning not only for the construction of a new seismic station at this place, but also the establishment of the USSR monitoring system for nuclear explosions conducted around the world.



## *Year 1961*

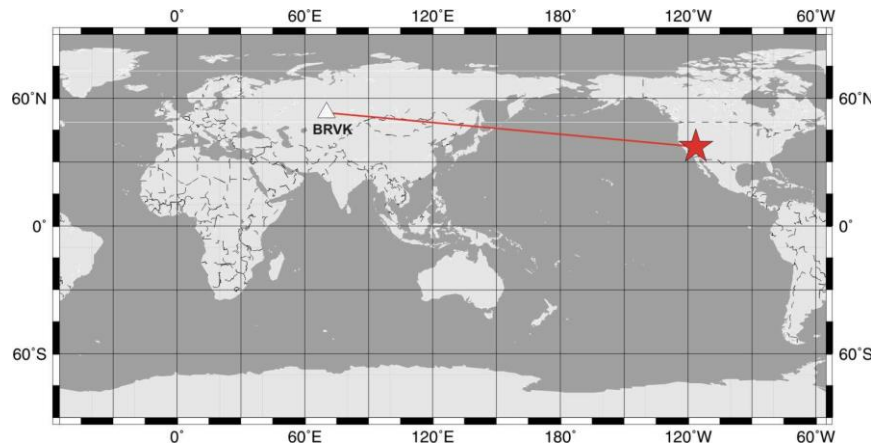
In 1958, during the second expedition to Borovoye, it was revealed that here, at the place of dense crystalline rocks exposure, the microseism level is extremely low. The station construction was started in 1960. The constructed seismic station started its operation on November 7, 1961.





## Year 1962

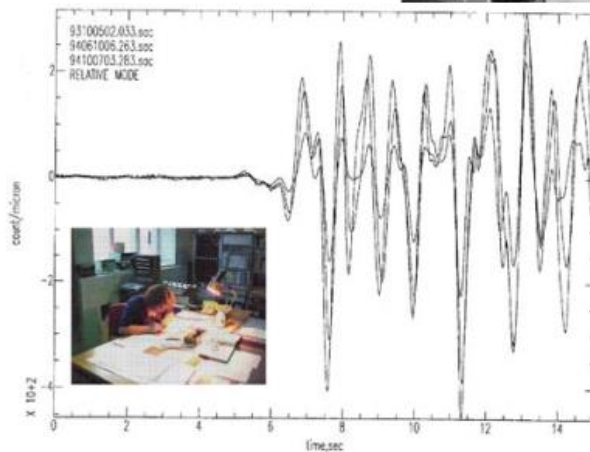
- Among 59 underground nuclear explosions conducted at Nevada Test Site (USA) in 1962, 22 were recorded by Borovoye seismic station. This was the best result comparing to other USSR seismic stations.
- In addition to seismic observations, the recording of the Earth electromagnetic disturbance from high-altitude nuclear explosions was arranged and initiated the numerous geophysical investigations. The work on testing the *digital recording instruments* was enlarged. The seismic observations for the underground *nuclear explosions of low yield* conducted at Nevada Test Site were improved, the work on automated geophysical observations was strengthened.



*In total, from 1961 to 1992, “Borovoye” station recorded 484 underground nuclear explosions conducted on the USA territory, 56 of them were not announced in advance.*

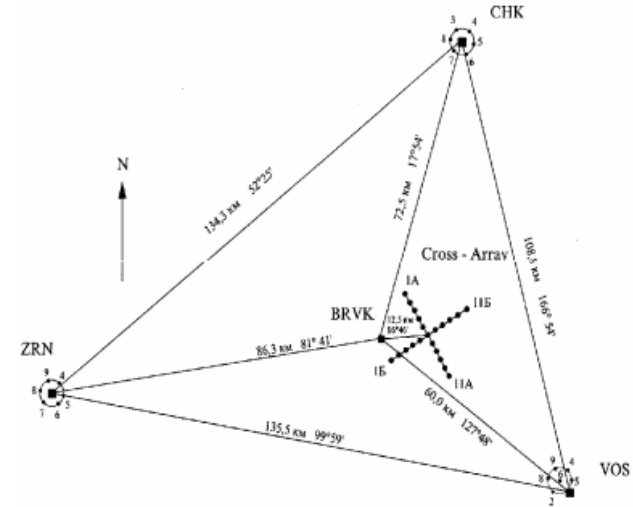
## Year 1965 - 1966

- New measurement equipment and technical instruments are installed;
- The first *digital instruments* start its operation;
- The *digital records* of nuclear explosions and earthquakes are collected;
- The recording of nuclear explosions signals from the USA, USSR, France, China, and India Test Sites is continued;
- The various researches are conducted: investigations of the Earth magnetic field, telluric current, acoustic vibrations of atmosphere, meteorological phenomena, velocity of radio waves propagation. The station is assigned with “observatory” status.



# Year 1973 - 1978

- For more accurate detection and assessment of explosions parameters conducted at Nevada and other foreign Test Sites, the array systems “Cross” and “Triangle” are created at Borovoye Laboratory area.
- The “Cross” array operated from 1975 to 1993.
- The large aperture array system “Triangle” was launched in 1976 and consisted of the remote stations “Chkalovo” (72 km away of “Borovoye” station), “Zerenda” (86 km), and “Vostochnoye” (60 km). Currently, the stations are being upgraded.



*Configuration of large-aperture “Triangle” array:  
3 circle arrays of 6 km diameter having 6 boreholes  
 (“necklaces”) and shafts at each remote site at the  
 tops of “Triangle”*

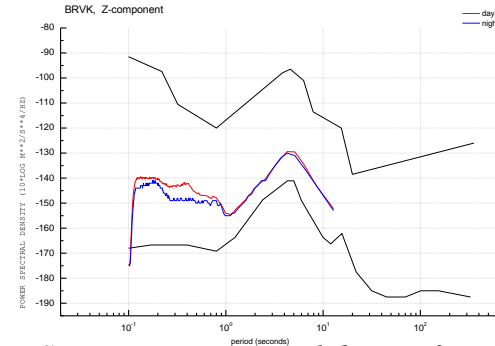


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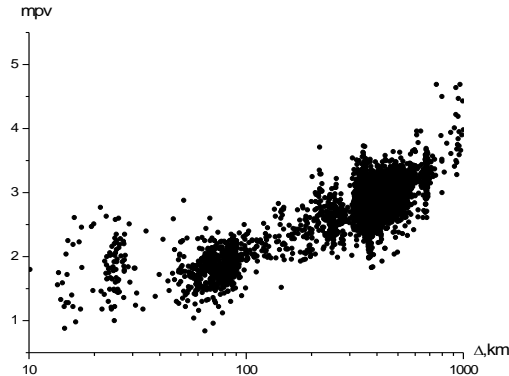
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## Year 1994

- “Borovoye” Observatory was transferred to the National Nuclear Centre of the Republic of Kazakhstan;
- The cooperation with IRIS Consortium has been started; within the cooperation, the four sites of the large-aperture Borovoye array were equipped with broadband three-component seismic stations, STS-2 seismometers and REFTEK72A digitizers;
- 1994-2019 IRIS IDA station (STS1, STS2, FBA23 +Q330HR) operated on the territory of BRVK Observatory.



*Seismic noise spectral density for BRVK station*

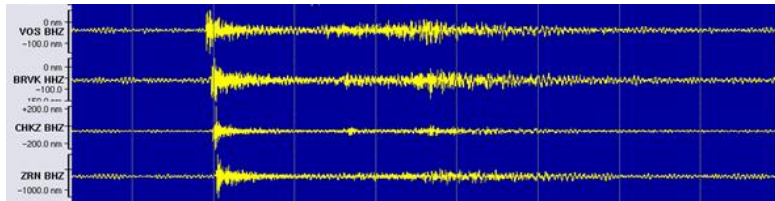


*Distance of recording for BRVK station*

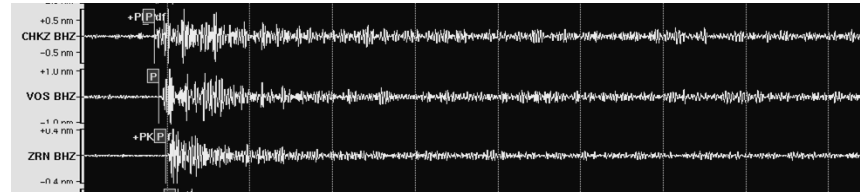


# Year 1994 - 1998

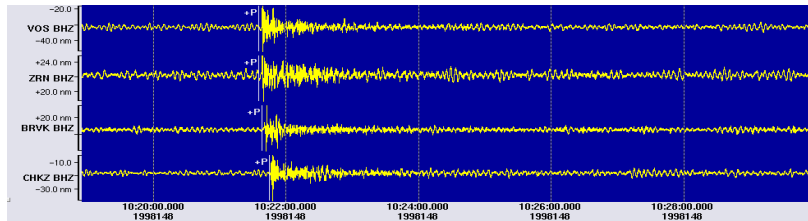
All station's elements successfully recorded nuclear explosions conducted at Lop Nor, Chagay, Pokharan Test Sites, and at Fangataufa atoll.



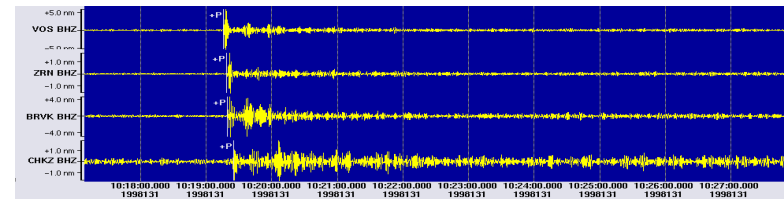
*Records of underground nuclear explosion conducted at Lop Nor Test Site on October 7, 1994*



*Records of underground nuclear explosion conducted by France at Fangataufa atoll on October 1, 1995*



*Records of underground nuclear explosion from Chagay Test Site, May 28, 1998*



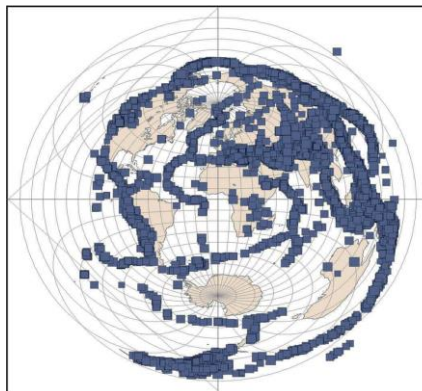
*Records of underground nuclear explosion from Pokharan Test Site (India), May 11, 1998*

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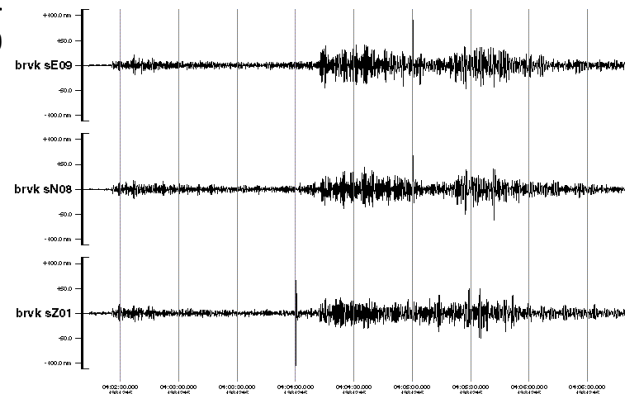
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### Year 1997

- Under the ISTC K063 Project in collaboration with LDEO, the system of data recording, acquisition and transition was modernized; 4 digital seismic stations Quanterra680 were installed (one per each remote site and at the central facility);
- Under the same Project, the work on saving the digital records archive that contains tens of thousands seismograms (different measurement channels) of underground nuclear explosions conducted by the USA, USSR, France, China, India, and Pakistan was begun. In particular, in cooperation with the Institute of Geosphere Dynamics RAS the digital seismograms archive was re-recorded onto 4mm magnetic tapes. The obtained archive contains the UNE records (in CSS3.0 format) and earthquakes associated with the NEIC USGS catalogue in SAC format.



*The map of seismic events epicenters from the database of digital seismic records of Borovoye station.*



*Seismogram of reformatted record of peaceful nuclear explosion of 09.02.1981 03-59-59.9,  $\varphi=60.60^\circ$ ,  $\lambda=55.70^\circ$ ,  $m=4.4$ , BRVK station.*

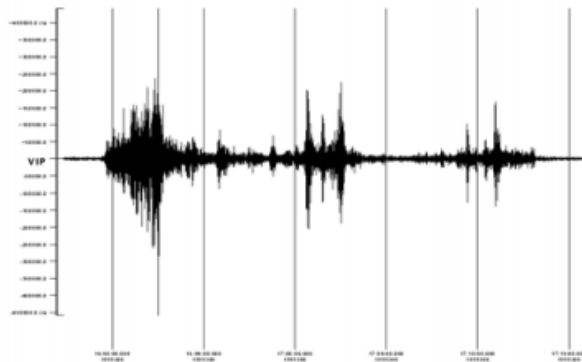
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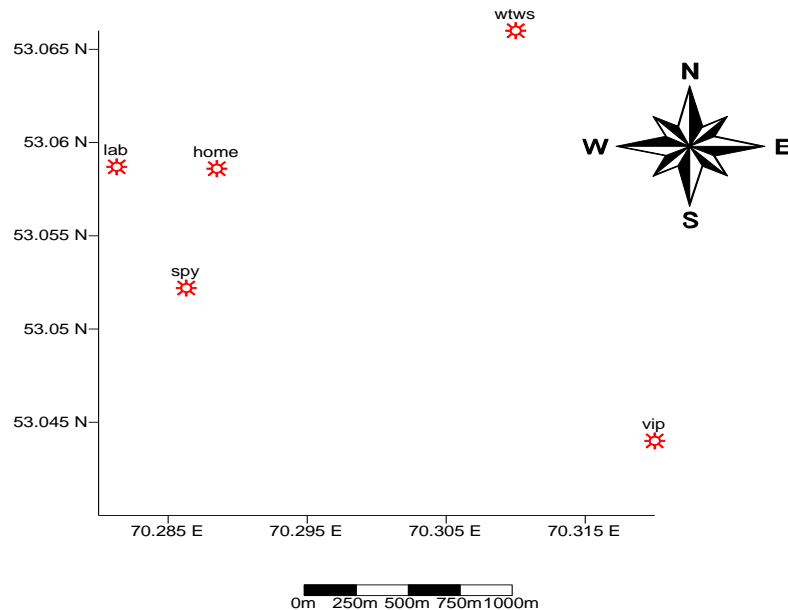
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## Year 1999

“Borovoye” GO restored the recording of infrasound acoustic signals generated by numerous natural and artificial sources. The main goal is recording of local and regional industrial blasts and its discrimination among other sources.



*Infrasound record of “Proton” spacecraft flight on October 27, 1999.*



*Location of receivers at Borovoye infrasound stations*

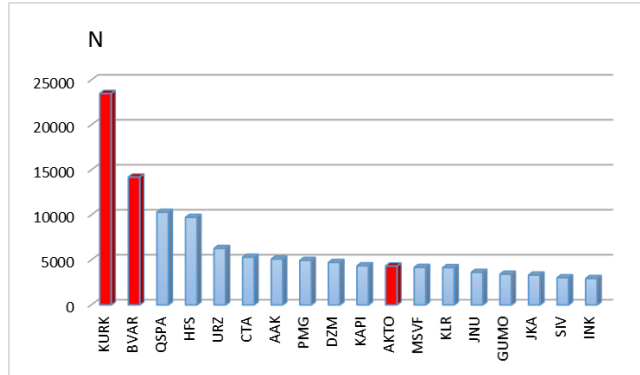


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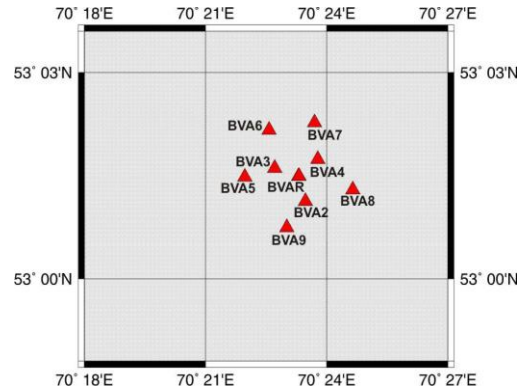
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# Year 2001 - 2002

The auxiliary seismic array AS057 “Borovoye” (BVAR) of the International Monitoring System (IMS) was constructed within Borovoye granite massif and certified.



*Distribution of auxiliary IMS stations on the number of associated phases in REB bulletin for 2020.*



*Configuration of the auxiliary seismic array Borovoye (AS057).*



*GS-21 seismometers being prepared for installation*

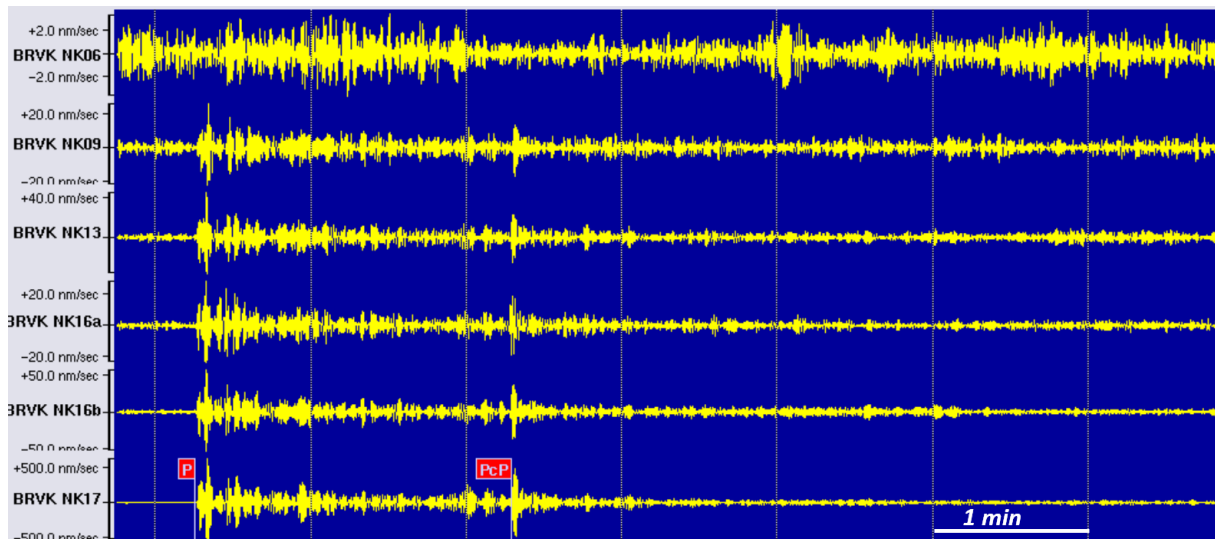


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## Year 2006 - 2017

**“Borovoye” GO continues its operation and records successfully all six North Korean nuclear explosions.**



*Seismograms of the North Korean nuclear explosions by data of BRVK station (records traces top-down: 9 October 2006, 25 May 2009, 12 February 2013, 6 January 2016, 9 September 2016, 3 September 2017). Z-component. Filter 1.25 Hz.*

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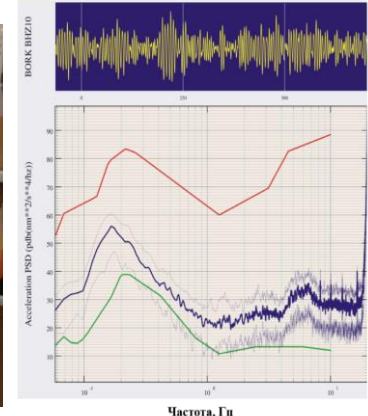
# Year 2019

Due to the public necessity, the whole infrastructure of “Borovoye” Observatory was moved to about 3 km south-east of the former location. BRVK IRIS IDA station was assigned with a new name – BORK.

The station’s instruments were also modernized the same year. Currently, the seismic station is equipped with sensors STS6, STS5A and accelerometer Kinometrics Episensor ES-T, and digitizer Quanterra Q330HR. The seismometers are installed in the boreholes of 42.5 m depth.

Borovoye seismic observatory possess the archive of seismograms. The archive records of nuclear and chemical explosions are digitized.

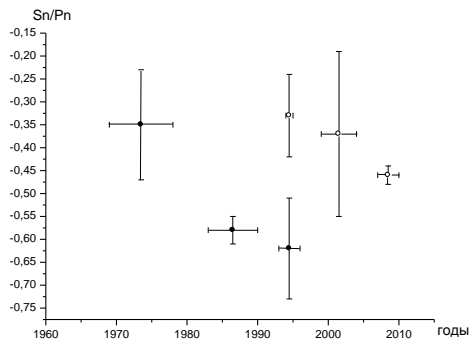
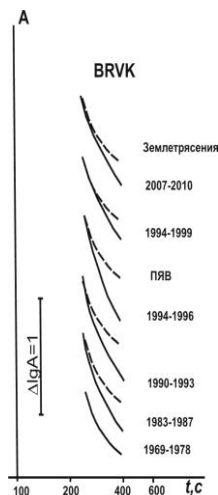
In addition to historical seismograms, the seismic bulletins were digitized at KNDС under the ISTC CASHA-BU Project (2018-2020).



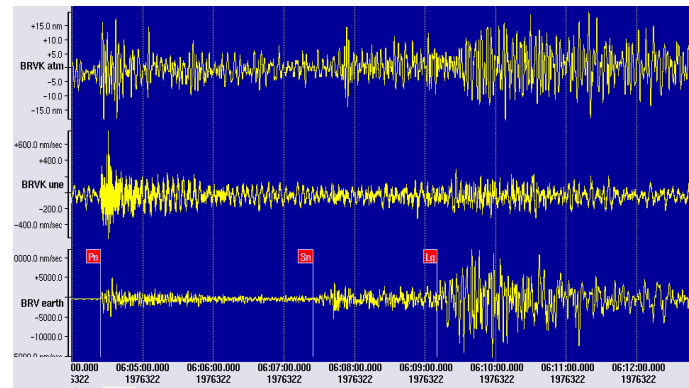
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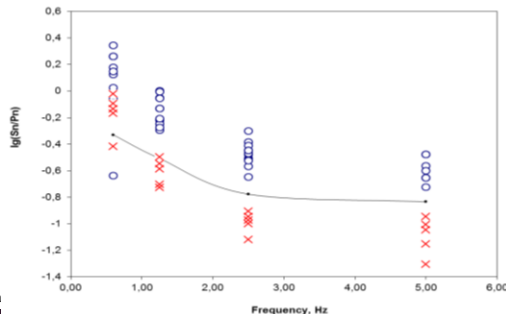
### Application of Borovoye station data in investigations on nuclear explosions monitoring



Dependence of Sn/Pn average values on time for the LNTS.  
The man values and standard deviations for UNE (filled signs)  
and earthquakes. Horizontal risks – intervals of data averaging.



Seismograms top-down: atmosphere explosion November 17, 1976  $t_0=06:00:12.7$ ,  $\varphi=40.696^\circ$ ,  $\lambda=89.627^\circ$ ,  $mb=4.7$ , underground nuclear explosion of July 29, 1996,  $t_0=01:48:57.8$ ,  $\varphi=41.82^\circ$ ,  $\lambda=88.42^\circ$ ,  $mb=4.9$ , tectonic earthquake of January 30, 1999,  $t_0=03:51:05.00$   $\varphi=41.586^\circ$ ,  $\lambda=88.455^\circ$ ,  $mb=5.8$ . Z-components, BRVK station.



Distribution of Sn/Pn values for explosions (crosses)  
and earthquakes (circles) from the region of Lop Nor  
Test Site, Z-channel, BRVK station



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### Conclusion

For 70 years of the existence, making the way from ordinary seismic station to the contemporary geophysical observatory, “Borovoye” station has repeatedly confirmed its effectiveness in nuclear explosions recording from the Test Sites all over the world. Despite that today the number of nuclear explosions is almost zero, data of Borovoye station remain highly demanded by the seismological society.

The station is one of the most effective in global monitoring of earthquakes and explosions. Its data are important for seismic monitoring of Kazakhstan territory and Central Asia.

One of the topical tasks today is the soonest finishing of modernization of the large-aperture array stations “Chkalovo”, “Zerenda”, and “Vostochnoye”.

The KNDC conducts and will continue the work on saving archive information of the station, on converting analogue data to digital format that, in addition to nuclear explosions records contain also records of earthquakes and chemical explosions. These data are used by seismologists in different countries for numerous scientific researches on studying the structure and dynamics of the Earth, discrimination of explosions and earthquakes, monitoring of seismic activity and other investigations.