Peaceful nuclear explosions at Azgir Test Site (West Kazakhstan)

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Between 1965 and 1987, 39 peaceful underground nuclear explosions were carried out in the Kazakh SSR, 17 of which took place at the Azgir test site in western Kazakhstan. The test site is located on the Bolshoy Azgir salt dome, on the western edge of the Caspian salt province, to the north of the Caspian Sea. For research purposes, underground cavities were created in the rock salt massif at the Azgir test site between 1966 and 1979 to develop technology for creating such cavities. As a result, nine underground cavities of various volumes and depths were created. The report examines the dynamic and kinematic parameters of the PNE conducted at Azgir and recorded by seismic stations in the USSR (CSE IPE RAS network) at epicentral distances ranging from 770 to 6500 km. A total of ~300 historical analogue seismograms were measured. Data was collected on the geological and tectonic state of the test site, as well as on the current state of the technological platforms on which the tests were conducted. Manifestations of modern seismicity near the test site were also investigated.

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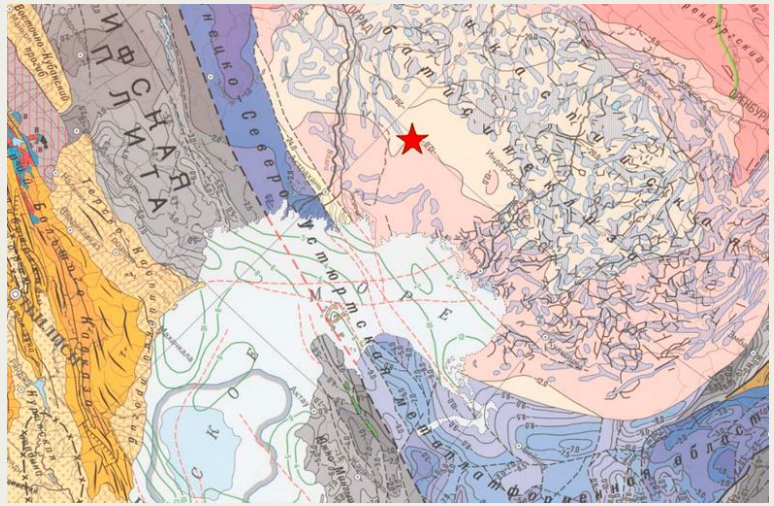
Introduction

Between 1965 and 1987, 39 PNE were conducted in the Kazakh SSR, 17 of which were carried out at the Azgir test site located in the north-western Caspian region.
Six PNEs were constructed in the central part of the Karachaganak salt dome in the north-west of West Kazakhstan Region (Caspian Depression) in 1983-84 to create six artificial cavities for the accumulation and storage of gas condensate from the Karachaganak oil field.
On the Ustyurt Plateau in the Mangistau Region (northeastern Caspian Sea), three PNE tests were conducted in clay formations to develop nuclear explosive technologies for the creation of reservoirs in sinkholes.
In other regions of the Kazakh SSR, one explosion was carried out for deep seismic sounding of the earth's crust in order to search for structures promising for mineral exploration (‘Region-3’ in the West Kazakhstan Region, ‘Region-5’ in the Kostanay Region, ‘Meridian-1’ in the Akmola Region, ‘Meridian-2 and 3’ in the South Kazakhstan Region, ‘Batholite-2’ in the Aktobe Region).

Geological and tectonic settings of the Azgir test site and adjacent territories

The Bolshoy Azgir salt dome uplift is part of the local structures of the Bogdo-Chapchachinsky Ridge. It is an extensive brachyanticline fold of the diapir type, complicated by two salt domes - Western and Eastern Azgir located at an average distance of 10-12 km from each other and separated by the Uzhantator compensation trough. The domes are spatially confined to the regional fault of the base of the sub-salt deposits located at a depth of approximately 7000 m.
The western dome is open - in its south-eastern part, rock salt lies directly on the surface, reaching absolute heights of plus 5-6 m. Here is the highest point of the dome, known as Mount Chapchachi, representing a salt stock breaking through the Western Azgir dome. The salt dome uplift of Eastern Azgir is complicated by Palaeozoic, Mesozoic and Cenozoic formations, similar to those of the Western dome. In tectonic terms, the Eastern Azgir salt dome is a closed brachyanticline fold of the second order, of the diapir type, elongated in a submeridional direction for approximately 15 km, with 7-8 km width.



Location of Azgir test site on the tectonic map of Northern Eurasia

Photo of a salt layer from the Azgir test site area.

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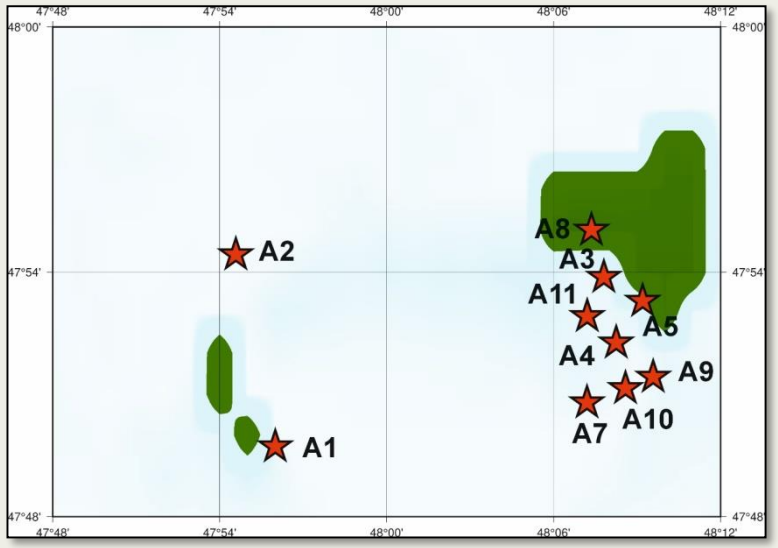
Features of conducting UNE at the Azgir test site

PNE tests were conducted at the Azgir test site between 1966 and 1979. A total of 17 explosions (22 charges) of varying yield were carried out at 10 technological sites at depths ranging from 161.4 m to 1491 m. The explosions yield ranged from 0.01 kt (30 October 1977 in borehole A2) to 103 kt (18 December 1978 in borehole A9). Around the working borehole, there were technological sites where equipment, mechanisms and structures were located. As a result of the PNE, nine cavities of various shapes were created with an initial total volume of about 1 million m^3.

Five cavities (A1-A5) filled with water after the explosion, while two cavities, A7 and A10, filled with water partially. The water inside the cavities, which has dissolved salt, is brine, a highly saline radioactive solution. Cavities A8 and A11 are dry. Six PNEs tests were conducted in the water-filled cavity A2 to develop a method for obtaining transplutonium elements in indicator quantities. A repeat PNE test was conducted in the dry cavity A3 (before it was filled with brine) to study the attenuation of the seismic effect.

The PNE in well A9 was carried out near the salt-clay boundary on the dome slope, so most of the explosion energy, after recoil from the salt body, formed an unstable cavity in the clay mass. After the cavity collapsed, a sinkhole measuring 35 m by 600 m formed, and it filled with groundwater and turned into an artificial reservoir with a volume of about 20,000 m^3.

After completion of the programme, the military boreholes were sealed with concrete plugs. In addition to production boreholes, sites A1, A3, A7, A8 and A11 have technological boreholes drilled in the cavity and its vicinity to conduct research and technological works.



The map of boreholes location on the territory of Azgir Test Site.

A-3 borehole location site (1971, 1976).

A-9 borehole location (1979) with a sinkhole.

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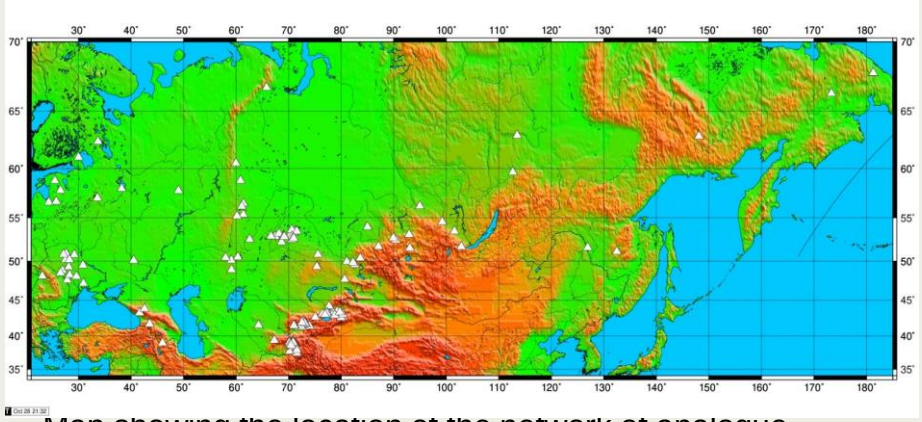
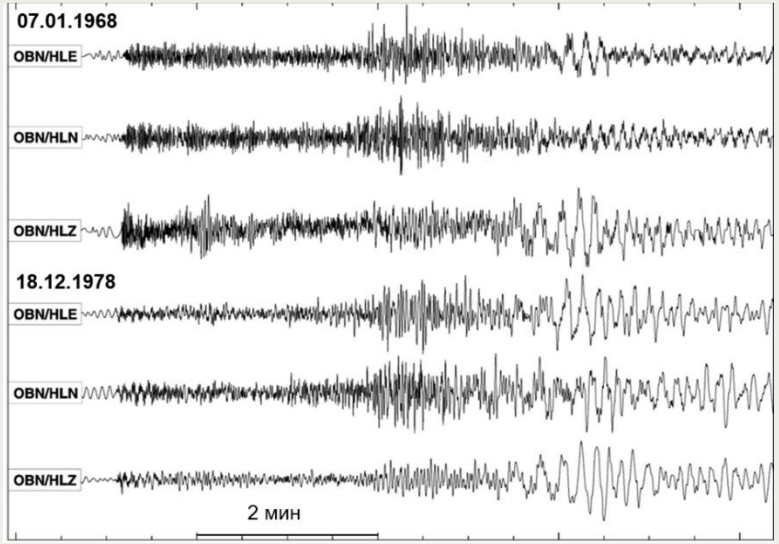
Kinematic and dynamic parameters of UNE

Since most seismic stations were analogue during the PNE, and only a small portion were digital, historical analogue seismograms were used to study the parameters of the explosions. Some of the analogue seismograms were digitized.

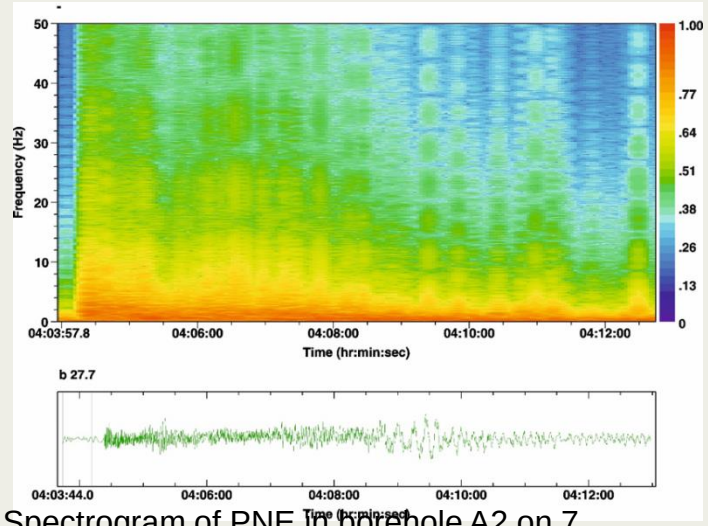
The analysis of the seismic records of the PNE on Azgir showed that the wave pattern of the explosions differs significantly depending on the geological environment in which they were conducted. The PNE on 07.01.1968 was carried out in salt, while the PNE on 18.12.1978 was carried out at the boundary between clay and salt. For the explosion carried out in salt, the ratio of maximum amplitudes ASn/APn, as well as ALg/APg, is less than the ratio of amplitudes for the explosion carried out in clay. For the explosion carried out in clay, the level of surface waves is higher than for the explosion carried out in salt. The recordings of the explosion in salt are higher in frequency. The figures show the spectrograms of both explosions recorded by the OBN station.



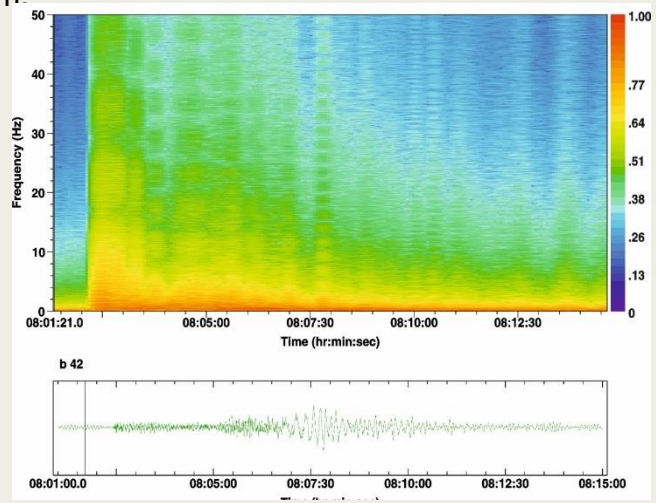
Map showing the location of the network of analogue stations of the CSE IPE AS USSR, whose records were used in compiling the seismic bulletin on the PNE.



Digitized seismograms from the OBN station, 3 upper seismograms from the A2 well on 7 January 1968, 3 lower seismograms from the A9 well on 18 December 1978.



Spectrogram of PNE in borehole A2 on 7 January 1968. Station OBN. Z channel. Δ=1122 km.



Spectrogram of PNE in borehole A9 on 18 December 1978. Z channel. Station OBN. Δ=1155 km.

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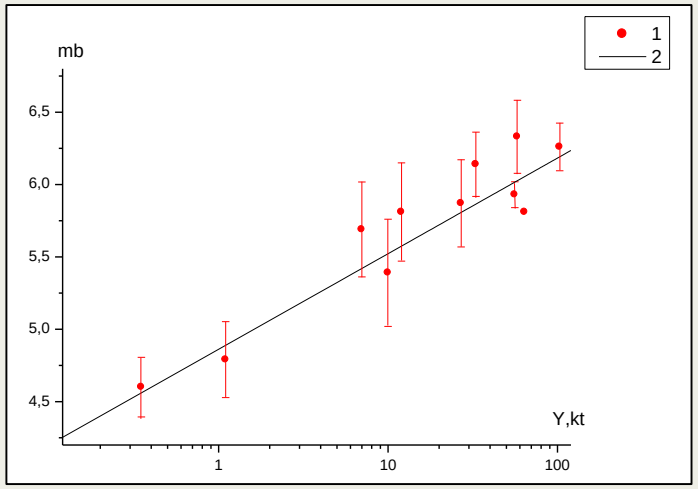
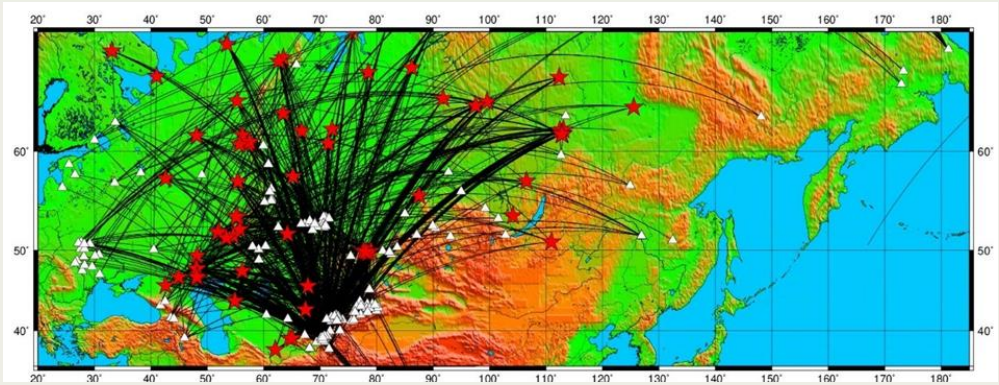
Kinematic and dynamic parameters of UNE

About 3,000 measurements were taken from 97 PNEs. The range of epicentral distances was 240 km (Peleduy) for the Kimberlite-4 explosion and 6,908 km (Iultin) for the Takhta-Kugult explosion. Most measurements were taken for the distance range from 500 to 2500 km. For the Azgir test site, 265 seismograms were measured between 1966 and 1979, with epicenter distances ranging from 773 to 6564 km.

The following dependencies of mb magnitudes on power were obtained for the Azgir test site :
mb=4.86+0.66*lg(Y(kt)),
Correlation coefficient R=0.96.



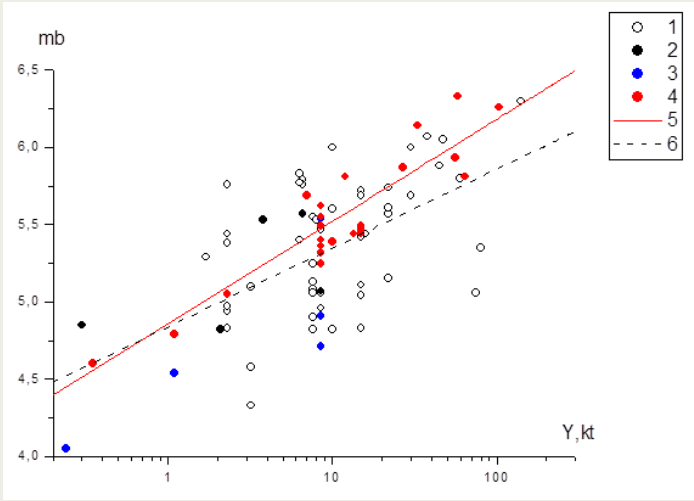
Dependence of magnitudes mb (a) and energy class K (b) for PNE conducted at the Azgir test site. 1 – average values, 2 – standard deviations.



Map showing the locations of PNE epicenters and the stations that recorded them. Stars - PNE locations, triangles - CSE seismic stations..

The following dependencies were obtained for PNEs conducted in various environments, except for salt: in sedimentary rocks (siltstones, dolomites, limestones, marls, clays, ferruginous quartzite), intrusive rocks (basalts, granites, apatite ore), effusive rocks (tuff sandstones, andesite-basalt tuffs).
mb=4.83+0.51*lg(Y(kt)),
Correlation coefficient R=0.58.

The obtained results showed that PNEs conducted in salt have a higher seismic effect than other host rocks.



Dependence of mb magnitudes for PNE conducted in the USSR in different environments: 1 – salt, 2 – sedimentary rocks, 3 – intrusive, 4 – effusive, regression lines: 5 – for salt, 6 – all except salt.

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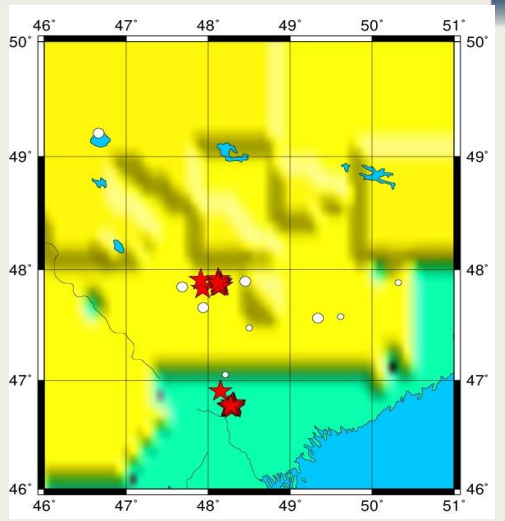
Seismicity near the Test Site

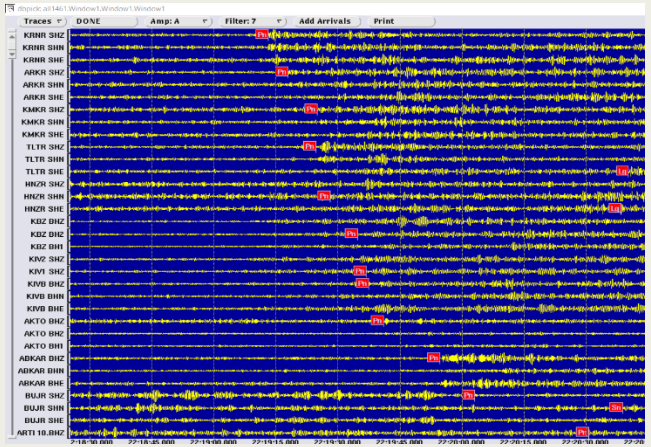
For a long time, the northwestern Caspian region was considered aseismic. For the first time, two events were included in the VEP earthquake catalogue in 2021: on 26 May at 22:17 with MsIDC=3.6 and on 27 May at 02:16 with mbNNC=3.3. A seismic zone was identified in the area – Azgirskaya. The parameters of the seismic regime of this structure are: Mmax=4.2, b=0.76, and the depth of the hypocenter source is h=20 km.

Earthquake parameters from the northwestern Caspian region.

Date	t0	latitude	longitude	Depth	Ndef	mb	mpva	Centre
1984/06/29	03:57:27.8	49.2070	46.6629	35.0f	14	3.9		ISC
2020/05/31	20:06:40.9	47.5628	49.3413	0.0f	5	3.3		IDC
2021/05/26	22:18:09.1	47.8738	48.501	30	21	3.3	3	KNDC+ GS RAS
2021/05/27	02:16:13.3	47.8454	47.6834	8	10	3.4	3	GS RAS
2022/01/24	20:08:17.5	47.5777	49.6177	10	32		2	KNDC
2022/03/19	14:15:39.1	47.883	50.3204	10	27		2	KNDC
2022/05/06	14:21:57.7	47.0517	48.2093	10	13		2	KNDC
2022/08/20	22:11:55.9	47.4756	48.5006	10	23		2	KNDC
2024/08/05	22:03:50.8	47.6594	47.9400	0.0f	4	4.5		IDC



Map showing the locations of PNE epicenters in the Azgir test site area and the Vega experiment (stars), earthquakes (circles).



Three-component recordings of the earthquake on 26 May 2021

Conclusion

The seismic effect of peaceful nuclear explosions in salt was examined and compared with those conducted in other environments.

It is shown that weak seismic events are recorded in the north-western Caspian region, the nature of which is defined as “natural tectonic events, possibly associated with karst processes and active salt diapers in this area”. The study of such phenomena, especially in this area, is extremely important, since in the period 1966-1979 at the Azgir test site (KazSSR) and in the period 1980-1984 in the Astrakhan region (Vega experiment), peaceful nuclear explosions were carried out in a rock salt massif, resulting in the creation of underground cavities of various sizes.

Monitoring geodynamic processes at test sites and seismic activity near them is important, as seismic events near cavities can cause adverse environmental consequences. In the north-western Caspian region, it is necessary to develop continuous seismic monitoring in order to assess the seismic regime and evaluate the seismic hazard of nuclear test sites.