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SEPARATION OF NATURAL AND TECHNOGENIC SEISMIC EVENTS ON THE TERRITORY OF AZERBAIJAN

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ABSTRACT. This article is devoted to the issue of recognizing the nature of seismic events in order to identify explosions. The results of analyzes of seismic events are presented. The criteria for the difference between explosions and earthquakes are established. A separate explosion catalogue has been created. Methodical bases of recognition of technogenic seismicity are developed.
Key words: seismicity, explosions, earthquakes, spectra.

Introduction

The expansion of the telemetric network of Azerbaijan and the commissioning of high-sensitivity digital seismic stations makes it possible to record weak earthquakes with M<1, which reduced the representativeness of the observed events. At the same time, the high resolution of modern equipment makes it possible to register also industrial explosions, which are conducted in the development of various deposits, in the laying of roads, pipelines, in the construction of tunnels, and explosions related to military exercises. The registration by highly sensitive equipment against the background of weak tectonic earthquakes makes the actual use of methods for recognizing the nature of seismic events to increase the information content of catalogues and to study weak seismicity. Studies have shown that industrial explosions are carried out in various zones of the Azerbaijani part of the Lesser Caucasus, the territory of which is rich in natural resources, as well as in the territories of Armenia and Iran adjacent to our republic. One of these zones is located in the occupied territory. It is possible that explosions related to military operations are also being conducted here.

The discussion of the results

The effect of chemical explosions is comparable to the effect of weak earthquakes. These explosions are recorded by sensitive stations of the republic and are treated as earthquakes. In this regard, the task was to control and monitor the explosive works carried out on the territory and near the borders of our republic. To solve this problem, was carried out the research to identify the criteria to differentiate in explosions from earthquakes. To work out the method of event identification, a number of methods were studied from international practice: the relationships of the spectral amplitudes of seismic phases, the method of spectrograms, the analysis of the wave pattern, the distribution of events in space and time, etc. [Gabsatarova, 2006].

For this purpose, the archive of seismic event records registered by seismic stations for the period 2011-2016 is being monitored. It was during this period that there was an increase in weak seismicity in these areas. The map (Fig.1) shows zones of increased density of weak seismic events' sources with M≤2.4 registered in 2015-2016.

A total of 4834 seismic events were considered and analyzed during this period. As can be seen from Table 1, over the years their number increased (with the exception of Chovdar zone) and in 2016 reached the greatest value.

In all these zones, mineral deposits are being developed. Only at Chovdar deposit, work since mid-2015 was suspended.

The overall picture of the sequential increase in the number of seismic events in the Lesser Caucasus and near the south-western border of the Republic, as well as separately for Kalbajar district is shown in the histogram (Fig. 2a, b).

[1] The Republican Seismic Survey Center of Azerbaijan National Academy of Sciences

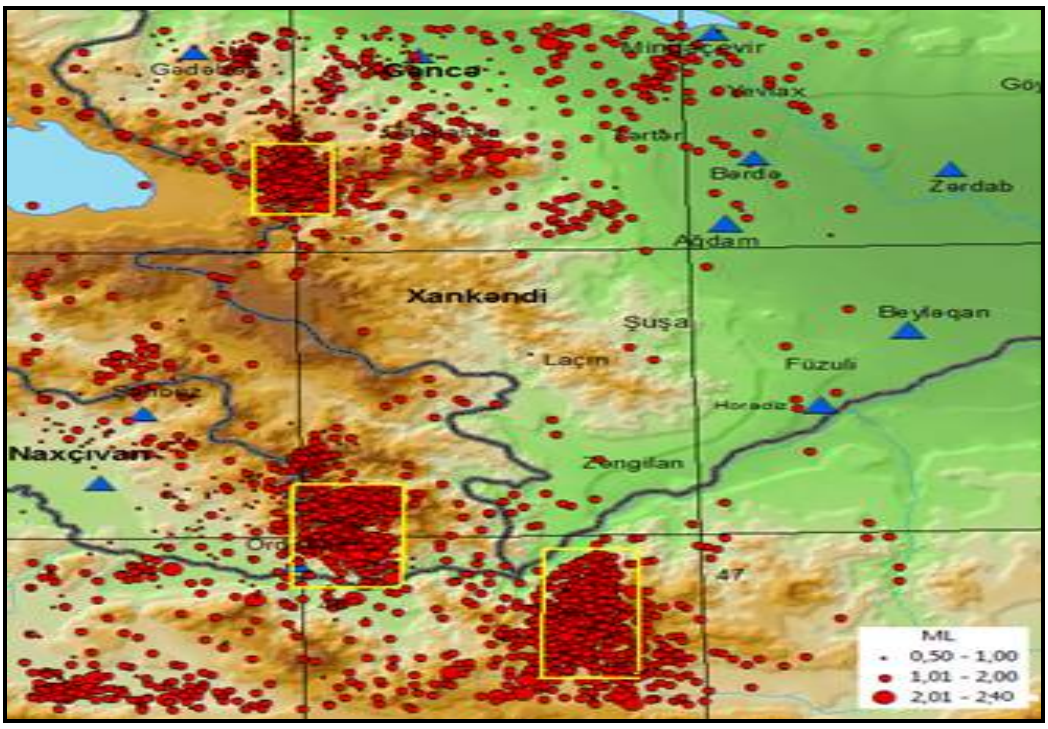

Figure1. Map of sources of weak seismic events for 2015-2016

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Table 1. Seismic events recorded for the period 2011-2016 for the considered zones

Years / Districts	2011	2012	2013	2014	2015	2016	Total
Iran	79	330	339	475	544	731	2498
Zangezur	35	279	272	246	284	431	1547
Kalbajar	50	38	47	84	151	180	468
Chovdar	45	65	39	39	29	0	217
Dashkesan	12	7	18	14	17	36	104
Total	208	705	698	832	1013	1378	4834

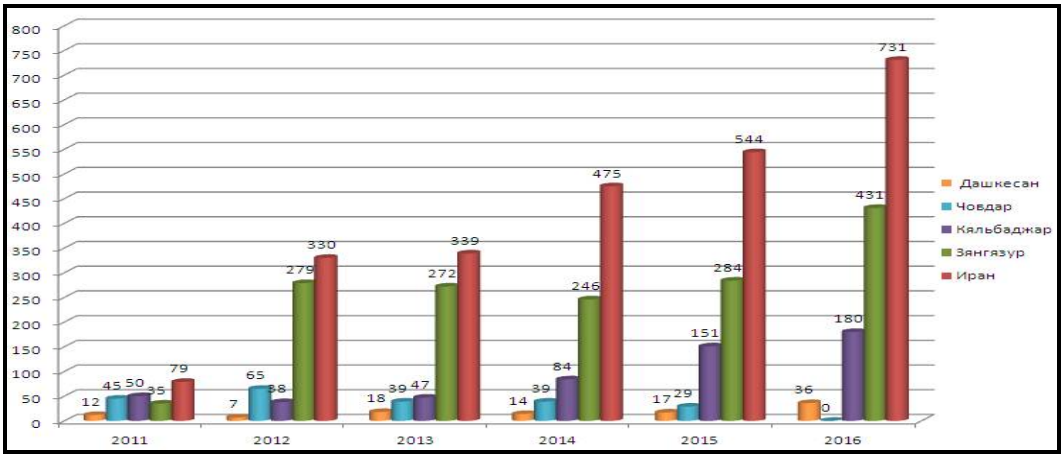

Figure 2a Seismic events in the Lesser Caucasus and near the south-western border of the republic for 2011-2016

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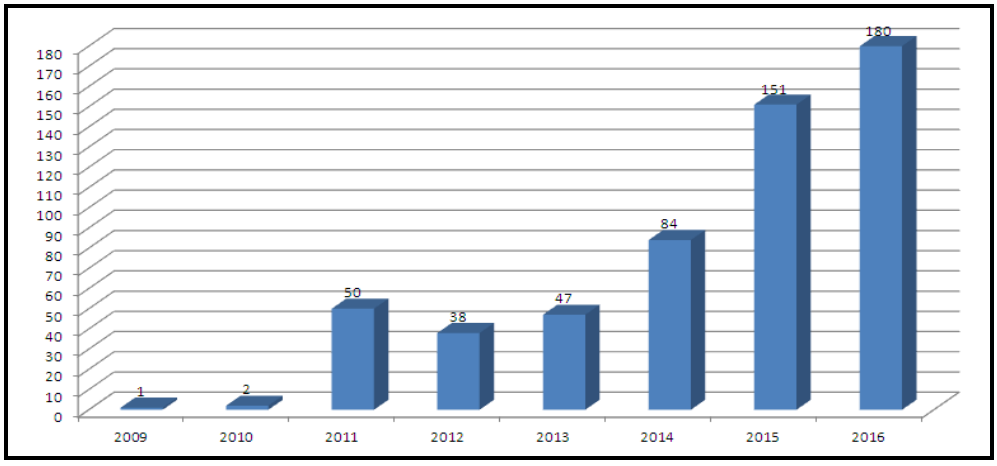

Figure 2b Histogram for Kalbajar district for 2009-2016

As an example, seismic events for 2016 are considered. On the map of the sources of seismic events (Fig. 3), the places of accumulation of epicenters were identified, on which industrial activity was observed. As noted above, on selected sites the number of seismic events increased every year and in 2016 reached its highest value.

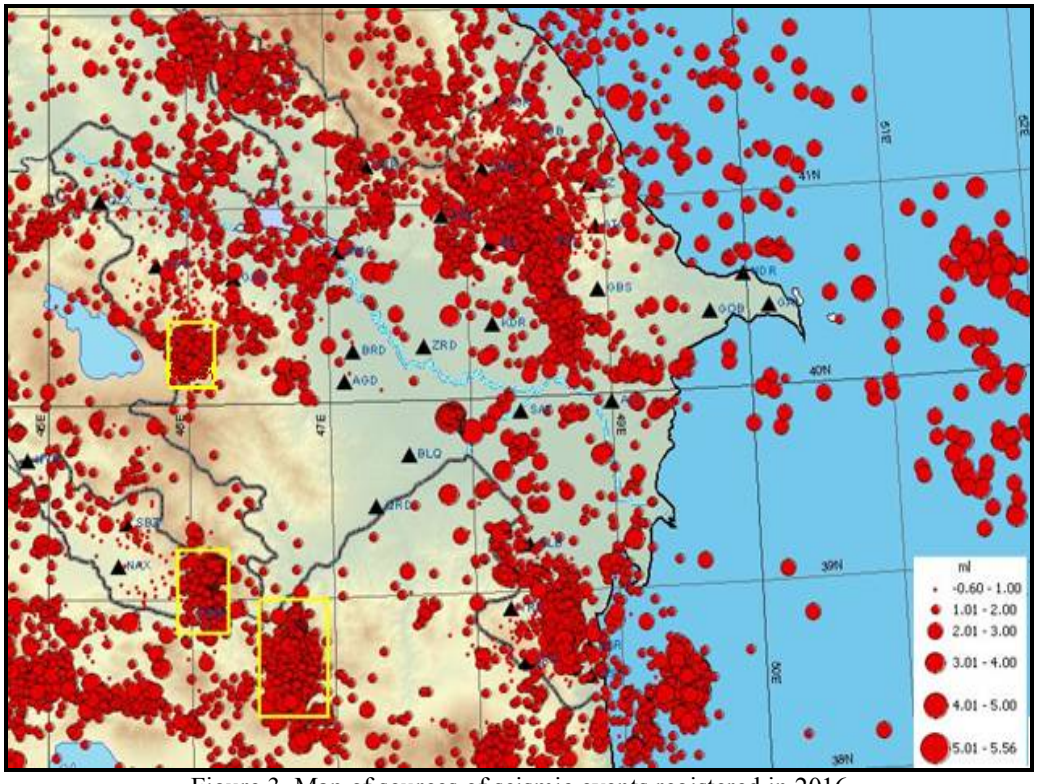

Figure 3. Map of sources of seismic events registered in 2016

An analysis of the distribution of the events occurrence time for a given year using the petal diagrams (Fig. 4) indicates the technogenic nature of seismic events at the selected sites [Godzikovskaya et al., 2000]. As an example, diagrams of the distribution of seismic events in Kalbajar district and the adjacent territory of Iran are given. The diagrams clearly show a sharp increase in events at 13-16 hours for Kalbajar zone and 9-10 hours for the zone of Iran, which is not typical for earthquakes.

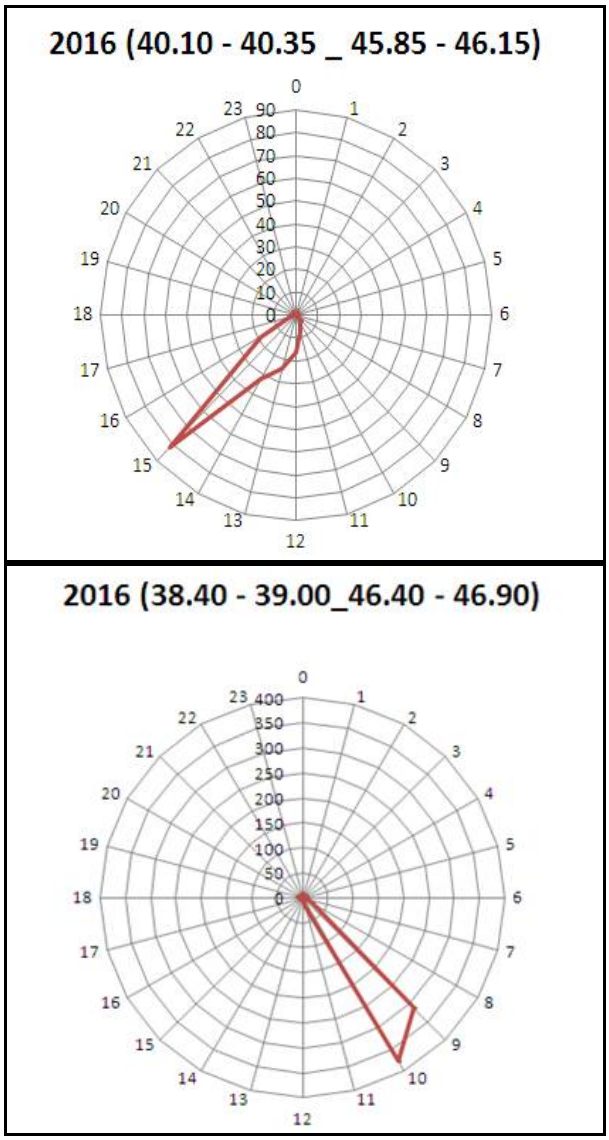

Figure 4. Diagrams of spatial and temporal distribution of seismic events for Kalbajar and Iran for 2016

The criteria for distinguishing explosions and earthquakes have been determined in the examined regions. For this purpose, the digital records of all seismic events were examined and analyzed, the spectral properties of their records were studied, spectrograms for each event were constructed, and the ratios of the spectral amplitudes of the volumetric P and S waves were calculated. The features of the wave pattern and spectra of seismic events of different nature are studied. To view and analyze industrial activity in the territory of Lesser Caucasus, the data of the stations close to the studied areas were considered: Ganja and Gadabey, for the territories of Iran and Armenia data from Ordubad station were considered.

As an example, records of earthquakes and explosions recorded by digital seismic stations of the republic are shown (Fig. 5-7). Analysis of spectrograms of seismic events records showed that during explosions the amplitude of the displacement spectra is less than 100 at a frequency of 1-10 Hz, while for earthquakes the amplitude of displacement is significantly more than noise spectrum, its

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value reaches 1000 at frequencies of 1-20 Hz (for example, on September 27, 2016 - earthquake, January 21, 2016 - for an explosion).

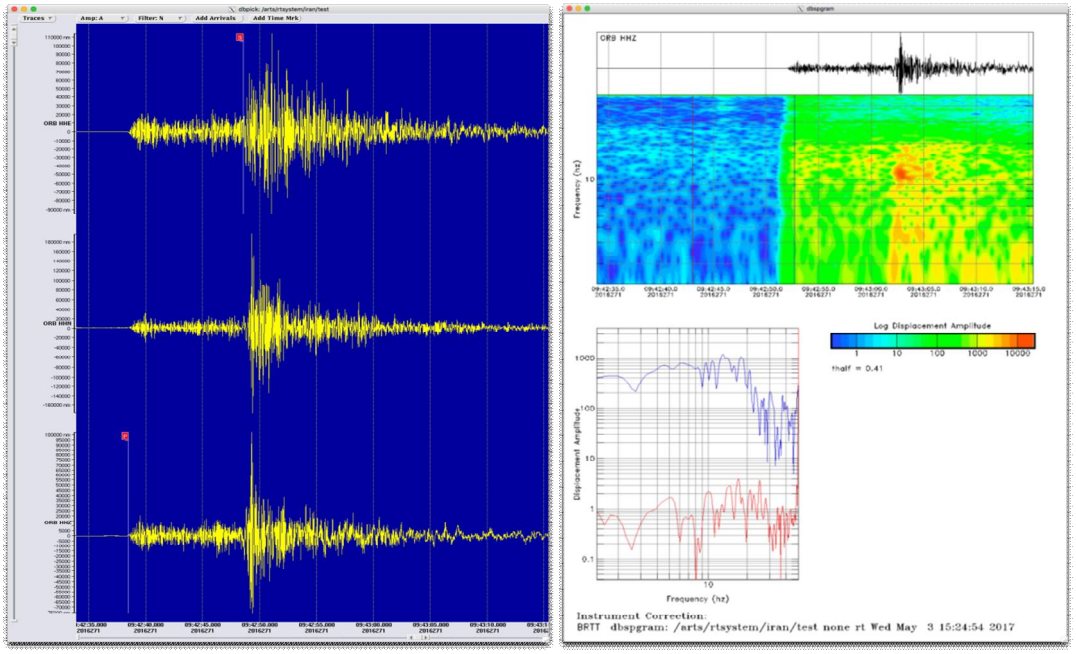

Figure 5. Wave pattern and spectrogram at the station of “ORD” of the earthquake occurred on September 27, 2016 in Iran

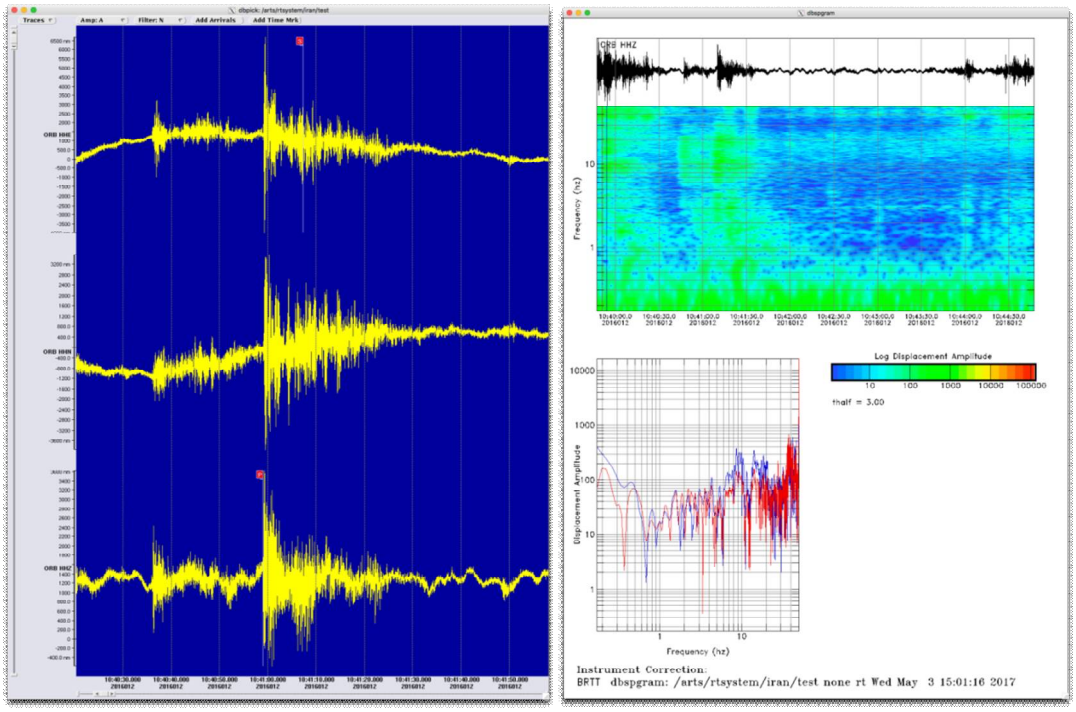

Figure 6. The wave pattern and the spectrogram at the station of "ORD" of the explosion produced on January 21, 2016 in the territory of Iran

Records of earthquakes recorded by these stations near the considered areas look different than explosions. In earthquakes, S-wave amplitudes predominate over P-wave amplitudes, in explosions the P-wave entry is distinct, the S-wave on all components is less clear, sometimes at noise level, i.e. the spectral ratios of P/S for explosions will be much higher than 1. In earthquakes, on the contrary - the spectral amplitude of S-waves is higher than P-waves, i.e. the spectral ratios of P/S for them are much lower than 1. The analysis of the wave pattern showed that such a pattern can be traced on the vertical and one of the horizontal components: EW at Ordubad station for Iranian and Zangezur explosions, NS at Ganja and Gadabey stations for small Caucasian explosions. In addition, in the case of an explosion in the records of horizontal components, a short-period surface wave *Rg* with a change in the oscillation periods of 1-2s, which occurs immediately after the transverse wave and is well distinguished in the indicated components.

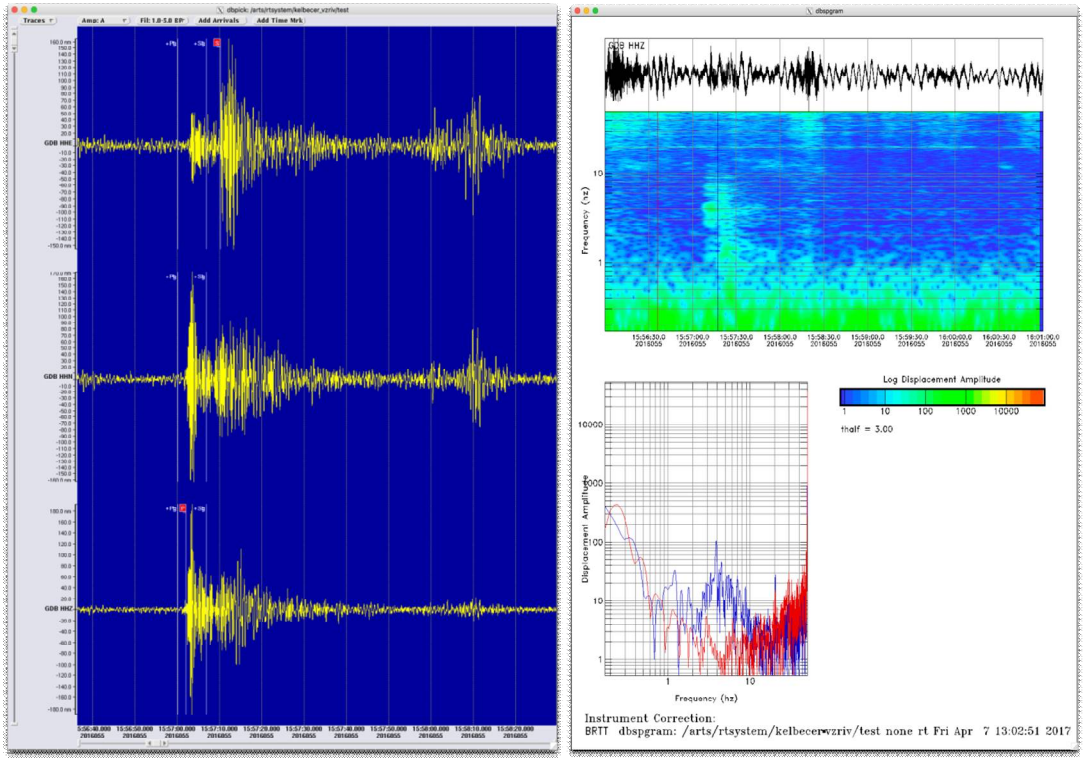

Figure 7. The wave pattern and the spectrogram at the station "GDB" of the explosion, produced on February 24, 2016 in the territory of Kalbajar district

Analysis of the time of explosions showed that they are produced mainly during working hours: for Kalbajar 11-16 hours, for Dashkesan 12-16 hours, for Iran 8-11 hours, for Zangezur 8-13 hours. Analyzing the seismic events in these zones, they found out that in 2016 earthquakes constitute 3.5% of the number of events in Kalbajar, i.e. from 180, 1.5% of those in the local area of north-western Iran, 5.4% in Dashkesan district and 1.6% in Zangezur district.

Conclusion

Taking into account the developed criteria, a separate database of explosions has been created. Creation of the cleaned catalogue of earthquakes in Azerbaijan allows to more accurately determining the spatial features of the distribution of weak seismicity in the territory of operating quarries, which is necessary to identify the seismic regime and the seismic risk of the studied territory. The monitoring of blasting operations makes it possible to determine the type of activity with which these explosions

are connected, whether military exercises or civil works, and to reveal the facts of the use of our deposits in the occupied territory. The work will provide an opportunity to control the actions of military formations in the occupied territories of our republic.

The established criteria for the difference in explosions will make it possible to further distinguish the records and times of nuclear explosions conducted in the world and, thus, control them.

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