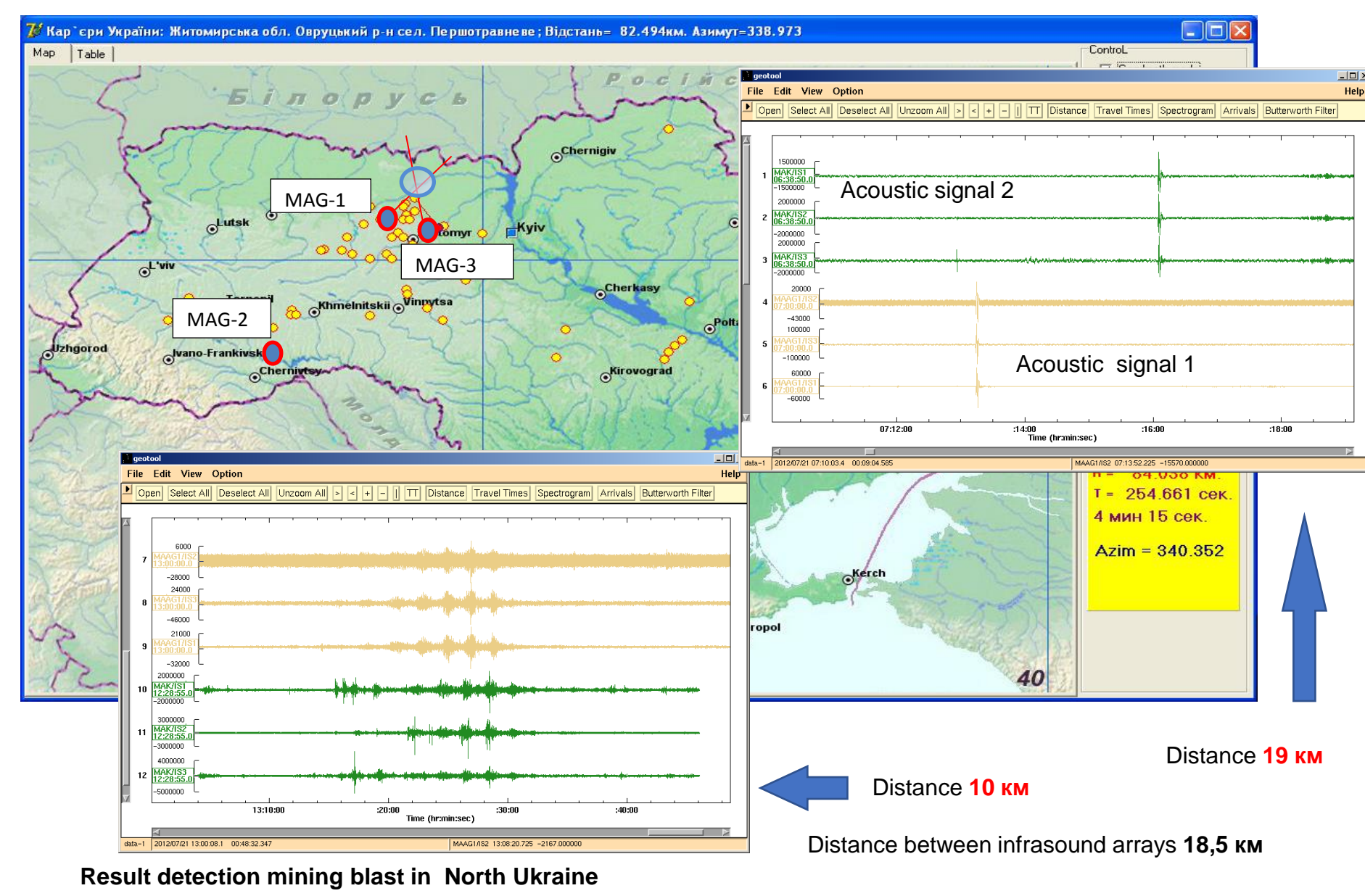




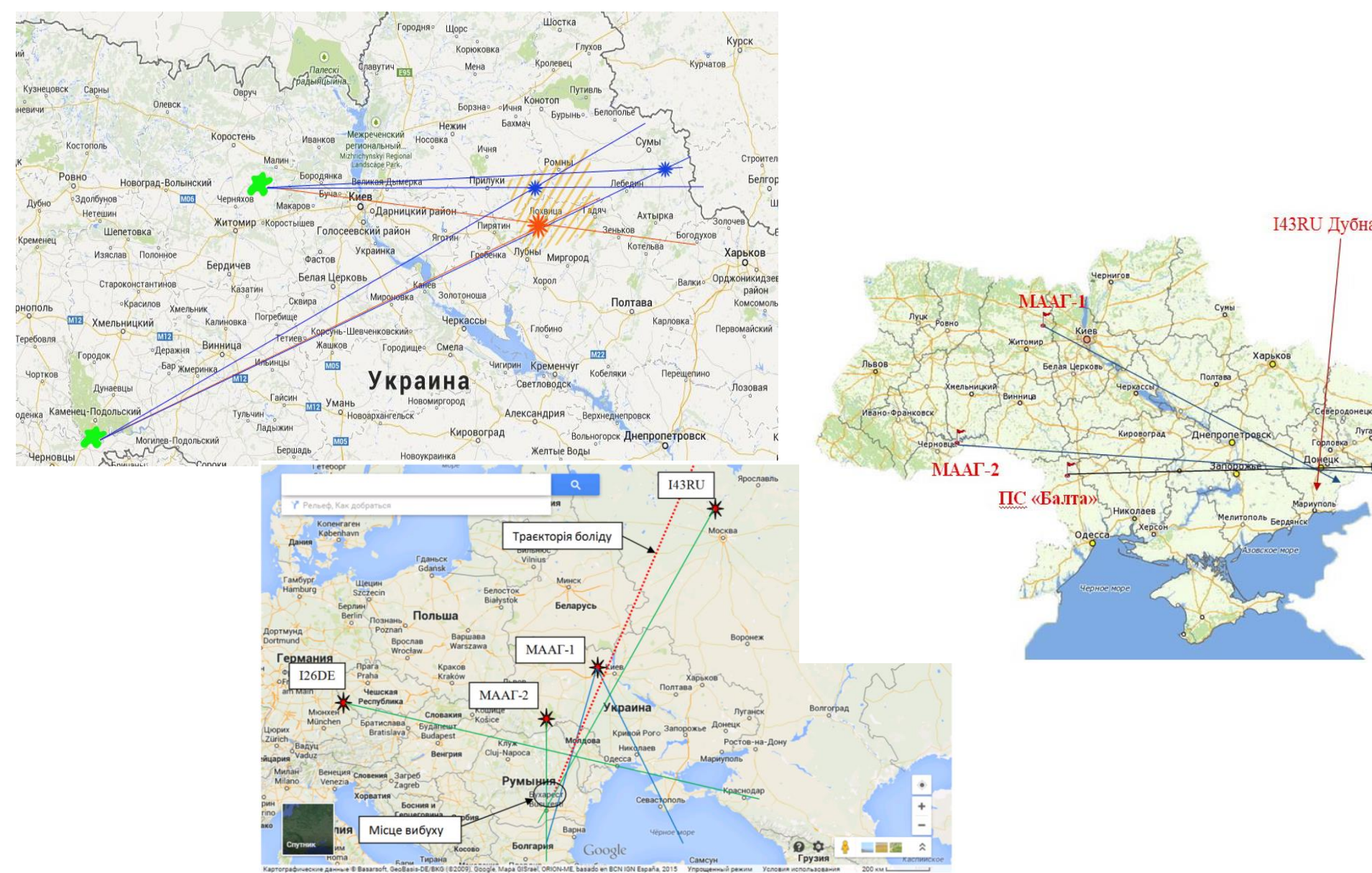
In recent years, Ukraine and the adjacent territory has been shaken by a large number of explosions. These are industrial explosions, fireball explosions, man-made accidents and the consequences of military actions. The geophysical network of the Main Center for Special Monitoring (MCSM) confidently records the signals from all these events. Additionally, data of the IMS and national networks of neighboring states are connected for processing. In addition, satellite images of emergency regions are actively used to refine data verification methods. At the same time, there is an urgent need to identify an event and calculate its spatial and energy parameters. Joint monitoring of seismic and infrasound data is the most effective for monitoring explosions. In this case, with a ground explosion, the location of the event by the seismic method is confirmed by infrasound data. At the same time, the presence of only an infrasonic response indicates an air explosion. In addition, such explosions are important for network calibration. To determine the energy of the explosions, empirical dependences were constructed based on hundreds of signals from career explosions, for which the coordinates and the amount of explosives are already known in advance. Subsequent evaluations for accidental explosions confirmed their viability.



Seismoacoustic network of Ukraine. The entire measuring geophysical network is united by a single data collection and processing center (UA NDC) connected with other international data centers.



Result detection mining blast in North Ukraine

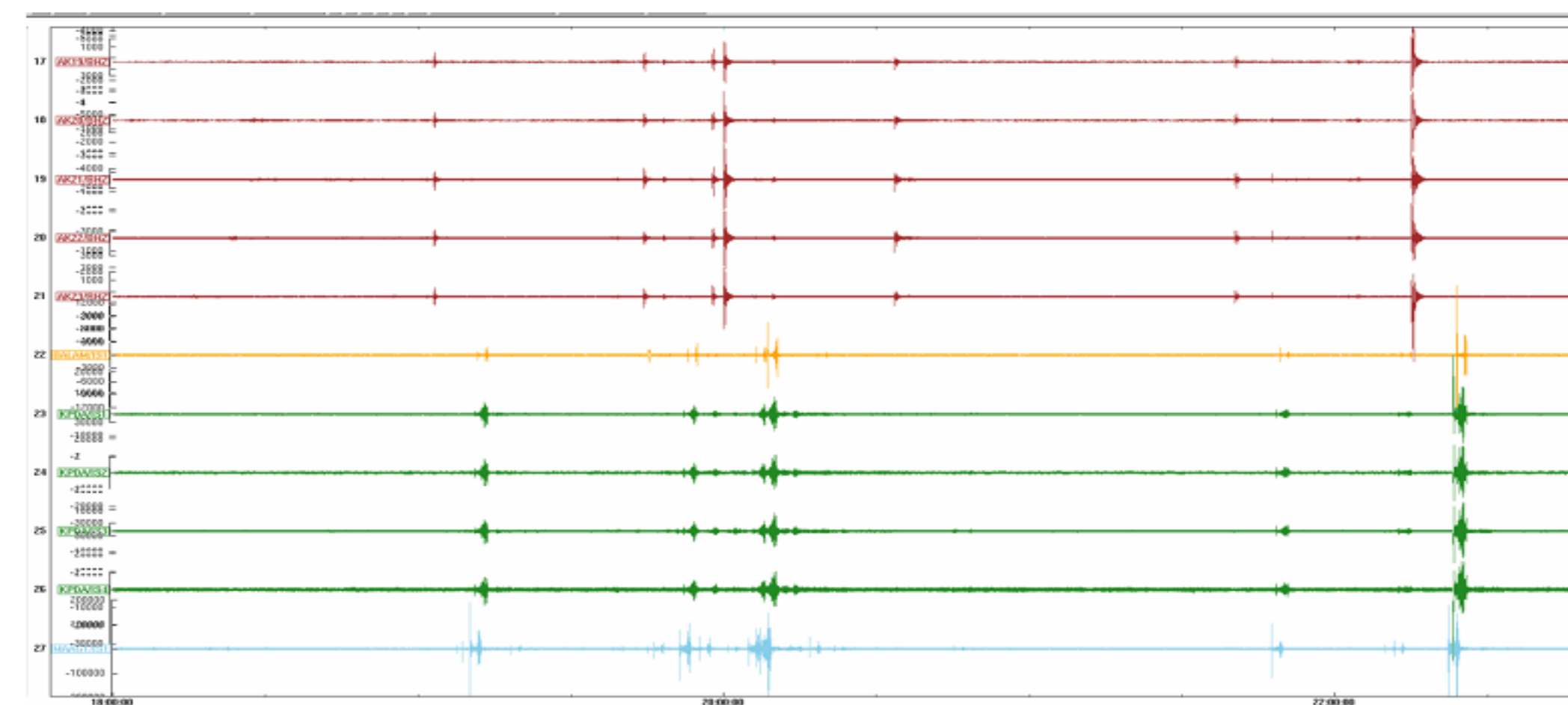


An example of the results of registration infrasonic network of explosions on the pipeline, flight and explosion of a meteorite, explosions at a chemical plant.

Explosions on gas pipelines, chemical plants, ammunition depots are classified as extraordinary anthropogenic events. Determining the place, nature of the event and its scale for assessing the consequences of an event and deciding is unquestionably an important and urgent task. The Main Centre of Special Monitoring (MCSM) organized 24/7 continuous monitoring of geophysical fields by a number of monitoring methods using a branched observation network. Events of an explosive nature are manifested primarily on the means of seismic and acoustic monitoring. A joint integrated analysis of seismic and infrasound data makes it possible to verify the source of energy excitation and to locate it, with an estimate of its intensity. The integration of seismic and infrasonic methods of recording wave fields can reliably separate ground and underground explosions, as well as distinguish events occurring in the lithosphere and hydrosphere, from various shock-explosive and geophysical perturbations that cause the generation of infrasonic waves in the lower and upper layers of the atmosphere. Consider the procedure for calculating the parameters of an emergency event using explosives at military depots on September 27, 2017, near the town of Kalinovka, Vinnytsia region.

**Instruments and Methods**

The events were recorded by a seismic network consisting of several dozen digital stations and three acoustic digital stations. Seismic stations are located in special instrumentation buildings - mines and wells at a depth of 20...120 meters. The sensitivity of the sensors is a few tens of nanometers. Frequency range: 0.05-20 Hz. The stations are three-component. In addition, the Ukrainian seismic array (PS45 according to STBTO classification) was used. The acoustic stations consist of several microbarographs spaced apart in space to form a phased array antenna. The frequency range is 0.03-10 Hz, the sensitivity is 100 Pa.



An example of recording seismic and acoustic waveforms from explosions

**Power estimation using acoustic data**

Determination of power at full record lengths for distances up to 2000 km. The calculation of power was carried out using the ratio:

$$\tau_s = 37R^2 \sqrt{q}, \quad (1)$$

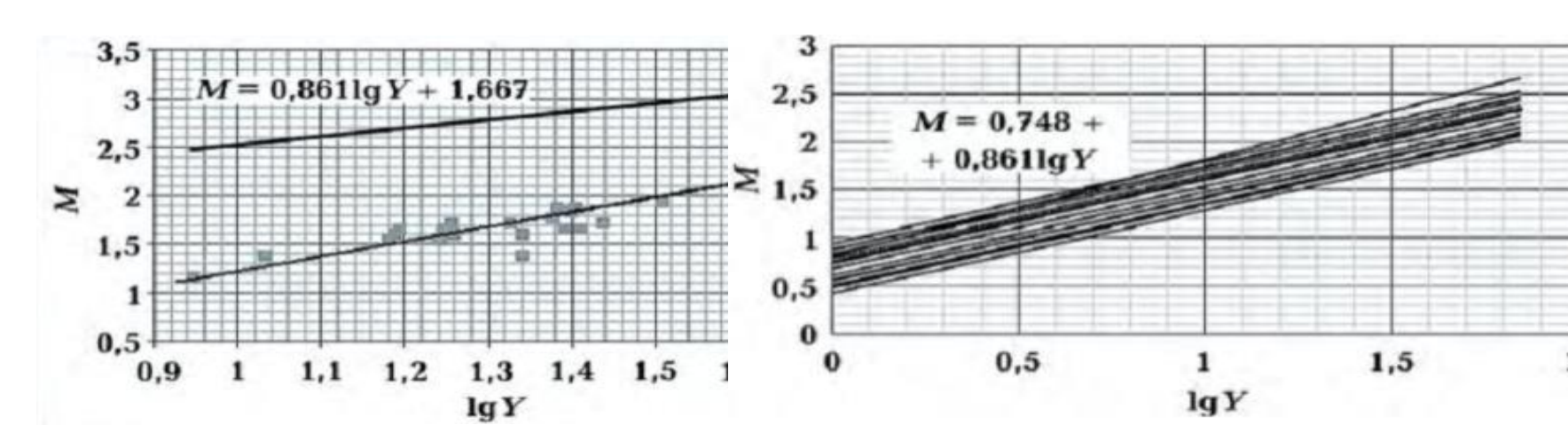
where  $\tau_s$  is the total duration of the signal in minutes, R is the distance to the epicenter of the explosion in thousand kilometers, q is the TNT in ths. tons.

From formula (1) for estimating the power q in tones we obtain:

$$q = (0.2703 \tau_s / R)^3 \quad (2)$$

Table 1 shows the rating of the power of the four most powerful explosions, calculated by the formula (2) using the data of the digital channel of the acoustic station.

No	Date	Time event	Full recording time in min.	Distance to the source. km	Blast power in tones
1	26.09.2017	22:57:14	n/a	n/a	n/a
2	26.09.2017	22:59:30	2,13	185	30,28
3	27.09.2017	01:14:44	2,52	185	49,72
4	27.09.2017	05:31:08	2,15	185	31
5	27.09.2017	08:08:31	1,73	185	16,24



Calculated power versus amplitude and experimental corrections for one of the quarries

Determination of power using parameters (amplitude of maximum difference, duration of maximum difference) of the second part of the record for the power of explosions to one megaton.

The calculation of power in tones was carried out using the ratio:

$$q = [\sqrt[3]{A^2 \tau_s}]^3, \quad (3)$$

where q is the TNT in tones,  $A^2$  is the amplitude of the maximum difference of the second part of the signal in Pa,  $\tau_s$  is the duration of the maximum difference of the second part of the signal in sec. The results are shown in tab. 2:

No	Date	Time event	Amplitude of the maximum difference of the second part of the signal in Pa	duration of the maximum difference of the second part of the signal in sec.	Blast power in tones
1.	26.09.2017	22:57:14	1,55	1,34	3,73
2.	26.09.2017	22:59:30	2,3	2,12	21,92
3.	27.09.2017	01:14:44	0,99	3,71	50,55
4.	27.09.2017	05:31:08	0,42	3,0	17,3
5.	27.09.2017	08:08:31	0,41	3,09	12,1

Determination of power over the period of the acoustic signal.

If we take the formula

$$E = 2 \left( \frac{T_0}{5.92} \right)^{3.34} \quad (4)$$

where E in kt, then for periods  $T_0 = 1 - 2$  seconds, we will get the energy of 0.0053 - 0.053 kt, or 5.53 tonnes of TNT. For various observation points, the maximum periods for the explosion 01:14:44 from 27.09.207 are from 1.9 to 2.1 seconds (45..63 tons)

**Power estimation using seismic data**

Seismic means of the GCSK registered 26 seismic signals from explosions. Determination of the power of explosions with the use of seismic data was carried out with the involvement of magnitude estimates, calculated magnitudes ML (local magnitude) and mb (magnitude by volume wave).

Determination of power using ML magnitude.

For the estimation of the power using the ML, the following relations are proposed:

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Determination of power using ML magnitude.

For the estimation of the power using the ML, the following relations are proposed:

$$q = 10^{(ML - 1.04) / 0.843} \quad (5)$$

where q is the TNT in tones, ML is the local magnitude. Table 3 shows the estimation of the power of five explosions, calculated using the formula (4) using the data of the Ukrainian seismic array.

No	Date	Time event	Magnitude ML	Blast power in tones
1	26.09.2017	22:57:14	2,0	13,76
2	26.09.2017	22:59:30	2,5	53,94
3	27.09.2017	01:14:44	2,5	53,94
4	27.09.2017	05:31:08	2,4	41,05
5	27.09.2017	08:08:33	2,1	18,09

Determination of power using magnitude mb.

For the estimation of the power using the magnitude mb, the relation is proposed:

$$q = 10^{(mb - 1.86) / 0.72} \quad (6)$$

where q is the TNT in tones, mb is the magnitude of the bulk wave.

The results obtained are similar to those in Table 3.

Several variants of remote evaluation of explosion energy are demonstrated. It is shown that the most accurate estimate can be obtained from seismic data, nevertheless, acoustic methods are acceptable, especially with the use of a period. The calculation methods are complementary and, under certain circumstances, can be used independently.

Ichnya Explosions in warehouses 10.09.2018. Top-down: infrasound and seismic signals, satellite images before and after events

