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SEISMIC MONITORING OF THE LONGWALL FACE NO. 138704 AT THE LAZY MINE*)

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ABSTRACT. In the framework of rockburst prevention system, the seismic monitoring in the eastern part of the Ostrava – Karviná Coal Mine District has been applied. The system is based on the seismological data acquisition and processing in the operational centre where data coming from three monitoring networks, i.e. experimental network at the Lazy Mine, local seismological network and seismic polygon of regional type, are gathered. Recently, a special attention has been paid to seismic monitoring of the broader area of the most productive longwall face No 138704 in the Lazy Mine. In this respect, seismoacoustic monitoring has been applied and long–term seismological data series created the conditions for application of statistical methods in data processing as well as rockburst focal mechanisms determination in case of strong seismic events induced by the coal extraction in this longwall face.

KEYWORDS: seismic monitoring, induced seismicity, statistics, focal mechanism, Ostrava–Karviná Coal Mine District

1. INTRODUCTION

At the beginning of November 1993, the longwall face No.138704 in Lazy Mine, OKD, Inc. was put into operation. This coal face is situated in the 7th tectonic block of the coal field where the seam No.38 is being mined in full thickness, i.e. in one slice of the height approximately 6 m, the very longwall is being mined using caving method.

As usually, in order to ensure the increasing safety of miners and in mining workings in the broader surrounding of the longwall face, seismic and geomechanic monitoring in the framework of rockburst preventative scheme was adopted. For the purpose of seismic monitoring, the output data of seismoacoustic system and three totally independent seismological networks operating in the mine district are been used. Long–term observations enable us to use frequency–energy relations, time dependent release of seismic energy and focal mechanisms determination of strong seismic events, as well. Solution of above mentioned problems is the subject of the paper presented.

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2. Seismic Monitoring Systems

a) seismoacoustic monitoring system

Seismoacoustic emission around the longwall face is monitored by pick–ups located in the seam and in the roof. For spatial monitoring of the longwall face, up to 15 pick–ups are applied. Substantial advantage of this network is not only the more precise hypocenter location but also the unambiguous discrimination of individual seismoacoustic signals originating in the coal seam and/or in the roof according to the shape of channel waves occurred. Similar technical and methodical approaches on seismoacoustic emission monitoring applied during the coal extraction in the longwall face No.13933 in the Mine ČSA were described by Kalenda & Slavík (1992).

b) local experimental network in the Lazy Mine

During 1990, a digital seismic network in the coal field was established. At the beginning of the coal face No.138704 operation (November 1993), the network consisted of one surface and four underground three–component stations. The digital instrumentation was developed in the Mine Institute of Czechoslovak Academy of Sciences (now Institute of Geonics, Academy of Sciences of Czech Republic); principal information concerning this monitoring system is given in Knejzlík et al. (1992). There are used output data in the shape of seismic event waveforms for further processing here, i.e. hypocenter locations, spectral analyses and focal mechanism determination. Primary interpretation in local computer center is performed.

c) local seismological network

At present, this network represents wide spread system which operates practically in all mines of the coal mine district. Due to the step–by–step construction of this monitoring system, different instrumentation was developed, tested and finally adjusted. The recent type of apparatus which has been installed at all surface as well as underground stations, is the UGA–15 instrument. The one enables automation data acquisition, preprocessing and transmission of data to the operational centre where the final processing procedures aimed at hypocenter locations and energy estimate are performed. The resulting data for practical applications are stored in the database and by using of back coupling transmitted to individual geophysical laboratories of appropriate mines. More detailed information concerning the local seismological network should be found, e.g. in Holub et al. (1993).

d) seismic polygon

The seismic polygon is a monitoring system of regional type. In principle the one is formed by ten three–component seismic stations. Three of these stations are situated underground, the rest is on the surface on test sites surrounding the whole eastern part of the Ostrava–Karviná Coal Mine District. The instrumentation was supplied by the Lennartz Electronic GmbH (Germany), its application in induced seismicity studies was described by Konečný (1989).

The seismic station layout is given in Fig. 1. Station BMZ is situated about 20 km distant from the centre of the coal basin towards the west. Its position is identical with the seismic station Ostrava (OKC) which is a part of the Czech national observing system.

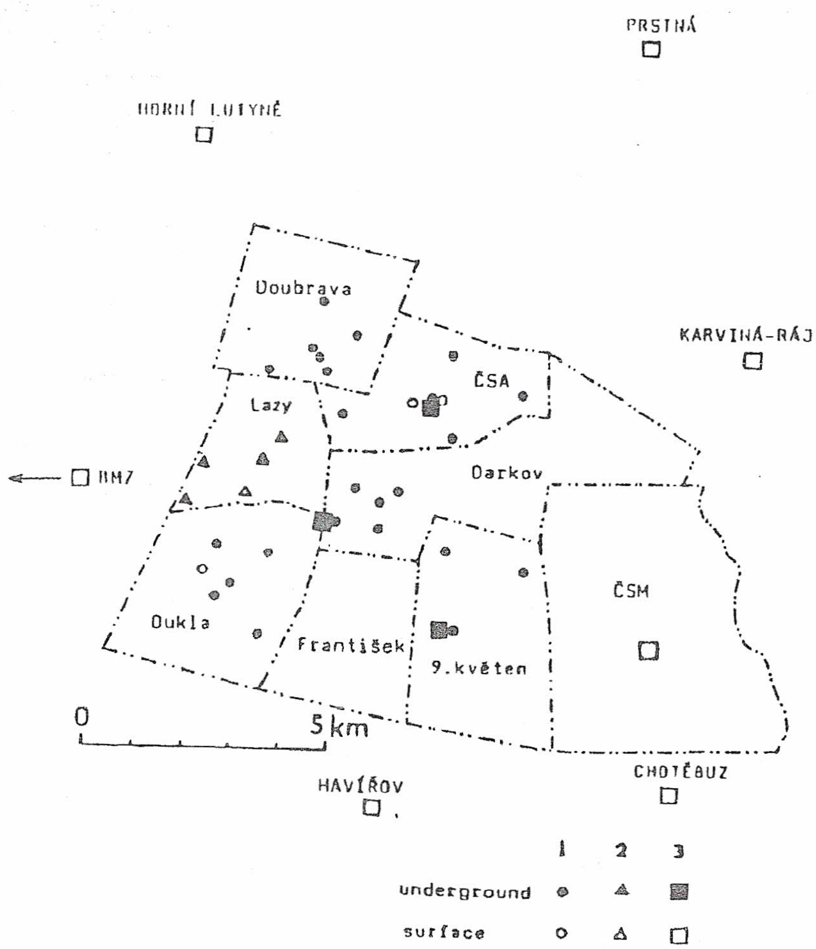

FIG. 1 Distribution of stations of monitoring systems in the Ostrava–Karviná Coal Mine District: 1 – local seismological network, 2 – local experimental network, 3 – seismic polygon.

3. METHODS OF DATA PROCESSING AND INTERPRETATION

Besides geophysical data, also the technological ones in common database are continually stored. The data contain, e.g. information concerning blasting operation, diurnal coal face advance, results of the up–to–dated seismological network and position of longwall faces. The longwall face No.138704 was in this system denotes as the region No.5710 including the area of the very longwall face enlarged by a strip having the width of 200 m in its vicinity. In course of sorting of all available data stored in the database, only those events which belonged to the region No.5710, demarcated above, were chosen for further analyses.

a) location plots

As mentioned above, higher precision of original hypocenter location performed on the basis of seismological data in combination with seismoacoustic ones was achieved, especially in vertical foci coordinate. In accordance to this fact a special database of so-called "common events" including both the seismic and seismoacoustic events was prepared. Hypocenter location plot of seismic events, whose energy was defined as $E \geq 10^3$ J with respect to the longwall face geometry and monthly coal face advance, is given in Fig. 2.

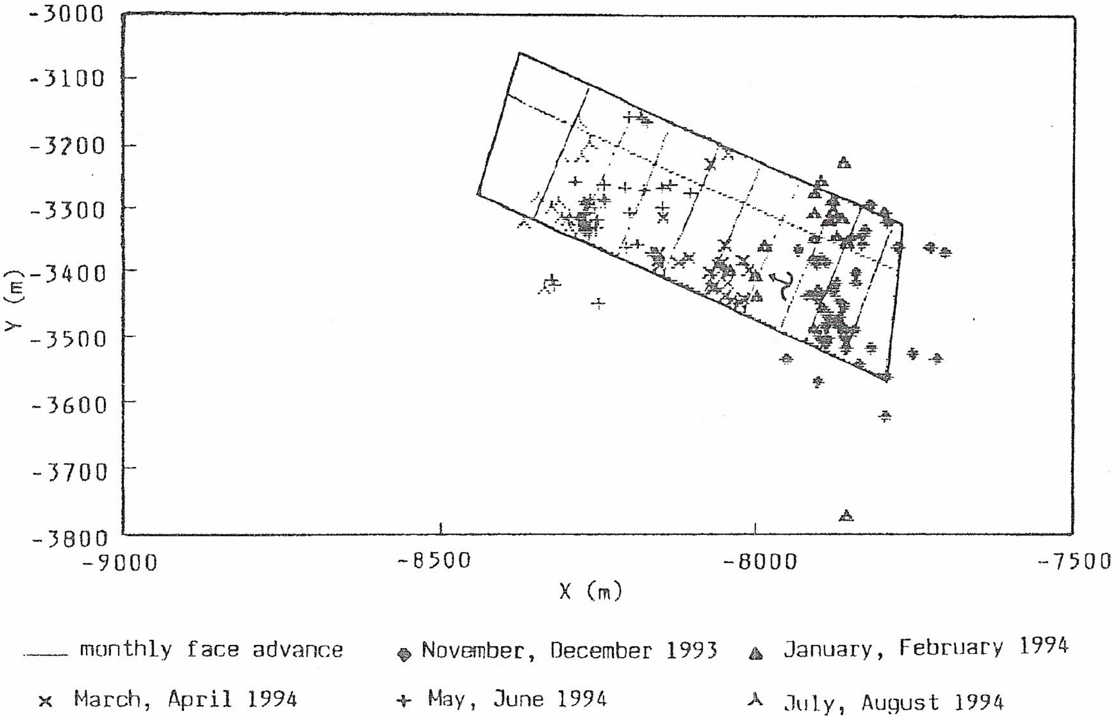

FIG. 2 Plot of seismic event hypocenters with $E \geq 10^3$ J since November 1, 1993 till August 23, 1994.

According to the plots of low energetic seismoacoustic signals, a very close response of immediate stress-strain state of rock mass influenced by the coal face advance was confirmed. On the other hand concentration of foci in a strip of the width approximately max. 80 m in front of the coal face, connected with moving of rock mass abutment pressure ahead of the coal face, was found out. On the other hand, a certain concentration of foci along the tail gate adjoined to the goaf of the mined out longwall face No.138704 was ascertained, as well. Concerning the vertical coordinate of hypocenters, the prevailing part of determined foci occurred above the seam (approximately less than 10 m), while the number of foci located in higher overlying strata (approximately max. 50–70 m) displayed a decay with respect to increasing value of vertical coordinate towards the surface.

b) Benioff's graph

The long–term process of the seismic energy release during the longwall face No.138704 operation is given in Fig. 3. On the cumulative graph there could be distinguished several segments with different slopes confirmed in daily slopes graph, as well.

The first period (I) in the cumulative graph during October 1993 connected with preparation phase of mining activities in the longwall face was characterized by the moderate increase of seismic activity pronounced by the slope lesser than $40\,J^{1/2}$/day. The following period (II) during November, joined with the beginning of mining operations in the longwall face, was reflected in the graph by steep slope of the value up to $280\,J^{1/2}$/day. Further time interval (III), approximately till the first half of December when the fully developed longwall face was achieved (slope proportionate to $380\,J^{1/2}$/day) was followed by the stoppage of longwall face advance from the second half of December till the second decade of January (IV). This interruption of coal extraction induced a reduction of the intensity of seismic energy radiation and was followed by decay of the slope values 30–120 $J^{1/2}$/day. After the restarting of mining activity in the longwall face, the seismic energy radiation was featured by a relatively regular increase. Slight oscillations of the summation curve caused due to the short–time interruption of mining activities and their restarts were pronounced by oscillating character of the Benioff's graph (V). The daily slopes did not exceed the value of $230\,J^{1/2}$/day. For detailed analysis of seismic energy release in the geomechanical practice, daily gradient or weekly slope values of the cumulative Benioff's diagrams are being used.

c) frequency–energy distribution

Seismic energy release in the given area could be described by a linear function

$$\log N = a - b \log E \,,$$

where N is the number of seismic events, E is the amount of released energy, a and b are absolute term and slope of approximating straight line, respectively. For calculation of the functional dependence $N(E)$, the least squares solution was applied. In general, the b value quantifies the mutual ratio of events with low and high energies thus it characterizes the seismic hazard estimate for regions assumed. Using the long–term seismological observations for the whole Ostrava–Karviná Coal Mine District, annual b–values during the period 1989–1992 $b = 0.68 - 0.94$ were ascertained. For the same time interval in the Lazy Mine $b = 0.82 - 1.04$ were determined. In course of detailed study of the b–value variations in the 7^{th} tectonic block of the Lazy Mine during the period since January 1989 till July 1993, $b = 1.14$, which according to Holub et al. (1993) corresponds to a relatively safe region with respect to seismic hazard assessment. A special attention paid to the longwall face No.138704 was concentrated to the analysis of the frequency–energy distributions. As an example of b–value changes during the coal extraction in this longwall face, the monthly b–values for seismic events with energy estimate

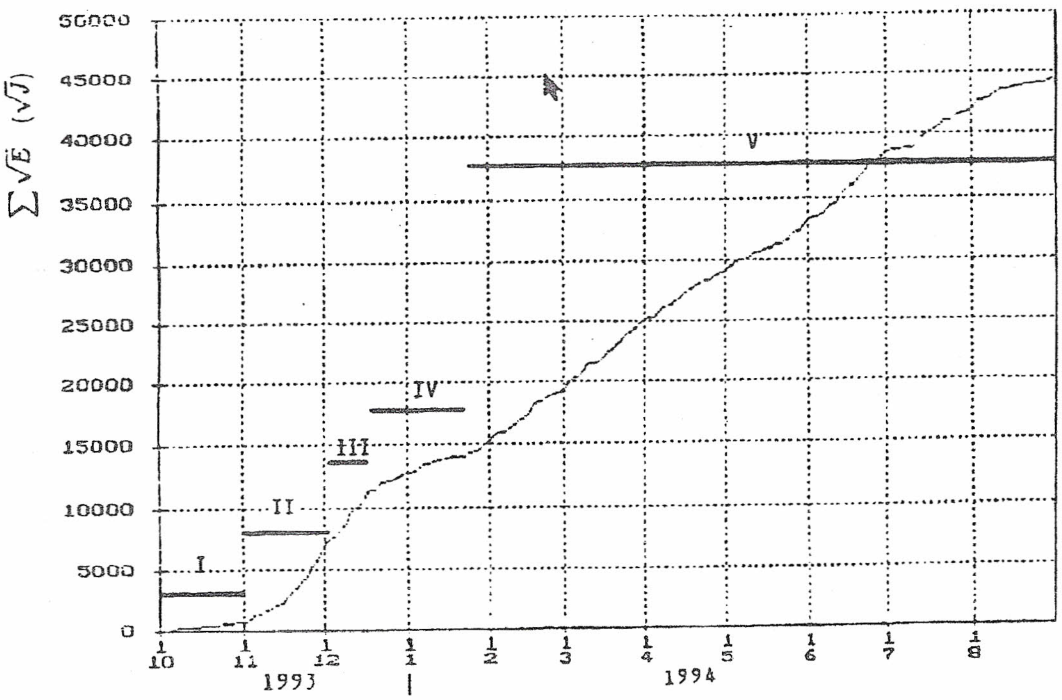

FIG. 3 Benioff's graph featuring the longwall face No.138704 operation since October 1, 1993 till August 31, 1994. Time intervals denoted by Roman numbers correspond to individual phases of the seismic activity development confronted with mining operations.

TABLE 1. A review of a and b values calculated.

	Oct. 1993	Nov. 1993	Dec. 1993	Jan. 1994	Feb. 1994	Mar. 1994	Apr. 1994	May 1994	June 1994	July 1994	Aug. 1994
N	55	398	443	183	265	267	275	230	304	182	125
a	2.49	3.97	4.08	3.74	3.50	2.63	3.73	3.94	3.34	3.04	2.37
b	0.68	0.91	0.92	0.97	0.78	0.45	0.88	0.95	0.68	0.66	0.49
$r_{E,N}$	0.99	0.96	0.99	0.95	0.94	0.91	0.89	0.80	0.93	0.83	0.87

$E \geq 10^2$ J were calculated. The results are given in Table. 1, where $r_{E,N}$ is the correlation coefficient.

From the Table. 1. one implies that omitting the data from October 1993 due small number of events recorded ($N = 55$), during the following months b – values varied within the range of values $b = 0.45$–0.95. When comparing the b – values with the level of seismic activity, there is obvious that a relatively serious occurring in March and August 1994 corresponds to the lower b – values. In Fig. 4, the resulting frequency–energy distribution is shown. The approximating straight line for the

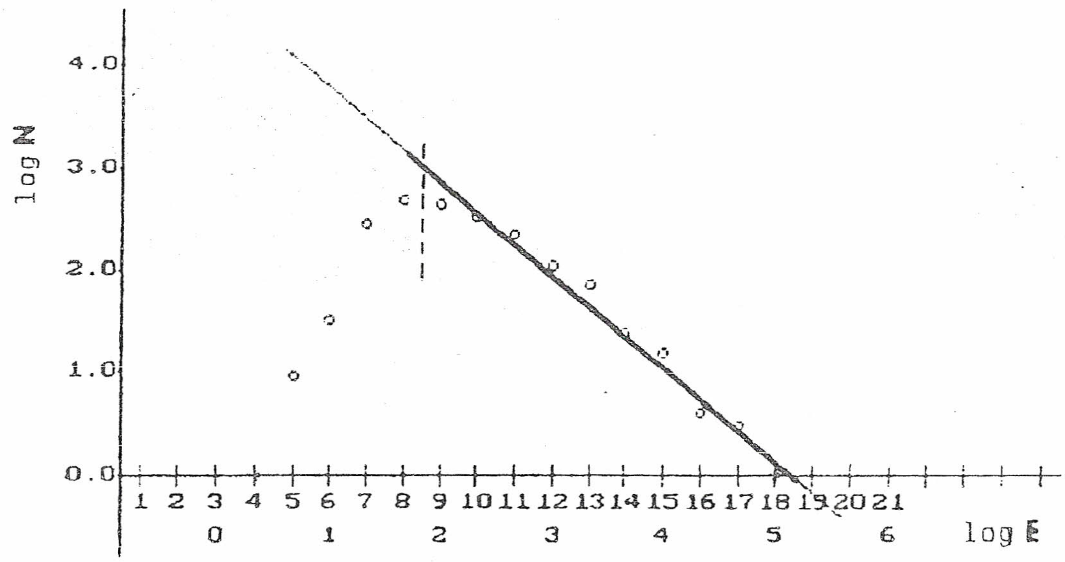

FIG. 4 Frequency–energy distribution of the seismic events induced by coal extraction in the longwall face No.138704. The parameters of approximating straight line were calculated for seismic events with energetic size $E \geq 10^2$ J.

time interval since October 1, 1993 till August 31, 1994 is defined by the formula

$$\log N = 4.70 - 0.91 \log E \, .$$

The equation given could be interpreted also in the manner of the recurrence time series, on the basis of which seismic event with prescribed energy could be expected.

d) rockburst focal mechanism

The method of investigation of the first motion amplitudes P – wave onsets, used for rockburst focal mechanism determination is based on the digital data application [Kaláb et al. 1991; Veselá & Staš 1992]. The reliable solution of this problem assumes the satisfactory number of observation sites and their optimum spatial distribution around the focus.

With respect to fulfilling presumed conditions for rockburst focal mechanism determination, data (waveforms) of the local experimental network in the Lazy Mine as well as data of seismic polygon have been usually applied. In course of computations, the velocity – depth function for model denoted as "mech 6. mod" was introduced [Veselá 1994]. During the appropriate waveform analysis of the stronger events ($E \geq 10^3$ J), there was ascertained, that identical types of seismic events in close overlying strata of longwall face and/or in the higher overburden, respectively, do occur. Another group of seismic events displaying different character of waveform originated since the second half of May, could be set down to the fact that the coal face was advanced into the region influenced by edges of unmined seams (remnant pillars) in the roof of the seam No.38. Besides it, there do exist some

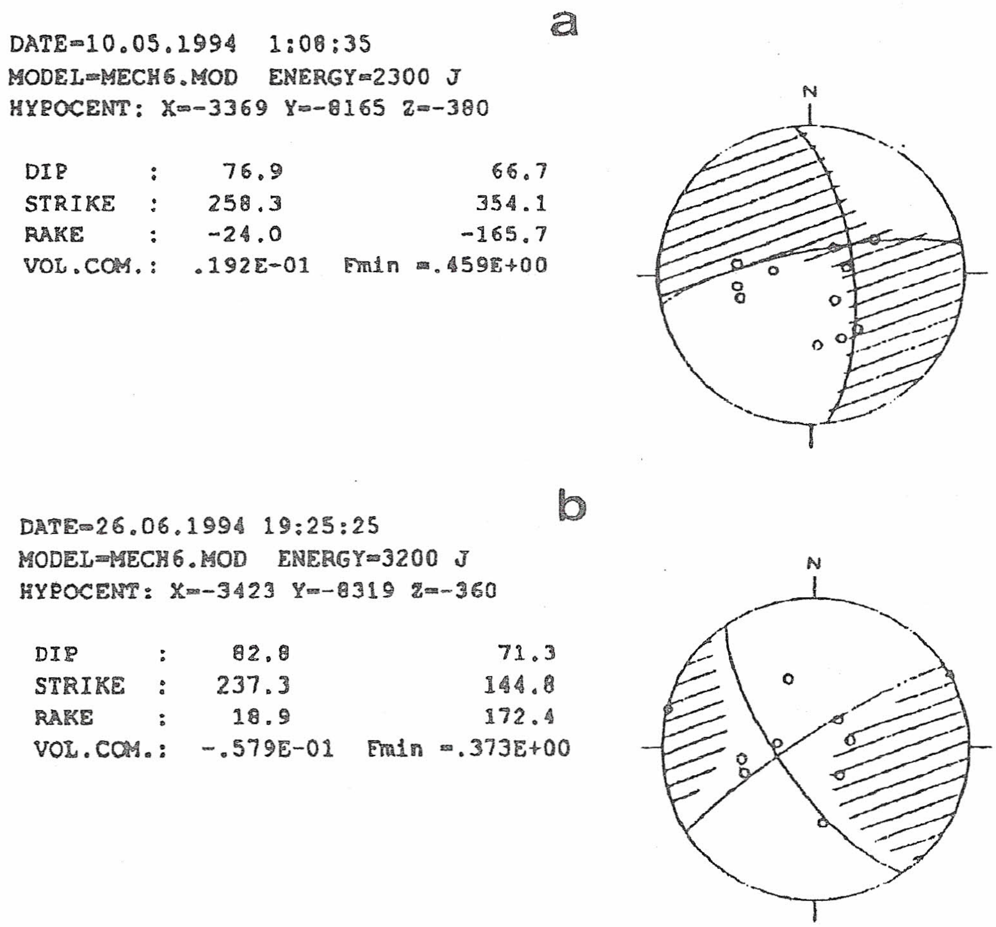

FIG. 5 Examples of focal mechanisms determination of seismic events originating in the close of the coalface (a) and/or higher overlying strata (b).

seismic events which could not be arrayed into any group discussed above. According to theoretical assumptions, the distribution of seismic events gained by means of the waveform type analysis would create identical distribution groups based on the character of the rockburst focal mechanism.

4. CONCLUSION

The operation of longwall face No.138704 in the Lazy Mine has induced seismic energy radiation due to the fracturing process in the rock mass. In respect to the importance of continuous checking the stress–strain state in the broader surrounding of mine workings, the seismic monitoring was introduced. Though, the mining operations in the longwall face have not been finished yet, some general conclusions from the contemporary experience of its operation can be withdrawn as follows:

- during the seismic monitoring of the longwall face, the utility of common use of seismoacoustic and seismological observations was proved, especially in foci coordinates precision;

- long–term seismoacoustic observation aimed at investigation of low–energetic seismic events confirmed the foci clustering above all in front of the coal face up to distances of about 80 m and along the demarcation between the tail gate and mined–out longwall face;
- a rough estimate of the foci vertical coordinate by means of seismoacoustic signal waveform can be performed;
- Benioff's graph reflects all changes and influences concerning the seismic energy release in respect of different phases of mining operation in the longwall face;
- for detailed analysis of the process of seismic energy release, besides the Benioff's graph its diurnal gradient and/or weekly slope seems to be very useful;
- with respect to analyses of frequency–energy distributions, significant changes of their slopes were ascertained. The minimum b – values of 0.45 – 0.48 in the time–period of dangerous rock mass state and the maximum b – values of 0.91 – 0.97 for the quiescent state were found out;
- for focal mechanism determination data from local experimental network were not sufficient, therefore data gained from seismic polygon were also applied;
- results of fault–plane solutions for stronger seismic events indicated the existence of several groups of events with identical and/or similar source characteristics. The most numerous group involved those events the foci of which originated in the zone of the close overlying strata of the longwall face.

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