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PRELIMINARY RESULTS OF b–VALUES ANALYSIS FOR MINING–INDUCED SEISMIC EVENTS

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ABSTRACT. The relation between the number of events N and their energetic size is one of the basic relations of earthquakes or mining–induced seismic events statistics. As an example, the analysis of frequency–energy distribution of seismic events, which were induced by coal extraction in the longwall coal face and which were contained in the database, is presented.

KEYWORDS: coal mining, induced seismicity, frequency–energy distribution, the Ostrava–Karviná Coal Mine District

1. INTRODUCTION

The long–term observations of induced seismicity development using data of the local seismological network in the eastern part of the Ostrava–Karviná Coal Mine District (Czech Republic) have proved, that in individual coal mine fields, tectonic blocks and/or in wider surrounding of the mined coal faces, respectively, the development of seismic activity had have its own specific features [Holub et al., 1993]. The differences between individual regions under investigation are being ascertained in the process of detailed analysis of separate induced seismicity parameters. These parameters have been usually presented using different ways, e.g. hypocenter plots, Benioff's graph with graph of its average slope and diurnal increment, frequency–energy distribution, Gumbel's functions etc..

Recently, a considerable attention was paid to seismic activity development in the wider surrounding area of one coal face in the Lazy Mine where the seam is being mined in full thickness, i.e. in one slice approximately 6 m height. A detailed investigation of mining–induced seismicity in the region was performed using a special statistical processing method, i.e. changes of frequency–energy distribution of seismic events. Subject of the present paper is some preliminary results achieved.

2. METHOD OF SEISMOLOGICAL DATA PROCESSING

The relation among the frequency of events N and their size parameter, which could be characterized here as the amount of released seismic energy E(J), should be approximated in bilogarithmic scale by linear function according to the formula

$$\log N = a - b \log E \,. \tag{1}$$

The parameter b (b–value) in the Eq. 1 generally describes the mutual ratio of weak and strong seismic events, while the parameter a in a certain sense determinates the seismic regime level in the area under investigation. In order to ensure the homogeneity of energetic level determination of individual induced events during their sorting, the whole energetic spectrum was divided into energetic classes C, whose relation to the categories of released seismic energy E has been defined by the following expression

$$\log 0.15 + (C-1)/3 < \log E < \log 0.15 + C/3 \,. \tag{2}$$

According to the expression (2), the frequency–energy relation was calculated. The corresponding frequency of seismic events N contained in the database of the local seismological network was attributed to every energetic class. Using this database and appropriate software, statistical analyses of frequency–energy distributions with respect to different time intervals were performed (Slavík et al. 1992). Based on calculations carried out and on their graphical displaying, as well, there was stated that the dependence graphs of $N(E)$ have specific pattern, namely within the intervals of energies $\log E < 2$ and $\log E > 4$. This fact was further taken into account in defining the energetic class ranges, for which the frequency–energy distributions were determined.

3. PRELIMINARY RESULTS OF STATISTICAL DATA PROCESSING

From the long-term observations of induced seismicity in the Ostrava–Karviná Coal Mine District implied that the Lazy Mine is with respect to the strong seismic events occurrence relatively safe (appreciated according to the slope of the frequency–energy distribution). During the time period from January 1989 till December 1993, the average value of $b = 1.04$ was ascertained, while during 1989–1993, the b–value ranged 0.82–1.04. According to similar calculation made for the 7$^{\text{th}}$ tectonic block within the time interval of $4\frac{1}{2}$ years (from January 1989 till June 1993) only b–value of 1.14 was determined.

After beginning of the operation of the coal face, the geophysical monitoring in its wider neighbourhood started. The graph of seismic events distribution according to the seismic energy release for $E \geq 10^2$ J or $C \geq 9$, respectively, is given in Fig. 1. During the gradual completion of seismic events database and in course of repeated computations of functions $N(E)$, there was noted that successive raise of strong events caused gradual changes of b–value, i.e. gradual change of the approximated straight line slope. During the monthly evaluation of distributions, an instability of recurrence series of these strong events was pronounced (see Fig. 2). This instability creates greater deviations as to calculated approximating regression straight lines. The accuracy of approximation is usually estimated by the coefficient of correlation r. For analytical determination of parameters a and b of the frequency–energy distribution discussed at this stage of investigation, only seismic events which were quantified by the values of released seismic energy within the limits of $E \div 100$–2150 J, were used.

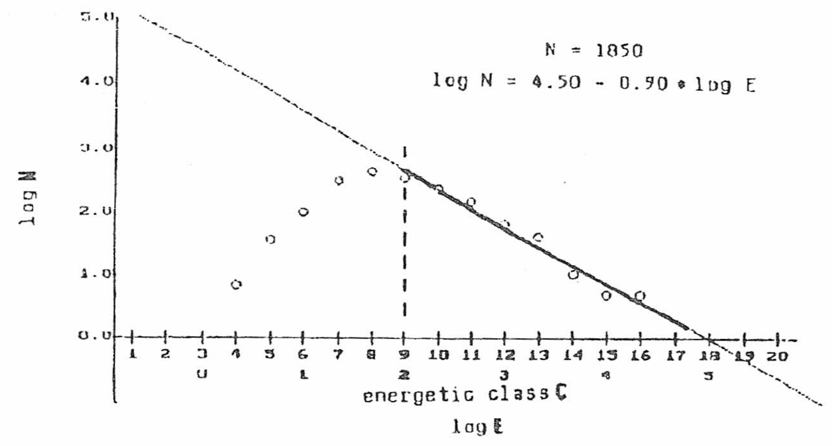

FIG. 1. Example of frequency–energy distribution of mining–induced seismic events for the wider neighbourhood of the coal longwall face in the time period from October 27, 1993 till March 17, 1994.

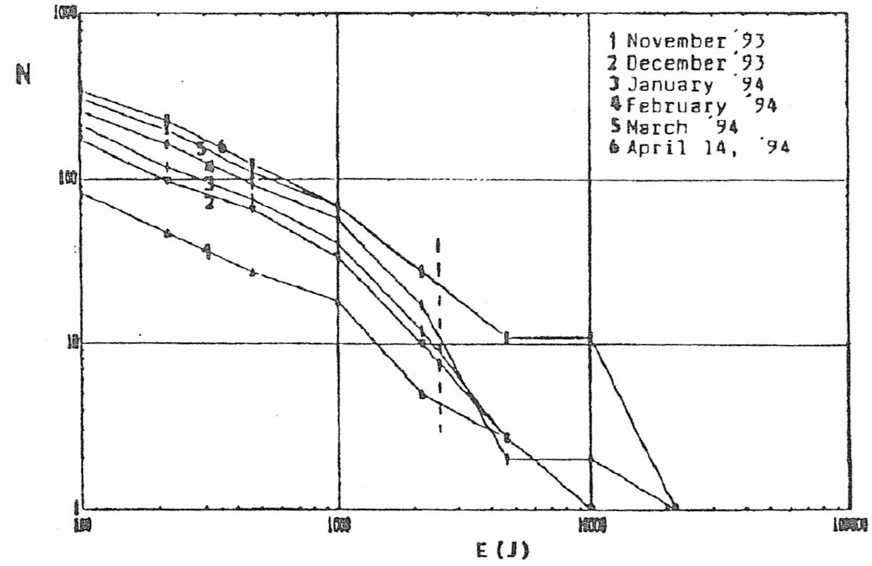

FIG. 2. Frequency–energy distributions of the seismic events for the individual months.

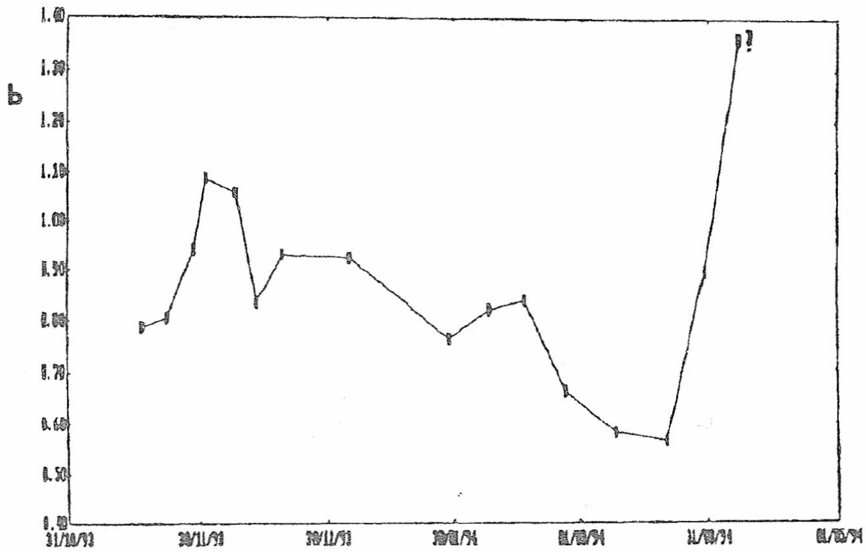

FIG. 3. Time dependent changes of b–values within the time interval from November 1993 till April 14, 1994.

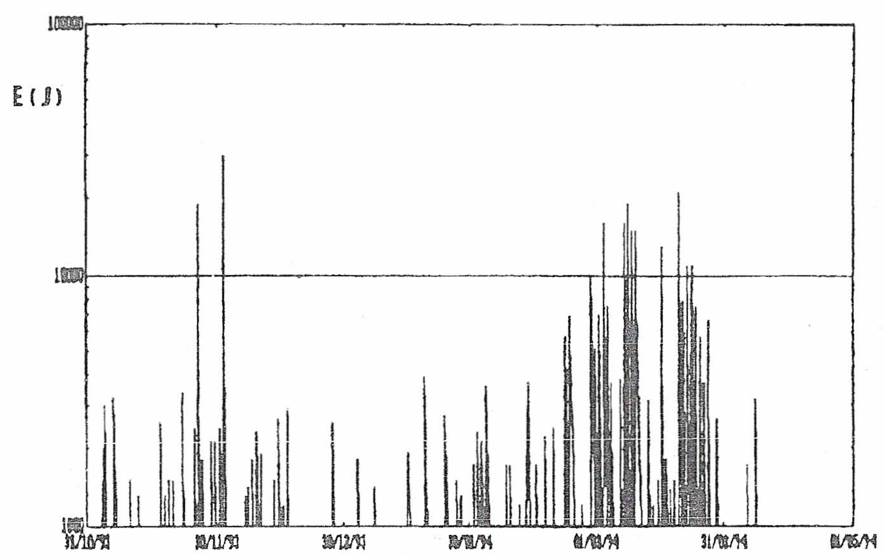

FIG. 4. Time development of seismic events of $E \geq 10^3$ J (November 1993 – April 14, 1994).

Further step of statistical set evaluation relied upon its dividing into individual subsets, so that every of them contained only 100 seismic events. Following calculations were conducted using the moving window of $\triangle N = 50$ events. The chosen procedure applied, e.g. by Gibowicz (1979) and Syrek (1992), in its consequences caused that the original data set fulfilling the criteria of energetic classification accepted was divided into 16 subsets including seismic events observed during a time period from November 1993 till April 14, 1994. Due to the fact that the last subset contained 90 events only, the resulting b–value ($b = 1.36$) seemed not be correct and comparable with other data and therefore was omitted. For every distribution (window), basic parameters, i.e. range of seismic events consecutive number, absolute values of a and slopes of straight line (b–values) are introduced. In Fig. 3 the graph of resulting time dependent b–value is represented, while seismic activity development for the same time period is given in Fig. 4.

4. CONCLUSION

Based on preliminary results of frequency–energy distribution analysis for the seismic events occurring in the wider area of the coal longwall face in the Lazy Mine, following conclusions could be drawn:

- in 15 subsets of seismological data, the slope of frequency–energy distribution (b–value) varied within the limits 0.56–1.09, while the corresponding coefficients of correlation $r \div 0.852$–0.999 were determined;
- the raised number of strong seismic events and consequently the higher hazard of a strong rockburst occurrence during March 1994 corresponded to low and reduced b–values, i.e. in the time when the coal face was in the phase of fully developed operation;
- high and raised b–values were observed within the time interval of low seismic activity level, with exception of the starting phase of the coal face operation during November 1993.

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