

SPECTRAL INVESTIGATION OF THE MINING INDUCED SEISMIC EVENTS IN THE LAZY MINE

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ABSTRACT. Data from both experimental digital seismic networks in the Lazy Mine and Frenštát network of the Regional Seismic Polygon were used. In this research task, about 30 mining induced seismic events were analyzed that originated during 1995 year in 1st block of Lazy Mine, Czech part of the Upper Silesian hard-coal basin. Source parameters of these seismic events ($0.5 \leq M_L \leq 2.0$) are calculated using spectral analysis of S-waves. Hypocentral distance was respectively in range 0.5–7 km and 21–38 km. Correlations of source parameters are linear with high values of the correlation coefficient except this one with source dimension.

KEYWORDS: mining induced seismic events, spectral analysis, source parameters

1. INTRODUCTION

The investigation reported here is focused on a search for spectral analysis of mining induced seismic events in the Ostrava–Karviná coal basin (OKCB). The OKCB is located in the southern part of the Upper Silesian basin. Exploitation of the hard coal found in this basin requires intensive mining activity that induced seismic activity. Altogether, the occurrence of about 200 mining induced seismic events with local magnitude $M_L \geq 1$ are documented annually. Mining induced seismic events originating in the 1st block of the Lazy Mine in this area were selected for this study. Data recorded both by experimental digital seismic network in Lazy Mine and Frenštát network of the Regional Seismic Polygon ($0.5 \leq M_L \leq 2.0$) were used.

2. SEISMIC MONITORING SYSTEM

The development and present state of seismological monitoring in the OKCB are given, e.g. in [Kaláb et al. 1994]. In this contribution, materials utilizing the records both of the experimental digital seismic network in Lazy Mine (formerly Zápotocký Mine) and Frenštát network of the Regional Seismic Polygon are used.

Experimental digital seismic network in Lazy mine

This seismic network has been put into operation in November 1989. Continuous registration of seismic phenomena has been functioning since the beginning of 1990. The seismic network consists of eight stations maximum and a PC computer

based data processing and analysis system [Knejzlík et al. 1992]. At present, five underground and one surface three-component seismic stations are operated. The network has been installed in the area 2×1.5 km in the Lazy Colliery. There are seismometers S5S and telemetric transmitter PCM3-T/Tx placed at the surface station. Digital signals from surface station are transmitted via telephone line to telemetric receiver PCM3-T/Rx in the central recording station. At the underground stations, there are seismometers SM3-JB, which are connected by cable to intrinsically safe inputs of apparatuses PCM3-JB.

The modular system of used digital seismic apparatuses PCM3 ensures digitalization of analog signal from seismometers in the frequency band 0.01–30 Hz in dynamic range of 90 dB and its digital signal transmission and recording. The sampling frequency is 100 Hz. The recording system ensures the acquisition of data from individual PCM3 apparatuses, the formatting of these data and their recording on a PC and a standard computer magnetic tape together with the DCF 77.5 kHz time code. The recording

Frenštát network of the Regional Seismic Polygon

A continuous registration of seismic events has been functioning since the beginning of 1992. The network consists of 5 three-component surface seismic stations with radio telemetric data transmission into a central recording station [Knejzlík, Zamazal 1992]. Seismic stations are located in Frenštát area i.e. about 30 km to the south from the OKCB. At the seismic stations, oriented WDS-202 seismometers are installed in boreholes in the depth of 30 m. Analog seismic signals are amplified, digitalized and transmitted by radio channel to relay station and then to central recording station. The used digital floating point code (tissa, 4 bits exponent) enables the transmission of signals in the dynamic range of 120 dB (MSB/LSB). The sampling frequency is 125 Hz, frequency range is 2–30 Hz. The fast time code generator is synchronized by received time code DCF 77.5 kHz. Data processing unit and recording unit are based on PC computers. For trigger the STA/LTA algorithm is used and a coincidence of trigger symptoms of individual stations in particular time window.

Software for data interpretation

The seismological analysis system called WAVE is implemented on PC computer. Software is working under WINDOWS system. It was developed in the Institute of Geonics of AS CR and consists of the following programs:

- analysis of waveforms,
- location of seismic events (Hypocent),
- spectral analysis (FFT, discrete Fourier transformation, determination of harmonic components),
- polarization analysis,
- analysis of focal mechanism (inversion of first P-wave amplitude),
- storage in local and main database files.

3. DATA SET AND SOURCE PARAMETERS

Analyzed data set contained 27 mining induced seismic events with energy between $8.9 \cdot 10^2$ and $1 \cdot 10^6$ J occurring in 1st tectonic block in 1995 (Fig. 1). These energies are calculated in the Seismological centrum in the CSA Mine [Holub, Veselá 1995], i.e. local magnitude between 0.5 and 2.1. Source area of these events is about 400×400 m. Data from both above mentioned seismic systems are taken into account. Seismic stations of seismic network Lazy Mine and Frenštát network are located respectively from focus area in range 0.5–2.1 km and 21–38 km. Examples of analyzed waveforms are on Fig. 2.

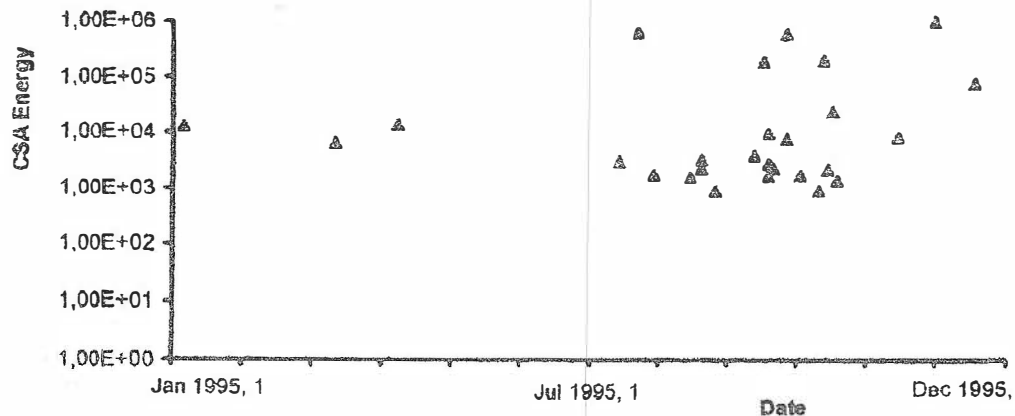


FIG. 1. Distribution of mining induced seismic events originated in 1st block of the Lazy Mine that were recorded by Frenštát network of the Regional Seismic Polygon

The spectral parameters were estimated directly from the spectra of the S-wave. Except the nearest stations of the seismic network spectra were obtained (Fig. 3). Therefore, simple source models in the form of a circular dislocation can be used successfully for the interpretation and calculation of source parameters. We usually use three-dimensional records, therefore, spectrum of signal Ω is calculated by the equation:

$$\Omega = (\Omega_Z^2 + \Omega_{EW}^2 + \Omega_{NS}^2)^{1/2}$$

To correct the ground velocity spectra for attenuation and scattering, they were multiplied by the term $\exp(\omega R/Q\beta)$, where $\omega = 2\pi f$, f is the frequency, R is the epicentral distance, Q is the attenuation factor (for this study in range 50 to 500) and β is the shear velocity (in this study $2.7 \text{ km}\cdot\text{s}^{-1}$). The spectra clearly display low- and high-frequency trend and it is possible to approximate them by two lines. In the case of event of complex type, may be composed of several subevents, the spectra are rather difficult to analyze because trends are not as well defined.

The basic relations for the source radius (Madariaga's model) r_0 , the seismic moment M_0 , the stress drop $\Delta\delta$, the average displacement D_0 and the seismic energy E_S are published in many contributions, e.g. [Gibowicz, Kijko 1993]. The

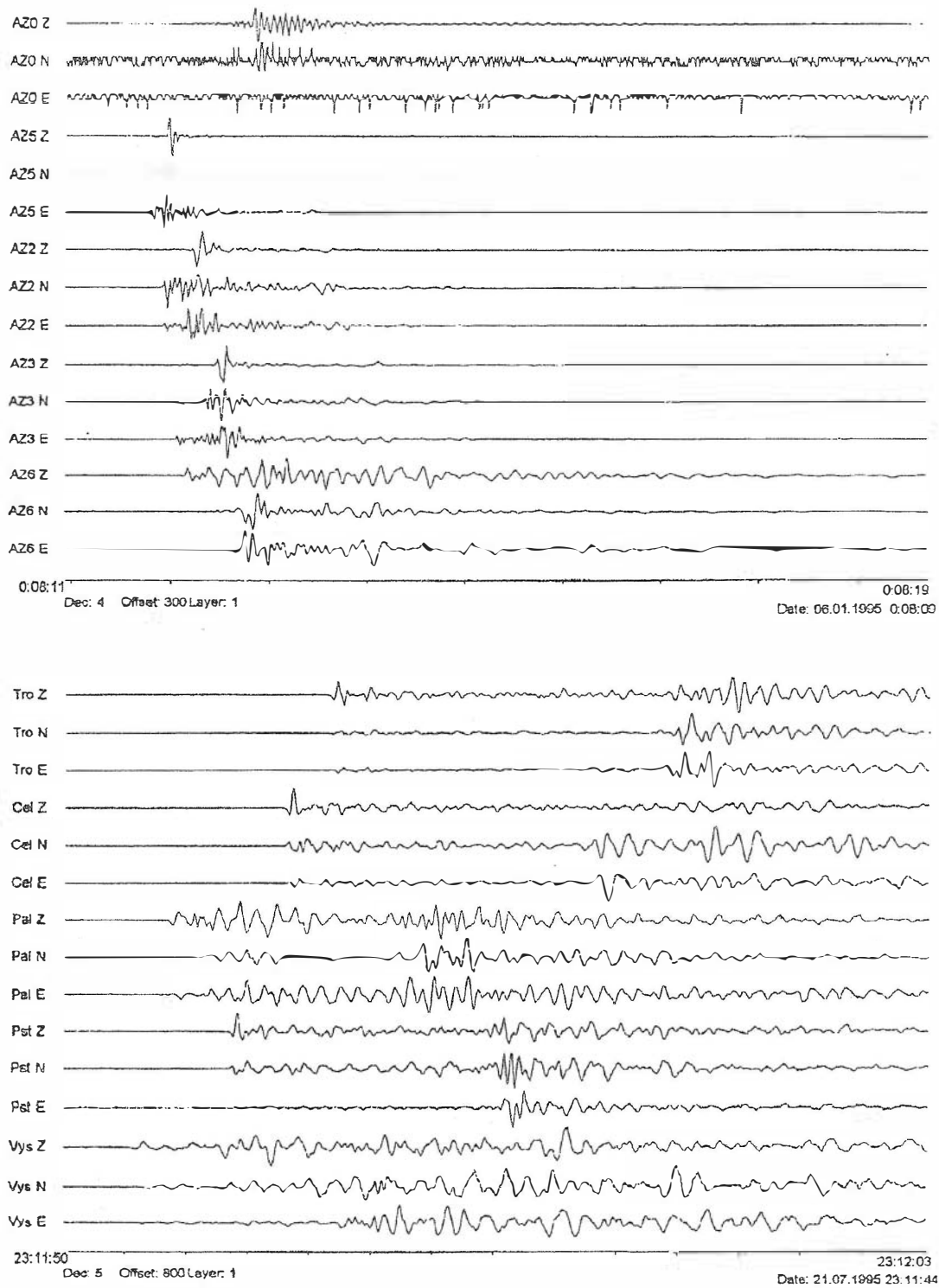


FIG. 2. Example of waveform of seismic event recorded by experimental seismic network in the Lazy Mine (upper part) and by Frenštát network of the Regional Seismic Polygon (lower part)

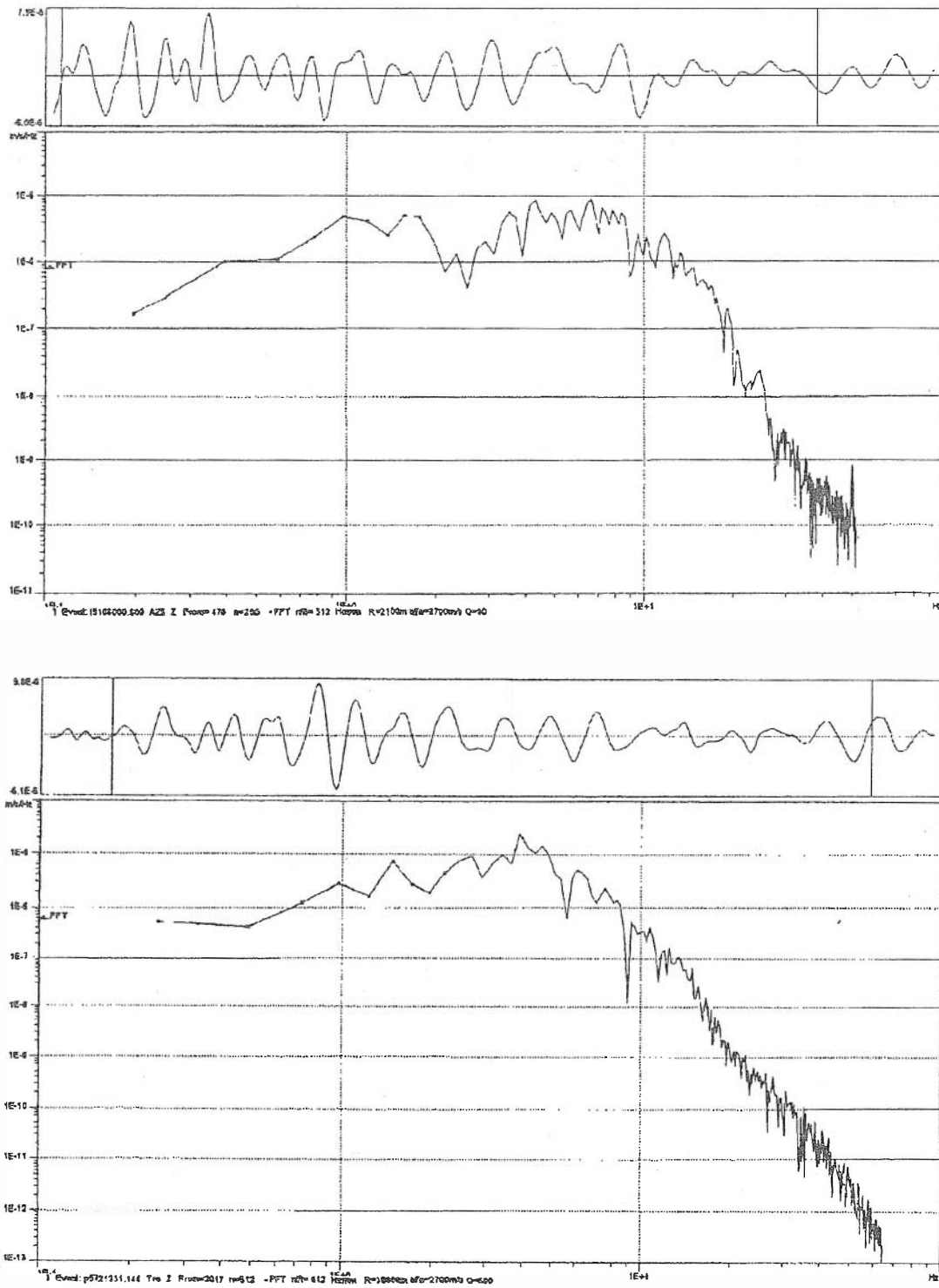


FIG. 3. Example of spectrum, vertical component of seismic event recorded by experimental seismic network in the Lazy Mine (upper part) and by Frenštát network of the Regional Seismic Polygon (lower part)

following values were accepted: the medium density 2700 kg.m^{-3} , the shear modulus in the source $2 \cdot 10^{10} \text{ N.m}^{-2}$, the radiation pattern 0.63. The values of source parameters for data set are listed in Tab.1. The values of source radius, seismic moment, stress drop, average displacement and seismic energy for this data set range between 64–138 m, $7.95\text{E}+09$ – $9.96\text{E}+11$ N.m, $4.83\text{E}+03$ – $5.00\text{E}+05$ Pa, $1.37\text{E}-05$ – $1.07\text{E}-03$ m and $7.99\text{E}+01$ – $1.01\text{E}+06$ J, respectively.

TAB. 1. Source parameters of mining induced seismic events, Lazy Mine, 1st block

Event-date	M_L	M_0	r_0	$\Delta\sigma$	D_0	E_S	E_{CSA}
1995, 6.1.	1.1	3.71E+10	80	3.18E+04	9.24E-05	3.75E+03	1.30E+04
1995, 12.3.	0.9	3.18E+10	79	2.84E+04	8.15E-05	2.87E+03	6.60E+03
1995, 8.4.	1.1	4.13E+10	87	2.72E+04	8.63E-05	3.57E+03	1.40E+04
1995, 13.7.	0.7	2.65E+10	73	3.01E+04	7.97E-05	2.54E+03	3.10E+03
1995, 21.7.	1.9	6.36E+11	82	5.00E+05	1.50E-03	1.01E+06	6.30E+05
1995, 28.7.	0.9	3.18E+10	78	2.96E+04	8.37E-05	3.00E+03	6.40E+03
1995, 13.8.	0.6	1.06E+10	82	8.33E+03	2.49E-05	2.81E+02	1.60E+03
1995, 18.8.	0.8	1.05E+10	64	1.71E+04	4.02E-05	5.71E+02	3.30E+03
1995, 18.8.	0.7	1.80E+10	86	1.24E+04	3.88E-05	7.11E+02	2.30E+03
1995, 24.8.	0.5	5.19E+09	78	4.83E+03	1.37E-05	7.99E+01	8.90E+02
1995, 10.9.	0.8	3.18E+10	73	3.61E+04	9.56E-05	3.65E+03	4.00E+03
1995, 14.9.	1.7	3.18E+11	90	1.90E+05	6.24E-04	1.93E+05	1.90E+05
1995, 16.9.	0.6	1.48E+10	78	1.38E+04	3.91E-05	6.52E+02	1.70E+03
1995, 16.9.	0.7	1.59E+10	79	1.42E+04	4.07E-05	7.18E+02	2.80E+03
1995, 16.9.	1.0	3.18E+10	70	4.04E+04	1.03E-04	4.09E+03	1.00E+04
1995, 18.9.	0.7	1.80E+10	78	1.68E+04	4.75E-05	9.62E+02	2.30E+03
1995, 24.9.	1.9	4.56E+11	82	3.58E+05	1.07E-03	5.20E+05	6.00E+05
1995, 24.9.	1.0	2.54E+10	79	2.27E+04	6.52E-05	1.84E+03	8.10E+03
1995, 30.9.	0.6	7.95E+09	80	6.81E+03	1.98E-05	1.72E+02	1.80E+03
1995, 8.10.	0.5	1.70E+10	79	1.51E+04	4.34E-05	8.17E+02	9.10E+02
1995, 10.10.	1.7	2.54E+11	82	2.00E+05	5.99E-04	1.62E+05	2.00E+05
1995, 12.10.	0.7	3.18E+10	87	2.09E+04	6.64E-05	2.11E+03	2.30E+03
1995, 14.10.	1.3	5.40E+10	72	6.38E+04	1.67E-04	1.10E+04	3.00E+04
1995, 16.10.	0.6	1.70E+10	92	9.67E+03	3.22E-05	5.22E+02	1.40E+03
1995, 11.11.	1.0	3.18E+10	82	2.50E+04	7.48E-05	2.53E+03	8.70E+03
1995, 27.11.	2.0	9.96E+11	138	1.64E+05	8.28E-04	5.21E+05	1.00E+06
1995, 14.12.	1.5	2.54E+11	96	1.25E+05	4.38E-04	1.01E+05	8.00E+04

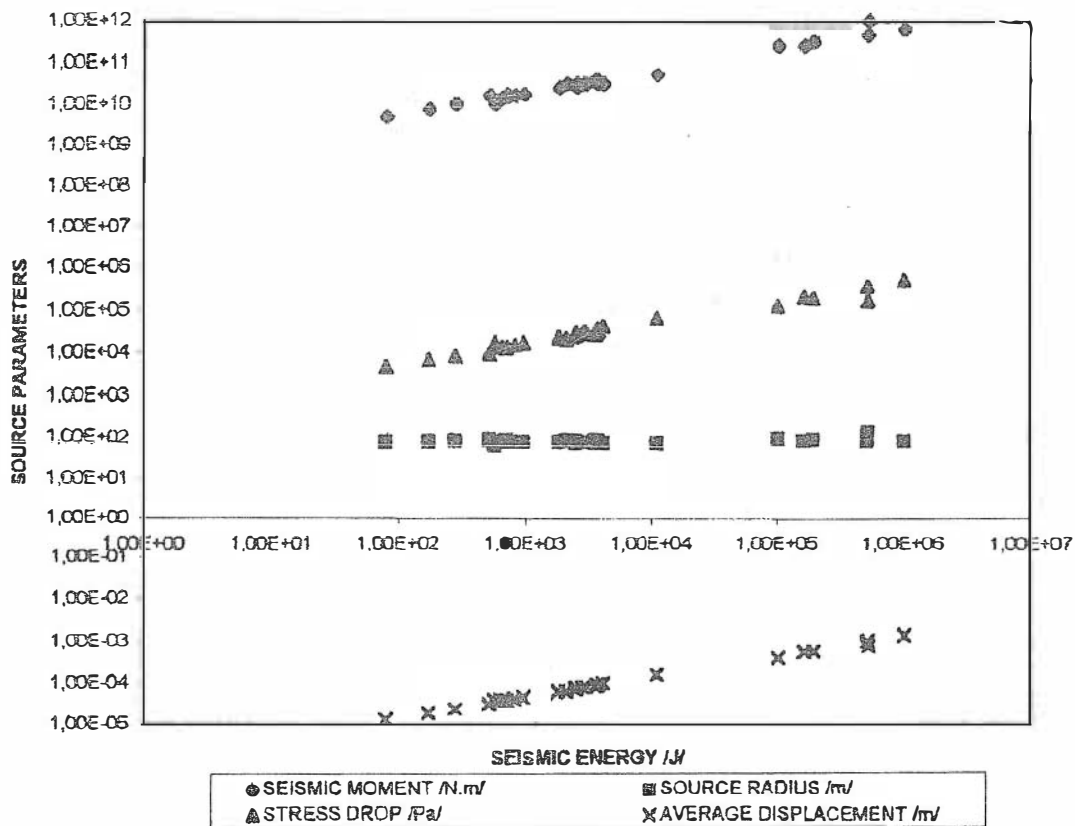


FIG. 4. Relations of source parameters and seismic energy – for data see Tab. 1

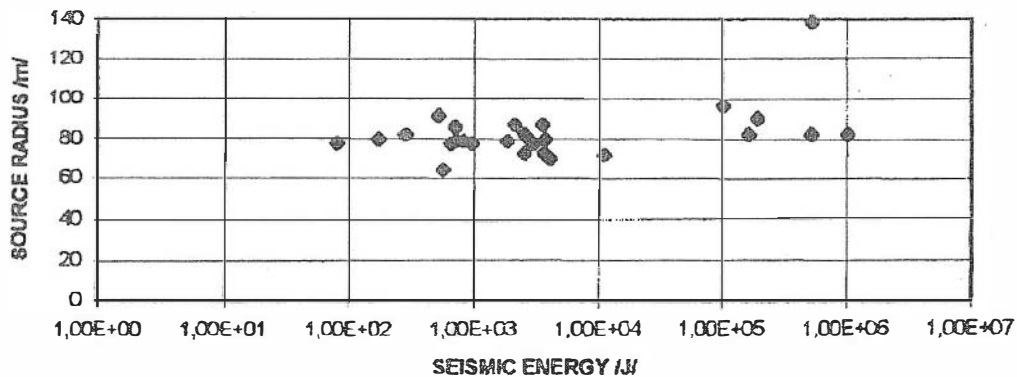


FIG. 5. Relation of source radius and seismic energy

4. ANALYSIS AND CONCLUSION

Fig. 4 overlays all the obtained source parameters from the analyzed data set. It is evidence that correlations between the seismic energy E_S and the seismic moment M_0 , the stress drop $\Delta\sigma$ and average displacement D_0 are linear with high values of the correlation coefficient (diagram is drawn in logarithmic scale). Correlation

between the seismic energy E_S and the source radius r_0 is not significant and r_0 is considerable stable (Fig. 5). But, this result agrees with [Gibowicz, Kijko 1994] that speculate that source dimension of induced seismic events and could be related to the geometry of mining operation.

The results of source parameter determination of mining induced seismic events originated in the Lazy Mine in the Upper Silesian basin are presented. These values agree with our studies that were made in our institute formerly, e.g. [Kaláb 1992; Kaláb 1994], with values that were calculated in Mining Institute of CSAS in Prague, see [Rudajev 1986], and with values mentioned in different references, see [Gibowicz 1990].

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