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THE MECHANISMS OF MINING TREMORS FROM SLĄSK COAL MINE AREA

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ABSTRACT. 75 mining events from Śląsk Coal Mine area which occurred in 1994–1995 were analysed. The focal mechanisms of these tremors were determined on the basis of digital recordings from the mine seismological network using the seismic moment tensor method for P–wave first motion in time domain. The percentage shares of DC, CLVD and isotropic components of the seismic moment tensor were calculated. The ratio of the isotropic to deviatoric component and the spatial orientation of nodal planes were also determined. The obtained results were compared to the focal mechanisms of tremors from the neighbouring Wujek coal mine area.

1. INTRODUCTION

The seismic moment tensor inversion method was elaborated to determine and analyse the focal mechanisms of large earthquakes. Recently the method has been adapted to study seismic events induced by mining [Wiejacz 1991; Gibowicz 1992]. Application of the seismic moment tensor in mining seismicity seems to be very promising because unlike the classic fault plane solution it affords the possibilities for a more complete study of the focal mechanisms, taking into consideration not only shear failure [Gibowicz, Kijko 1994]. The decomposition of seismic moment tensor into three components shows the percentage shares of:

- isotropic component (I) corresponding to volumetric change,
- compensated linear vector dipole component (CLVD) corresponding to uniaxial compression,
- double couple component (DC) corresponding to shear failure.

The mechanisms of 75 seismic events from Śląsk coal mine area which occurred in 1994 – 1995 were analysed. The sources of tremors were localized in the 510 seam in the vicinity of two longwall faces. The mechanisms were determined on the basis of digital recordings from the 12 vertical seismometers of the mine seismological network using the seismic moment tensor inversion method for P–wave first motion polarity in time domain. The spatial orientations of nodal planes were also calculated.

The SMT computer programme elaborated by Wiejacz was used [Wiejacz 1994].

2. THE ANALYSIS OF THE OBTAINED RESULTS

The seismic energies of the investigated tremors were rather low. The highest energy was 4.10^5 J ($M_L = 2.08$), the lowest was 1.10^3 J ($M_L = 0.71$). The energy distribution of the tremors is shown in Fig. 1.

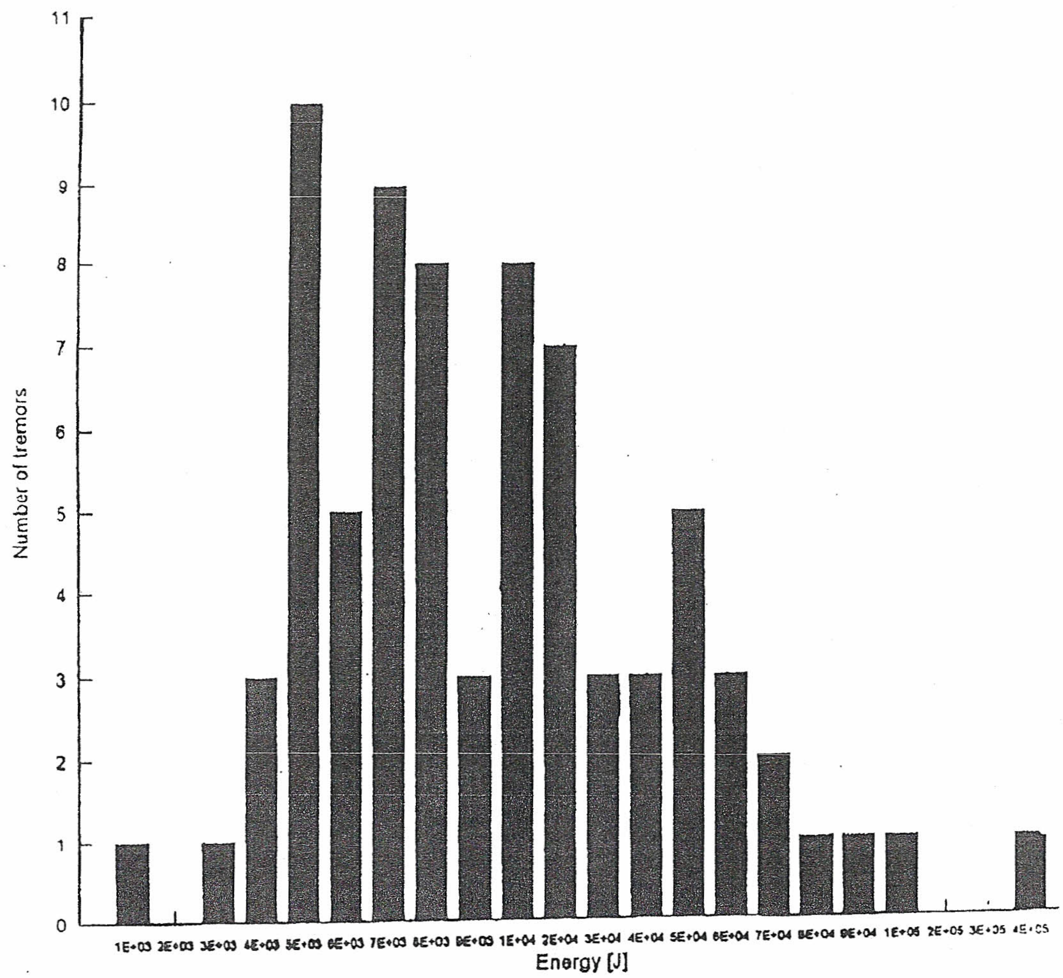

FIG. 1. The energy distribution of the analysed seismic events

Fig. 2 shows the percentage shares of particular components of the seismic moment tensor of the analysed tremors. For 35 tremors the double couple part was dominant. The mechanisms of the other tremors consist of two dominant components: isotropic and CLVD.

As we can see one can divide tremors into two main groups:

group 1 – with dominant DC part (more than 50 %); minor isotropic and CLVD parts (about 20 % each).

group 2 – with dominant isotropic and CLVD parts (about 40 % each); share of DC part of several percent.

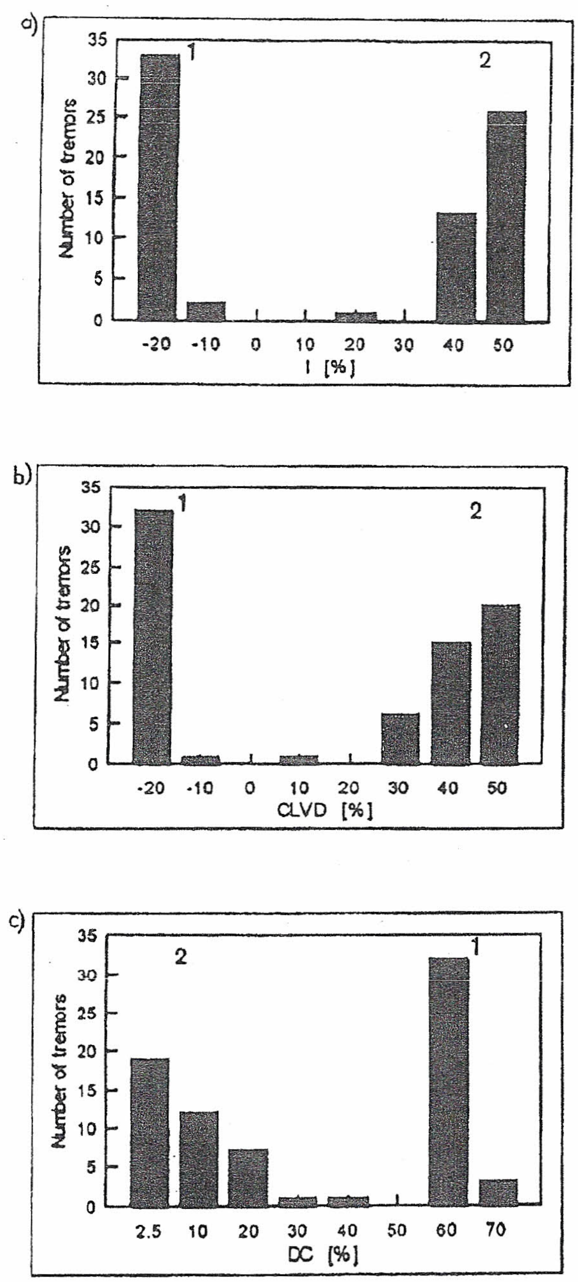

FIG. 2. The shares of particular components in focal mechanisms for 75 seismic events from Sląsk mine area.

a) the isotropic component (+ means increase of the volume, – means decrease of the volume)

b) the CLVD component (+ means tension, – means compression)

c) the DC component

1 – tremors of group 1

2 – tremors of group 2

The tremors of intermediate mechanisms between group 1 and group 2 occurred occasionally.

Additionally the ratio of isotropic to deviatoric (the sum of DC and CLVD) component was determined. The average ratio for 75 tremors is 0.57.

Therefore the mechanisms of investigated tremors consist of relatively small DC and large CLVD and isotropic components.

Earlier the study on mining tremor mechanisms of the neighbouring Wujek coal mine area was carried out [Sagan et al. 1994; 1995]. The mechanisms of 202 tremors and 6 rockbursts were investigated. The sources of the tremors were localized all over the mine area in the vicinity of the openings as well as at a long distance from the openings. The obtained results for Śląsk and Wujek mine area were compared. The geological structures of both areas are similar. One may assume that the mechanisms of seismic events should be also similar. For more than 70 % of 202 tremors (fig. 3) and for 5 of 6 rockbursts from Wujek Mine area the DC component was dominant. The average I/D ratio for 24 large seismic events (seismic energy higher than or equal to 1.10^5 J) was 0.43. It is evident that the mechanisms of tremors are rather different for both areas.

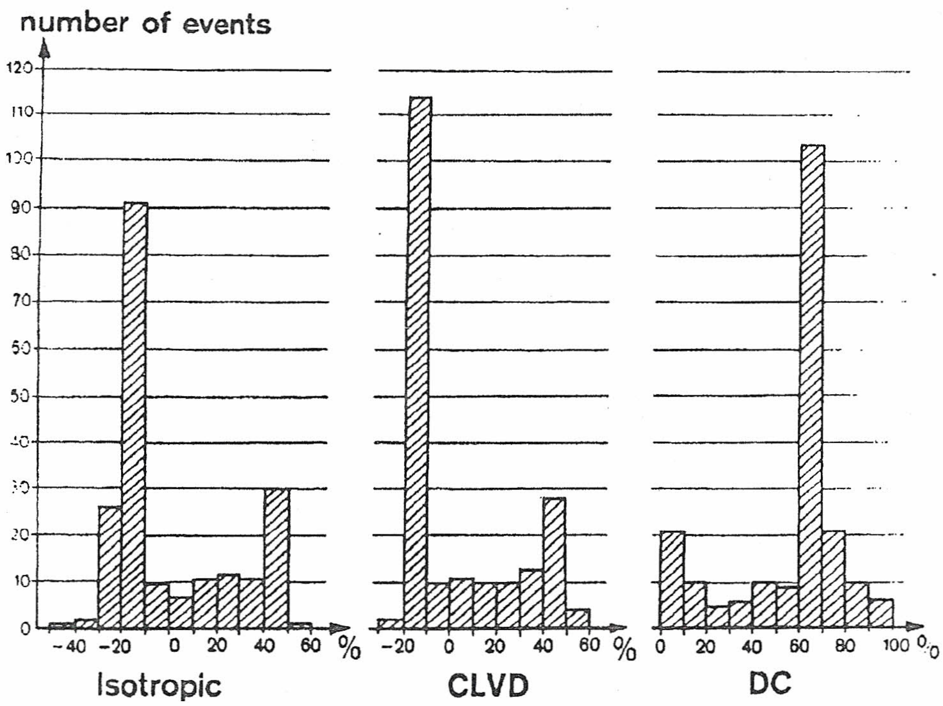

FIG. 3. The shares of particular components in focal mechanisms for 202 seismic events from Wujek mine area. [Sagan et al. 1994]

The DC component is more and the isotropic component is less significant for seismic events of Wujek mine area than for seismic events of Śląsk Mine area.

The dip angles of nodal vertical planes A were higher than 70° for 69 of 75 events.

Spatial orientations of nodal planes A are shown in Fig. 4. There are 2 dominant directions: N–S and NE–SW. The N–S direction corresponds to the seismic events with the dominant DC component (group 1) whereas the NE–SW direction corresponds to the tremors of group 2. It shows the probable existence of the privileged discontinuities in the rockmass.

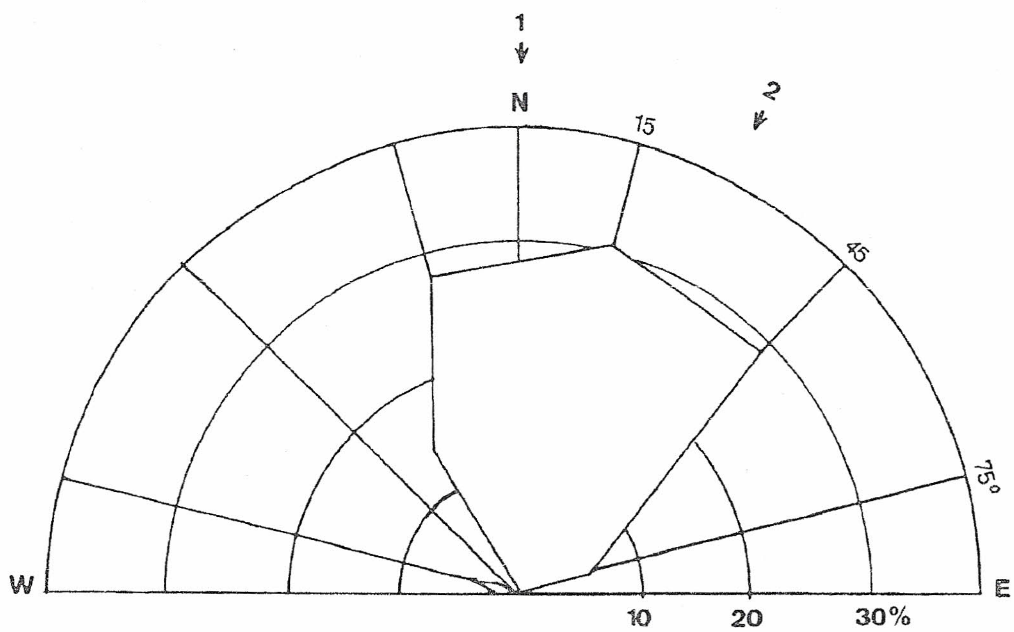

FIG. 4. Orientations of nodal planes A
1 – tremors of group 1
2 – tremors of group 2

It is very difficult to determine the Z co-ordinate of foci which is not reliably determined in Polish coal mines.

In the presented study the Z co-ordinate was estimated on the basis of the coal seam depth. This procedure however may cause errors. To verify the influence of the Z co-ordinate value on the solution of the mining tremor mechanisms the following test was carried out: for the different values of the Z co-ordinate the inversions of the seismic moment tensor of the same seismic events were done. The results are shown in Table 1. Decreasing or increasing of focus depth in 100 m interval did not change the percentage share of the particular components radically. However the changes in the orientation of nodal plane A were more significant because they can change the orientation about 83° as it can be seen from the tremor of 1995–March–28.

3. DISCUSSION

The mechanisms of mining tremors from Śląsk mine area consist of relatively small DC component. For less than 50 % seismic events the DC component is dominant. There is also a relatively large isotropic component (I/D ratio equals 0.57). The obtained solutions are not typical mining tremor mechanisms.

TABLE 1. Solution of tremor mechanisms in dependence on the Z co-ordinate

the Z co-ordinate	Isotropic component	CLVD component	DC component	orientation of nodal plane A	The dip angle of nodal plane A
−430	43.8 %	35.4 %	20.8 %	36.36°	86.08°
−480	43.3 %	45.5 %	11.2 %	8.52°	83.65°
−380	48.6 %	49.6 %	1.8 %	41.93°	85.07°

The seismic event of 1995–March–31 5.37 p.m.

the Z co-ordinate	Isotropic component	CLVD component	DC component	orientation of nodal plane A	The dip angle of nodal plane A
−410	43.0 %	38.0 %	4.0 %	356.77°	88.94°
−460	42.6 %	43.4 %	14.0 %	338.65°	85.71°
−360	49.5 %	48.3 %	2.2 %	273.60°	83.08°

The seismic event of 1995–March–28 1.10 a.m.

In spite of the different origin of some tremors from Wujek and Śląsk mine areas it is hard to explain that their mechanisms are so different from each other. The problem may be probably explained by the analysis of seismometer distributions within the mine seismic network. If the seismometers are not properly distributed around the focus of the tremor it is possible that the recordings may be insufficient for correct solution of the mining tremor mechanism. Fig. 5 shows the locations of tremor sources in the relation to Śląsk coal mine seismic network. As it is shown, the tremor sources are not localized in the central part of the network but practically outside the network. Obviously the studies on the focal mechanisms of tremors from Śląsk mine area should be continued to confirm the obtained results. However the sources of the analysed tremors should be localized in the other part of the seismological network (the best localization would be in the central part).

On the other hand the large isotropic component could be caused by the false assumption that the sources of the tremors are the points [Gibowicz 1992]. In this case the DC component of the seismic moment tensor may be small in spite of being large in the real focal mechanism.

The spatial orientations of the nodal planes are different for different focal mechanisms. It seems to prove the probable existence of discontinuities in the rockmass corresponding to the different focal mechanisms.

Some significant changes of orientation of nodal plane A in dependence on the Z co-ordinate value were established. This may generate serious errors. Therefore one should estimate the Z co-ordinate very precisely before carrying out the solution.

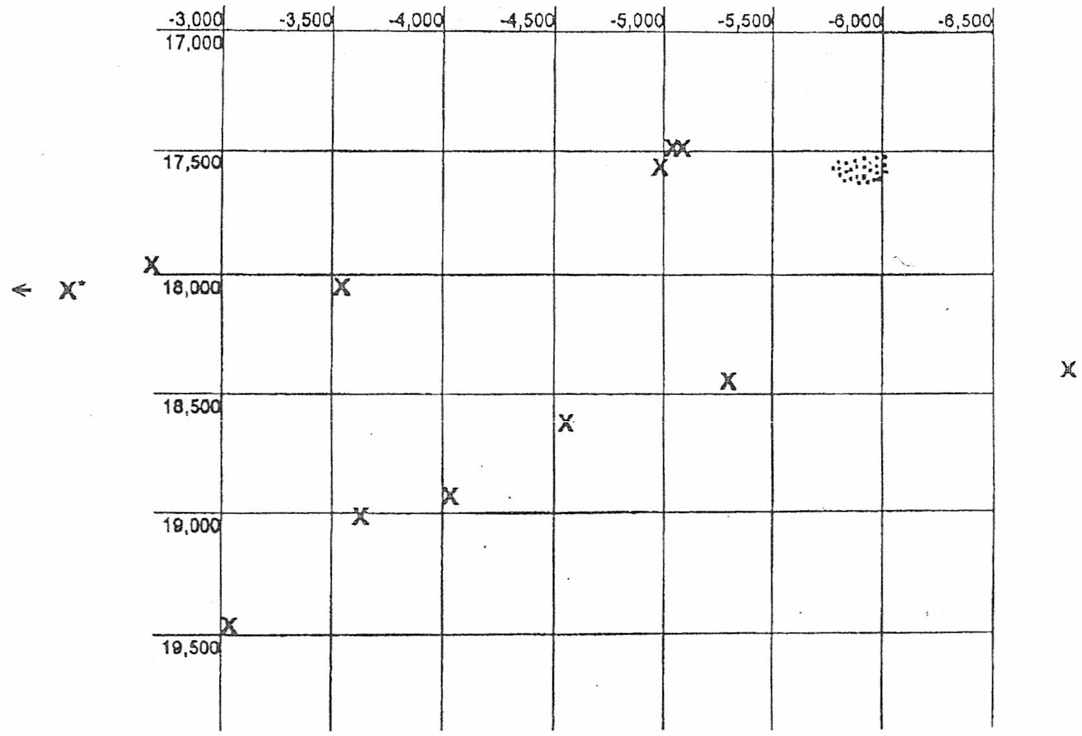

FIG. 5. The location of tremor sources in relation to Sląsk mine seismological network
X – seismometer site,
* – the seismometer site lies outside the figure area (the X co-ordinate is -1021)
• – locations of tremor sources

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