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ANALYSIS OF THE SEISMOACOUSTIC EMISSION DURING THE COAL EXTRACTION

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Abstract: In the paper the excavation of the coalface No.13933 in the 3rd tectonic block at the ČSA Colliery is used as an example to analyse the relation between the seismoacoustic activity and mining operations. In the paper the assumptions of origin of the in-seam rockbursts and their separation from the off-seam rockbursts are discussed. The spacial distribution of events is influenced mostly by structural elements of the rock mass including the structural elements formed by the mining activity.

Key words: Seismoacoustic emission, spatial and time emission variations, Ostrava-Karviná Coal Basin.

1. INTRODUCTION

The paper takes up the subject of the previous work (Kalenda et al. 1990) at the 20th Czech-Polish Conference in Prčice, 1990. This work analysed the possibilities of the seismoacoustic monitoring system designed for one of the seismically most active and most dangerous areas in the Ostrava-Karviná Coal Basin - the 3rd tectonic block at the ČSA Colliery in Karviná. There, an attention was payed to the optimum distribution of the registration base, to the automated processing of a wave image, to the localization of events and the evaluation of their energy as well as to the creation of the seismoacoustic database.

In the presented paper, the quality of final data obtained by the automated wave image processing is decribed. Further, the questions of possible creation of the in-seam and off-seam rockbursts are discussed.

Based upon the seismoacoustic database, the aim of the paper is to determine the development of the seismoacoustic emission in time and in dependence on geomechanical and structurally tectonic elements of the rock mass.

Under the term of a coalface, the coalface No.13933 is ment implicitly in the whole paper.

2. MEASUREMENT SYSTEM AND DATA QUALITY

In the coalface No.13933 in the 39th coal seam, the geophones were set according to the suggested conception with the step of 100 m both in the intake roadway No.13908 and in the return roadway No.13905. Above these geophones, other geophones were placed on the 4 m height in the coal seam roof. In the measurement base, at least two geophones placed in the coal seam in both entries were always connected and, as a minimum, one geophone placed in the coal seam roof. In the roadway No.13704/1 in the 37th coal seam, i.e. 20 - 30 m in the roof over the coalface (see Fig.1), seismoacoustic geophones were placed both in the roof and the coal seam with the step of 100 m. In the measurement base, at least two of these geophones were connected in various stationings according to the situation, which of those geophones were not damaged during the excavation and convergence of the roadway No.13704/1. During the excavation of the coalface in the years 1990 - 1991, 8 geophones as a minimum and 15 geophones as a maximum were connected in the registration base according to the physical state of the measurement intrument.

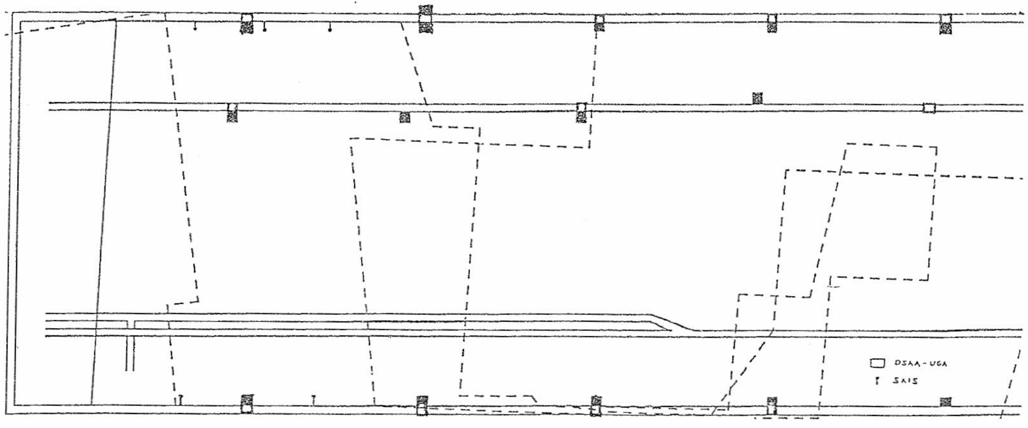

Fig. 1. Distribution of the registration base of the seismoacoustic system for monitoring the seismic activity during excavation of the coalface No.13933 in the 3rd tectonic block at the ČSA Colliery in Karviná.
sensor mounted in the coal seam,
sensor mounted in the roof.

The configuration of geophones guaranteed the unambiguous assignment of localization of seismic events to the following four categories:

- to the 39^{th} coal seam,
- to the layers between the 39^{th} and 37^{th} coal seams,
- to the 37^{th} coal seam,
- to the roof of the 37^{th} coal seam.

The important parameters for performing the measurements were as follows: dimensions of the registration base of 220 x 200 m, the voltage gain of the measurement instrument equal to 32 or 128, the A/D converter of 12 bits, the input voltage of ±10 V and the sampling frequency of 4000 Hz. These parameters enabled to record without any distortion the seismic events coming from the area up to 100 m outside the registration base. The energy range of the recorded events was 0.1 J - 50 J for events from the coal seam and 5 - 1000 J for those from the coal seam roof.

Localization accuracy in the coal seam was tested by blasting works and compared with geomechanical observations. In accordance with theoretical assumptions, the mean value of the localization error was about 10% of the measurement base radius, ie. 20 - 25 m. During the 3D localization in the roof of the coal seams, the maximum errors up to 100 m in horizontal direction were found for events localized outside the measurement base. The localization error for events localized inside the measurement base moved from 50 to 70 m, which was proved by the geomechanical observations and the known geological situation.

Vertical localization errors of events originated in the roof depended on the height of their foci above the measurement base. The events originated in the layers between the 37^{th} and the 39^{th} coal seams were vertically localized with the accuracy of about 10 m, the events from the high roof of the 37^{th} coal seam were vertically localized with the accuracy of about 50 - 70 m.

3. RESULTS OF THE SEISMOACOUSTIC OBSERVATIONS

3.1. In-seam and off-seam rockbursts

During the excavation of the coalface in the years 1990 - 1991, the wave images of all important seismic events recorded by the seismoacoustic measurement system were investigated. It was found that seismoacoustic events originated in the coal seam within the zone of 10 - 50 m in front of the coal face, i.e. in the moving preface stress zone, have the greatest frequency of occurrence (see Fig.2). The maximum of their frequency reached 150 events per hour in June 1990, when the maximum stress was caused by additional stress of the residual pillar in the 33rd coal seam.

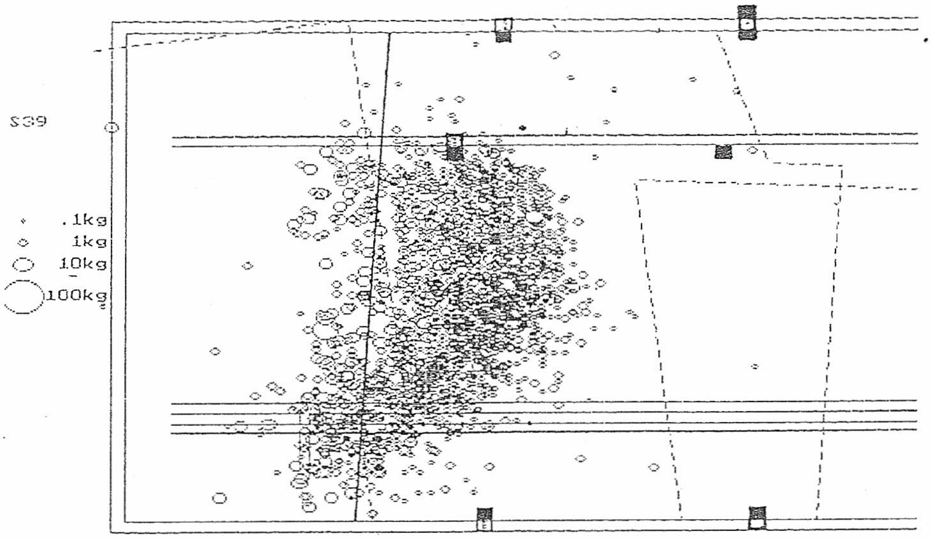

Fig. 2. Location plot of seismic events localized to the 39th coal seam in the period of April 1 to April 24, 1990.

These seismoacoustic events recorded by the geophones located in the coal seam had their typical wave image with a distinguished channel wave. The channel wave amplitude was much higher than the amplitude of volume waves P and S (see Fig. 3). The frequency of channel waves was in typical hypocentral distances of 150 m about 300 - 700 Hz.

Seismic energies of seismoacoustic events originated in the coal seam moved mostly in the range of 0.5 - 5 J. Events with energies over 10 J were observed rarely. Energies of maximum energy events originated in the coal seam were about 100 J. Events originated in the coal seam with energies greater than 100 J were not observed. From the facts mentioned above, it follows that the coal seam itself was largely plastic in comparison with the roof and there was no long-time accumulation of seismic energy in it. Any changes of stress in this coal seam were quickly eliminated by radiation of seismic energy by small seismic events.

In the wave images of maximum energy seismic events originated in the layers between the 39th and 37th coal seams, the channel waves were observed. These channel waves were induced secondarily in places where the roof of the 39^{th} coal seam was broken or where the pressure cleat of the 37^{th} coal seam appeared. Their amplitudes were comparable with those of the volume waves or were smaller than these amplitudes (see Fig.4).

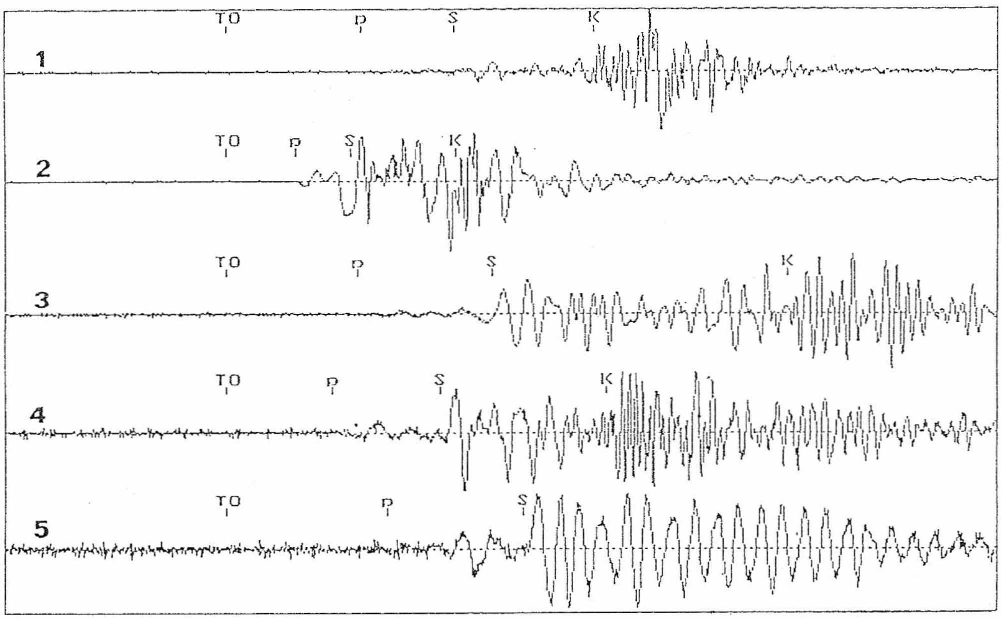

Fig. 3. An example of a seismic event with energy of 70 J localized to the 39^{th} coal seam. The sensors Nos. 1 - 4 mounted in the coal seam recorded evidently the channel wave in addition to the volume waves P and S. The sensor No.5 was mounted in the roof and there is no channel wave recorded in its wave image.

Dominant volume waves frequencies of seismoacoustic events originated in the coal seam roof and mainly in the high roof were considerably lower and moved within the range of 20 - 150 Hz. Except the cases mentioned above, the channel waves were absent in the wave images of these events.

In case of the seismic events originated in the coal seam or in the adjacent coal roof, acceleration of the rock mass movement reaches the values greater than in case of the seismic events originated in the higher roof. This conclusion is obtained by frequency and amplitude comparison of volume and channel waves. Therefore, the minimum threshold energy to create a rockburst or a microrockburst is lower for events originated in the coal seam than for those originated in the roof. During the rockbursts originated in the coal seam, seismic energy is not accumulated in the coal seam, but in the close roof. In case of its crack and burying into the coal seam, the channel waves of high amplitude and frequency are generated. These channel waves subsequently induce the devastation of roads or coalfaces. In case of the seismic events originated in the coal seam roof, the devastation of roads or coalfaces is induced by volume waves P and S. That is why the minimum energy of these events necessary for inducing the devastation is higher than 10^6J.

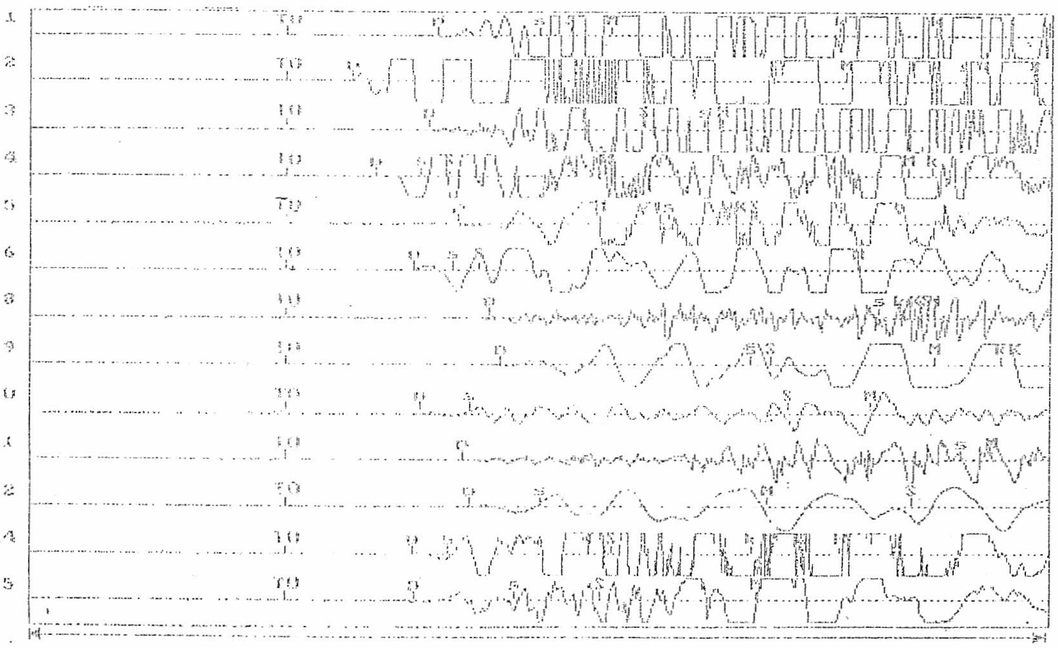

Fig. 4. An example of a seismic event with energy of $2x10^6$ J localized to the roof of the 37^{th} coal seam. The value of seismic energy of this event exceeded completely the measuring scale of the seismoacoustic system.

Within the area of the coalface, the adjacent roof of the 39^{th} coal seam was not able to accumulate energy higher than 10^6J (Slavík et al. 1992). The foci of events were localized in most cases to the front part in the centre of the coal pillar. This zone was influenced by additional stress caused by the residual pillar in the 37^{th} coal seam. Position of this zone was in a sufficient distance from the intake and return roadways of the coalface. Therefore, during the excavation of the coalface, no anomalous event was observed. In these conditions, an anomalous event may occur in case of the crack of the 36th coal seam roof. This roof is capable to accumulate energy greater than 10^8 J.

3.2. Relationship between seismic events and structurally tectonic elements of the rock mass

Seismic events originated in the coal seam were localized first of all to the travelling stress zone of 10 - 50 m in front of the coal face. The side boundary of this zone corresponded to edges of the 37^{th} coal seam pillar in the roof (see Fig. 5). When the coalface approached the influenced zone of edges of the 33^{rd} coal seam pillar to the distance of 50 - 150 m, the area of high seismic activity was created in a long distance in front of the coalface. This area joined the travelling stress area in front of the coalface during the proceeding of excavation activity. In this way, the areas of increased seismic activity both in the coal seam and the roof were indicated in advance by events originated in the 39^{th} coal seam.

Seismic events originated in the roof of the 37^{th} and 39^{th} coal seams were connected to the areas situated perpendicularly under edges of pillars in the 33^{rd} coal seam (see Figs.6, 7). These areas were indicated in advance both in the 37^{th} and 39^{th} coal seams.

At the finish of excavation, the safety pillar area of the Jan - Karel shafts was activated in a large area to the south and to the north of the coalface.

Excavation in the 3^{rd} tectonic block together with mining activity in the 2^{nd} tectonic block influenced the stress state of the tectonic fault separating both these tectonic blocks. This influence became apparent by several seismically significant events with energies greater than 10^4 J.

By the analysis of seismic events originated in coal seams as well as in their roof, including the high roof of the 37^{th} coal seam, their relation to the areas under pillar edges in the 33^{rd} coal seam was found. During the time passed since the creation of these residual pillars, formed as artificial structural elements in the rock mass, up to the start of excavation in the coalface, weakened zones situated under edges of residual pillars were created. These zones were caused by copying of the residual pillars through the underlying strata of the rock mass. During the further excavation, the weakened zone acted in a similar way as a stress concentrator surrounding the natural tectonic fault. Energy of seismic events bound to these areas may reach higher values than energy of events originated around the tectonic faults. It is caused by the fact that the rock mass under a residual pillar is not so deformed as a tectonic fault.

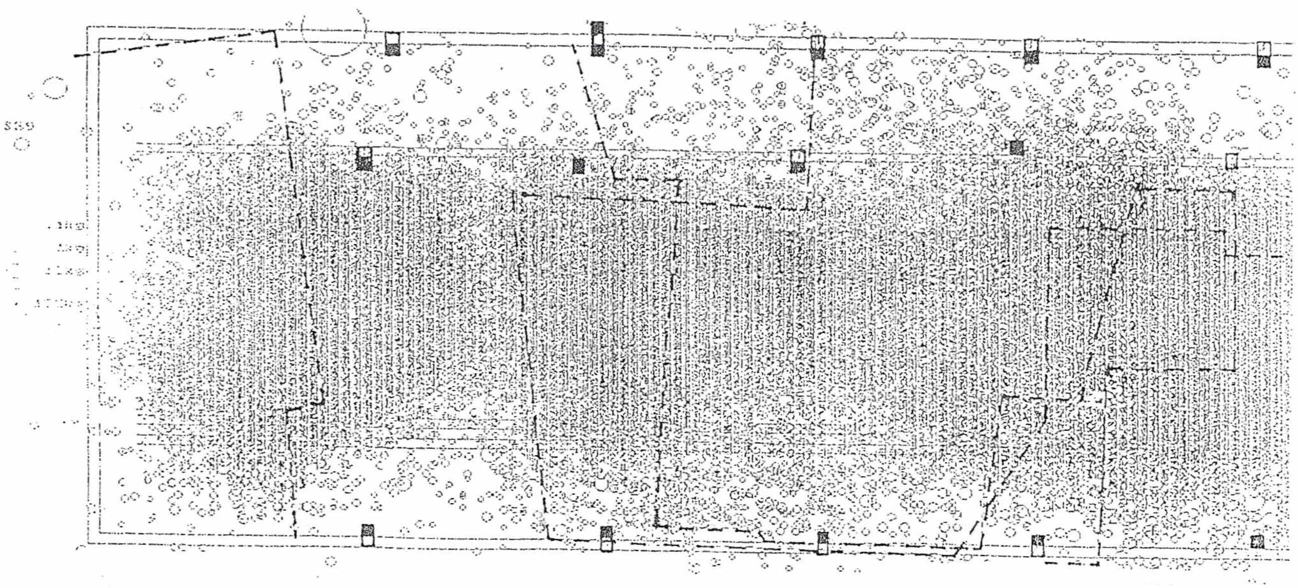

Fig. 5. Location plot of seismic events recorded by the seismoacoustic system and localized to the 39th coal seam during the whole period of excavation of the coalface No.13933 since January 1, 1990 to November 24, 1991.

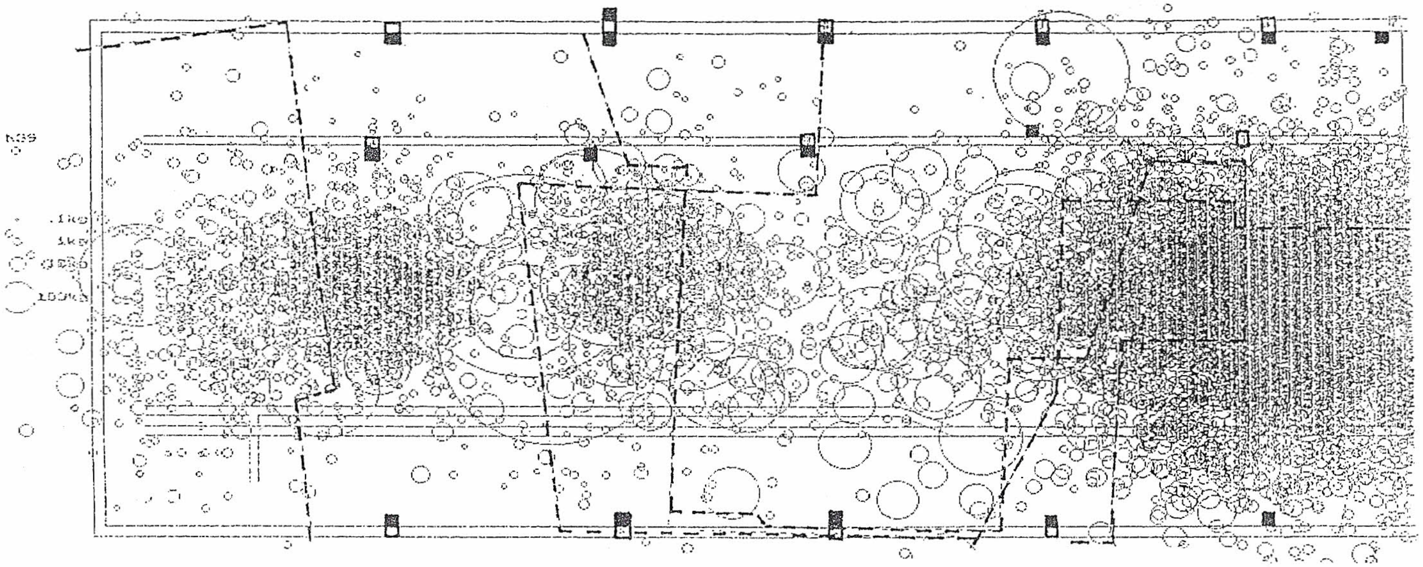

Fig. 6. Location plot of seismic events recorded by the seismoacoustic system and localized to the roof of the 39th coal seam during the whole period of excavation of the coalface No.13933 since January 1, 1990 to November 24, 1991.

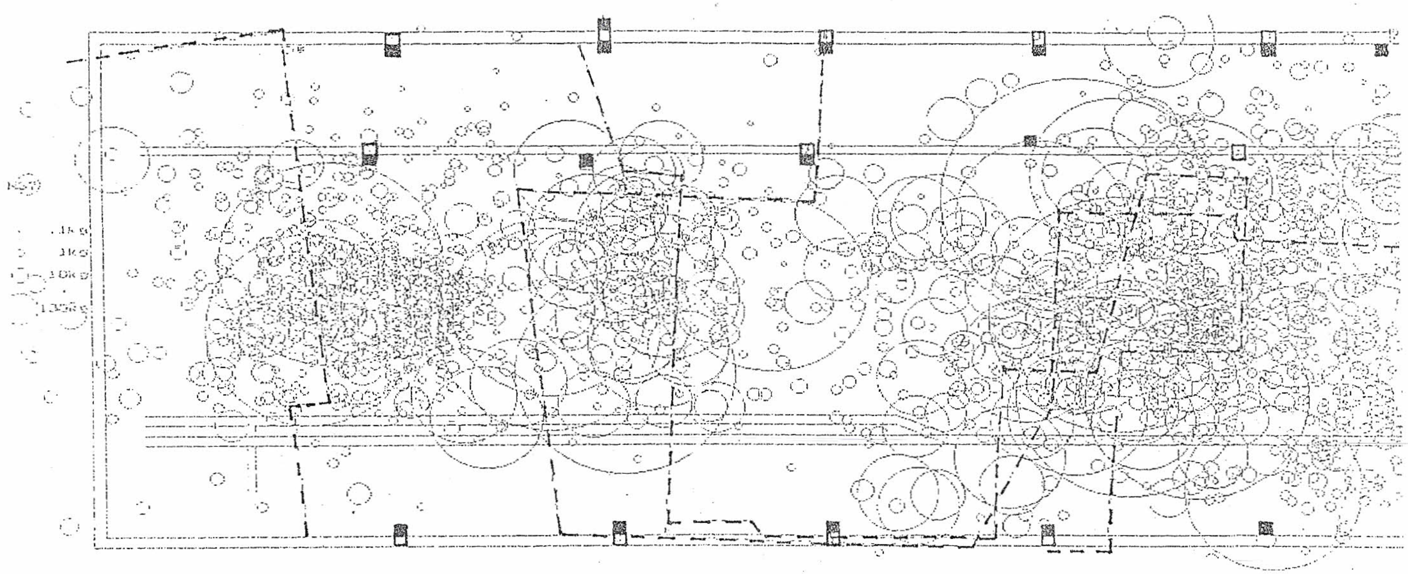

Fig. 7. Location plot of seismic events recorded by the seismoacoustic system and localized to the roof of the 37^{th} coal seam during the whole period of excavation of the coalface No.13933 since January 1, 1990 to November 24, 1991.

4. CONCLUSIONS

The seismoacoustic monitoring in the coalface No.13933 in the 3rd tectonic block of the ČSA Colliery contributed to determine the seismic models of the in-seam and off-seam rockbursts. The results may be summarized as follows:

1. In case of excavation of the 39th coal seam, the off-seam rockbursts were of the greatest importance, namely those originated in the roof of the 36th coal seam. This area was able to accumulate the energy greater than 10^8J which was not, however, released during the excavation of the coalface.
2. The in-seam rockbursts are dangerous by the fact that their minimum threshold energy can be less than that of the off-seam rockbursts. In this case, the layer accumulating the large amount of energy, must be situated in close roof of the excavated coal seam. This condition was not fulfilled in case of the coalface.
3. Seismic energies of seismoacoustic events originated in the coal seam moved mostly to 100 J. It follows from this fact that the coal seam itself was largely plastic in comparison with the roof and there was no long-time accumulation of seismic energy in it. Stress changes in this coal seam were quickly eliminated by radiation of seismic energy by small seismic events.
4. During excavation of the coalface, the relation of an origin of seismic events to the areas under the pillar edges in the 33rd coal seam was found. It was also found that under edges of these residual pillars the weakened zone was created during the time passed. This zone has similar character as a stress concentrator surrounding the natural tectonic structure.
5. Energy of seismic events bound to stress concentrators under the residual pillars may reach higher values than energy of events originated round the tectonic faults. It is caused by the fact that the rock mass under a residual pillar is not so deformed as a tectonic fault.

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