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Particle velocity generated by rockburst during exploitation of the longwall and its impact on the workings

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ABSTRACT

As a consequence of geomechanical and geotechnical conditions and also anthropogenic activities in mines of the Ostrava-Karviná Coal Basin (Czech Republic) rockbursts have been recognized to be a serious seismic risk. Therefore, local as well as regional monitoring arrays were deployed there in order to investigate the actual seismic activity continually. One of the essential parameters which was observed at the seismic stations situated *in-situ* was the particle velocity of P- and S-waves. The aim of this paper is to derive some empirical dependences by determining the decrease of seismic wave amplitudes with distance from rockburst foci. Seismic energy, local magnitude, co-ordinates of seismic stations, rockburst foci and positions where damage to workings occurred were employed as additional imput. Moreover, the degree of this damage was tested based on the values of particle velocity and, simultaneously, stress due to the loading of the workings by the stress wave was also calculated.

1. Introduction

This paper considers the fundamental role of seismic monitoring in the eastern part of the Ostrava-Karviná Coal Basin (hereinafter referred to analysis as OKCB), where rockbursts have occurred almost two hundred years [14], while instrumental detection of these phenomena started in the 1980s of the last century [22,26]. The origin of these mining-induced events is closely related to coal-extraction processes and is also affected by other factors, e.g., by specific mining and geological conditions, physical and mechanical properties of the rockmass, the mining technique used in the past and at present, stability of all types of pillars, changes in stress–strain state of rock mass, etc. [12]. In layers underlying our coal deposit, induced seismic events occur very often, and moreover, some of them have the character of damaging rockbursts. Therefore, in areas affected by these dangerous seismic events both the passive (e.g., mine design, choice of mining equipment, selection of suitable mounting, etc.) and active preventive measures (e.g., destressing drilling and blasting, water infusion of coal seams, large-scale non-productive blasting operations in the roof, etc.) have been applied in order to mitigate their devastation of the workings underground [11,6].

In the scope of the geomechanical service of the Ostrava-Karviná mines, a rockburst is characterized as a seismic event, in consequence of which workings are permanently destroyed so that they can no longer fulfill their operational function. For the purpose of this study, a series of rockbursts was selected, recorded in the years 1993–2009 simultaneously at three underground seismic stations where triaxial sensors were deployed. The particle velocity of P- and S-waves was chosen as the basic observed parameter, while the focus location, released seismic energy and local magnitude, were calculated subsequently also using the first-arrival times of these seismic waves. The subject of our interest was the determination of the coefficient of decay of the maximum P- and S-wave particle velocity in dependence on scaled distance in the rockmass and estimation of the extent of damage to workings after the rockburst.

2. Short characteristic of the coal deposit

The Ostrava-Karviná Coal Basin represents roughly a third of the Upper Silesian Basin which is mostly situated on the territory of Poland. The sedimentation of this basin started in the latest Upper Carboniferous stage, and the coal bearing strata belong to the Namurian A through C and Westphalian A. The whole mining district of the OKCB is divided into three partial coal basins referred to as the Ostrava, Petřvald and Karvină basins, the central Petřvald basin being separated from other two by the Michálkovice and Orlovská structures of anticlinal character. These three basins and the general position of the OKCB within the Czech Republic, and simultaneously the distribution of the seismic stations A, C, D, K and M are shown in Fig. 1. Considering that mining started in this region more than two hundred years ago, the mines in the Ostrava and Petřvald basins have already been closed and, since 1980s of the last century, the mining has been concentrated in the eastern part of the OKCB, i.e. in the Karviná basin. At present

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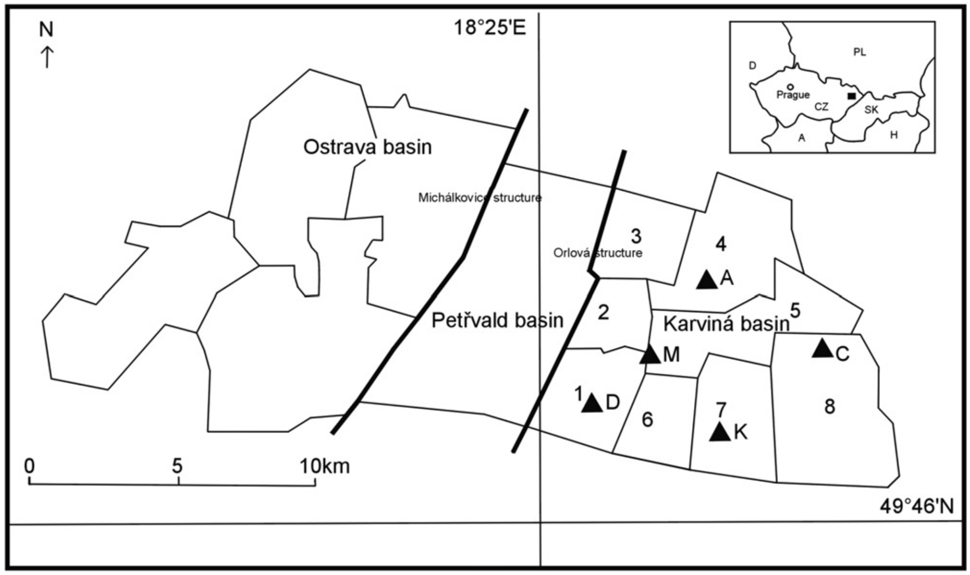

Fig. 1. Map of boundaries of coal basins (**—**) and demarcation of mines (—) combined to the Ostrava-Karviná coal mine district. 1—# Dukla (closed), 2—# Lazy, 3—# Doubrava (partially closed), 4—# ČSA, 5—# Darkov (partially closed), 6—# František (closed), 7—# 9. květen, 8—# ČSM (according to Dopita et al. [4]). ▲ A, C, D, K and M positions of underground seismic stations, ■ area of the Ostrava-Karviná Coal Basin (see regional map in the upper right hand corner).

mines Dukla (#1), František (#6) and partly also Doubrava (#3) and Darkov (#5) are closed now.

The evolution of the basin was seriously affected during the Cadomian, Variscan and Alpine structural stages, which caused the disruption of all the layers in the coal deposit oriented roughly east–west and north–south. The tectonic faults now form demarcations between the individual mining and/or tectonic blocks. The inner structure of the coal seams consists of two basic formations: the Ostrava Formation (Lower Namurian) in the basement of the basin, and the Karviná Formation (Middle and Upper Namurian and Westphalian) which represent the higher horizons.

The most important and dangerous was the space between coal seams nos. 33 and 37 which is built of hard rocks (e.g., solid siltstone, sandstone and conglomerate) having a compression strength of 70–100 MPa, while samples of coal exhibit values much lower, approximately 20–25 MPa. Due to this strength of rocks the space mentioned above, the thickness of which amounts about 120–175 m, was considered a dangerous zone where during coal exctraction in coal seams nos. 37–40 stress concentration took place. Once the limit of the ultimate strength of rocks in the roof is exceeded, the strain energy in the rock mass is released in the form of individual seismic-induced events, sometimes also generated in the form of rockbursts. The course of a schematic vertical crossing the Saddle Members of the coal deposit along the line *X–Y* is displayed in Fig. 2; as for the proper geological structure, we refer to Fig. 4 in Holub [15]. The upper part of the geological profile (above coal seam no. 33) up to the surface consists of similar rocks and its uppermost part, where also thinner coal seams occur, e.g., coal seam no. 29, is built almost of superficial deposits of Miocene age. The geological structure of the region under discussion was described in detail by Dopita and Kumpera [3].

As for mining method, retreating mining system with controlled caving and/or pneumatic filling is prevailingly applied in the OKCB.

3. Seismic activity monitoring

Mining-induced seismicity in the region under investigation is continuously observed by two monitoring systems, i.e. both the local and regional seismographic networks. The local network

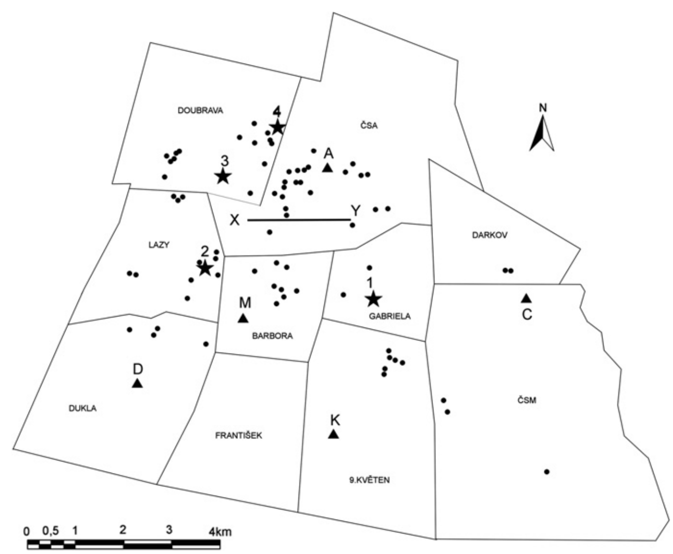

Fig. 2. Plan of coal mines: ● localized rockburst foci, ★ 1, 2, 3 and 4 position of rockburst discussed in detail, ▲ A, C, D, K and M underground seismic stations.

provides important information to the geomechanical service of individual mines.

On the other hand, the regional system consists of ten seismic stations which are distributed on the territory of the eastern part of the OKCB. Three of them are deployed underground and can also be moved as the mining approaches. The six fixed stations are situated on the surface in shallow boreholes ($h \approx 30$ m) and the tenth is situated in a short gallery near the seismic station Ostrava-Krásné Pole (OKC). The individual stations are equipped with three-axial short-period seismographs WDS 202 ($T_s = 0.5$ s). Five positions of underground seismic stations denoted as A, C, D, K and M, pertaining to the regional network, are displayed in Fig. 1. Only one trio of stations was used to monitor the induced seismic events, including rockbursts, during the period 1993–2009. The indvidual schedules of seismic station operations are as follows: A+K+M (1/1993–7/2004), A+D+K (2/2005–9/2006) and A+C+K (6/2008–till now) and some insubstatial changes in the spatial distribution of the trios of stations during the whole time of the regional system's operation were