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Slawomir Jerzy GIBOWICZ	RELATIONS BETWEEN SOURCE MECHANISM AND THE RATIO OF S OVER P WAVE ENERGY FOR SEISMIC EVENTS INDUCED BY MINING	7
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**Abstract**

There is growing evidence that alternative earthquake mechanisms other than shear failure are possible. In particular, seismic events with non-shearing components are expected to occur in close vicinity to the mining faces, where favourable conditions for generation of shear failures with tensile components are present. The moment tensor approach is in this respect the most general one. A moment tensor can be decomposed into an isotropic part, a compensated linear vector dipole and a double couple. The ratio of S- to P-wave energy radiated from mine tremors, on the other hand, is in many cases anomalously low, and the high P-wave energy tremors are expected to be generated by the sources with prominent non-double-couple components as estimated from the moment tensor solutions. The relevant data, the source mechanism and the energy ratio, were available for 158 seismic events which occurred at Ziemowit coal mine (63 events), Wujek coal mine (38 events) and Rudna copper mine (22 events) in Poland, and Western Deep Levels gold mine in South Africa (35 events). The double-couple (DC) component of the source mechanism forms in most cases 60-90 percent of the solution, though more prominent non-double-couple components are also observed. There is a strong negative correlation between the DC and compensated linear vector dipole (CLVD) and DC and isotropic components, characterized by the correlation coefficient as high as -0.9, and not so clear positive correlation between the CLVD and isotropic components with the correlation coefficient equal to 0.6. The relations between the ratio of S- to P-wave energy and the indicators of a DC, a CLVD and an isotropic components in the general solution are not as straightforward as might be expected. Although there is a positive correlation between the energy ratio and the DC indicator, and negative correlations between the ratio and the CLVD and isotropic indicators, the correlation coefficients in all three cases are small, not exceeding 0.4.

Jozef DUBINSKI, Grzegorz MUTKE and Krystyna STEC	FOCAL MECHANISM AND SOURCE PARAMETERS OF THE ROCKBURSTS IN UPPER SILESIA COAL BASIN	17
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**Abstract**

The rockburst hazard in Polish hard coal mining industry has for many years been one of the most serious, in consequences, natural hazards. With all the progress in both the sphere of scientific activity and the mining practice it self a dozen or so of rockbursts occur annually. This fact gives rise to a number of question concerning the methods used for the assessment and fighting against the hazard. The solutions that could bring more progress in this field. Among the different studies being developed is the searching for certain particular elements of those seismic events. Which cause the occurrence of rockbursts. The objective of the analysis is find a correlation between the focal mechanism and source parameters and the mining and geological conditions. A computer date base that includes the following parameters of the rockbursts has been created: mining conditions, tremor focal mechanism parameters, seismic source parameters. The Rockburst Base thus created allows us to conduct a broad analysis concerning the physical processes of dynamic destruction of the rock structure around mine workings. The results hither to obtained confirm the usefulness of conducting this kind of interdisciplinary research and point out at the necessity of developing new trends in the activity of the mine geophysical services.

Ryszard DUBIEL	The Mechanisms of Mining Tremors from Slask Coal Mine Area	27
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**Abstract**

75 mining events from Slask 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.

Zdeněk KALÁB and Jaromír KNEJZLÍK	POLARIZATION DIAGRAMS OF ROCKBURSTS FROM THE OSTRAVA - KARVINÁ DISTRICT	35
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**Abstract**

Local network denoted as Seismic Polygon Fren't t records intensive rockbursts from Ostrava - Karvin District also (distance about 30 km). The overall evaluation of these wave patterns can be summed up as follows: the rockbursts are easy-to-identify in the set of records, a wave pattern is developed, phases of P and S wave group are separable (S-P time ranges between 3 to 8 s) and their first arrivals are usually marked. First analysis of polarization diagrams is presented in this contribution.

Jan KOZÁK, Tomáš LOKAJÍČEK and Vladimír RUDAJEV	Non-linear Source Processes under Tensile Load Regime?	45
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**Abstract**

In the past years the non-linearity of the processes was detected and verified during which - under compressional loading the solid body - elastic waves were radiated. In the paper presented an attempt is made to find out whether also radiation from a solid body (steel string) subjected to tension loading displays non-linear behaviour as well. The first results obtained indicated the existence of non-linear component of such a source of radiation.

Piotr KOŁODZIEJCZYK and Kazimierz WANAT	POSSIBILITY OF DIMENSION DECREASE IN THE PROBLEM OF SEISMIC EVENTS LOCATION	51
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**Abstract**

A classical approach to the location of seismic events consists in identifying the coordinates of epicentre or hypocentre of the tremor and time  $t_0$  origin time. The time is treated as equivalent to focus coordinates. It is one of the unknowns numerically determined by means of iterative calculations. Since the equations connecting arrival times with seismometer coordinates and unknown focus coordinates are linear, the  $t_0$  parameter can easily be eliminated. As a result, the dimension of the problem with regard to  $t_0$ , this parameter decreases and numerical properties of the seismic events location task are improved.

Pavel KALENDA	SPACE AND TIME DEVELOPMENT OF THE FOCAL ZONE IN THE NEIGHBOURHOOD OF UNDERGROUND WORKINGS	55
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**Abstract**

Along the underground working the stress is displaced by any hit to the rock mass. There were defined zones of aggravation, influence, impact and destruction on the basis of continuous seismoacoustic monitoring of the saddle layers in the Ostrava-Karviná Coal Basin (OKR) in the neighbourhood of underground working. These zones develop in time from the beginning of mining operations in underground working through the stages of preparation, development, fully developed underground working till the final stage ending the mining activity in underground working. Two types of seismic events were defined on the basis of a space and time model of the foci zone: local events (developed events) and global ones (triggered events). The possibilities of prediction of seismic events in the influence and impact zones were discussed. Phenomena related to the extraction of the saddle layers were explained.

Adam IDZIAK and Leslaw TEPER	FRACTALITY OF SPATIAL DISTRIBUTION OF BOTH FAULTS AND SEISMIC EVENTS WITHIN BYTOM SYNCLINE, UPPER SILESIA	65
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### Abstract

The Bytom syncline is one of main structural units forming the Upper Silesian Coal Basin (USCB). It is the region where the great seismic activity is observed. The energy of seismic event is usually less than  $10^7$  J but from time to time tremors with energy greater than  $10^8$  J occur. To explain if the biggest seismic events can be connected with recent tectonic activity the fault network geometry and spatial distribution of seismic event epicenters were studied using fractal analysis. The calculated fractal dimension of fault network was close to 1.6 and it was similar to the fractal dimension of epicenters equal to 1.52. This similarity may suggest that the whole fault network of the Bytom syncline is engaged in generating seismic events.

Zofia MORTIMER and Stanislaw LASOCKI	Variations of the Fractal Dimension of Epicentre Distribution in the Mining-Induced Seismicity	73
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### Abstract

Epicentre distribution in the mining-induced seismicity is analysed for individual longwalls of some mines of the Upper Silesia Coal Basin. The fractal nature of this distribution has been stated. Time variations of the fractal dimension, calculated by means of box-counting method, are correlated with other geophysical parameters related with induced seismicity of the exploited area. At the same time methodology of the fractal dimension calculations is analysed.

Stanislaw LASOCKI	Dispersion of Foci - a Possible Precursor of Strong Tremors?	83
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### Abstract

A process of tremor generation taking place close to mining stopes is non-stationary. The seismic hazard, that is the probability of occurrence of a devastating event, varies then in time. Recent quantitative methods employed to evaluate the time-dependent seismic hazard in the local process of induced seismicity generation usually make use only of information contained in energies of a sequence of events. Variations of tremor epicentre distribution in the non-stationary generating process were studied in the presented work. Two parameters of the distribution were controlled:

1. directional coefficient A of the least-square straight line fit to a given number of successive events. The fitted line represented the temporary linear trend of epicentres;
2. root-mean-square error of the straight line fit. This parameter accounted for a dispersion of epicentres with respect to the trend.

Andrzej JAWORSKI	RELATIONSHIP BETWEEN ROCK MASS DEFORMATION AND ENERGY RELEASE OF INTERDEPENDENT MINING TREMORS IN THE AREA OF BYTOM BASIN	91
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### Abstract

The paper presents selected results of studies carried out in 1994 linking the level of induced seismicity with the condition of rockmass in view of deformation and energy, with the rock mass having been formerly subjected to mining which induced the discussed tremors. The studies comprised a group of tremors which have been recorded over last few years in the area of Bytom Coal Basin - an area posing the greatest seismic hazards. For the analysis of tremor interdependence, the method of event clustering was applied dividing them into clusters in accordance to probable reasons for their occurrence. It was suggested that the analytical model used so far should be applied for all resistant rock layers influenced by mining induced deformation. A strict conformity was found between observed and calculated contour maps of seismic event energy release.

Karel HOLUB and Vlasta VESELÁ	APPROACHES TO THE ENERGY CLASSIFICATION OF MINING-INDUCED SEISMIC EVENTS IN THE OSTRAVA-KARVINÁ COAL BASIN	107
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### Abstract

Continuous monitoring of induced seismic events in the Ostrava-Karviná mining district is one of the necessary assumptions in investigation of the time dependent development of seismic activity in this region. Basic information concerning individual seismic events included in the database contains origin time, focus coordinates and appropriate class of energies. The present paper represents a special examination of individual approaches to the energy classification of induced seismic events recorded by individual monitoring systems operating in this mining area, and the seismic station Ostrava-Krásné, Pole (OKC), as well. The resultant values of seismic energy and/or magnitude determined on the basis of accepted approaches of the parameter evaluation are being mutual correlated and the respective relations are established.

Vladimír RUDAJEV, Tomáš LOKAJÍČEK and Radim ČÍŽ	Structure Elements of Rocks and Energy-Frequency Distribution of Seismic Phenomena	121
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### Abstract

Pavel KALENDA	A Contribution to Discussion on Lower Limitation of Energy-Frequency Distribution	131
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### Abstract

On the energy-frequency (E-F) distribution compiled from data acquired by seismological observations in all coal fields there is an evident lower energy limitation which leads to the interpretation as a possible influence of structural arrangement of a rock mass and its lower geometric dimension which results in significant changes of material properties being observed on the rock samples. On the other hand, this lower energy limitation may be interpreted as a principal influence of monitoring basis abilities which does not reliably allow to register and localize weaker events. Based on comparison of seismologic (SL) and seismoacoustic (SA) monitoring of the same area this contribution solves the problem whether the observed limitation of E-F distribution resulting SL network, or it is given by structural impacts of the rock.

Jiří BUBEN, Robert BROŽ	Interpretation of Rockbursts Recorded by the Local Seismic Station Kladno-Vinařice during the Year 1994	139
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### Abstract

During the year 1994, seismic station Vinařice recorded a total of 3201 rockburst events (brittle fracturing) with foci located in the volume of the safety shaft-pillar Kladno. Liquidation of this pillar continued by new drifts and by coal extraction at several stopes. Evaluation of the site, size and time of rockburst events resulted in: a)~seismic energy flow (seismic power) does correlate with drifting rate of new galleries and with the coal extracting rate, b)~distribution of foci depths shows maximum in the overlying sandstone bed, c)~estimate of seismic source zone dimensions being within tens to one hundred meters.

Vladimír TOBYÁŠ	INDUCED SEISMICITY BY OPEN PIT MINING IN NORTHWEST BOHEMIA	159
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### Abstract

Triggering of seismic events by unloading of the Earth's surface in case of deep pits is discussed by means of the Mohr diagram with the Coulomb failure criterion. All basic mechanisms of earthquakes with dip-slip, strike-slip and thrust faulting may possibly occur. Reduction of the vertical stress by mining can be quantified but the other factors may be only estimated. The potential for induced seismicity appears also by loading effect of big external spoil heaps during mining and interaction of loading and pore-pressure effects due to the filling of pits with water after the exploitation of mines.

**Abstract**

The deconvolution of a seismic signal is to separate information - both about the rockmass and about the signal in the shock source. In prospecting seismology use is made of a variety of deconvoluting methods, but none of them was found to be effective in the analysis of shock-induced signals gathered in the mines of the Lubin Copper Mining District (referred to as LGOM). This lack of effectiveness stems from the inadequacy of the model involved. Each of the methods dealt with in blind deconvolution is based upon certain assumptions describing the signal model, and unless these assumptions are satisfied - reliable results cannot be expected. Neither can we simply transfer the methods of deconvolution from prospecting seismology to mining seismology. For the signals gathered in the LGOM copper mines we formulated a different model which involved the following assumptions:

1. The signal in the shock source is a short-term signal.
2. The signal-transmitting system (rockmass) forms a parallel connection of elementary systems.
3. The elementary systems are of resonant vibration type.

The adoption of such a model was justified by theseismic wave propagation conditions inherent in the geological structure, as well as in the location of shock focus and seismometers. The resonant nature of vibration was indicated by physical premise, signal trajectories, time-frequency transformations of signals, and - finally - by the results obtained via classical deconvolution. While reflections from rockmass layer boundaries are undoubtedly present in the signals, we believe that the contribution of resonant-type vibration is decisive. The adequacy of the new model, as well as the efficiency of the blind deconvolution method proposed, was corroborated by the results from the approximation of the signal (high approximation accuracy with the use of a small number of elements; relations between the parameters describing the signal), and by the results of blind deconvolution (estimators obtained for the signal in the shock source).

Zofia MAJEWSKA, Stanislaw LASOCKI and Jerzy ZIETEKi	SPECTRA OF ACOUSTIC EMISSION INDUCED IN COAL BY GAS SORPTION	175
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### Abstract

Frequency spectra of acoustic emission (AE) induced in coal by gas sorption-desorption have been investigated in order to answer the following questions: Is there any difference between spectra of AE from coal prone and not prone to outbursts? Do spectra of AE signals indicate one or more source mechanisms? Changes in dominant frequencies of AE signals have been examined by means of statistical nonparametric methods: the Spearman's rank correlation, the Kolmogorov-Smirnov two sample test, the Wald-Wolfowitz runs test and the Mann-Whitney U test. These preliminary studies lead to the following conclusions:

- There are two distinct frequency modes: low frequency (LF) and high frequency (HF) corresponding to mechanisms which produce AE in coal under gas sorption-desorption process. The emission source mechanisms are not clear at this point.
- The dominant frequency distribution of AE signals from coal prone to outbursts significantly differs from that of not prone coal.
- Results of frequency domain AE analysis agree with conclusions arising from our earlier time domain studies.

The results obtained are encouraging from the standpoint of outbursts prediction.

Václav BUCHA	Rendering of 3D Seismic Model	183
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### Abstract

3D seismic model is described by the velocities in a rectangular grid and by the curved interfaces between geological blocks. PEXlib is a 3D graphics library which gives us an opportunity to render 3D seismic models in the X Window System. Differences between velocities are expressed by colors and shades. The curved interfaces are computed by means of the B-spline surfaces.

Václav BUCHA	PEX IMAGE OF WESTERN BOHEMIA A PRIORI SEISMIC MODEL	187
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### Abstract

A possible method how to visualise Western Bohemia a priori velocity model is described. The model is composed of the realistic topography and of the artificial single complex block of velocities. Computer program PEX that utilizes 3D graphics library PEXlib was developed and used to render the model in the X Window System.



Bogdan ŽOGALA and Waclaw M. ZUBEREK	Changes of Acoustic Emission and Ultrasonic P-wave Velocity in Sedimentary Rock Samples during Cyclic Heating	193
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**Abstract**

Samples of sedimentary rocks subjected to thermal stresses show an effect of thermal memory. As the time goes, this effect disappears which is assumed to be related to the process of rock deformation. Changes of acoustic emission caused by thermal stresses are accompanied by changes of time of propagation of longitudinal waves. The investigations were carried out basing on samples of Carboniferous sandstones of the Upper Silesian Coal Basin. The obtained velocities of wave propagation, in comparison with memory fading and with the values of cumulated count numbers, showed that velocities in samples are clearly connected with processes of memory fading. Together with the cooling of the sample and closing of the cracks the velocity comes back to its original value and the memory effect in the course of AE gradually disappears.

Zuzana KRIŠŤÁKOVÁ and Blažej PANDULA	THE RELATION BETWEEN LABORATORY AND IN SITU DETERMINED DYNAMIC MODULI OF ROCK	201
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**Abstract**

Utilization of deformation characteristics of rocks has great importance in any geotechnical purposes. These techniques involving the propagation of acoustic or seismic waves are becoming of increasing importance since there are relatively inexpensive and quick in performance and suitable to apply in situ condition. However, in spite of this, such determined elastic moduli are not very common in rock engineering projects. For this reason there is an effort to find some correlation between static and dynamic constants of rocks to find their application in geotechnical praxes. In this paper we compared Young's moduli determined in situ with corresponding properties determined on samples subjected to testing in the laboratory of Technical University in Košice. In situ measurements were carried out by seismic signal enhancement instrument Bison in some Slovakian quarries. Data collection and analysis are discussed in detail and the results appeared to be promising.

Pavel KALENDA and Ivan POMPURA	SEISMIC MONITORING AT THE JELŠAVA DEPOSIT	207
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**Abstract**

All significant events registered by continuous seismic monitoring system at the Jelšava magnesite mine during the period from July 17, 1993 to May 1, 1995 are described in the paper. It is shown that in all cases of significant geomechanical events the increase in seismic activity was observed 6 - 8 hours before the main event. Such behavior of seismic activity was not observed before events of gravity character or at sudden stress redistribution after big destruction blasting work. On the basis of continuous seismic monitoring it is possible to determine the places with high stress and to predict the significant anomalous geomechanical events several hours before.

J.KVETKO and P.KALENDA	SEISMICITY MONITORING AT THE LUBENIK DEPOSIT	217
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**Abstract**

The continual observation of the stress-strain changes at Lubenik magnesite deposit was conditioned by searching for the possibilities of geomechanical control of the extracted spaces. The introduction of continual seismoacoustic monitoring was aimed at the localization of microseismic events, at the evaluation of their energies and at the formation of a database. Results achieved during one year of monitoring represent possibility of continual gathering of geophysical data and show the development of seismoacoustic activity in time and in dependence on mining operations. Series of A and ( parameters were evaluated for the sequences of tremors from different regions of various mines. Then statistical tests were performed to find out whether the values achieved for some days just before a strong tremor differ from the values obtained for randomly selected time periods. The analysis proved the significance of differences in the mean value, median and the shape of distribution of  $\epsilon$ . The result suggests a possible usefulness of parameter  $\epsilon$  as a precursor of strong events in the regions of mining works.

Lumír SKALSKÝ and Vladimír TOBYÁŠ	MONITORING OF TILTS AND MICROTREMORS FOR DETECTION OF SLOPE FAILURE IN the FOREFIELD OF an OPEN PIT MINE	225
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**Abstract**

Tilt changes and microtremors were measured in the exploration gallery and on the surface of the slope in the forefield of a deep open pit mine in connection with the slope stability monitoring. Pendulum tiltmeters with the resolution limit of 0.5 nrad were installed in a free block near the surface and deep in the stable rock mass. Two vertical short-period seismographs in the gallery and on the surface and one horizontal intermediate-period seismograph with the resolution limits of 0.1 (m and 1 (m, respectively, were in operation simultaneously. The Earth's tides course on the stable block corresponded to the theoretical one for the given geographical latitude but was about three times greater in amplitude and of an opposite phase in the free block. The non-tidal part of tilt changes contained long-term drift with some seasonal variations. In the free block short-term tilt loops with several days duration were accompanied by local tremors which were probably generated by slope failures. Step change of tilt with following intermediate-period seismic noise observed in the free block was excited by seismic loading of usual size induced by quarry blasting.

L. STAŠ, Z. RAKOWSKI, K. HORTVÍK	SOME RESULTS OF HORIZONTAL STRESS MEASUREMENTS BY HYDROFRACTURING METHOD IN UNDERGROUND MINES OF KARVINÁ PART OF "OKR" COALFIELD	237
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**Abstract**

Actual knowledge of stress in rock mass is one of basic prerequisites of successful solving of a number of research tasks within the area of sciences dealing with stress conditions and stress phenomena in Earth crust. One of the few methods enabling direct stress measuring in the areas accessible only by boreholes is hydrofracturing method. The following paper describes the application of such a method in the Institute of Geonics, it gives a short characteristics of the apparatus applied evaluating existing results of horizontal stress measurement in locations of Ostrava-Karviná coalfield.