

## **DESCRIPTION OF INDUCED SEISMICITY LEVEL BASING ON ANALYTICALLY CALCULATED CHANGES OF ELASTIC ENERGY IN ROCK LAYERS SUBJECTED TO DEFORMATION**

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### **Abstract**

The paper develops the approach (already presented – Acta Montana – s.A. No.16) where the analytically calculated changes in rockmass involving the distribution of the components of stress (strain) tensor are applied for long-term prediction of seismicity level induced by multi-bed mining. In consequence, the increase (decrease) of the appropriate elastic strain energy is calculated. Also the damage of rocks is investigated. It has been showed that as it is in the case of induced seismicity, these quantities are strongly dependent on the geometry and space-time development of multi-bed mining, and hence, to determine extreme values in their distributions, it is required that effective in terms of calculation three-dimensional – spatial solutions are applied. The results of exemplary analytical solutions, which are based on a relatively simple solution of the shift boundary problem of elasticity theory were presented. Expressing the relation between the observed seismicity and the analytically calculated changes of elastic energy by means of the linear regression model – for example for the particular headings – we forecast the changes of seismicity level, including the distribution of predicted energy of tremors.

**KEYWORDS:** seismicity, stresses, strain, seismicity prediction

## **DETERMINATION OF POTENTIAL LEVEL OF ROCKBURST HAZARD BASED ON THE RESULTS OF ANALYTICAL PREDICTIONS OF STRESS DISTRIBUTIONS AND THE LEVEL OF INDUCED SEISMICITY**

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### **Abstract**

The presently applied method of mining reconnaissance used for the designing of mining works in areas subject to seismic hazards is often providing erroneous read-outs involving the states of potential rockburst hazards. It results from the fact that a number of factors characterizing the influence of mining works on the stress-energy state of rockmass are not taken into consideration. In the paper it is suggested developing the currently binding method of mining reconnaissance which consists in allowing for the results of analytical stress predictions pertaining to mining conditions and the level of induced seismicity, in the classification of potential rockburst hazards. Making use of a real example of mining project the article presented how to apply the results of prediction calculations to determine the state of potential rockburst hazard.

**KEYWORDS:** rockburst hazard, vertical stress, vertical strain, analytical predictions

## STUDIES ON THE PHASE SPACE OF MULTISCALE SEISMICITY

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### Abstract

Sets of seismic events of different origin and different scale of the observed failure processes were analysed. The data sets, from micro-scale - seismoacoustic emission recorded from a rock sample under stress through coal-mining induced seismicity to macro-scale represented here by earthquakes caused by the Yake-dake volcano activity and San Andreas fault were studied to seek the deterministic chaos. The goal was to characterize the fracturing processes in terms of some chaotic parameters: the phase space and the dimension of the reconstructed attractor estimated for time-space distribution and energy distribution of the events. The calculated values were used to determine whether fracturing processes have similar features in different scales and on this basis to verify the usefulness of the applied data analysis methods for description of studied seismic processes, and finally to draw the conclusions about the time evolution of this systems.

**KEYWORDS:** deterministic chaos, phase space, attractor, fracturing processes, induced seismicity, earthquakes, seismoacoustic emission, time-space and energy distribution

## **IMPACT OF SEISMICITY ON SURFACE IN MINING AFFECTED AREAS: GENERAL DESCRIPTION**

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### **Abstract**

General description of expected types of seismicity in mining affected areas is given in this paper (mining induced seismicity, natural earthquakes, technical seismicity and industrial vibrations). Their basic characteristics are specified. The main parameters influencing the intensity of seismic effect on the surface will be pointed out and the specifications of seismic loading in mining affected area will be briefly discussed. Except direct influence of seismicity on building objects it is also necessary to consider indirect influences, e.g. changes of slope stability.

Mining tremors represent some of the most important causes of damages and acceleration of technical wear of buildings in mining area. The evaluation of influence of seismicity on buildings in the Czech Republic is solved by the technical standards (ČSN 73 0036, 73 0040), eventually by prepared Eurocodes. The intensity of seismic effect is providing by mathematical or physical simulation, generally supplemented by experimental measurement in investigated areas or in areas with similar conditions.

**KEYWORDS:** seismicity, mining affected areas

## **ESTIMATION OF THE LOCAL STRESS FIELD USING SEISMOLOGICAL DATA**

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### **Abstract**

Focal mechanisms of 400 mining induced seismic events were determined using seismic moment tensor inversion method. The seismic moment tensors were calculated in time domain for P-wave first arrivals. All the seismic events were induced in the vicinity of one longwall opening localised in the Halemba coal mine area (Upper Silesian Coal Basin, Poland).

Assuming that the tremors occurring in the same area in short time intervals are generated by similar stress conditions, mean local stress tensors for sets of seismic events were calculated.

Only shearing focal mechanism seismic events were taken into account. The stress tensors were calculated for ten succeeding seismic events. The study showed that the state of stress was very unstable in the investigated area. Variation of the local stress field manifested itself by instantaneous interchanging of the positions of main stress axes. Variations of the state of stress were probably the result of mutual interaction of lithostatic, mining and tectonic stresses.

**KEYWORDS:** mining induced seismicity, mean local stress tensor, focal mechanism

# **ROCKMASS DEFORMATIONS CAUSED BY ZINC AND LEAD ORES MINING IN THE OLKUSZ REGION (SOUTHERN POLAND)**

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## **Abstract**

Results of study on continuous and discontinuous deformation are presented. Ground surface deformations formed in 1980-2002 period. Conical potholes, depressions, cracks, as well as edges like scarps and ridges have been observed. The depth of some structures reached 25 metres and their areal dimension achieved ca. 500 square metres. Continuous deformations can form as sag structures with subsidence ranging from 500 to 600 mm. Deformations were frequently filled up with Quaternary sands from the cover. A model of the deformation development has been adopted, which helped predict subsidence parameters for the part of the "Klucze" orefield scheduled to open in the future. Mining has influenced changes of physical features of the Triassic complex in the close vicinity of excavations. In this region, influence of groundwater drainage on the rockmass state is of major importance. Knowledge of the deformation growth helps to correct building development and to recognise the occurrence of new hydraulic connections of the Quaternary water horizon with the Triassic aquifer. Reclamation of post-mining areas will be particularly important after closing the last operating zinc and lead mine in this region what is expected in a few years.

**KEYWORDS:** sinkhole, discontinuous ground deformation, subsidence trough, continuous ground deformation, subsidence prediction, Zn-Pb ores, Silesian-Cracovian district

**FRENŠTÁT SEISMIC NETWORK AND ITS CONTRIBUTION TO OBSERVATIONS  
OF THE NATURAL AND INDUCED SEISMICITY ON THE TERRITORY OF  
NORTHERN MORAVIA AND SILESIA**

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**Abstract**

We present comprehensive information on the Frenštát seismic network operated in 1992-2002 by the Institute of Geonics AS CR in Ostrava. The proposed regional diagnostic polygon in the Ostrava-Karviná Coal Basin consisting of 15 observation points was later divided into two parts. The first part (10 stations) surrounded the mining area of the Karviná partial basin, the other (5 stations), denoted as SPF, was distributed in the wide outskirts of Frenštát p. Radh. where a new mine was under construction. Special attention in this paper is paid on the description of developed instrumentation and methodical approaches in the data interpretation. The regular continuous operation started on January 1992. The network consisted of 5 three-component short period stations. Data from individual seismic stations were transmitted by telemetry to the recording centre via a relay station.

The primary seismic digital data were sorted into the following groups: earthquakes, induced seismic events from Ostrava-Karviná coal mines as well as from Polish ore and coal mines, quarry blasts and other unidentified sources.

Quarry blasts were used for the construction of travel-time curves and for deriving Pg- and Sg-waves velocities. The SPF network significantly contributed to the detection of seismic events, foci localization and seismic regime investigation in the mines Paskov and Staříč situated in the southern part of the Ostrava-Karviná Coal Basin.

The operation of the SPF monitoring system discontinued in December 2002.

**KEYWORDS:** Ostrava-Karviná Coal Basin, seismological monitoring, seismic network, instrumental equipment, data acquisition and data processing

# DATA TRANSMISSION FROM SEISMIC STATIONS VIA NETWORK AGNES USING GSM-GPRS TECHNOLOGY

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## Abstract

Global System for Mobile Communication (GSM) is frequently used for data transmission from seismic stations because it allows an easy realization of data connection from field observation points where metallic telephone line isn't available. Communication channel is established as a dial-up connection. As a GSM communication adapter either separate GSM modems or modems integrated to some standard mobile phone are used. Data are transferred through GSM network the same as voice digital signal using service Circuit Switched Data (CSD), but the priority of data is lower. Therefore data rate fluctuates according to the load of GSM network and theoretical value of 9.6 kbps (14.4 kbps Eurotel) is achieved rather rarely. Moreover, this way of data transfer is expensive with regard to a high price of CSD service. To reach low-cost access to Internet from mobile phone the GSM network was supplemented by General Packet Radio Service (GPRS). The GPRS technology allows usage of associated free channels of CSD system and data packet switching technology for data transfer. It allows users to stay continuously connected to the Internet. Data rate is theoretically higher on CSD, in practice it considerably depends on network loading. The main advantage is that GPRS user pays only for the amount of transferred data, not for online time per-minute.

In the paper principles of GPS, GPRS and telemetric data transmission using GPRS are briefly described. System of seismic data transmission from PCM3-EPC apparatuses with the help of virtual private network (VPN) AGNES, operated by company Conel Ltd. in the GPRS T-Mobile network, is tested in the Institute of Geonics AS CR. Communication adapters (which convert PPP protocol to RS232 protocol), the CGU02 Intelligent GPRS modems (Conel Ltd.) and communication software pcAnywhere are used. Our experience obtained during the trial operation is discussed.

**KEYWORDS:** seismic data transmission, GSM, GPRS

# **CONTROLLING OF MEASUREMENT PROCESS OF STRONG GROUND MOTION USING MOBILE TECHNOLOGIES IN SEJS-NET SYSTEM**

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## **Abstract**

The SEJS-NET system is based on Internet technology and is designed for monitoring of strong ground motion and building vibration. The system, making use of present feasibilities of telecommunication, conducts automatically, practically without maintenance, recording of seismic vibrations at any number of measurement points. The access through a WWW browser to a recording database, equipped with handy and flexible functions for visualization, selecting, editing, and maintained in the Measurement Central Base – the system's server, is independent of mutual location of Recording Stations, the Central Base and user's workstation. Thanks to implemented solution, SEJS-NET system, supporting routine processing of collected data, builds at the same time a simple and flexible basis for advanced processing.

Designers of sophisticated measuring systems try to use high telecommunication technology, which gives possibility to make easier controlling of measurement process and data distribution. The work presents practical application of WAP technology in SEJS-NET system. Implemented WMOBILE module gives access to system resources via WAP browser from mobile phones and palmtop browsers.

**KEYWORDS:** seismology system, engineering seismology

# VERIFICATION THE ATTENUATION RELATIONS FOR SEISMIC WAVES IN THE BOHEMIAN MASSIF

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## Abstract

The SEJS-NET system is based on Internet technology and is designed for monitoring of strong ground motion and building vibration. The system, making use of present feasibilities of telecommunication, conducts automatically, practically without maintenance, recording of seismic vibrations at any number of measurement points. The access through a WWW browser to a recording database, equipped with handy and flexible functions for visualization, selecting, editing, and maintained in the Measurement Central Base – the system's server, is independent of mutual location of Recording Stations, the Central Base and user's workstation. Thanks to implemented solution, SEJS-NET system, supporting routine processing of collected data, builds at the same time a simple and flexible basis for advanced processing.

Designers of sophisticated measuring systems try to use high telecommunication technology, which gives possibility to make easier controlling of measurement process and data distribution. The work presents practical application of WAP technology in SEJS-NET system. Implemented WMOBILE module gives access to system resources via WAP browser from mobile phones and palmtop browsers.

Anti-earthquake design of facilities with high earthquake risk is based on design spectra, which are prescribed on the basis of earthquake hazard to a building site in question. In the Czech Republic, the determination of earthquake hazard, expressed in the units of ground motion acceleration, makes use of acceleration attenuation relations, which had been derived in abroad regions with greater seismic activities. Verification the applicability of abroad formulae must be based on authentic accelerograms of earthquake events in the region of localities in the Czech Republic. Since 2003, four temporarily seismic stations are taken in operation in the N-S profile Šonov – Znojmo towns. For the sake of establishing great number of measuring points in the whole region, automated peak acceleration recorders were constructed. The up to now maps of macroseismic fields could be, step by step, completed by much more objective data.

**KEYWORDS:** earthquake hazard assessment, design spectra, ground motion acceleration, acceleration attenuation monitoring, seismic profile, acceleration response recorder



## SEISMOACOUSTIC EMISSION FIELD AND ITS APPLICATIONS

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### Abstract

Seismoacoustic emission field and its intensity are useful notions when – as usually in practice of mining seismoacoustic observations – acoustic emission (AE) sources are not localized. Given observed (with a few sensors, during a time interval  $\Delta t$ ) values of a so-called „conventional (AE) energy” and postulating reasonable parametric form of emission intensity  $e(x, y)$ , parameters of intensity equation can be estimated allowing – when the sources are not localized – to estimate the physical AE energy emitted during the  $\Delta t$ , what is needed (e.g.) to evaluate the seismic hazard.

**KEYWORDS:** mining induced seismic hazard, acoustic emission/seismoacoustics, energy estimation, emission field, emission intensity

## UTILIZING OF ULTRASONIC EMISSION TO THE PREDICTION OF ROCK SAMPLE INSTABILITY

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### Abstract

The evaluation of stress-deformation stage of rocks, mainly time prediction of the origin of extensive brittle fracturing, belongs to the present important tasks of geomechanics. Laboratory results obtained are very important for the assessment of the origin of natural earthquakes as well as induced seismic events.

Laboratory experiments were oriented to the evaluation of the possibility to predict the time of the total fracturing of the rock samples subjected to the uniaxial loading. The sandstone samples were studied. In all experiments the ultrasonic emission was recorded. Time series of ultrasonic emission were analyzed by autocorrelation method.

It was found that during the fast rock sample loading the ultrasonic emission could be observed when 65% of total strength of the material is exceeded. Following parameters of the course of autocorrelation function were used:

- the first value of autocorrelation coefficient  $R(1)$
- the number of positive autocorrelation coefficients (correlation radius)
- the trend of autocorrelation function according to linear time dependence.

For the short term rock sample loading, after the crossing of the 90% of the total strength of the material, the significant increase the value of correlation coefficient of linear approximation are observed. The dependence of the autocorrelation function is nearly linear. It means that the value of the first autocorrelation coefficient  $R(1)$  increase as well. The correlation radius at different values of acting load (starting from the 90% of strength limit) however is nearly the same.

For the cyclic loading, in the case of second cycle, the autocorrelation methods can be applied, due to the Kaiser effect, after the maximum acting stress of the first loading cycle is exceeded. The nature of the ultrasonic emission originating during short-term test is influenced mainly by the response of the sample to acting force. During long-term test the parameters of ultrasonic emission reflect rheological properties of rocks sample.

Results obtained under laboratory conditions could be applied to seismoacoustic investigation of rock burst occurrence.

**KEYWORDS:** Ultrasonic emission, loaded rock samples, prediction of total rupture, autocorrelation analysis, stress- strain state of rocks.

## **EVALUATION OF ULTRASOUND EMISSION FOCI IN LOADING ROCK SAMPLES**

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### **Abstract**

Laboratory experiments proved that during loading of rock samples the migration of ultrasound signals (US) foci occurred in the volume of sample. There is distribution of US foci analysed in this paper. On the base of ultrasonic signals location the segments of higher concentration were determined. For the purpose of the assessment of detailed future part of total rupture the whole volume of the rock sample was divided in eight segments. The experiments were carried out for various loading rate. Detailed analysis, based on the cross-correlation of the foci number in the separate segments, proved that the occurrence of US in the individual segments are mutually influenced. The results indicate that the used correlation method allowed to assess the future part of the total sample fracture.

**KEYWORDS:** ultrasound emission, rock samples, location, correlation analysis, loading rate, prediction of total rupture

## **ELECTROMAGNETIC & ACOUSTIC EMISSION FROM THE ROCK – EXPERIMENTAL MEASUREMENTS**

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### **Abstract**

Measurements of electromagnetic emission (EME) from hard coal, grey dolomite, sandstone and magnesite samples subjected to a uniaxial compression are described. The measurements were performed using a system specifically designed to measure the radiation immediately preceding sample failure. The measurement results are analysed and the rocks are classified according to the potential use of their EME. The occurrence of acoustic emission (AE) in conjunction with EME as the rock sample is being loaded is analysed. Typical applications of EME to predicting hazards in the underground workings of mines are presented.

**KEYWORDS:** electromagnetic emission, subjecting rocks to loading, spectrum of emission

## **KNOWLEDGE RESULTING FROM THE GEO-MECHANICAL MONITORING OF THE ROCK MASSIF AT DRILLING**

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### **Abstract**

Monitoring systems of the rock disintegration process set in drilling and driving in the rock mass provide scanning and quantification of input (thrust, revolutions, power supply) and output (drilling rate, disintegration energy, working ability) values of the process. The systems also enable obtaining the information on mechanical properties of the drilled rocks. The problem arising in the process is their interpretation as the relations between mechanical rock properties and individual monitored values show the ambiguity. The paper introduces the approach to eliminate the ambiguity. The data on drilled rock mechanical properties acquired in a way mentioned above are not reliant to mechanical logging and may be used for rock mass failure zones prediction.

**KEYWORDS:** drilling, monitoring, rock, drilling rate, rock compression strength

## **THE SCANNING OF ACOUSTIC SIGNAL AS A COMPONENT OF MONITORING THE ROCK DISINTEGRATION PROCESS**

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### **Abstract**

A classical monitoring system enables measuring of the thrust, revolutions and power supply as input values and advance rate of the tool as an output value during the disintegration process. The monitored data provide a source for calculation of the specific volume disintegration energy and consequently the working ability as a ratio of advance rate and specific volume energy. Both variables serve as the rating values of disintegration process efficiency. The acoustic oscillations arise during the rock disintegration process. The sources of the oscillations are all of the components taking part in disintegration, i.e. the disintegration equipment, the disintegration tool and the rock. The classical monitoring system was adjusted to acoustic signal scanning in the experimental laboratory conditions. After the scanning, the acoustic signal was evaluated and studied, showing the dependencies between the input values and the acoustic signal characteristics. This experience leads to the potential use of acoustic signal for evaluation and control of the disintegration process.

**KEYWORDS:** acoustic signal, monitoring, disintegration process, rock

## DEPOSITION OF LIGHT ASH MIXES IN MINED SPACES

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### Abstract

The possibility of filling empty underground spaces, which exist owing to extracting mineral raw materials, with light ash and cement light ash mixes have been studied for the purpose to reduce the impact of deep mining on the surface. The method of physical modelling was used to study the behaviour of light ash mixes deposited in extracted mine spaces. The models were constructed for two different geometries of underground extracted mine spaces - into cavities of the type of large slits created in the course of mining in steeply lode deposits without subsequently filling the empty space and in vertical shafts of rectangular or circular cross-section with horizontal side headings which have partly caved in due to mine shocks or other seismic events.

**KEYWORDS:** physical modelling, reducing the impact of deep mining, deposition of the light ash mixes

## RECORDER ROTATIONAL GROUND VIBRATION

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### Abstract

The rotation components of seismic ground motion can be radiated from the source, or can be generated when seismic waves spread through anisotropic (micromorphic) rock massif or rise as the response of building structures on dilatational excitation. In order to experimental study these questions, new sensors of rotational ground motion were constructed. They use cooling air blowers from standard PC. This easy construction seems to be satisfactory for monitoring strong ground motion forced by near earthquakes, rockbursts and production blasting. In principle this sensor is as an elementary mechanic oscillator with constant natural frequency  $f_S$  and small damping constant  $D$ . The value of maximum amplitude of oscillatory response to seismic ground motion is digitized and stored on hard disc of PC in a triggered regime. The time of events is taken from PC clock synchronised by the time signal of DCF 77 station.

**KEYWORDS:** rotation component, ground motion, seismic, recorder, rockburst, transfer function, amplifier, electronic, filter, selective, response, natural frequency, AD converter, cooling blower, damping, quality factor