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SEISMICITY MONITORING AT THE LUBENIK DEPOSIT

J.KVETKO and P.KALENDA

Ing.J.Kvetko,CSc., Slovmag Lubeník a.s., 049 18 Lubeník, Slovak Republic
Dr.P.Kalenda, CSc., CoalExp Ostrava, Kosmonautů 2, 700 30 Ostrava–3, Czech Republic

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.

1. Introduction

Liability to ensure the continuous measurement of stress and deformation conditions at the Lubenik deposit results from the investigation of an extraordinary event of Sept. 6, 1991, when a huge tumbling of overlying strata occurred.

Continuous monitoring of seismoacoustic (SA) activity which began at the deposit in 1992, despite the limited number of processed parameters of SA pulses, enabled initial evaluation of conditions in the massif as for its seismicity and proved the necessity of applying such a method.

The need for a more detailed investigation of seismicity at this deposit was met by the installation of a new monitoring system UGAC–SL (Coal Exp Ostrava).

2. Network Set–up and Measuring System Description

The seismic network at the deposit was set up on the basis of presupposed seismic activity considering the possibility of installing some sensors. It consists of 11 active seismoacoustic sensors and 4 seismometers covering almost the whole deposit.

Deployment of the sensors is apparent from Fig. 2 where projection of all the sensors is outlined up to the level of Horizon VII.

Seismometers were located in the marginal extracted areas with minimum disturbances at the level of Horizon VII (sensors No. 105, 106, 107, 108).

Signals from these sensors with no amplification were transmitted by cables up to the surface to the preamplifiers with amplification factor of 100.

Seismoacoustic sensors (SA) were located as follows:

Horizon V – sensors No. 101, 102
Horizon VI – sensors No. 103, 104, 109, 110
Horizon VII – sensors No.111, 112, 113, 114, 115.

All the SA sensors were designed as the active ones with the amplification factor of 200 at 200 – 600 Hz with current transfer of their signals up to the surface.

Complete set–up of a new system starting with trial operation was effected by the end of June 94. It was intended to carry out a real–time monitoring of underground seismic situation throughout the deposit area with the possibility to separate natural seismic events from blasting (as well as from interfering pulses). Localization of arisen events together with their energy evaluation aimed to investigate the magnitude of emitted seismic energy in time and space.

The software enabled:

- continuous data acquisition,
- preliminary data processing, elimination of erroneous events,
- data transfer,
- determination of energy and localization of events,
- archiving database of events,
- archiving database containing selected wave images,
- interpretation and data plotting including the map documentation.

3. Results from Continuous Monitoring

The initial database of seismicity development at the deposit, which enabled to possibility of evaluate relation between seismicity and intensity of blasting and extraction was obtained during the period of continuous registration (from June 94 to May 95). The following time intervals are evident from the Benioff's graph slope during the period of monitoring this deposit as a whole (Fig. 1):

- up to July 28, 1994 – normal development
- July 28, 1994 – anomalous event
- up to Oct 1, 1994 – normal development
- Oct 1,1994 – Jan 1, 1995 – intensified extraction
- Jan 1, 1995 – Apr 15, 1995 – normal development at moderately intensified extraction

The horizontal interval on the graph in the period from Oct 29 to Nov 17, 1994 represents the time interval without any measurement carried out.

3.1. Normal Development

Based on increments in Benioff graph (Fig. 1) the mean daily increment was determined from valid seismic events to the value of 4.5 $\sqrt{J}$ per day.

The daily increment in the Benioff graph from the registered blastings is approx. 32 $\sqrt{J}$ per day.

Substantially higher energy level of blastings against registered natural events requires their persistent separation to avoid the devaluation of the responding ability of the database.

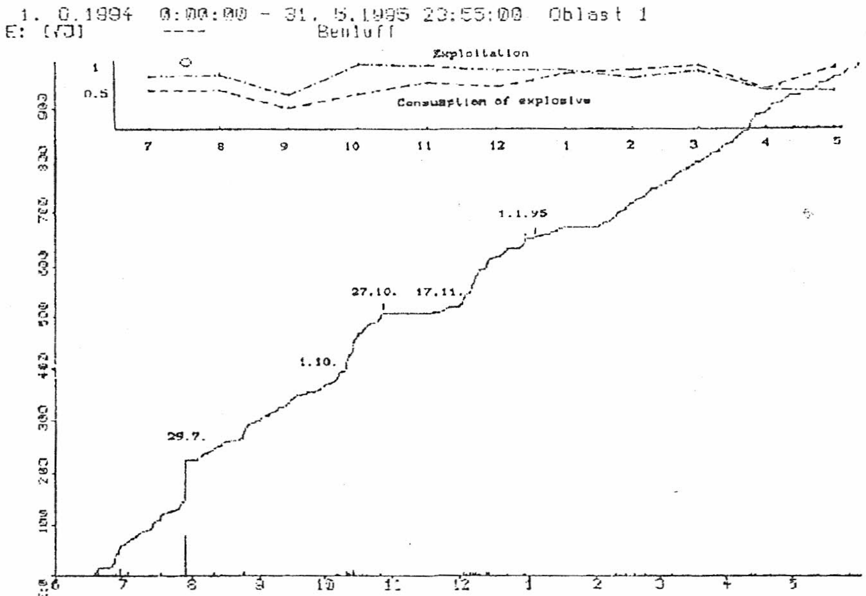


FIG. 1. Benioff graph of seismic events recorded by the seismoacoustic system in the period from June, 1994 to May, 1995

3.2. Anomalous Event

One of significant events with the energy of approx. 2900 J was registered at 1:13:33 a.m. on July 29, 1994 during the starting period of operation of the system. Localization of the event falls to the area where the deposit centre is in contact with the overlying strata (Fig. 2).

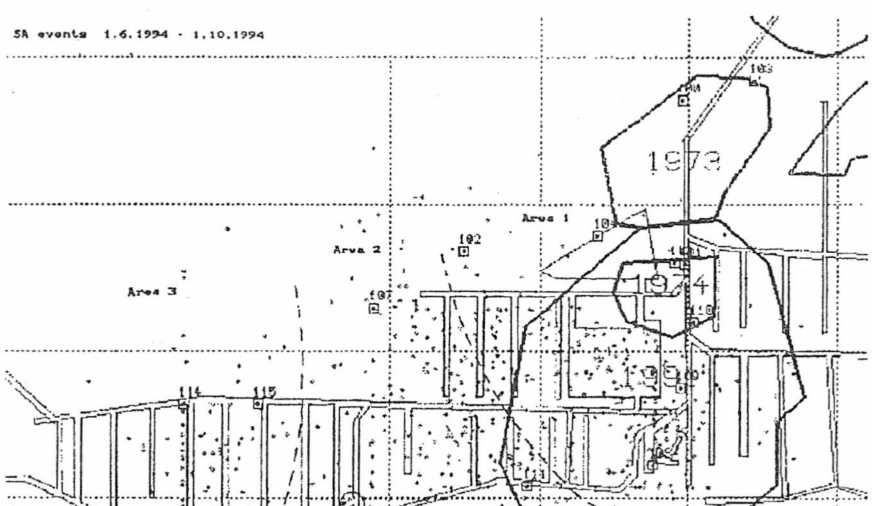


FIG. 2. Location map of seismic events recorded in the period from June 1, 1994 to October 1, 1995

The indicated event was preceded by three minor ones which occurred in the area on 28.7.94.

Anomalous behaviour of the deposit touching the less solid overlying strata is confirmed by the results which were acquired from the bar extension gauges on Horizon VII where the highest deformations were measured at the nearest measuring station to the localized anomalous event.

3.3. Seismicity Development during Intensified Extraction

As for the frequency of occurrence of the microseismic events, the active part of the deposit can be divided into 3 areas (they are evident from Fig. 2):

- area 1 – central part of the deposit (the one under the last collapse – in 1991),
- area 2 – the one between the central and west parts of the deposit limited approx. by sensors No. 102, 107, 113, 111,
- area 3 – west part of the deposit – surroundings of sensors No.114 and 115.

From the beginning of registration to Oct 1, 1994 it was possible to state that the response of seismic activity to extracting activities was comparable among all the parts of the deposit (Fig. 2). The blasting intensity in the deposit was almost uniform (Fig. 3).

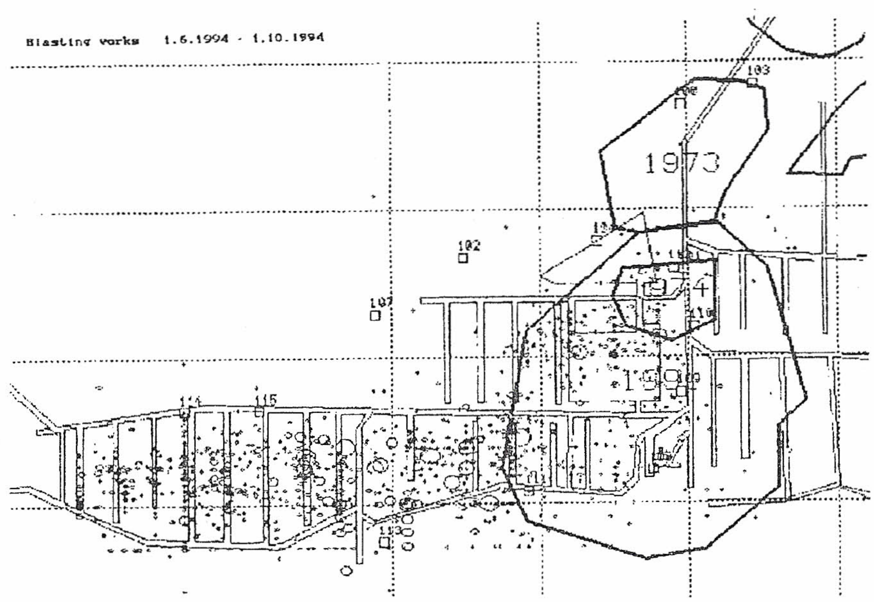
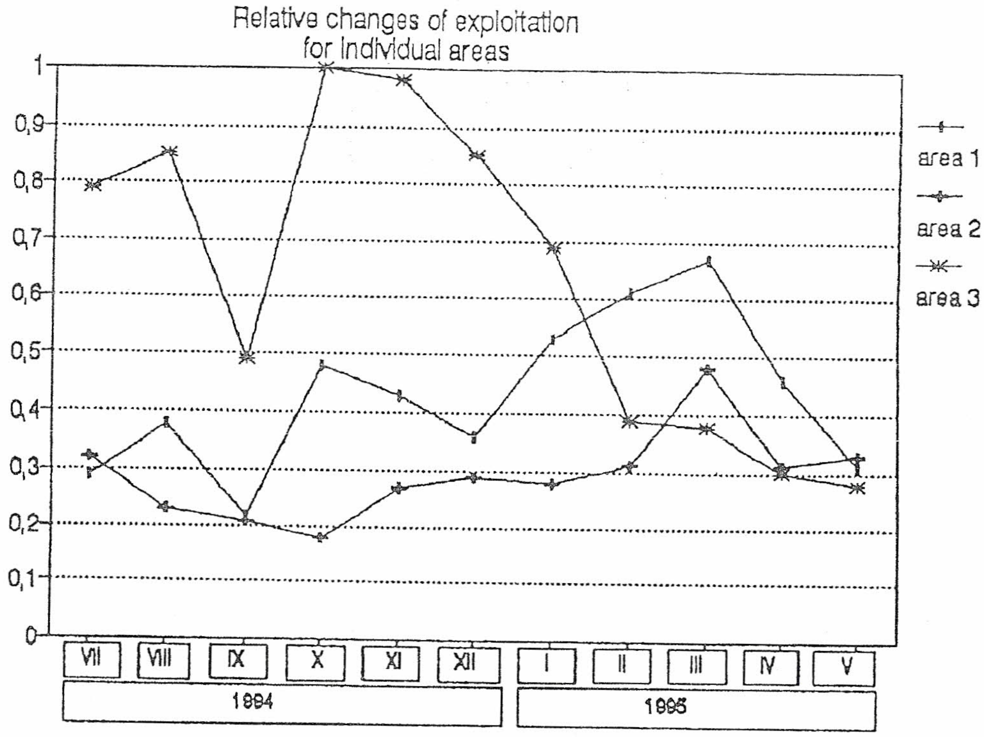


FIG. 3. Location map of blasting works recorded in the period from June 1, 1994 to October 1, 1995

Fig. 4 represents relative alterations in intensity of the extraction and alterations in consumption of explosives for each area individually. It is evident from the graphs that the extraction in 09/94 was substantially reduced as it corresponds with the consumption of explosives.

Seismic loading given by the consumption of explosives in the deposit, correlating with the intensified extraction (from 10/94 to Dec. 31, 1994), was roughly comparable for all three areas (Fig. 5).



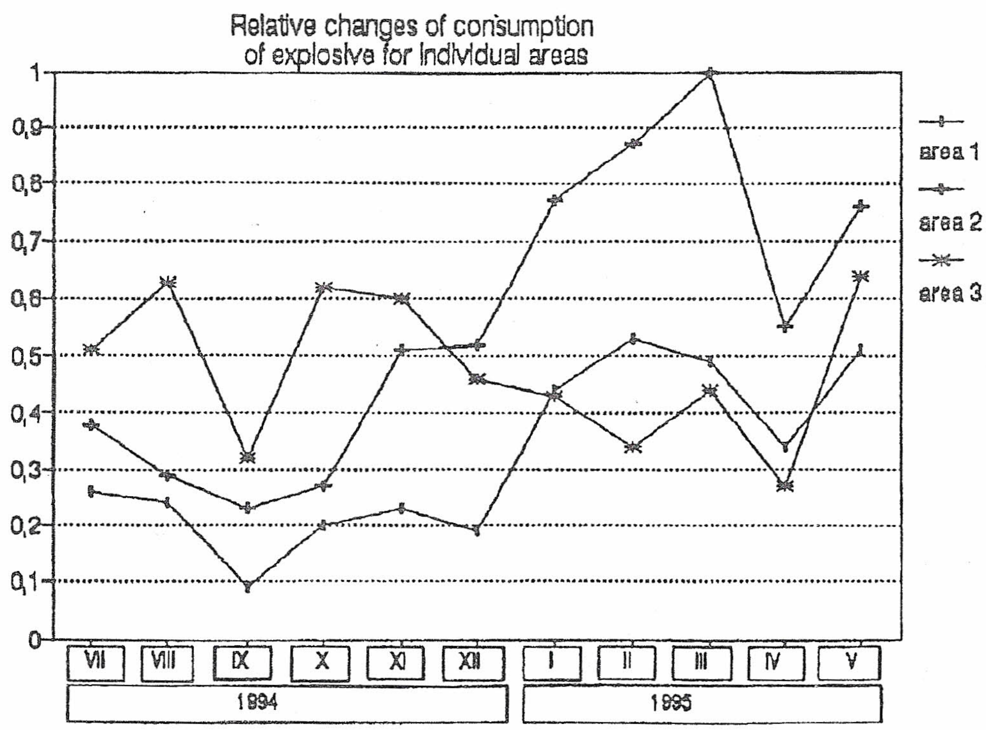


FIG. 4. Relative changes of exploitation and relative changes of consumption of explosives for individual areas in the period from July 1994 to May 1995

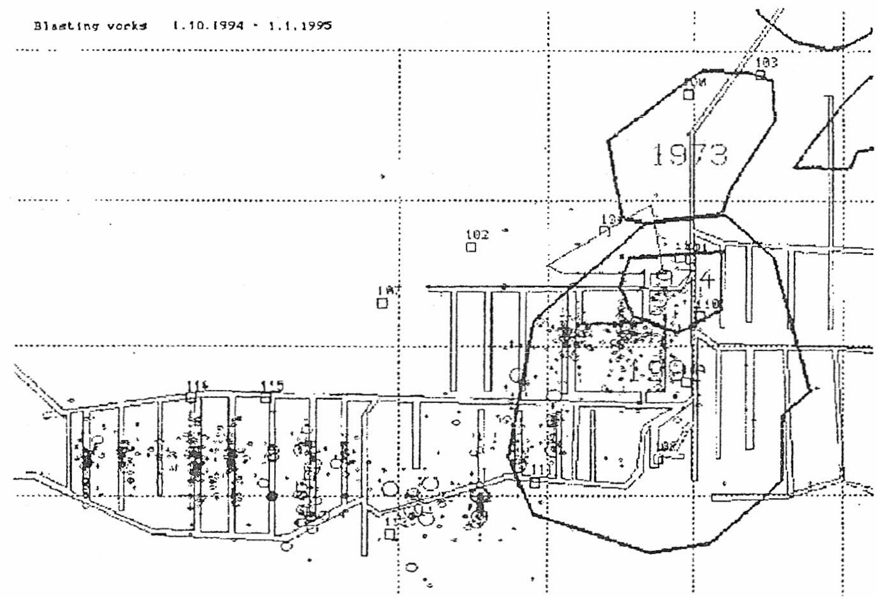


FIG. 5. Location map of blasting works recorded in the period from October 1, 1994 to January 1, 1995

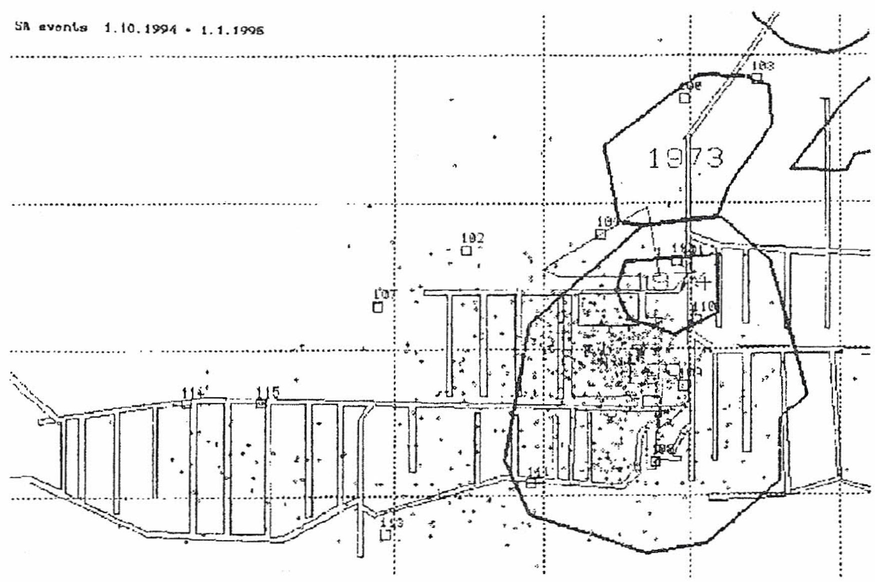


FIG. 6. Location map of seismic events recorded in the period from October 1, 1994 to January 1, 1995

Seismic response of the massif to intensified extraction from 10/94 was substantially higher under the tumbling, i.e. in area 1 as it is evident even from the number of events in that area (Fig. 6).

The seismic response of the massif to the extraction was calculated as a ratio of seismic loading resulting from induced events and blasting smoothed by means of a convolution filter with 20 m diameter, comparable with localization error. This response of the massif varied from Oct 1, 1994 to Jan 1, 1995 in area 1 within the values of 8 – 30 %, in area 2 1 – 10 % and in area 3 – less than 3 % (see Fig. 7).

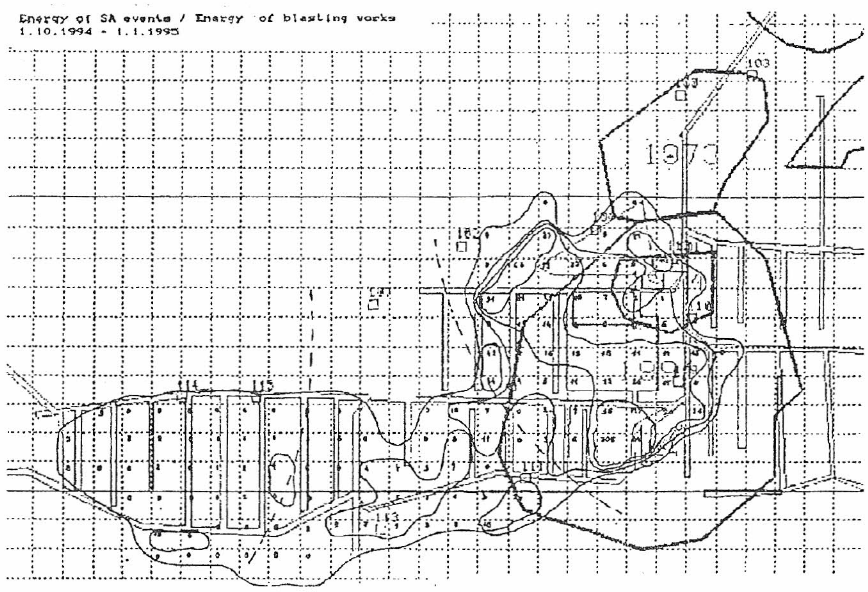


FIG. 7. Relation between energy of SA events and energy of blasting works in the period from October 1, 1994 to January 1, 1995

It follows from the above indicated values that the stress under the tumbling in area 1 (chamber K–726) reached the strength limit of the "cracked part of the massif".

The seismic activity in this area was initiated by blastings (even by the small scale ones) and also by the extraction of waste from filled chambers under the tumbling.

Falling of rocks and landslides filling empty spaces were evident from the wave forms. Different wave registrations, typical of fragile cracking of the rocks in that area, were probably caused by pressure of waste material on remnants of non–destructed parts of some roof and interchamber pillars.

The events were located into the central and the west part of the last tumbling at the level of Horizon V (above K–726,K–724–25). The events were relatively equally distributed in time and had quite a low energy value (below 0.5 J). The growth of induced seismicity is evident also from the Benioff graph (Fig. 1).

The figure also included the global intensity of extraction and global consumption of explosives at the deposit. Although this was the question of assessment of the deposit as a whole, there was an apparent growth of seismicity after interrupted uniformity of extraction intensity which could be seen from the figure.

The trend of growing response of the massif to the extraction in area 1 continued with the same symptoms also after Jan 1, 1995 till the end of the monitored period

(May 1, 1995).

By comparing the induced seismicity in areas 1, 2 and 3 the safe state could be stated in area 3.

Area 2 was featured by sporadic occurrence of natural events, particularly in the contact area of the deposit and the overlying strata at the southern edge of the area. As a rule, the events did not exceed the energy of 1 J.

4. Conclusion

By comparing the induced seismicity in the period from June 20, 1994 to May 1, 1995 it was possible to divide the Lubenik deposit into three areas having individual behaviours of induced seismicity. The seismic activity was displayed to its greatest extent in the region beneath the last tumbling – in area 1 – as a rule above the level of Horizon VII – i.e. above the level of active workplaces.

It can be assumed on the basis of relatively uniform occurrence of events having low energy levels (below 0.5 J) that growth of energy accumulation does not occur within the massif in that area. However, certain fragile damages to the remaining non–destroyed parts of the massif exposed to stress caused by collapsed material resulting thereby in a possibility of sudden drop of the released material into empty spaces of active chambers cannot be excluded.

Some significant events with more energy (against the event beneath tumbling), but with less uniform occurrence in time (in the period of increased activity approx. 1 – 3 events per day), were registered at the contact of the deposit with the overlying strata, particularly in area 2, but also in the south part of area 1.

These events were coherent with less solid overlying rocks stepping in the deposit.

Variable extraction intensity in the west part of the deposit – in area 3 – had a little effect on the magnitude of induced seismicity.