ACTA MONTANA IRSM AS CR (1996)
Series A, No.9 (100), 207–215

SEISMIC MONITORING AT THE JELŠAVA DEPOSIT

Pavel KALENDA and Ivan POMPURA

RNDr. Pavel Kalenda, CSc., CoalExp Ostrava,
Kosmonautů 2, 700 30 Ostrava–3, Czech Republic
Ing. Ivan Pompura, SMZ a.s. Jelšava, 049 16 Jelšava, Slovak Republic

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.

1. Introduction

An extraordinary event which occurred at the Jelšava deposit in 1991 resulted in a collapse of the roof in the uppermost chamber of the Dubrava part of the deposit causing a surface crater with dimensions approx. 150 × 100 m and 50 – 70 m deep. Due to the fact that this happened by pure coincidence on a holiday, no casualties were registered.

Since there was a chamber with dimensions of approx. 350 × 180 m and 50 – 80 m high made at the horizon of 482 m in the Mikova part of the deposit (hereinafter the Mikova chamber), the problem was approached by continuous monitoring of seismoacoustic (SA) activity and by convergency measurement of the roof in this chamber.

The monitoring system UGA–15 (VVUU Ostrava–Radvanice), which enabled a more detailed investigation of induced seismicity, was installed in the area of the Mikova chamber in 1993.

Continuous SA monitoring was intended to localize seismic events with sufficient accuracy, to determine their energies and seismic operational modes for individual areas of the deposit, particularly for parts of the Mikova chamber. After a year's trial operation and determination of a normal seismic mode, activities were initiated to monitor anomalous stress conditions of the massif and seismic activity which precedes these conditions. The aim of seismic monitoring was to find prediction parameters for anomalous seismic events and safety criteria for extraction in lower levels beneath the Mikova chamber.

All significant events registered during the period from July 17, 1993 to May 1, 1995 including analyses of some possible prediction parameters are described in this paper.

2. Network Set–Up and Measuring System Description

The seismic network at the deposit was set up in the surroundings of the Mikova chamber and comprises three seismometers and 13 pcs of seismoacoustic sensors. The seismometers (No. 101,102 and 103) were located 482 m above sea level and their amplification factor is 100 (see Fig. 1). The SA sensors were located at the following horizons:

390 m a.s.l. – sensor No. 100
430 m a.s.l. – sensors No. 104, 105 and 111
440 m a.s.l. – sensors No. 106 and 107
482 m a.s.l. – sensors No. 108, 109 and 110
500 m a.s.l. – sensors No. 112, 113, 114, 115

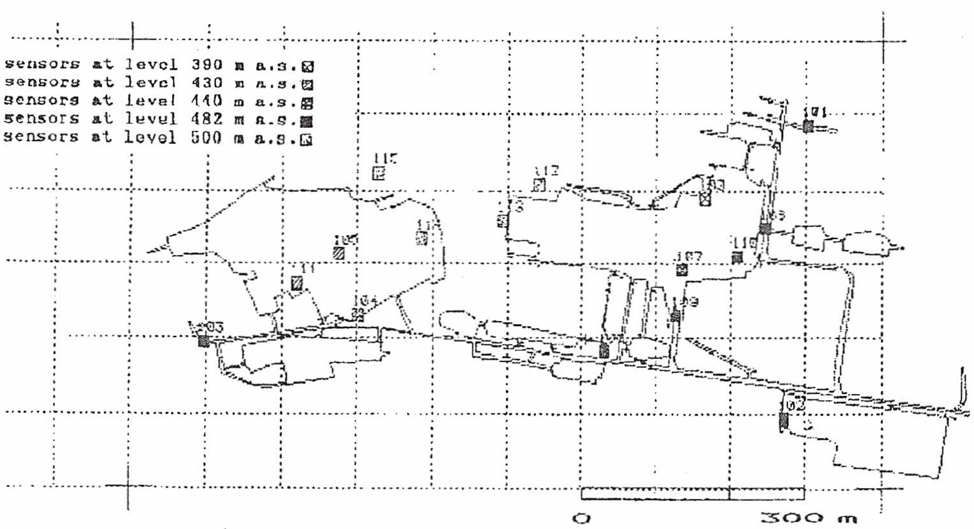

FIG. 1. Map of the Jelšava mine at a level of 482 m a.s.l. with sensor localization

Preamplification of the SA sensors is 200. In July 1994 all the SA sensors were rebuilt to active ones having preamplifiers located directly at geophones including active DC current loops to eliminate peaks resulting from stormy weather and interfering with cable routes and sensors.

The software enables:

- continuous data acquisition,
- preliminary data processing and elimination of interfering events (peaks),
- data transmission from the collecting PC to a laboratory (monitoring)

- determination of localization and energy of events
- keeping the records of events
- keeping records of selected wave images
- interpretation and data plotting including map documentation

3. RESULTS FROM CONTINUOUS MONITORING

Fig. 2 represents the course of a summary Benioff's graph together with a line graph showing individual seismic events. The height of the individual line is proportional to the roots of energy. The data file from Sept 1, 1993 is complete except for a drop out in the measurement caused by a lightning. New parameters were entered and a higher sensitivity of the sensors was preset on Feb 1, 1994 and a new software version was installed. All of that was reflected in the changes in the slope of Benioff graph.

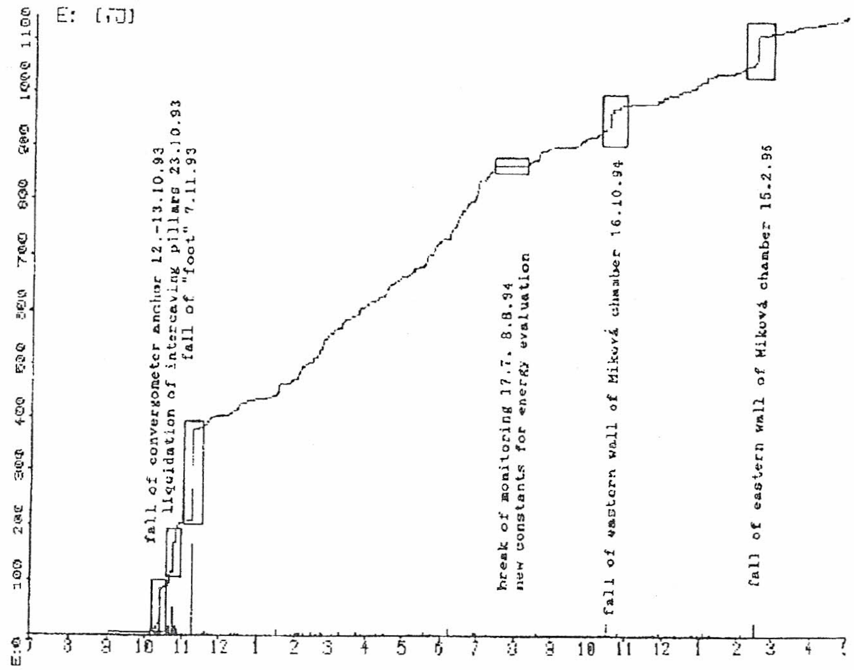

FIG. 2. Benioff graph of the Dúbrava massif at the Jelšava mine from July 1, 1993 to May 1, 1995

Altogether six significant events were registered during the period of continuous registration from July 17, 1993 to May 1, 1995, three of which at the beginning of registration in the period of trial operation. At that time all parameters of the apparatus were not preset to optimum. And despite of this, the quality of data enabled comparable interpretation of all events.

3.1. Normal Development

The slope of the Benioff graph ranges from 1 to 1.2 $\sqrt{J}$ per day within the entire deposit. Since the slope of the Benioff graph was very low even local events could be seen well from the summary Benioff graph. Separation of natural events from blastings was of the utmost importance because a number of blastings are more significant than the natural events.

Daily increment of the Benioff graph from the registered blastings was approx. 20 $\sqrt{\mathrm{J}}$ per day.

3.2. Anomalous Events

Anomalous events were registered on the following days:

Oct 13, 1993	– loosening of a block in the chamber roof together with an anchor
Oct 23 – 25, 1993	– loosening of a block in the southern part of the chamber after destructive blasting
Nov 7, 1993	– gravity breakdown of the scrap interchamber pillar i.e. "leg" and break–through of interlevel panels
Jan 16 – 17, 1994	– crumbling of the sides of the Dubrava abyss and movement of mass surrounding the "leg"
Oct 16, 1994	– breakdown of a block in the south–east corner of the Mikova chamber
Feb 15, 1995	– breakdown of a "groin" in the east part of the Mikova chamber

During the event of Oct 13, 1993 a block with dimensions of approx. $10 \times 10 \times 10$ m came off from the roof of the Mikova chamber and a geomechanic measuring anchor came off as well. The first seismic events from the Mikova chamber were registered as early as Oct 9,1 993 (see Fig. 3). Their numbers and energies were growing. Rapidly increasing spread of deformations was taking place from 10:00, Oct. 12. Loosening of the block from the roof of the chamber occurred at 7:47, Oct. 13. Seismic activity after the anomalous event was fading away in the course of two days. The Benioff graph shows a typical "S" curve with an increasing part, lasting two days and with rapidly increasing number of events, lasting 8 hours.

Destruction blasting with approx. 9 tons of explosives was carried out at 12:23, Oct.23, 1993, approximately beneath the centre of the Mikova chamber. A few seconds after the blasting the south side of the chamber began to crack, which resulted in sharp and frequent SA pulses detected by sensor No.7 (see Fig. 4) and blocks of rock began to fall into the chamber which was registered by all sensors. A block of rock of approx. 10000 m^3 in volume together with sensor No. 7 came off.

No other pre–shaking (before 12:23) was registered before the event since this was a response of the massif to the rearrangement of stress in the chamber wall after the destruction blasting. Another smaller part from the southern side of the chamber came off without pre–shaking, which was a consequence of the destruction of the chamber's wall effected on Oct 21, 1993.

One of the most significant anomalous events was registered on Nov 7,1993 when the gravitational separation of interchamber pillar i.e. "leg" of the chamber roof including its drop by 1 – 10 m took place (estimated according to the photo) in the southeast part of the chamber. At this process parts of the pillar were broken into blocks in bulk of almost 1000 m^3 which broke through the interlevel roof pillar and

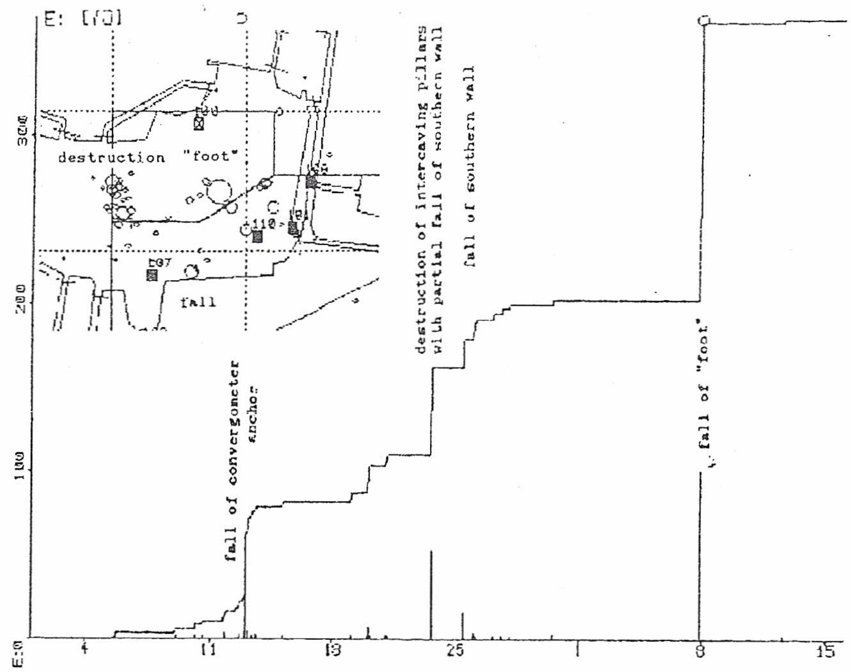

FIG. 3. Benioff graph of the Dúbrava massif at the Jelšava mine from Oct. 1, 1993 to Nov. 16, 1993 with the localization of events

came down from the height of approx. 450 m a.s.l. to 323 m a.s.l.. At the same time dynamic effects (cracked sides of the chambers and manipulating spaces as well as movements at tectonic faults) occurred at the horizon of 323 m a.s.l. On the basis of seismic monitoring it was possible to analyse the individual stages of this process from the "leg" coming off via breaking through the interlevel pillar as far as to the fall of rocks down on the level of 323 m a.s.l. and it was evaluated as a result of stress rearrangement in the east and southeastern parts of the Mikova chamber when stability of the solitary interchamber pillar was lost without its growing stress [Kalenda 1993; Pompura 1994a].

The increased number of the rock blocks tumbling into the Dubrava abyss and the simultaneous growth of seismic activity in the "leg" area were taking place on Jan 16 – 17, 1994, even though no other event having significant consequences was registered. This event had also a typical exponential waveform with activity growing as early as on Jan. 14 and culminating in the night from Jan. 16 to 17 and with gradual fading of the activity till Jan. 18 (see Fig. 5).

Growing activity in the eastern corner of the Mikova chamber was observed again from 17:40, Oct. 16. It was finished at 20:39 by the destruction of the chamber wall and by a rock block of 10000 m^3 in bulk tumbling down into the chamber. This significant event was preceded by a rapid succession of small ones. Fading sequence lasted as long as till 3:00, Oct. 19 (see Fig. 6).

Another significant event occurred on Feb 15,1995 when a part of a "groin" in

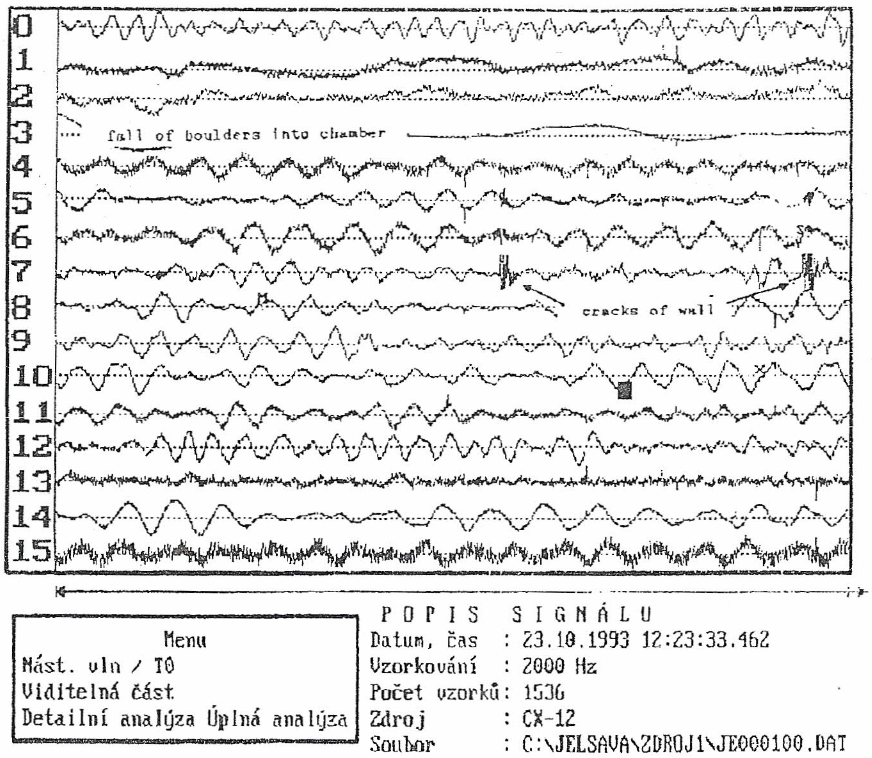

FIG. 4. Wave record of partial destruction of the south wall

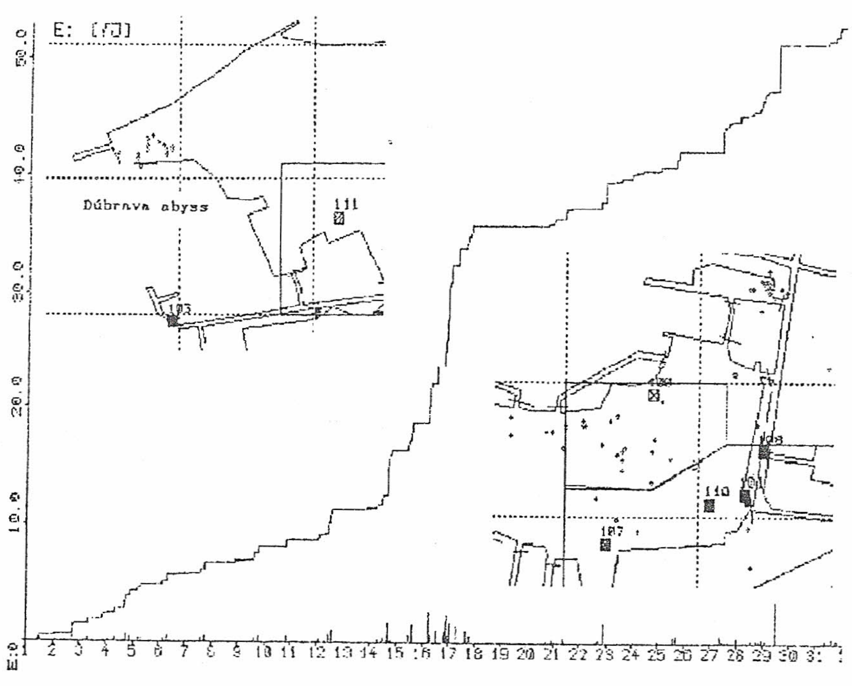

FIG. 5. Benioff graph of the Dúbrava massif at the Jelšava mine from Jan. 1, 1994 to Feb. 1, 1994 with the localization of events

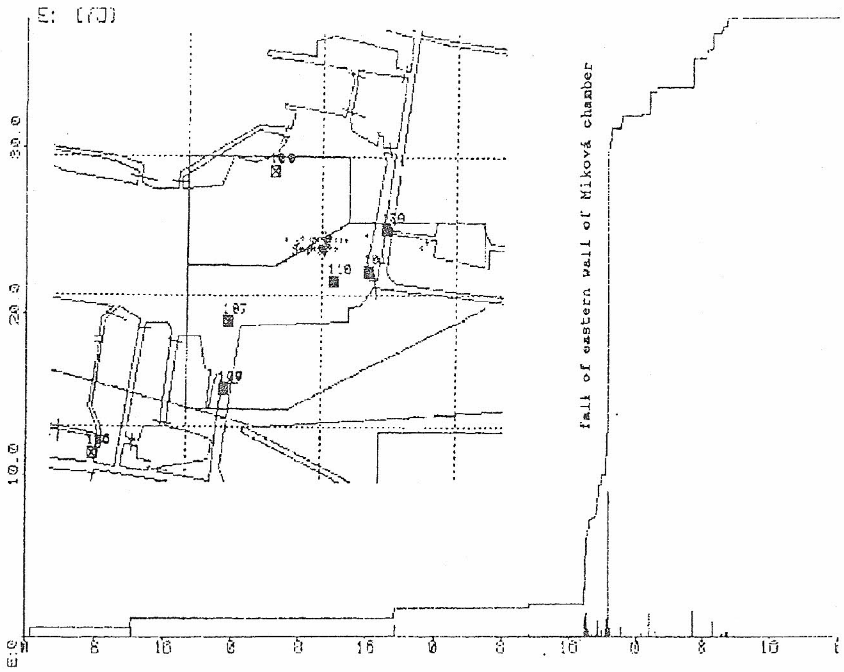

Fig. 6. Benioff graph of the Dúbrava massif at the Jelšava mine from Oct. 14, 1994 to Oct. 18, 1994 with the localization of events

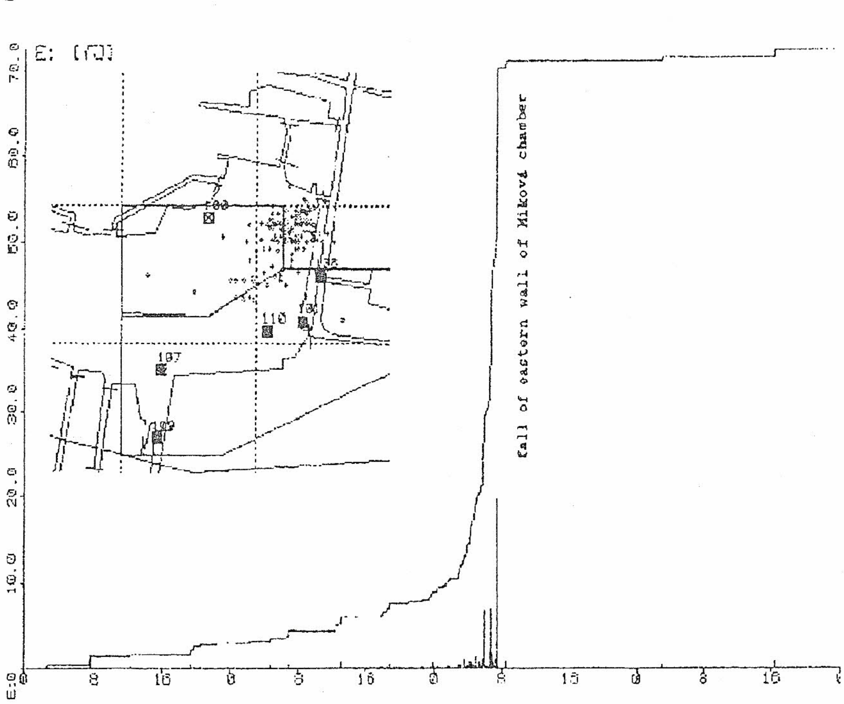

Fig. 7. Benioff graph of the Dúbrava massif at the Jelšava mine from Feb. 13, 1995 to Feb. 17, 1995 with the localization of events

the east side of the Mikova chamber collapsed (see Fig. 7). This event was linked with the previous ones of Oct 23, 1993, Nov 7, 1993 and Oct 16, 1994, however, the seismic activity was shifted farther northwards into the east side of the Mikova chamber. Fig. 7 indicates the exponential increase of seismic activity which started with tiny events as early as Feb 7, 1995 and continued growing more significantly from 0:00 on Feb. 16 and culminated between 5:50 – 7:50 on Feb. 16., when a part of the "groin" with dimensions of $10 \times 5 \times 30$ m came off from the chamber wall. Cracking process in the area of the northeast tunnel at the horizon of 482 m and falling of the sides of chamber 4502 took place at the same time. The fading sequence was relatively short.

The area of the southeast corner of the Mikova chamber between the horizons 323 and 482 a.s.l. was measured repeatedly in January, March and September. These measurements confirmed higher stress in this area as far as about 80 m from the walls of the chamber which was indicated by higher velocities of the P waves (up to 7200 m/s) in January and March 1994 and by moderate rearrangement of stress in this part at a drop of the P wave velocities to approx. 6700 m/s in September 1994 [Kalenda 1994; Pompura 1994b].

4. Conclusion

Normal development of seismic activity was determined on the basis of monitoring the seismic activity during the period of July 17 ,1993 – May 1, 1995. Significant events were registered during the period and their genesis was monitored.

All the significant seismic events characterized by deformation demonstrated distinct exponential growth in seismic activity just before the main particular event, when the destruction of weakened spots of the massif was taking place. This was accompanied by SA emission. This growth lasted for a couple of hours (the event of Oct 23, 1993 after blasting took only a few minutes) to a couple of days (the event of Feb 15, 1995). The growth and extensive spread of SA activity was registered by the original SA apparatus beneath the location of the future abyss surely two days before the disastrous event of 1991.

This growth of SA activity was not registered before the events of gravity character which were caused by the loos of their stability.

On the basis of seismic monitoring it is possible to predict some areas with higher risk of the sides or roofs of chambers collapse and from the process of stress deformation of rock. It is possible to foresee the main event a couple of days in advance on the basis of extensive development of SA activity. It is not possible to predict the fall from the roof and walls of the chamber.

References

Kalenda P. (1993), *Metodický návod pro zpracování seismoakustických měření na magnezitových dolech Jelšava*, Internal report of the SMZ Jelšava. (in Czech)

Kalenda P. (1994), *Zpráva o výsledcích seismické tomografie mezi horizonty 323 m a 482 m na dole Jelšava*, Internal report of the SMZ Jelšava. (in Czech)

Pompura I. (1994a), *Výsledky meraní napeťovo deformačných zmien hornín v ložisku Dúbravský masív. Obdobie od 1.10.93 do 31.12.1993*, Internal report of the SMZ Jelšava. (in Slovak)

Pompura I. (1994b), *Seismické meranie Jelšava IV. 323–482, marec 1994*, Internal report of the SMZ Jelšava. (in Slovak)

Pompura I. (1994c), *Seismické meranie Jelšava V. 323–482, september 1994*, Internal report of the SMZ Jelšava. (in Slovak)

Pompura I. (1995), *Vyhodnocení stability ložiska Dúbravský masív – roční zpráva 1994*, Internal report of the SMZ Jelšava. (in Slovak)