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CONTRIBUTION OF THE INSTITUTE OF GEONICS OF THE ASCR OSTRAVA TO SEISMOLOGICAL MONITORING IN SILESIA AND NORTHERN MORAVIA

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ABSTRACT
The paper presents selected results of seismological observations in Silesia and northern Moravia between 01/2004 - 08/2008, which are based on interpretation of three-component digital recordings at solitary seismic stations operated by the Institute of Geonics of the ASCR Ostrava (IGN) distributed in the region under investigation. Five seismic stations had recorded local tectonic seismic events in a continuous regime until 12/2005, when the grant project GA CR No. 205/03/0999 terminated. Meanwhile, the Ostrava – Krásné Pole (OKC) seismic station have continued in operation as a part of the Czech regional seismological network since 1983 up to present. Other three stations have been operating in a so-called triggered regime. At the mid-January 2007, seismic station in Klokočov village was re-opened in continuous regime. During 55 months of observation, 90 tectonic events have been detected at one or more seismic stations mentioned above. However, database of the Institute of Physics of the Earth of the MU contains more than 640 microearthquakes during the same time. This discrepancy is caused mainly due to a higher concentration of microearthquake foci distributed all over the western part of the region under investigation where the IPE seismic stations are situated. On the other hand, the IGN seismic stations are spread predominantly within the eastern part of the territory, i.e. relatively far from the recent foci, and moreover, some stations are operated using the triggered regime.

KEYWORDS: Moravo-Silesian region, natural seismicity, microearthquake, earthquake swarm

1. INTRODUCTION

Based on the continuous observations at the seismic stations of the regional network distributed around the whole Ostrava-Karviná mining area and at the seismic station Ostrava-Krásné Pole (OKC), individual microearthquakes have been detected on the eastern territory of Moravia and Silesia since November 1989 (Holub a Müller, 1997; Holub et al., 2004). Started on May 20, 1993 till September 3, 1993, series of 25 microearthquakes occurred in the surrounding of Opava town. This series of seismic events was characterized in this region for the first time as a swarm-like phenomenon (Holub et al., 1994; Kaláb and Holub, 1994). After occurring of seismic swarm in 1993, solitary seismic stations operated by the Institute of Geonics of Academy of Sciences of the Czech Republic (IGN) have been built (e.g. Kaláb and Knejzlík, 1999**;** Schenk et al., 2000).

The aim of seismological monitoring pursued by IGN is to contribute to observing of mobility trends in the given territory (e.g. Schenk et al., 2000**;** 2004, Schenková et al., 2003). The number of detected and located events depends on the quality of input data. It should be mentioned that 2 or 3 stations that are operated by IGN worked in a so-called triggered regime, which makes it possible to record only the more intensive events. That is why some microearthquakes of small magnitude, though they were detected, could not be reliably localized.

On the other hand, seismological research programme of the Institute of Physics of Earth of the Masaryk University (IPE) in Brno started in 1983, when seismic network of 5 stations in the area of planned nuclear power plant near Blahutovice was put into operation. A swarm of earthquakes was recorded in 1986 in Jeseníky Mts. (e.g. Firbas et al., 1993; Kárník, 1996; Procházková and Šimůnek, 1999). The erection of the seismic station near Moravský Beroun (signed as MORC) in 1994 started to monitor natural seismicity. Later several seismic stations were erected, among others Vranov u Brna (VRAC) and Mutkov (MUTC). Moreover, the seismic array around the pumped-storage power plant in Hrubý Jeseník Mts. was deployed. It recorded a lot of tectonic microearthquakes during the time interval of its operation in the area of special-interest. Numerous papers dealing with seismicity in the Silesia and Moravia issued from interpretation of IPE data were published, e.g. Skácelová, 1996; Havíř et al., 2001, 2006; Sýkorová et al., 2003; Špaček et al., 2006, 2008 etc.

Table 1 Digital seismic stations operated by the IGN in 2004-2008.

Name and code of the station	Type of records	Sensor	Data acquisition system	Period of operation	References
Ostrava – Krásné Pole (OKC)	Continuous (digital records since 1998)	Guralp CMG-3ESP + 3 x SM-3	EarthData + SeisComP	Since January 1983, station of CRSN	1)
Zlaté Hory (ZLHC)	Triggered	3 x SM-3	PCM-EPC	Since September 2003	2)
Raduň (RADC)	Triggered	3 x S-5-S	PCM-EPC	March 2001 – January 2009	
Slezská Harta (SHAC)	Triggered	3 x SM-3	PCM-EPC	June 2002 – October 2006	
Klokočov (KLOK)	Continuous	Le-3D (3 x SM-3)	GAIA (VISTEC)	2003 - 2005	3)
Stěbořice (STEB)	Continuous	Le-3D (3 x SM-3)	GAIA (VISTEC)	2003 - 2005	
Fulnek (FULN)	Continuous	Le-3D (3 x SM-3)	GAIA (VISTEC)	2003 - 2005	
Radíkov (RADI)	Continuous	Le-3D (3 x SM-3)	GAIA (VISTEC)	2003 - 2005	
Palkovice (PALK)	Continuous	Le-3D (3 x SM-3)	GAIA (VISTEC)	2003 - 2005	
Klokočov (KLOK)	Continuous	ViGeo 2	GAIA 2	Since January 2007	4)

CRSN - Czech regional seismological network
1) http://www.ig.cas.cz/en/structure/observatories/czech-regional-seismological-network/okc/
2) Knejzlík and Kaláb, 2002; Kaláb and Knejzlík, 2002; 2003
3) Holub, 2005
4) Holub et al., 2007.

Observatory activity of IGN has continued up to now; results from period 1/2004 – 8/2008 are briefly presented in this paper.

2. SEISMIC STATIONS OF THE IGN (2004-2008)

Seismological monitoring is based on observations at various seismic stations that created a virtual network for detection and recording of local weak earthquakes on the territory of Silesia and northern Moravia. All stations have stored data in digital form until now. Seismic stations of IGN are possible to divide into four groups (see also Table 1):

- Permanent seismic station in Ostrava – Krásné Pole (OKC) that is a part of the Czech regional seismological network: This station with continuous record is equipped by two types of sensors (short period seismometers SM-3 and triaxial broadband sensor Guralp CMG-3ESP). OKC is operated by the IGN, the VŠB – Technical University of Ostrava and the Geophysical Institute of the ASCR Prague.
- Solitary seismic stations in Zlaté Hory (ZLHC), Raduň (RADC) near Opava and Slezská Harta (SHAC): The advantage of this instrumentation is application of embedded single-board PC and GSM modem, which is used for remote checking of apparatus reliable function and for data transmission via a GSM network. The only disadvantage of this system is recording of seismic events by means of triggering regime.
- 5-stations seismic network - Stěbořice (STEB), Fulnek (FULN), Radíkov (RADI), Palkovice (PALK) and Klokočov (KLOK): These stations were in operation during the grant solution GA CR No. 205/03/0999 (Holub, 2005). It is worth mentioning that this network was able not only to detect individual events, but also to localize seismic event foci.
- Seismic station in Klokočov (KLOK): After termination of the seismic station SHAC in October 2006, the station KLOK was re-opened after the interruption which lasted from January 2006 to the mid of January 2007.

Sketch of distribution of seismic stations operated by IGN is presented in Figure 1. As is mentioned in introduction, IPE is operating by its seismic stations distributed in the western part of the territory.

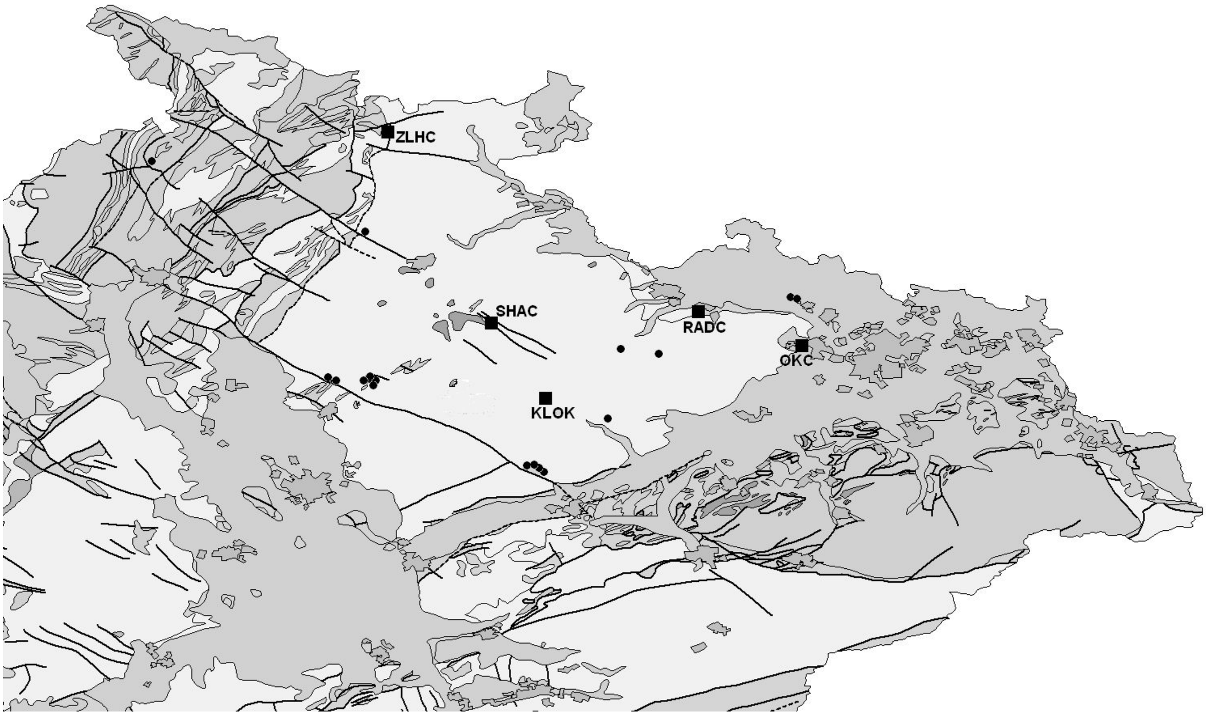

Fig. 1 A general survey of seismic stations (■) distribution and position of located epicentres (●).

3. DATA

Due to different types of the IGN seismic station systems, different ways of data acquisition and subsequent interpretation were adopted. These are as follows:

- Data from the array (KLOK, STEB, FULN, RADI, PALK) and re-opened station KLOK was gathered roughly monthly at individual sites by means of its transcription from PC HD or flashcard to HD of the laptop.
- Data recorded at the stations ZLHC, SHAC and RADC was transmitted anytime via GSM.
- Data from the station OKC was transmitted via Internet to the Geophysical Institute AS CR in Prague and to the Institute of Geonics AS CR in Ostrava; data is available anytime.

4. SEISMIC EVENTS

4.1. MICROEARTHQUAKES

Considering that during the time period from January 2004 to August 2008 the number of active seismic stations operated by IGN was changing, the possibility in microearthquake locations was adequate to this situation. Within the years 2004-2005, i.e. the last two years of the GACR grant project solution, nine seismic stations including the OKC seismic station were distributed and operated in the territory under investigation, which enabled us to perform localization of hypocenters and/or epicenters. After the year 2005 only four (and later three) stations were at disposal, so that only the more intensive events were detected (as the seismic stations recorded seismic events using triggering criterion for ZLHC, RADC and SHAC). Even the substitution of the seismic station of SHAC by KLOK did not facilitate reliable location of epicenters. Therefore, only characteristic features of tectonic events, first of all expressive P-wave onsets on vertical component and S-waves on both horizontal components, were accepted as a criterion for differentiation among other seismic events. A typical example of tectonic event seismogram is displayed in Figure 2. This approach is well known as a so-called „type analysis“. Characteristic properties of waveforms are used here for adjoining and gathering individual types of seismic events to a predefined group connected with the appropriate known focal region. A more effective way to identify these events was mutual comparison with data quoted in the seismic bulletin of IPE MU and/or implementation of data from IGN seismic stations, especially seismic station KLOK, to localization procedure performed by the IPE MU. Due to this approach, the suitable sitting of the KLOK station was proved, as it seems to be closer to majority of focal regions of microearthquakes.

During 55 months of observation, 90 tectonic events have been detected at one or more IGN seismic stations mentioned above. However, database of the

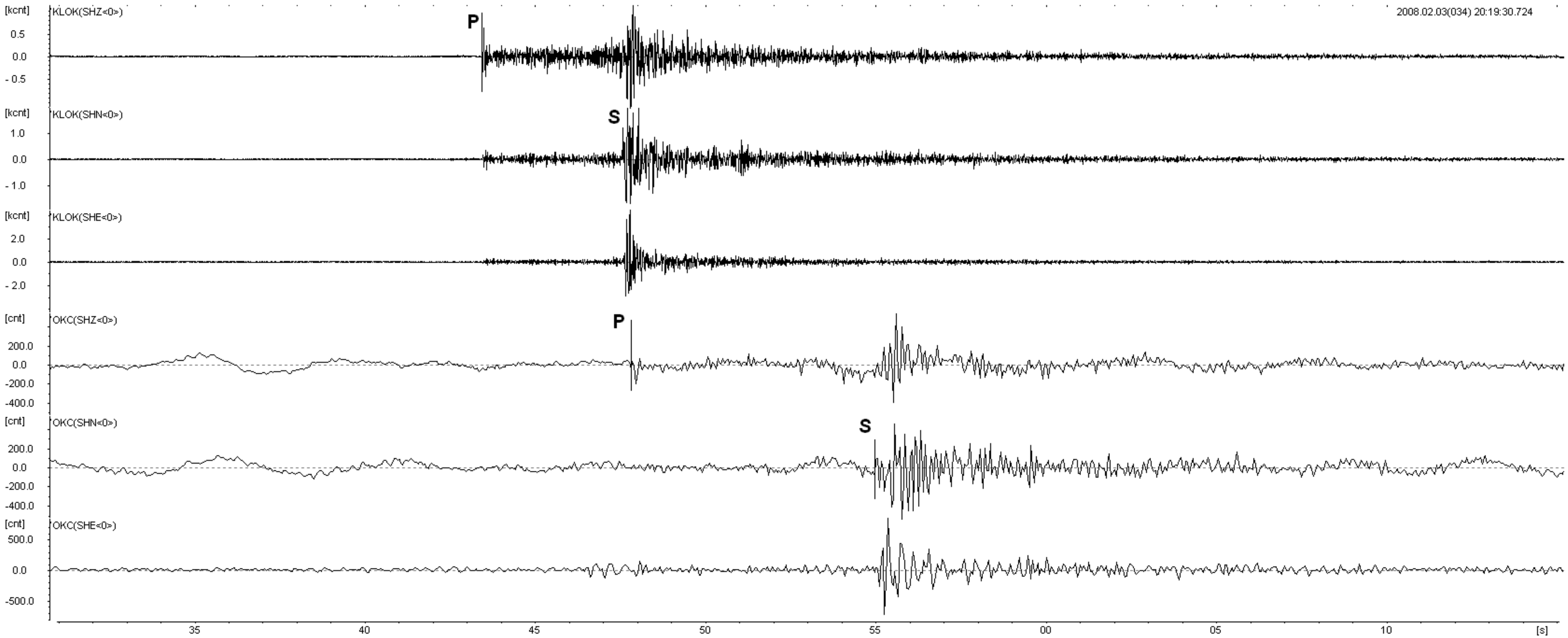

Fig. 2 Tectonic event occurring on February 3, 2008 near Mutkov recorded at the KLOK and OKC seismic stations; epicentral distances d ≈ 30 km and d ≈ 59 km, respectively.

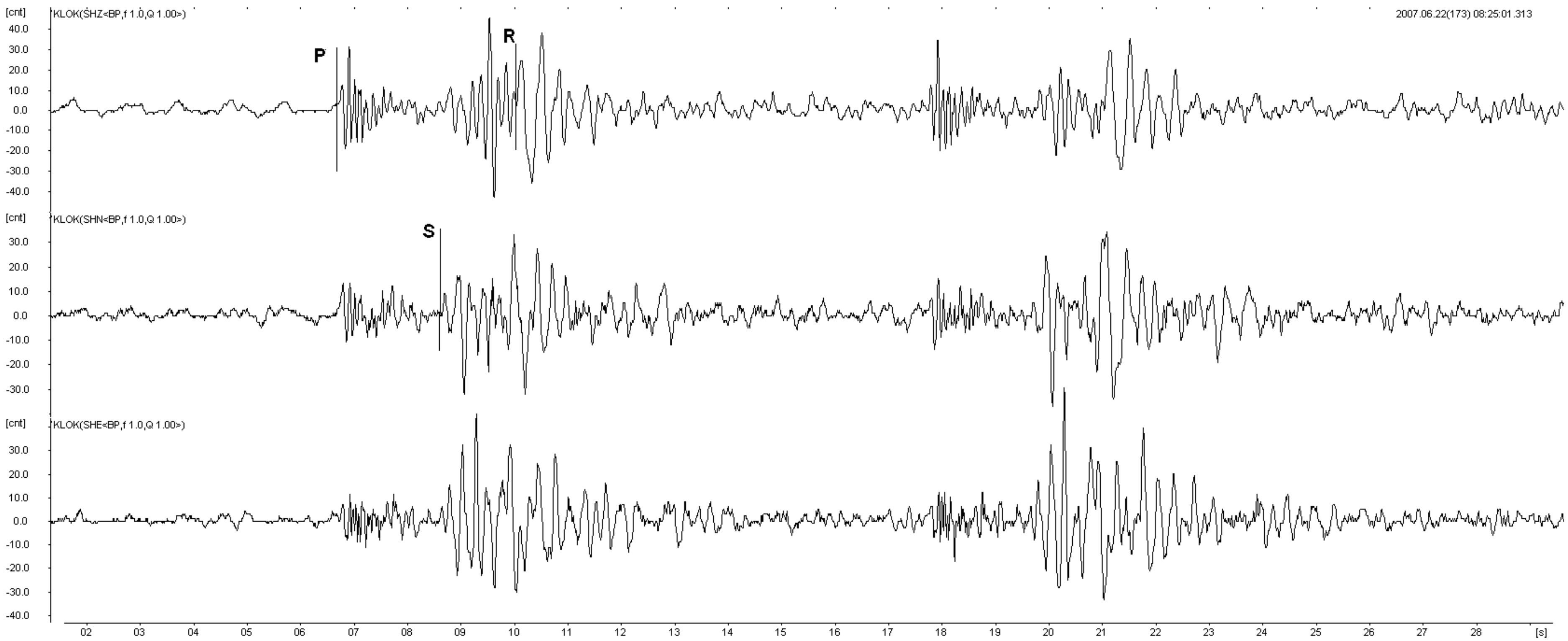

Fig. 3 Series of blasting operations during the liquidation of outdated ammunition which were recorded at the KLOK seismic station on June 22, 2007; d ≈ 14 km.

Institute of Physics of the Earth of the MU contains more than 640 microearthquakes at the same time. This discrepancy is caused mainly due higher concentration of microearthquake foci distributed all over the western part of the region under investigation where the IPE seismic stations are situated. On the other hand, the IGN seismic stations are spread predominantly within the eastern part of the territory, i.e. relatively far from the recent foci.

Epicentral zones in the territory Silesia and Moravia (including also its central part) were situated to adjacent towns and villages; numbers of detected and/or located events are in brackets: Vizovice (10), Dolní Benešov along the marginal Jeseníky fault (5), Opava near the deep seated tectonic fault of Opavice observed also in 1993 and mentioned in historical documents (2), around Odry, where epicenters followed roughly the Bělá fault (5), near Šternberk, near Hranice na Moravě (3), surroundings of Šumperk (3) and Prostějov (3), Jakubčovice nad Odrou (2), Budišov nad Budišovkou (2). Moreover, many isolated epicenters were detected in environs of Fulnek, Hradec nad Moravicí, Bruntál, Mutkov, Kralický Sněžník, Malá Morávka, Olomouc and Svitavy. A complex of IGN seismic stations and located epicenters distribution within the area of interest is displayed in Figure 1.

4.2. DESTRUCTION OF EXPLOSIVES

A new phenomenon at the seismic station KLOK was observed, some induced seismic events from coal mines and quarry blasts were detected, but they are not the subject of this paper. This phenomenon, occurring from time to time, was represented by a series of weak events that were detected and later, during the interpretation of seismograms, identified. The time differences of P and S waves were estimated approximately as $\Delta t \approx 2.0$-2.1 s. Similar seismic events were found also during the survey of seismic bulletin of the IPE MU, which coincided in time with the events recorded at the station KLOK having almost the same time difference, i.e. $\Delta t \approx 1.9$ s. Detailed analysis of individual events displayed in Figure 3 documented that we were dealing with explosions. The important common feature of these events was the existence of marked dispersive Rayleigh waves. Considering that rough epicentral distance of both seismic stations, i.e. KLOK and MORC, from the source is almost the same, i.e. 14 and 12 km, respectively. Only two solutions for source of seismic wave estimation were possible. Further investigations proved that source and/or sources of these explosions were concentrated to the military area where outdated ammunition was liquidated. The ammunition was put into shallow pits and covered with the earth, and therefore, these shallow seated sources generated very intensive surface waves which proved these events different from microearthquakes.

4.3. SEISMIC BULLETIN

Data from the OKC seismic station is transmitted via the Internet to the Geophysical Institute, where comprehensive data interpretation is performed. This interpretation is focused on complex analysis of waveforms of near and distant earthquakes recorded at all seismeic which are included into the Czech regional seismic network. (www.ig.cas.cz/en/welcome; seismic service). On the contrary, the interpretation which has been carried out by the IGN is only focused on picking up P_n, Pg and Sg phases corresponding to local tectonic events, seismic events induced by coal mining in the Czech and Polish mines within the Upper Silesian Coal Basin and ore mining in Poland denoted usually as „Lubin", quarry blasts and other seismic phenomena (Růžek et al., 2004). Part of this seismic bulletin is represented in Table 2, which is for further application by various institutions and private companies at *http//www.ugn.cas.cz (Department of Geophysics).*

Number of seismic stations is small and insufficient for the large investigated area, especially for events with M_l<0 (e.g. Kaláb and Knejzlík, 2003). In addition, only triggered regime of recording is used for the ZLHC, SHAC and RADC seismic stations. Considering that all stations are situated in buildings on the ground without special seismic pillar, high level of seismic noise exists there. This fact significantly influences detectibility of weak seismic signals as well as the pre-set trigger level. Location of seismic events was partly performed by the IGN within the time period 1/2004 - 12/2005 and later by the IPE; occasionally with contribution of readings from the OKC and KLOK stations (sporadic from the ZLHC and RADC), which were included into the location procedure.

Detailed recording performed by the IPE in Brno documents more weak earthquakes in area under discussion (e.g. Havíř et al., 2006; Špaček et al., 2008).

5. CONCLUSIONS

- The KLOK station substituted the closed station Slezská Harta (SHAC) in January 2007 within the seismic stations operated by the IGN. Its operation has proved a suitable position which seems to be closer to the focal region of microearthquakes.
- The advantage of continuous recording was documented due to detection of weak microearthquakes, which sometimes did not trigger the apparatuses PCM3-EPC installed at the Zlaté Hory (ZLHC), Slezská Harta (SHAC) and Raduň (RADC) seismic stations.
- Location of seismic events was partly performed by the IGN during the time period 1/2004 - 12/2005 and later by the IPE, occasionally with contribution of readings from the OKC and

Table 2 An illustration of seismic bulletin based on data of KLOK from May 2008.

Station KLOK			
1.5.		Sg 03:02:35.694	OKCB
1.5.	Pg04:21:01.416	Sg 04:21:15.653	Poland
1.5.	Pg05:52:39.412	Sg 05:52:43.287	Tectonic event
1.5.		Sg 08:06:37.153	OKCB
1.5.	Pg21:50:46.121	Sg 21:50:58.227	Poland
1.5.	Pg23:03:19.531	Sg 23:03:30.550	Poland
2.5.	Pg00:00:35.950	Sg 00:00:50.028	Poland
2.5.		Sg 06:11:05.289	Poland-Lubin
2.5.	Pg07:28:28.882	Sg 07:28:43.661	Poland
2.5.		Sg 14:49:20.746	Poland
2.5.		Sg 20:23:11.620	Poland-Lubin
2.5.		Sg 23:37:28.168	Poland
3.5.		Sg 08:26:29.382	Poland
3.5.	Pg08:50:19.929	Sg 08:50:26.804	OKCB
4.5.	Pg02:07:49.710	Sg 02:07:56.782	OKCB
4.5.	Pg05:41:06.948	Sg 05:41:14.190	OKCB
5.5.	Pg02:16:31.425	Sg 02:16:55.605	Poland-Lubin
5.5.	Pg07:50:56.358	Sg 07:50.59.050	EXP
5.5.		Sg 09:11:36.785	Poland
5.5.	Pg19:02:08.940	Sg 19:02:22.675	Poland
6.5.	Pg01:13:54.578	Sg 01:14:08.804	Poland
6.5.	Pg05:06:32.041	Sg 05:06:38.108	OKCB
6.5.	Pg08:52:17.381	Sg 08:52:19.719	EXP
6.5.	Pg09:51:39.158	Sg 09:51:40.076	EXP

KLOK stations, which were included into the location procedure.

- Readings from seismograms of local and near microearthquakes, mining induced seismic events from the Czech and Polish coal and ore mines, quarry blasts and other seismic phenomena recorded at the OKC, KLOK, RADC and ZLHC seismic stations are available at *http//www.ugn.cas.cz.*

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