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DECADE OF SEISMOLOGICAL OBSERVATIONS IN THE NORTHERN PART OF MORAVO-SILESIAN REGION

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ABSTRACT
The essential point for seismological observation in the northern part of Moravia, Czech Republic, is a permanent seismic station Ostrava – Krásné Pole (OKC) that is a part of the Czech regional seismological network (hereafter CRSN). Institute of Geonics AS CR, v.v.i., has also operated temporary seismic stations in this region since 1997. Current seismological stations are located in an abandoned mine working located in Zlaté Hory and in cellars in Klokočov and castle Raduň near Opava.
The natural seismicity is after the swarm of microearthquakes in the vicinity of Opava in 1993 very low now. In region under discussion, seismic manifestations generated by mining induced seismicity in Upper Silesian Coal Basin (both Karviná and Polish parts) and in Legnica-Głogów Copper District (LGOM) are also detected. Significant part of observations in this region is made by the Institute of Physics of the Earth (hereafter IPE), Masaryk University Brno, and about 1000 microearthquakes have been detected during the last ten years with maximum local magnitude up to 1.9.

KEYWORDS: Moravo-Silesian region, seismic network, microearthquake

1. INTRODUCTION

Complex geodynamic analysis in the northern part of Moravo-Silesian region started in 1997. Coordinates $\varphi = 49.5^{o}N - 50.5^{o}N$ and $\lambda = 17^{o}E - 19^{o}E$, roughly demarcate the area under investigation. Within the scopes of two projects (that were supported by Czech Science Foundation - No. 205/97/0679 and 205/01/0480) the following issues were investigated:

- measurement of GPS signals at sites of newly established geodynamic network in area under study,
- monitoring of local earthquake activity at newly built up seismic stations,
- measurements of brittle tectonic and structural mapping focusing to rejuvenated Variscan deformations.

These projects were solved in cooperation with the Institute of Rock Structure and Mechanics, AS CR, v.v.i., Prague, Institute of Geonics, AS CR, v.v.i., Ostrava (hereafter as IGN) and VSB – Technical University of Ostrava.

Seismological project objectives pursued by staff of the IGN, were establishment of seismic stations, monitoring of regional seismic activity, identification of natural and/or induced seismic events and their detailed analysis.

In this contribution, particular results reached during ten years of seismological monitoring in the northern part of Moravo-Silesian region are presented.

2. SEISMIC STATIONS AND INSTRUMENTATION

First temporary seismic stations were built in the cellar of castle Hradec nad Moravicí and in a niche of the road at the second mining floor of an abandoned mine near Zlaté Hory. More than 20 various sites were tested from the viewpoint of admissible seismic noise level for deployment of seismic stations ahead. Finally, 13 sites of observation for temporary station erection were chosen and portable instrumentation was gradually installed there. Detailed overview of seismic stations operated by the IGN, is given in Table 1, where bold letters denote currently operated stations.

All temporary seismic stations provided three-component digital records, as sensors, seismometers SM-3 and/or S-5-S are usually used in connection with the recording apparatuses of PCM3 type. This instrumentation works under triggered regime applying the algorithm of exceeding predefined level (e.g. Kaláb and Knejzlík, 1999). At present, upgraded instrumentation PCM3-EPC with embedded single-board PC and GSM modem are used at the Raduň and the Zlaté Hory seismic stations, controlled remotely through data transmission via a GSM network (e.g. Knejzlík and Kaláb, 2002).The PCM3-EPC is built up as a modular system consisting of self-standing functional blocks, which are designed as modules of EUROCARD standard. From different blocks various configurations of recording apparatus can be assembled, such as autonomous recorder,

Table 1 An overview of seismic stations operated by the IGN, within 1997-2006 (bold letters denote currently operated stations, some coordinates were estimated from map).

STATION	LOCATION	COORDINATES	OPERATION
HRMC	HRADEC NAD MORAVICÍ	*φ = 49°51´51.05´´N* *λ = 17°52´26.16´´E* *h = 325 m*	23.10.1997-7.11.1999
ZLHC1	ZLATÉ HORY - MINE	*φ = 50°13´23.40´´N* *λ = 17°24´22.68´´E* *h = 540 m*	4.11.1997-7.7.1998
ZARC	ŽÁRY NEAR MĚSTO ALBRECHTICE	*φ = 50°09´07.84´´N* *λ = 17°33´29.39´´E* *h = 490 m*	5.8.1998-30.5.2000
PORC	PORUBA	*φ = 49°50´15.30´´N* *λ = 18°08´50.25´´E* *h = 250 m*	6.5.1999-22.11.1999
RADC	RADUŇ NEAR OPAVA	*φ = 49°53´35.20´´N* *λ = 17°56´28.50´´ E* *h = 290 m*	30.6.2000-14.12.2000 SINCE 8.3.2001
SMEC	STARÉ MĚSTO	*φ = 50°09´46,09´´N* *λ = 16°56´48.62´´E* *h = 520 m*	16.5.2001-8.8.2001
JNVC	JANOV NEAR JINDŘICHOV	*φ = 50°14´51.39´´N* *λ = 17°28´57.68´´E* *h = 530 m*	22.6.2001-8.5.2002
JVRC1	ČERVENÝ DŮL NEAR JAVORNÍK	*φ = 50°21´08.77´´N* *λ = 16°59´32.13´´E* *h = 515 m*	23.7.2001-17.10.2001
JVRC	JÁNSKÝ VRCH IN JAVORNÍK	*φ = 50°23´17.71´´N* *λ = 17°00´02.62´´E* *h = 340 m*	17.10.2001-12.11.2002
SHAC	SLEZSKÁ HARTA	*φ = 49°53´20.98´´N* *λ = 17°35´01.96´´E* *h = 480 m*	25.6.2002-26.10.2006
ZLHC	ZLATÉ HORY - GALLERY	*φ = 50°13´23.40´´N* *λ = 17°24´22.68´´E* *h = 625 m*	SINCE 12.9.2003
KLOK	KLOKOČOV	*φ = 49°45´23´´N* *λ = 17°43´10´´E* *h = 600 m*	SINCE 11.1.2007
OKC	*OSTRAVA – KRÁSNÉ POLE*	*φ = 49°50´15.30´´N* *λ = 18°08´50.25´´E* *h = 250 m*	*PERMANENT STATION OF NATIONAL NETWORK*

different telemetric variants with on-line digital data transmission by means of telephone line or eventually by means of radio link. A system of analog transmission of signals from remote seismometers by current loop with high resistance against interference has been developed. The amplifiers with measuring range adjustable to 32, 16, 8, 4, 2 and 1 $mm.s^{-1}$ and frequency band 0.1-30 Hz are used. Sampling frequency is adjusted to 100 Hz (max. 250 Hz), dynamic range of signal digitizing is 90 dB (MSB/LSB corresponds to 16-bit converter). These instruments record data using triggering criterion. The data acquisition system GAIA 2 and triaxial sensor ViGeo 2 have been installed recently at the station in Klokočov. The advantage of this instrumentation represents continuous data recording with sampling frequency of 100 Hz (Holub et al., 2007).

It is worthwhile to mention that also 5 temporary seismic stations, i.e. stations denoted as: RADI, FULN, KLOK, STEB and PALK, were operated in the region under investigation having continuous recording with sampling frequency of 100 Hz. This research was carried out in the frame of project financially supported by the Czech Science Foundation under project No. 205/03/0999 within the time interval 2003-2005; these stations are not displayed either in Table 1 or in Fig. 1 (Holub, 2005; Holub et al., 2007).

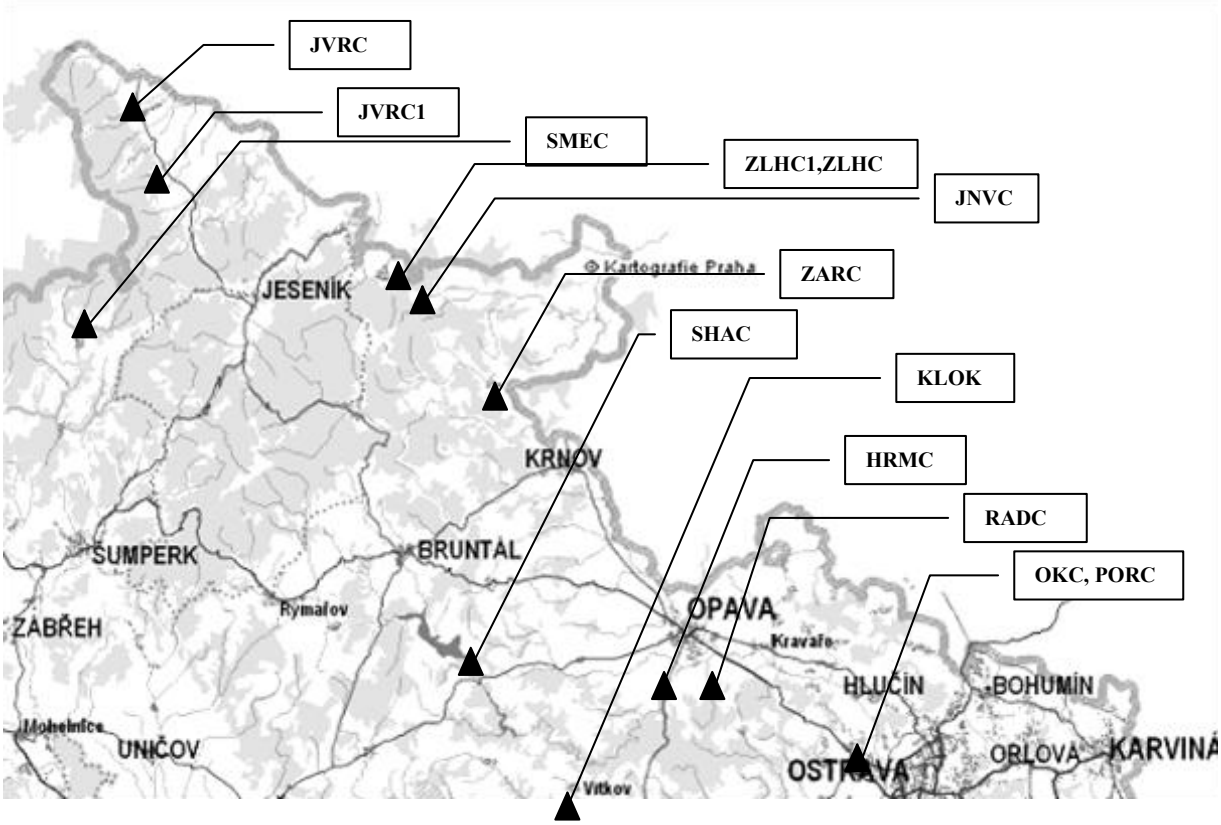

Fig. 1 Seismic stations operated by the IGN**,** during period 1997-2006 (see Table 1).

Seismic station Ostrava – Krásné Pole (OKC), operated by the Institute of Geonics of AS CR, v.v.i., in Ostrava, VŠB-Technical University of Ostrava and Geophysical Institute of AS CR, v.v.i., in Prague, is a permanent station of the Czech regional seismological network. Digital data acquisition recorder system EarthData and SeisComP and triaxial longperiod seismometer Guralp with continuous recording mode is used at this observatory.

Interpretation of our recorded data is performed in close co-operation with the staff of the Institute of Physics of the Earth (IPE), Masaryk University Brno (e.g. Havíř et al., 2006).

Following seismic stations of the IPE operated in North Moravia and Silesia during evaluated period are as follows (these stations are not displayed either in Table 1):

- Moravský Beroun (MORC) – stations are equipped with Quanterra and STS-2 and provide continuous data transfer to the data center in Brno in real time. However, the stations KRUC and VRAC are remote from the investigated regions, their input data is applied also in focus localization procedures performed by the IPE from time to time.
- Temporary station Mutkov (MUTC) is equipped with Lennartz LE-5800 and MARK and provides data in trigger mode.
- Temporary stations in the surrounding of the Dlouhé Stráně pumped storage power plant (KAMC, DLSC, SVYC, ANAC, and ALFC) – instrumentation of Guralp CMG SAM and CMG seismometers have been used for continuous recordings there.

3. RESULTS OF OBSERVATIONS

The last significant increase of natural seismicity in the northern part of Moravo-Silesian region occurred in Opava area in 1993 and was at the same time recorded at the seismic station Ostrava-Krásné Pole (OKC) (Holub et al., 1994; Kaláb et al., 1996). Seismic activity of that time can be described as a swarm-like series of microearthquakes. Among them, the only event felt by inhabitants was one having maximum macroseismic intensity of about 5^{o} according to MSK-64, i.e. its local magnitude was estimated roughly to the value 2.5.

The revival of seismic activity influenced detailed study of fundamental mobility trends in this area, and therefore a proposal of several seismic station constructions was elaborated. These new stations were distributed on the special-interest

Table 2 Earthquakes recorded at the stations operated by the IGN, (coordinates of foci were calculated in cooperation with the IPE).

Date	Time (UTC)	φ (°N)	λ (°E)	Location	Station
21.03.2006	16:26	49.69	16.31	Polička	OKC,ZLHC
04.09.2006	07:07	49.83	17.79	near Hradec nad Moravicí	OKC,SHAC,RADC
14.09.2006	02:03	49.69	17.50	near Šternberk	OKC
14.10.2006	19:53	49.42	17.22	Prostějov	OKC
21.10.2006	07:26			near Dolní Benešov	OKC,RADC
19.11.2006	08:09			Tovačov	OKC

territory aimed at continuous investigation of the seismic activity there. The construction of new seismic stations contributed to the higher number of recorded microearthquakes without macroseismic effect. A lot of results of seismological observations have already been published (e.g. Schenk et al., 2000, 2004; Zedník et al., 2001; Havíř, 2002; Sýkorová et al., 2002, 2003; Holub et al., 2004, 2005; Kaláb and Knejzlík, 2003, 2004; Špaček et al., 2006). The sensitivity and the triggering parameters of the used equipment determined the amount of recorded events on stations operated by the IGN. Due to triggering conditions, the lowest practically considered magnitudes of earthquakes are of about 1.0 for the region under investigation. Many false events of technical seismic events and other vibrations are also recorded. To decrease the amount of these false events, the trigger mode and the parameters were adjusted according to the seismic characteristics of the individual positions. However, the investigated area is too large and the number of mutually "very far" stations in places with high anthropogenic noise (especially for weak earthquakes with magnitude less than 0) is small.

Significant part of observations in this region has been made by the IPE, which detected about 1000 microearthquakes during the last ten years; the maximum magnitude was estimated up to 1.9. According to Špaček and others (2006), three types of seismic activity can be distinguished considering the recurrence rate: single events, sequences of 2-5 events with inter-event times ranging from several minutes to several hours or days, and micro-swarms of a larger number of events. The spatial distribution of epicenters suggests their clustering into NW-SE to N-S aligned groups. Most epicentral areas are repeatedly activated – e.g. several areas in the surrounding of Šternberk na Moravě town, areas near Králický Sněžník and Šumperk town, and NW areas of Bruntál town. Depths of hypocenters range up to 18 - 20 km; most of the respective areas are characterized by their typical depth of hypocenters (Růžek et al., 2004).

Natural seismicity has been very low since 1993 (1997 – beginning of monitoring, 1998 – 13 local seismic events, 1999 – 10, 2000 – 2, 2001 – 1, 2002 – 3, 2003 – 5, 2004 – 4, 2005 – 7) and during the year 2006 only six weak earthquakes were recorded (see Table 2 and Fig. 2). An example of a microearthquake wave pattern recorded at the seismic station OKC is shown in Figure 3. This earthquake took place on September 4, 2006, at 07:07:59.355 UTC, epicentral location φ = 49.832°N and λ = 17.799°E (surrounding of Hradec nad Moravicí), focal depth 15 km, local magnitude 1.2. These parameters were calculated in cooperation with the staff of IPE.

In the region under discussion, seismic manifestations in Upper Silesian Coal Basin (both Karviná and Polish parts), Legnica-Głogów Copper District (LGOM) have been frequently detected due to mining activities. For example, the strongest rockbursts from Karviná basin, which occurred in September and October 2006, were estimated at local magnitude 2.2 and 1.6, respectively. Of course, the majority of shocks represent seismic manifestations of vibrations generated by anthropogenic activities as quarry blasts, heavy traffic, industrial sources etc.

In October 2006, the Slezská Harta seismic station was closed. Records obtained during its operation showed similar composition as records at other stations, i.e. weak earthquakes from studied area, mining induced seismic events from the Czech and Polish coal and copper mines, manifestation of technical seismicity (first of all seismic effects of quarry blasts) and onsets of near and teleseismic earthquakes. Except for the blasts from the nearest quarry in Bílčice, maximum values of velocity amplitude did not exceed the limit of 0.5 $mm.s^{-1}$. At the end of the existence of this station, seismic noise generated especially by traffic rapidly increased, and therefore, new location for detection of weak seismic events in this region was searched for.

As mentioned above, the latest solitary station operated by the IGN, was deployed in Klokočov, which is near to the closed station Slezská Harta. The first natural event recorded at this new site occurred near Šumperk town in January 31, 2007 at 00:25 UTC, coordinates of its focus are: φ = 50.01°N and λ = 16.89°E (Fig. 4). Magnitude of this event was estimated as MV = 0.7 (OKC).

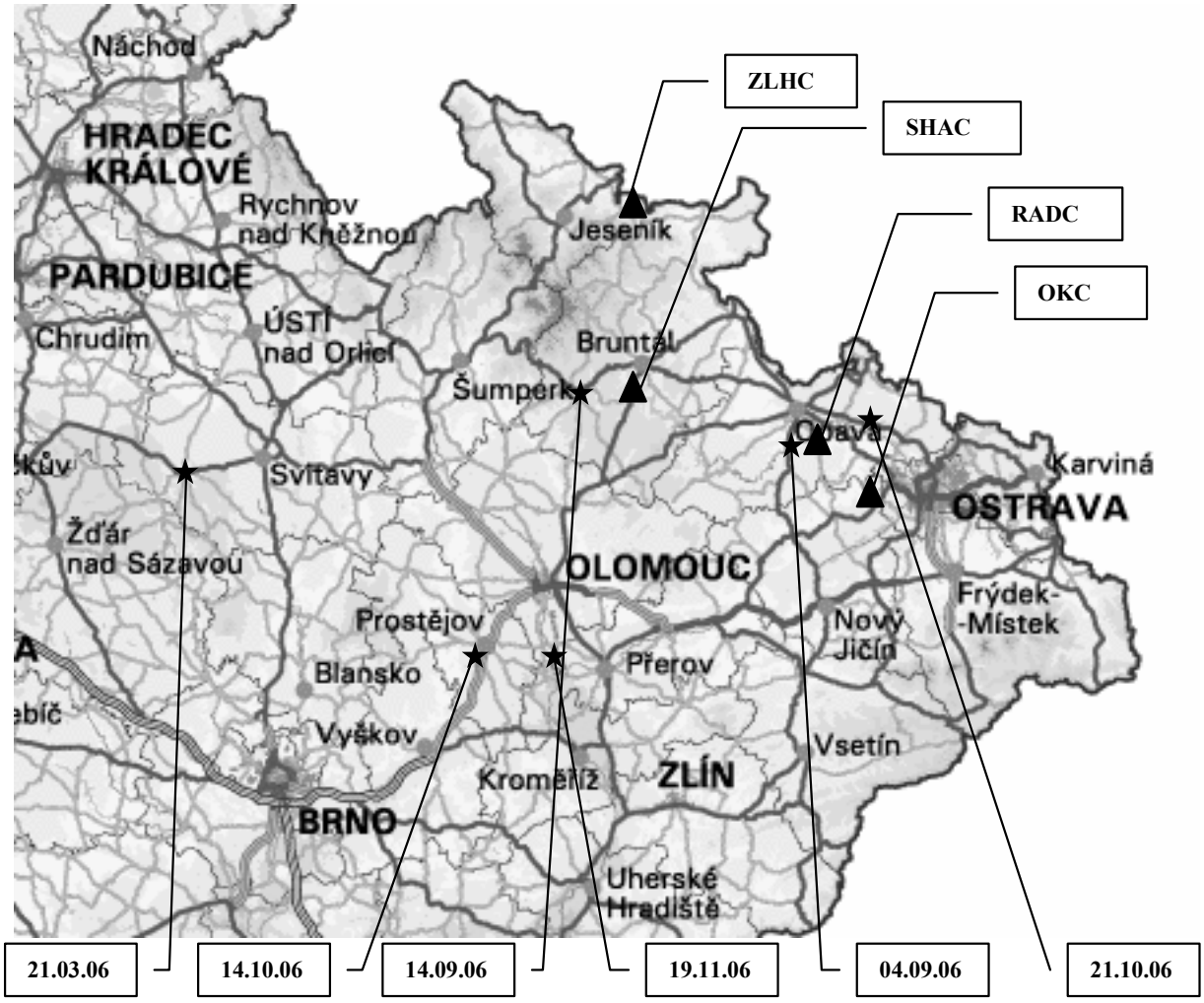

Fig. 2 Earthquakes recorded at the temporary seismic stations operated by the IGN in 2006; stars present focal regions, triangles are current stations.

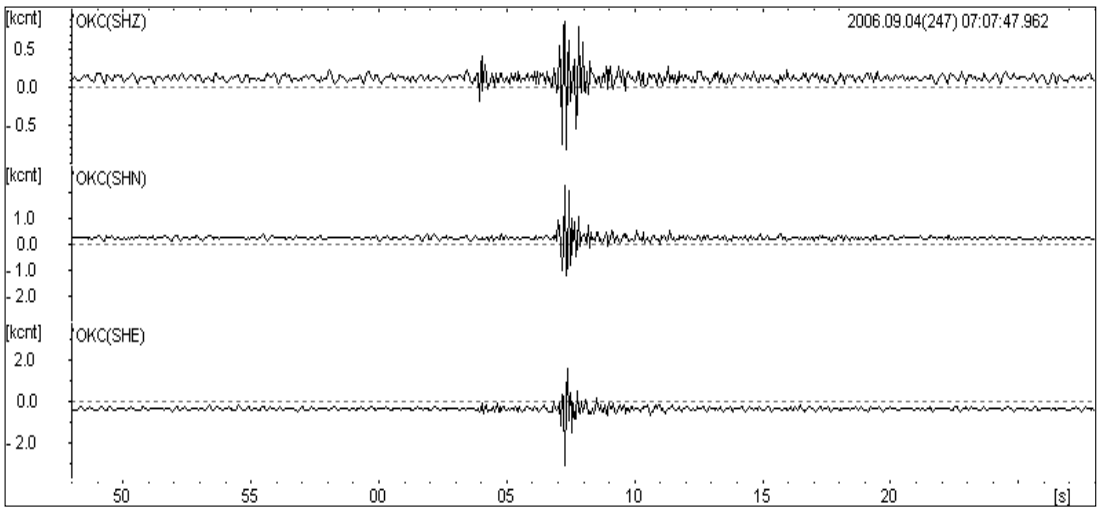

Fig. 3 Wave pattern of the earthquake originated near Hradec nad Moravicí in September 4, 2006 at 07:07 UTC, which was recorded at the station Ostrava – Krásné Pole (OKC).

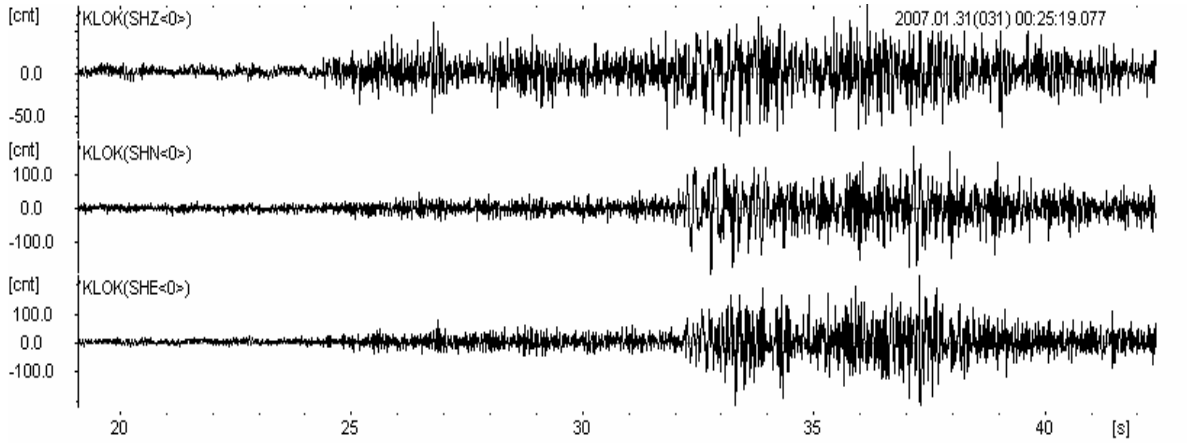

Fig. 4 Wave pattern of a weak earthquake occurred near Šumperk city in January 31, 2007 at 00:25 UTC, recorded at the Klokočov seismic station.

4. PERSPECTIVES

The northern part of Moravo-Silesian region is an interesting region in term of seismic activity of the Czech Republic. Although current seismic activity in this region is weak and variable in space and time, historical materials and observations document also stronger earthquakes (e.g. Kárník et al., 1958). A comprehensive geodynamic analysis, especially fundamental mobility measured by GPS geodynamic network (the latest results are presented by Schenk et al., this issue), confirms recent geodynamic movements.

To obtain a correct conception concerning current seismicity in the area under study, it is necessary to maintain the present permanent monitoring. Stations of the CRSN (the nearest stations are Ostrava – Krásné Pole and Dobruška, see Fig. 1) do not monitor very weak earthquakes here. It means that the seismic stations operated by the IGN, in northern part of Moravo-Silesian region and those operated by the IPE in the southern part, are apt for completion of the database of natural seismic events in the Czech Republic. Modernization of applied instruments including their parameters and establishment of seismic stations in better seismogeological conditions close to known focal regions are basic requirements. New quality in this field can be obtained using instruments with continuous registration and transmission of data via Internet. However, the last requirement jars usually against suitable seismological conditions.

Obviously, the interpretation of recorded data must be performed using all available information. Good knowledge of technical event sources (e.g. quarries, factories etc.) in the studied area is required. For a detailed interpretation of local seismic events and evaluation of natural seismic activity, comparison of seismological observations with geomorphologic, geological, geophysical patterns in the region and additional parameters is mandatory.

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