RE-ESTABLISHED SEISMIC STATION AT STĚBOŘICE IN THE NOVÝ DVŮR ARBORETUM NEAR OPAVA

ZNOVUOBNOVENÁ SEISMICKÁ STANICE STĚBOŘICE (STEB) V ARBORETU NOVÝ DVŮR U OPAVY

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Abstract

The paper provides brief information on the operation of this re-established seismic station and some partial results of seismological observations made between the second half of October 2010 and the end of February 2011. The existing seismic bulletin of local events was extended by adding these results and using arrival times of the Pg and Sg waves induced by mining events in Polish mines (Rybnik region) which were recorded at the seismic stations Klokočov (KLOK) and Stěbořice (STEB) the apparent propagation velocities of „fictitious seismic waves“ were determined.

Abstrakt

V článku jsou uvedeny stručné informace o provozu této znovuotevřené stanice a dílčí výsledky seismologických pozorování od druhé poloviny října 2010 až do konce února 2011. Na základě interpretace seismických dat této stanice byl rozšířen současný seismický bulletin lokálních jevů a s využitím časů příchodu vln Pg a Sg otřesových jevů z polských dolů v rybnické pánvi na stanice Klokočov (KLOK) a Stěbořice (STEB) byly určeny rychlosti šíření fiktivní seismické vlny.

Keywords

Silesia and northern Moravia, seismic monitoring, apparent velocities

1 Introduction

In connection with approving the CzechGeo/EPOS Project in the first half of 2010, the first activities were started in October 2010. The purpose of this European project is to create a distributed all-European acquisition system of observatory and field data of various geophysical fields. A large number of scientific institutions participated in this project under the guidance of the Institute of Geophysics of the Academy of Sciences of the Czech Republic (AS CR) in Prague. This group of various institutes also includes the Institute of Geonics AS CR (IGN AS CR) in Ostrava. The essential goal of the activity of the Department of Geophysics of the IGN AS CR was aimed at

further expansion of the local seismic network in northern Moravia and Silesia. Moreover, these activities were also concentrated on obtaining a new source and/or sources of information, namely about the spatial and temporal occurrence of local micro-tremors on the territory of interest. It is expected that the database of tectonic micro-tremors will be enlarged with the expansion of the seismic network and, simultaneously, will be used for more accurate foci localization in the process of refining the 3D model of the uppermost part of the Earth's crust (Růžek et al. 2011).

The new seismic station Stěbořice (STEB), as well as other stations, i.e. Ostrava-Krásné Pole (OKC), Klokočov (KLOK) and Zlaté Hory (ZLHC) are intended to detect and observe the occurrence of local events, the character of which can be described as induced seismic events caused by deep mining in Polish as well as in Czech coal or ore mines, quarry blasting, but also by local tectonic micro-tremors. Beside these local events, which are interpreted in the geophysical laboratory of the IGN AS CR, also earthquakes originating at different epicentral distances are recorded. The seismograms of these earthquakes are interpreted within the scope of the comprehensive assessment in the centre of the Czech National Seismic Network (CNSN) in the Institute of Geophysics AS CR in Prague.

Fig. 1 The administrative building „Zámeček" of the arboretum Nový Dvůr near Opava

The present seismic network operated by the IGN AS CR consisted up to now of three seismic stations, i.e. Ostrava-Krásné Pole (OKC), Klokočov (KLOK) and Zlaté Hory (ZLHC) (Holub et al. 2004; Růžek et al. 2004; Holub et al. 2007, Špaček et al. 2006 and 2008; Holub et al. 2009). Recently this network was expanded by adding a new seismic station, i.e. seismic station Stěbořice (STEB) which was a part of a local seismic network consisting of 5 seismic stations in the course of performing Grant Project GA ČR (No. 205/03/0999) (2003-2005). After finishing the Grant Project, the seismic station was closed.

2 Seismic station Stěbořice (STEB) and its instrumentation

The new seismic station Stěbořice (STEB) is situated in the cellar of the administrative building „Zámeček"in the Nový Dvůr Arboretum near Opava, see Fig. 1. The h ≈ 375 m m.s.l.

The instrumentation of this station consists of a mobile data acquisition system GAIA 2 whose timing is controlled by GPS signals, its sampling frequency is 100 Hz and the recording medium represents 2 flashcards with a capacity of 1GB. A triaxial Lennartz seismometer Le3D with an Eigen frequency of 1 Hz and velocity output of 400 Vs/m is used as sensor. The substantial advantage of this apparatus is the possibility to work in a continuous regime which enables to gather experimental material at this station once per month at least. Fig. 2 displays the positions of the seismic stations within the local network together with the roughly estimated positions of micro-tremor epicentres denoted by Nos 1-5.

3 Interpretation of records

The procedure of seismogram interpretation is based on picking of individual pronounced seismic phases in the recorded waveforms. In principle, three types of body wave onsets were investigated, i.e. Pn, Pg and Sg. Surface waves of the Rayleigh type, generated by quarry blasts and/or generally by explosions fired on the surface, were also recorded, but they were not analyzed in detail. The waveforms of these waves were very often helpful in discriminating between events of natural and man-made origin, e.g., due to explosion.

Fig. 2 A layout of the seismic stations operated by the Institute of Geonics AS CR and several estimated focal regions. 1 area of Opava, 2 Loučná nad Desnou , 3 Rýžoviště, 4 Odry, 5 Litovel.

As for the interpretation of the individual wave types, the Pn onsets were usually detected within the group of first arrivals when an induced seismic event occurred in the region of the Lubin copper mines. These onsets are prevailingly very weak and, therefore, sometimes cannot be reliably detected, nevertheless, this phase has been considered as typical for induced seismic events and/or rock bursts from the Lubin mine district. Another two phases, i.e. phases Pg and Sg, were detected and interpreted in most cases depending on the dynamics of both waves. As for the reliability of detection, that depends on the character of the ambient noise, whose changes in intensity can be influenced by many various factors, e.g., traffic, industry, geological conditions at the station and/or around the seismic source.

Another helpful tool for discriminating between micro-tremor and common seismic event was found by comparing body wave amplitudes recorded by a triaxial sensor. The maximum amplitudes of Pg waves are recorded in the vertical component and, at the same time, minimum amplitudes by both horizontal seismographs, while the maximum amplitudes of Sg waves are observed in the horizontal components, but minimum amplitudes are detected in the vertical component. For understanding of our deliberations related to the preliminary classification of a micro-tremor based on amplitudes of Pg a Sg waves, a set of waveforms of micro-tremors from the area of Opava is displayed in Fig. 3. Another example of seismograms of an

induced seismic event (rock burst) from a Polish coal mine is shown in Fig. 4. One can see that the onsets of both body waves, i.e. Pg and Sg are clear, and therefore, this type of record was applied in constructing the travel-time curves originating at seismic stations KLOK and STEB. Finally, the relevant triaxial record of a strong earthquake in Japan observed at the STEB seismic station is given in Fig. 5. The obtained readings were included in the relevant local seismic bulletin for each seismic station, a short sample of which is presented in Fig. 6. All the bulletins of the OKC, KLOK, STEB and ZLHC seismic stations are available at htt*://www.ugn.cas.cz.*

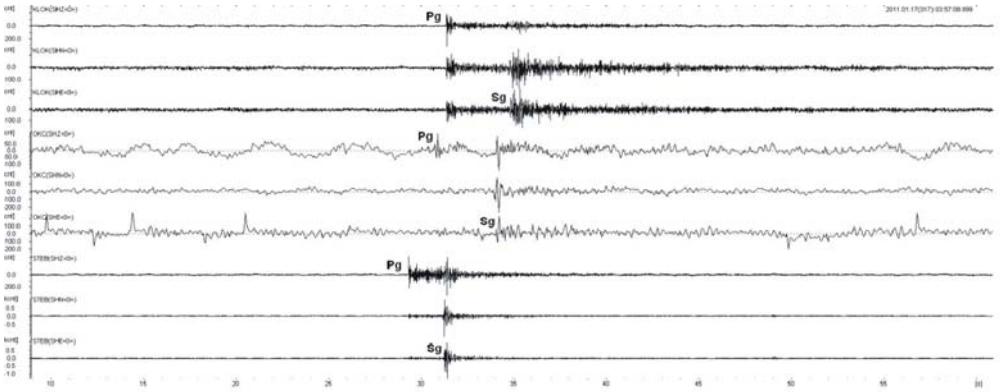

Fig. 3 Records of the microtremor originated in the Opava area on January 11, 2011 recorded at the stations KLOK, OKC and STEB (from top to bottom); H = 03:57 UTC.

4 Data in the processing

4.1 Statistical distribution

The particular recorded seismic events are distributed according to their character into several classes, and the corresponding histograms are displayed in Fig.7. The column „OKCB“ includes all induced seismic events from the eastern part of the Ostrava-Karviná Coal Basin, and, moreover, a few induced events from its southern part surrounding Frenštát pod Radhoštěm. The column „Poland“presents the number of recorded induced mining events from the Rybnik and the Katowice coal mines. The rock bursts and mining shocks from the copper mines near Lubin at approximate epicentral distances r ≈ 250 km from the STEB seismic station are in column „Lubin“. As for Explosion, it should be noted here that the number of explosions included in this graph is relatively low, because the time interval of data interpretation coincided with the winter season, when the number of quarry blast fired is at a minimum. In the column „Tectonics“are included nine micro-tremors, the preliminary

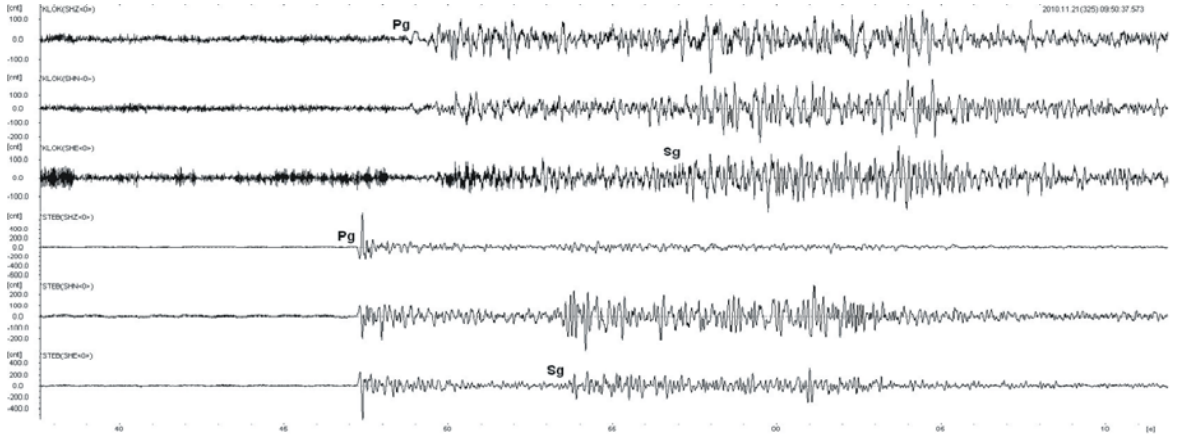

Fig. 4 Records of induced seismic events originating in the Anna mine in the Rybnik coal mine district on Nov. 21, 2010, at 09:50 UTC, released energy E = 1x10^5 J. In the upper part of the seismograms from KLOK, r ≈ 58.22 km, α = 56.9˚, in the lower part of the record from STEB, r ≈ 46.27 km, α = 75.4˚.

localization of which is shown in Fig. 2. The column „Other“ contains, e.g., a few mining induced events from the open-pits of the brown coal district near Belchatow, and also the rest of the unidentified seismic events.

4.2 Travel-time curves and apparent velocity of the fictitious seismic wave „t_{Sg} -t_{Pg}“

It was reported that the STEB and KLOK seismic stations record mining induced seismic events from the coal mines of the Rybnik basin from time to time. Considering that the recorded waveforms of these events are suitable for accurate picking of Pg and Sg arrival times, they were used for constructing travel-time curves. Since the epicentral distance was needed for this purpose, the data (foci coordinates) from the monthly seismic bulletin of the Institute of Geophysics AS CR in Prague were applied and the epicentral distances for both stations were calculated. The individual data, i.e. epicentral distance vs. arrival times, of the Pg and Sg phases were plotted in the graph, and both data sets were separately approximated by straight lines as shown in Fig. 8; the corresponding equations are as follows:

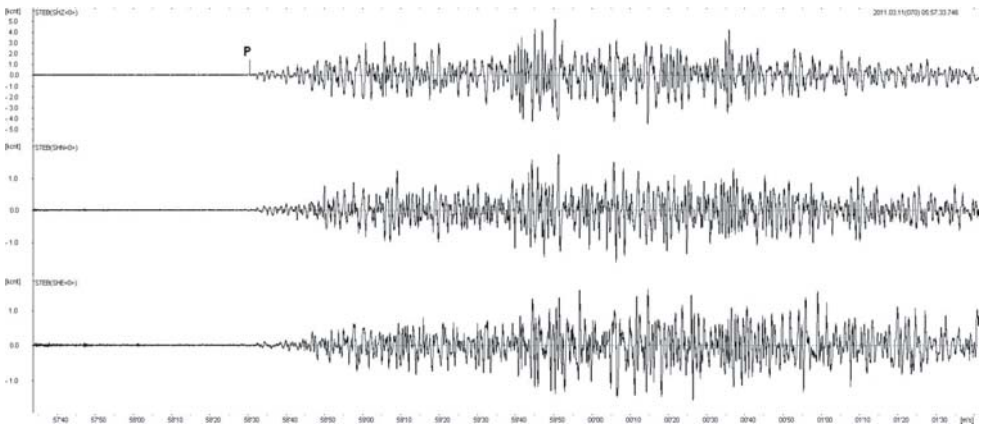

Fig 5 Seismogram of a distant earthquake in Japan - Honshu of March 11, 2011 recorded by a short-period seismometer at the STEB seismic station, H = 05 46 24.4 UTC, h = 32 km , M = 9.0.

for STEB $t_{Sg-Pg} = 0.0937r + 2.0807 \quad , R^2 = 0.7892$ (1)

for KLOK $t_{Sg-Pg} = 0.1151r + 0.9969 \quad , R^2 = 0.5946$ (2).

One can see that the data sets in Fig. 8 create two clusters at epicentral distances r ≈ 45 km and r ≈ 60 km for the STEB and KLOK seismic station, respectively. In the next calculation step both data sets were approximated by one straight line only: the resultant equation is expressed in the following form and displayed in Fig. 9:

STEB + KLOK $t_{Sg-Pg} = 0.1031r + 1.6621 \quad , R^2 = 0.7595$ (3)

It must be emphasized that the accuracy of determining the foci coordinates is affected by various errors, e.g., by the variation of the velocity model within the environment and inaccuracies of the input readings, and therefore the scatter of the values displayed in Fig. 8 and 9 and in Esq. 1 – 3 is observable. Nevertheless, for our purposes, i.e. estimating the epicentral distance of the individual foci from seismic stations STEB and KLOK for the north-eastern direction is sufficient. Finally, the slope of the calculated straight line in Eq. 3 was successively used for determining the apparent seismic wave propagation „t_{Sg-Pg}“for both seismic stations STEB and KLOK. A similar approach was applied, e.g., by Holub (1985) and the resultant equation for the apparent propagation velocity of the fictitious seismic wave was calculated using Eq. 4 and subsequently estimated as $v_{app} \approx 8$ km/s

$$v_{app} = r/\left(t_{Sg} - t_{Pg}\right) \quad . \tag{4}$$

Since the value of the apparent seismic velocity is known and the arrival times of the Pg and Sg phases were determined in the process of interpretation, the epicentral distance can be estimated using the formula:

$$r = v_{app} \times \left(t_{Sg} - t_{Pg}\right) \tag{5}$$

5 Conclusions

The preliminary results based on the short operation of the seismic station Stěbořice (STEB) can be briefly characterized as:

station STEB

1.12.		Pg 02:48:03.712	Sg 02:48:13.668	Poland
1.12.	Pn 04:25:05.915	Pg 04:25:08.588	Sg 04:25:34.861	Poland - Lubin
1.12.		Pg 05:26:53.445	Sg 05:27:06.771	Poland
1.12.		Pg 11:38:41.496	Sg 11:38:51.338	Poland
1.12.		Pg 12:35:19.842	Sg 12:35:25.550	EXP
1.12.		Pg 15:33:17.204	Sg 15:33:24.115	OKCB
1.12.		Pg 20:16:15.648	Sg 20:16:28.906	Poland
1.12.		Pg 21:26:26.396	Sg 21:26:33.147	Poland
1.12.		Pg 22:52:51.354	Sg 22:53:01.230	Poland
2.12.		Pg 04:26:34.988	Sg 04:26:41.434	Poland
2.12.		Pg 08:06:39.357	Sg 08:06:52.022	Poland
2.12.		Pg 10:14:26.996	Sg 10:14:32.781	OKCB
2.12.		Pg 10:44:24.923	Sg 10:44:38.022	Poland
2.12.		Pg 11:07:34.226	Sg 11:07:38.478	EXP

Fig. 6 A part of seismic bulletin based on data of the STEB seismic station from the beginning of December 2010.

- The station is a reasonable addition to the present local seismic network operated by the Institute of Geonics AS CR in Ostrava.
- Among other seismic events a total of 9 micro-tremors from localities Opava, Rýžoviště, Králíky, Odry a Litovel were detected within the time interval of 19 weeks.
- The advantage of continuous records was again documented by the detection of weak micro-tremors, while at the seismic station Zlaté Hory (ZLHC) equipped with a triggered PCM3 device these weak seismic events were not detected at all.
- Two equations of straight lines were derived using the time differences between the readings of the Pg and Sg phases on records of mining induced seismic events for the respective epicentral distance. Afterwards the slopes of these straight lines were computed and subsequently applied in calculating the final apparent velocity of the fictitious seismic wave $v_f \approx 8.0$ km/s.
- Readings from seismograms of local and near micro-tremors, mining induced seismic events from the Czech and Polish mines, quarry blasts and other phenomena recorded at the OKC, KLOK, STEB and ZLHC seismic stations are available at *htt://www.ugn.cas.cz.*

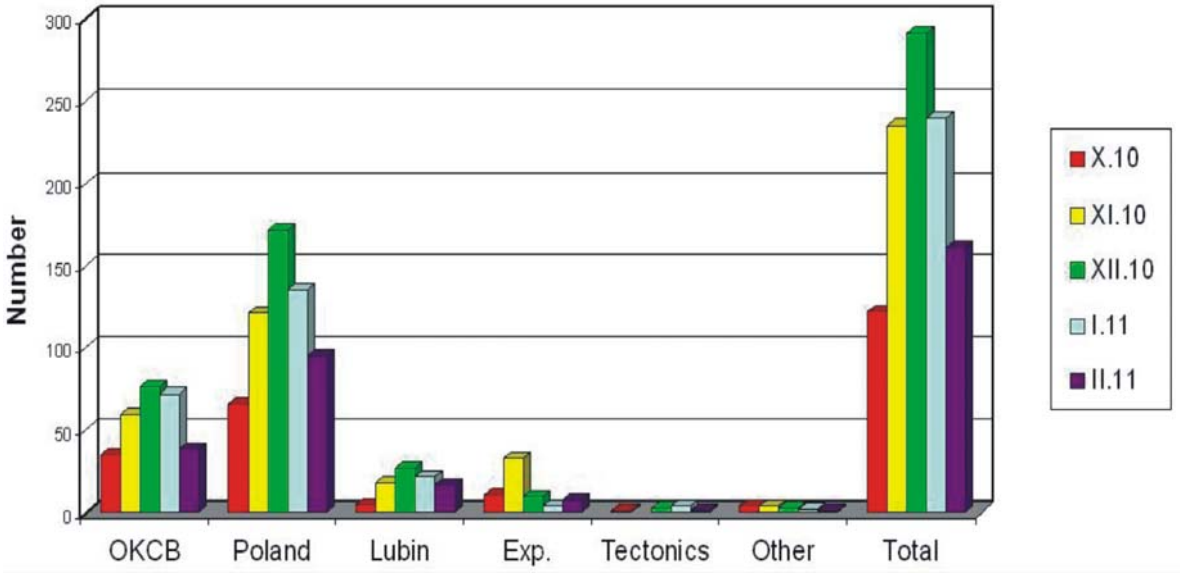

Fig. 7 Distribution of the seismic events recorded between Oct. 19, 2010 and Feb. 28, 2011.

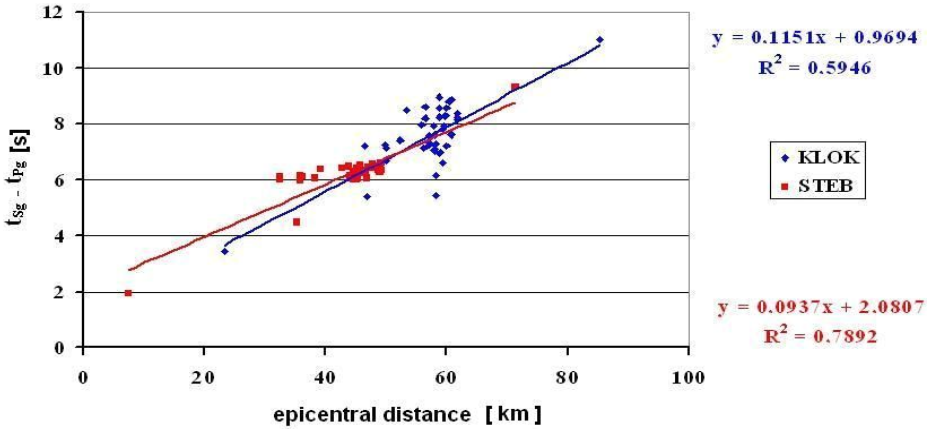

Fig. 8 Travel-time curves of the apparent velocities for the space between the STEB and KLOK seismic stations and coal mines of the Rybnik mining district generally oriented northeastwards.

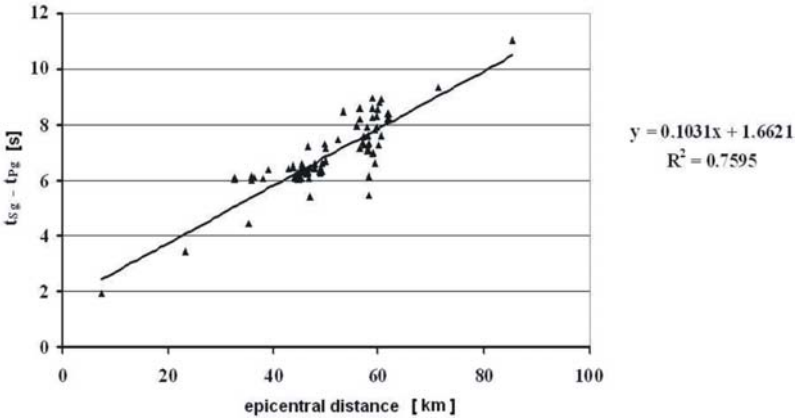

Fig. 9 Averaged travel-time curve of the apparent velocity valid for the space between the STEB and KLOK seismic stations and coal mines of the Rybnik mining district.

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