Acta Geodyn. Geomater., Vol. 5, No. 2 (150), 171–175, 2008

LOCAL SEISMICITY AT THE HRONOV-POŘÍČÍ FAULT (EASTERN BOHEMIA)

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(*Received* January 2008, *accepted* April 2008)

ABSTRACT
In October 2005 local seismic monitoring started in the area of the Hronov-Poříčí Fault Zone. In the present paper we summarize seismic measurements using a small-aperture seismic array Ostaš. Parameters of the array and methodology of the data registration and processing are described. The list of local microearthquakes during two years of registration is presented.

KEYWORDS: Hronov-Poříčí fault, local seismicity, small-apperture seismic array

INTRODUCTION

The seismological investigation in the vicinity of the Hronov-Poříčí Fault Zone (HPFZ) on the NE margin of the Bohemian Massif is focused on possible relations between a seismic activity and crustal fluids (groundwater and carbon dioxide). In October 2005 local seismic monitoring started in the area of the HPFZ. From May 2005, observations of groundwater level in deep wells and concentration of CO_2 in a mineral spring Třtice are performed (Stejskal et al., 2007). In the present paper we summarize seismic measurements, which are realized by a special small-aperture seismic array (SSA) Ostaš.

Hronov-Poříčí Fault Zone belongs to a broader seismoactive area on the NE margin of the Bohemian Massif, which is approximately 40-60 km wide and 150 km long and comprises a number of NW–SE and NNW–SSE-striking faults. This zone forms a SE termination of the important central European tectonic structure – the Elbe Fault System (see e.g. Špaček et al., 2006). HPFZ is a system of parallel fractures, dividing two important structural units – the Intra-Sudetic Basin and the Krkonoše Piedmont Basin (Fig. 1). The NW–SE-striking fault zone is approximately 40 km long and up to 500 m wide.

A present-day activity of the fault is manifested by relatively frequent local earthquakes. The strongest seismic event occurred on January 10, 1901 (Woldřich, 1901) and reached the epicentre intensity of 7° MSK (Procházková, 2002). This intensity corresponds to the magnitude estimation M=5.0 (Kárník, 1996). Isoseists of this earthquake are elongated in NW-SE directions. It was felt even in Dresden at the epicentral distance of about 130 km with an intensity of 5° MSK.

Table 1 Earthquakes with macroseismic effects on the territory of NE Bohemia since 1900 (After Procházková, 2002 and the list of felt seismic events since 1991 of Geophysical Institute AS CR available at http://www.ig.cas.cz).

Date	*Coordinates*	*Epicental intensity I_o (MSK-64)*
Jan 10, 1901	50.50°N 16.10°E	7°
Aug 28, 1903	50.60°N 15.70°E	3°
Dec 21-22, 1905	50.30°N 16.10°E	3-4°
May 13, 1908	50.60°N 15.70°E	4°
Sep 9, 1910	50.30°N 16.30°E	3°
Mar 26, 1928	50.40°N 16.10°E	3-4°
Jan 30, 1949	50.50°N 16.10°E	4-5°
Apr 24, 1957	50.50°N 16.00°E	5°
Dec 2, 1961	50.60°N 16.30°E	4-5°
Nov 3, 1963	50.60°N 15.90°E	5°
Nov 21, 1979	50.50°N 16.00°E	5°
May 5-15, 1984	50.52°N 16.09°E	5°
Mar 20, 1985	50.60°N 16.15°E	4°
Apr 22, 1992	50.40°N 16.30°E	4-5°
Aug 24, 1992	50.50°N 16.00°E	3°
Jun 24, 1999	50.50°N 16.00°E	4°
Aug 10, 2005	50.52°N 16.08°E	2°
Oct 25. 2005	50.50°N 16.10°E	5°

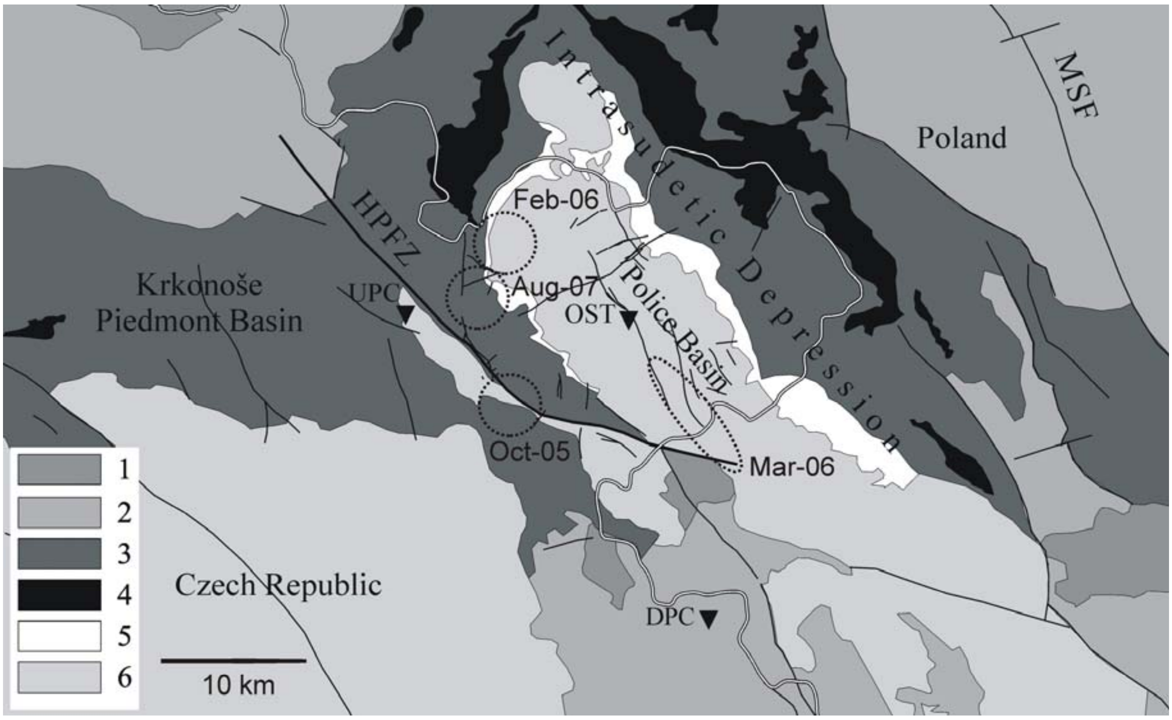

Fig. 1 Geological map of the region with four epicentral zones (circles and an ellipse), which were active during the operation of the Ostaš array. 1 - plutonic rocks (granites, granodiorites), 2 – metamorphites (gneisses, schists, granulites, migmatites), 3 – Permian and Carboniferous sediments, 4 – Permian volcanics, 5 – Triassic sediments, 6 – Cretaceous sediments. HPFZ – Hronov-Poříčí Fault Zone, MSF – Marginal Sudetic Fault, OST – SSA Ostaš, DPC, UPC – stations of the Czech Regional Seismic Network.

Since 1900, 18 earthquakes were felt in the HPFZ region, see Table 1. During last two decades, the local earthquakes are monitored by the Czech Regional Network, especially by stations Dobruška (DPC) and Úpice (UPC). A local seismic network was operated at the NW margin of HPFZ for several years in 1980s (Málek and Peňáz, 1988). Last earthquake was felt on October 25, 2005, and reached the magnitude of 3.3. During the aftershock sequence of this event, a small-aperture seismic array with high sensitivity started its operation.

SMALL-APPERTURE SEISMIC ARRAY OSTAŠ

The array is situated at the foot of the Ostaš Hill, about 10 km from the Hronov-Poříčí Fault, Fig. 1. The array consists from a central station OSTA (with broadband CMG-40T sensor) and three satellite stations OST1, OST2 and OST3 (with short-period sensors SM6), Fig. 2. All stations are three-component. The satellite stations form a triangle with sides of 50 m. The central station has coordinates 50.5565 °N, 16.2156 °E and 611 m above see level. The sensors are connected by cables with a central station, where the data are stored in a computer. The internal sampling frequency is 1 kHz. The digital anti-alias filter is used and the data are stored with the frequency of 100 Hz. The RUP 2004 acquisition system (Štrunc and Brož, 2006) is used. The array is connected through mobile-phone data transfer with the interpretation centre in Prague. This data transfer enables quality control of the array and a transfer of selected events. The full continuous data are transferred monthly using a USB hard disk.

A recognition and interpretation of weak local earthquakes take advantage of the coherency of the

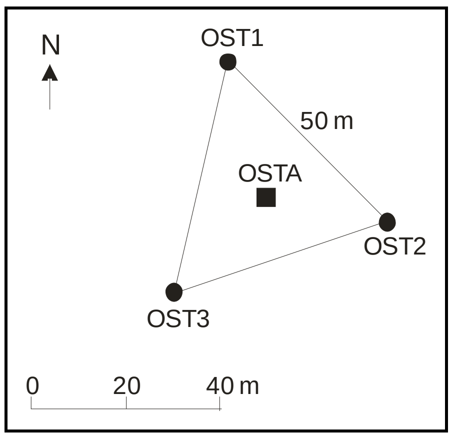

Fig. 2 Small-aperture seismic array OST. Central broadband station - square, satellite short-period stations - dots.

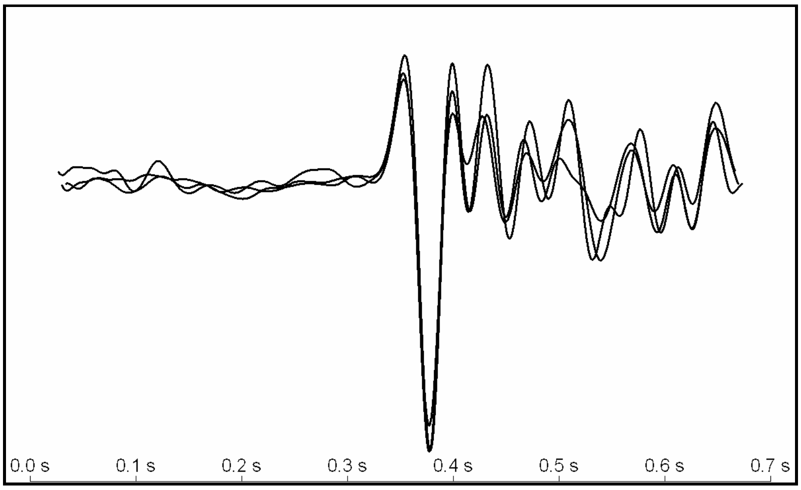

Fig. 3 Coherency of the P-onsets on the Z-component at the 3 satellite stations of the array OST1, OST2 and OST3. Time shifts between seismograms are calculated for azimuth of 240° and apparent velocity 6.0 km/s.

seismic signals, which are recognized from non-coherent noise. By comparing the waveforms, we can precisely determine time differences and compute the azimuth and apparent velocity of a propagating (planar) seismic wave. An example of the coherency of direct P-wave is shown in Fig. 3.

Locations of the earthquakes could be also roughly estimated with the help of the OST array. The azimuth and apparent velocity of P-wave enable us to determine the direction of a seismic ray approaching the array. This ray is traced back in 1-D velocity model. The ray tracing is terminated, when the travel time of the *P* wave (denoted as T) is reached. It is estimated from the time difference between *S* and *P* waves using the formula:

$$T = \frac{t_S - t_P}{k-1}, \qquad (1)$$

where t_P is a time of *P*-wave onset, t_S is a time of *S*-wave onset and k is a v_P/v_S ratio, which is assumed to be constant and equal to 1.73. The assumed *P*-wave velocity model is the average velocity model derived for West Bohemia region (Málek et al., 2005).

The precision of such locations is rather poor. Numerical tests show that the azimuth to the epicentre is determined with the error of 10° and the hypocentral distance is determined with an error of 20%. We can check the azimuth of events using polarization of the first onset. There is a strong trade-off between an epicentral distance and a depth, which is almost unconstrained. The location can be computed only for local earthquakes with the small hypocentral distance, typically about 15 km. The absolute value of the location error (20% of the distance) is in this case about 3 km. The local magnitude could be determined from the maximal amplitude on the Z-component. However, the main problem is that we have observations only from OST array and the maximal amplitude (of S-waves) is strongly affected by the focal mechanism of local events, which is unknown. For this reason, the magnitude is not computed for all events, but only for those, which are detected also by stations UPC and DPC of the Czech Regional network.

REGISTERED LOCAL SEISMICITY

Since October 2005, 37 local microearthquakes were observed at Ostaš array in the area of the HPFZ. Their parameters are given in Table 2. The method of stacking of seismograms from the array enables us to detect microearthquakes with maximal amplitudes from 0.1 μm/s. So far, the epicentres are concentrated to 4 epicentral zones (Fig. 1). Earthquakes from October and November 2005 are aftershocks of the main (M = 3.3) earthquake. They are located to the SW at the hypocentral distance of about 12 km. This seismic activity is connected with the central part of the Hronov-Poříčí Fault. The single event from February 2006 has the azimuth of 290° and the hypocentral distance approximately 11 km. All these events are probably shallow, because their apparent velocity is relatively low (less than 10 km/s).

The events on March 20, 2006 are located to the Police Basin near the SE termination of the main Hronov-Poříčí Fault at the hypocentral distance of about 14 km. For these events the apparent velocity is high (more than 20 km/s), so the depth is probably comparable with epicentral distance. In this situation, there is a strong trade-off between a depth and an

Table 2 Registered earthquakes.

Date	Origin Time	M (GFU)	Ampl Z (μm/s)	Hyp. distance (km)	Azimuth (°)
Oct 25, 2005	12:46:59.28		3.60	12.4	240.0
Oct 25, 2005	13:14:34.37		1.09	12.2	240.0
Oct 25, 2005	16:46:11.99		1.08	12.2	240.0
Oct 30, 2005	05:56:41.07		0.69	12.2	240.0
Nov 7, 2005	19:24:11.69	1.3	17.18	12.2	240.0
Feb 12, 2006	19:00:54.09		0.26	11.2	290.0
Mar 20, 2006	20:24:21.85		0.71	14.2	150.0
Mar 20, 2006	20:32:39.11		0.33	14.2	150.0
Mar 20, 2006	21:35:29.32		0.20	14.2	150.0
Mar 20, 2006	21:37:06.35		0.51	14.2	150.0
Mar 20, 2006	21:45:36.12	0.3	7.57	14.3	150.0
Mar 20, 2006	21:55:04.00		0.43	14.2	150.0
Mar 20, 2006	23:44:50.08		3.02	14.2	150.0
Aug 3, 2007	22:25:13.60		0.72	11.5	150.0
Aug 3, 2007	23:07:58.60		0.12	11.6	150.0
Aug 3, 2007	23:10:27.27		0.08	11.5	150.0
Aug 3, 2007	23:11:09.42		0.13	11.5	150.0
Aug 4, 2007	02:54:28.00		0.35	11.5	150.0
Aug 4, 2007	03:17:41.10		0.15	11.5	275.0
Aug 4, 2007	03:19:55.10		0.71	11.5	275.0
Aug 4, 2007	03:26:41.25		0.54	11.6	275.0
Aug 4, 2007	03:26:42.52		0.66	11.5	275.0
Aug 4, 2007	03:43:51.46		0.32	11.5	275.0
Aug 4, 2007	03:45:22.94		0.11	11.5	275.0
Aug 4, 2007	03:46:27.92	0.7	5.14	11.5	275.0
Aug 4, 2007	03:49:17.98		0.35	11.5	275.0
Aug 4, 2007	03:49:32.48		0.11	11.6	275.0
Aug 4, 2007	03:49:40.90		0.11	12.1	275.0
Aug 4, 2007	03:50:16.09		0.14	11.5	275.0
Aug 4, 2007	03:51:09.30		0.20	11.5	275.0
Aug 4, 2007	04:02:43.44		0.17	11.4	275.0
Aug 4, 2007	04:34:32.62	0.5	3.26	11.5	275.0
Aug 4, 2007	04:36:12.26		1.50	11.5	275.0
Aug 4, 2007	04:39:17.63		0.15	11.5	275.0
Aug 4, 2007	07:46:10.45		1.07	11.4	275.0
Aug 4, 2007	07:46:14.35		0.41	11.6	275.0
Aug 4, 2007	07:46:19.75		0.40	11.5	275.0

epicentral distance. The error of the location is symbolized by ellipse in Figure 1. The whole sequence lasted for less than 3.5 hours.

Finally, seismic events in August 2007 have their epicentres in the central part of the Hronov-Poříčí Fault at the epicentral distance of about 11 km. This seismic sequence has typical features of a seismic microswarm. It begins with 11 weak earthquakes and culminated after about 5 hours with the strongest shock of a magnitude (M = 0.7). It continued with 12 other events. The whole swarm lasted for less than 10 hours.

CONCLUSIONS

Two years of seismic observations in the vicinity of the Hronov-Poříčí Fault reveal relatively frequent weak seismic activity. The hypocentres are distributed over a broader region of the Hronov-Poříčí Fault. There are four epicentral zones, in which microearthquakes are located in the studied period.

Last earthquake sequence in the August 2007 had a typical character of seismic swarms (or microswarms) and lasted for less than 10 hours. On the other hand, last felt earthquake and seismic events that followed it in October 2005 had a typical mainshock - aftershocks character.

ACKNOWLEDGEMENTS

This study was supported by the Czech Science Foundation (Grant Project No. 205/05/H020).

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