Results of two years seismo-hydrological monitoring in the area of the Hronov-Poříčí Fault Zone (West Sudeten)

V. Stejskal, M. Brož, L. Kašpárek, L. Skalský, J. Štrunc

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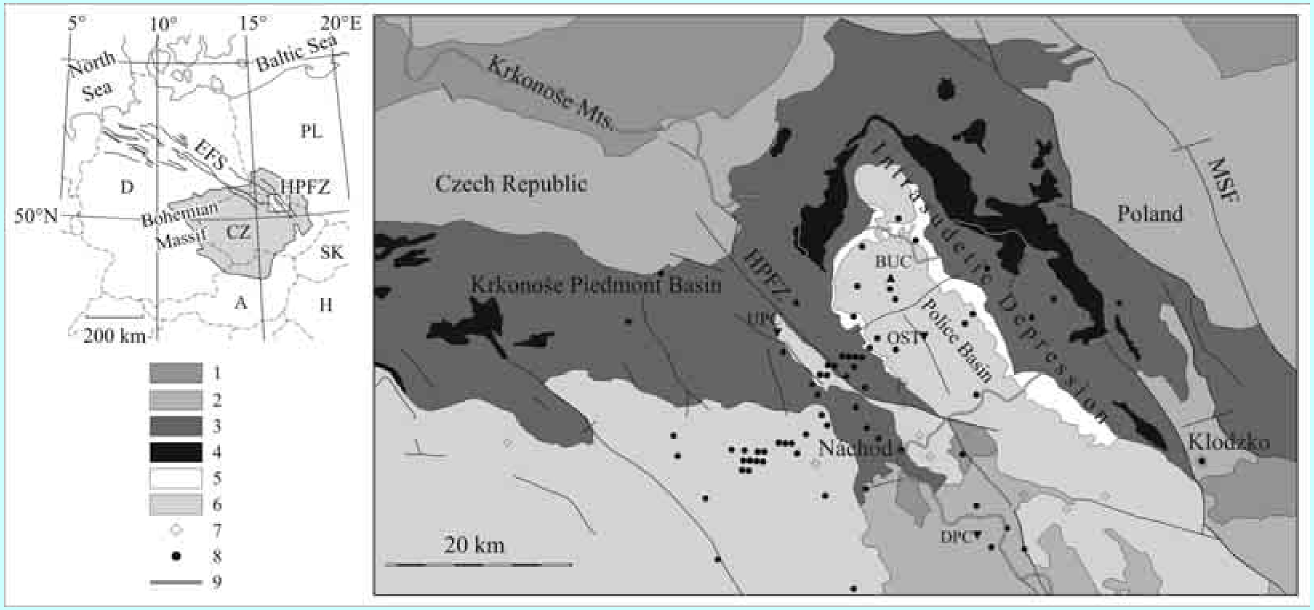
Hronov-Poříčí Fault Zone (HPFZ)



1 - plutonic rocks, **2** – metamorphites, **3** – Permian and Carboniferous sediments, **4** – Permian volcanites, **5** – Triasic sediments, **6** – Cretaceous sediments, **7** – CO_2 – rich mineral springs, **8** – epicentres of seismic events recorded from 1985 to 2005. **HPFZ** – Hronov-Poříčí Fault Zone, **MSF** – Marginal Sudetic Fault, **EFS** – Elbe Fault System, **BUC** – hydro-meteorological station Bučnice, **DPC, OST, UPC** – seismic stations.

•Approximately 30 km long and up 500 m width fault zone.

•Complicated and long-lasting evolution of the fracture begun in the Late Paleozoic.

•Geomorphological record of tectonic movements dating back to Pliocene/Pleistocene to Early Pleistocene.

•Present-day activity of the fault one is manifested by the frequent occurrence of local seismic events.

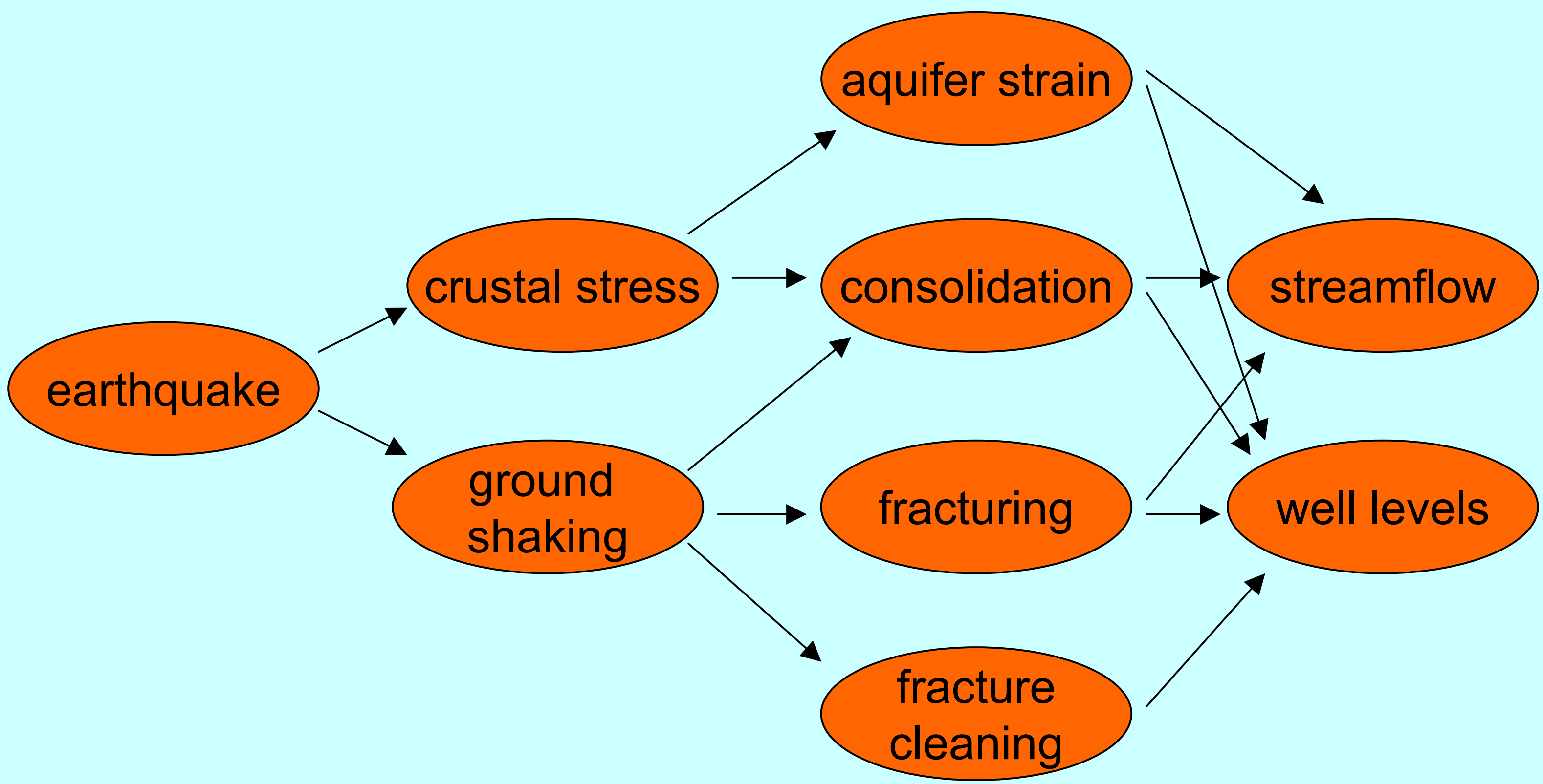
•The strongest seismic event – January 1901 earthquake, M = 4.6.

•Presence of acidulous waters along the Hronov – Poříčí fault zone.

Aims of the project

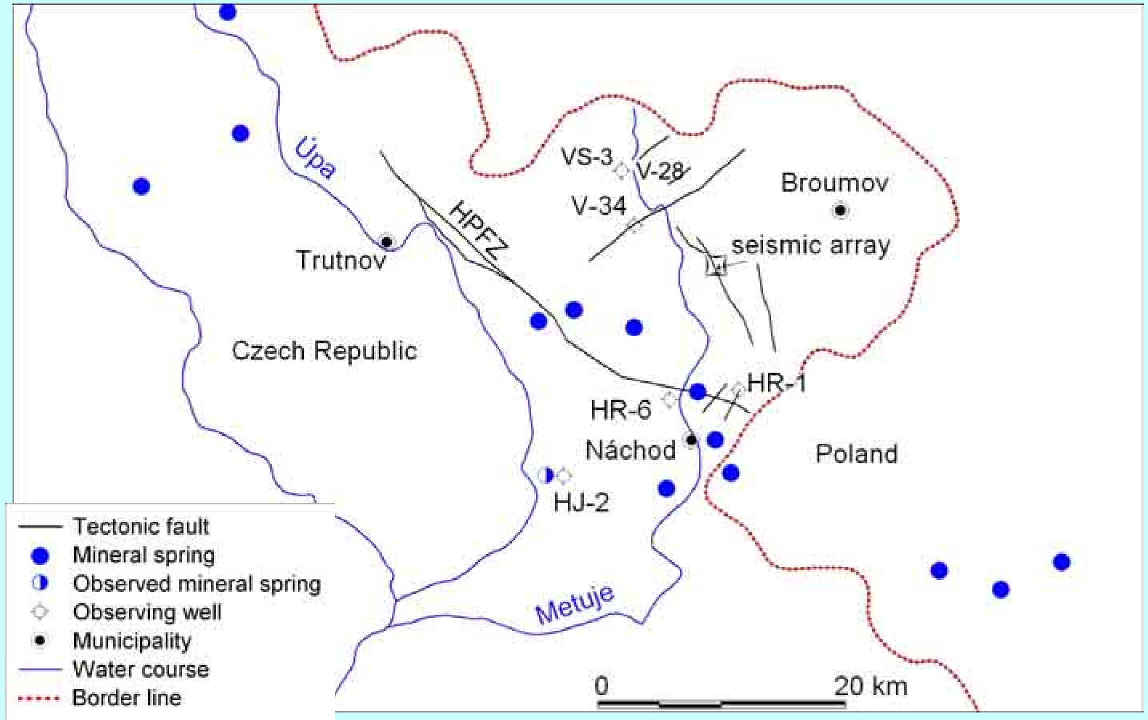
•research of seismic regime in the Hronov-Poříčí fault zone area

•effects of the local seismicity on the groundwater regime.



After Montgomery and Manga (2003).

Observations



Hydrological observations

- **Water level measurements of the IRSM**
  - **deep wells:** VS-3 (305 m), HR-6 (130 m) and V-34 (282 m)
  - **shallow well:** HJ-2 (35 m); CO_2 – rich mineral water.
- **Water level measurements of the Water Research Institute** (fully automatic since 1998):
  - **deep wells:** VS-3 (305 m) and V-28 (300 m)
- **CO_2 measurements**
  - acidulous water spring Třtice (HJ-2 well).

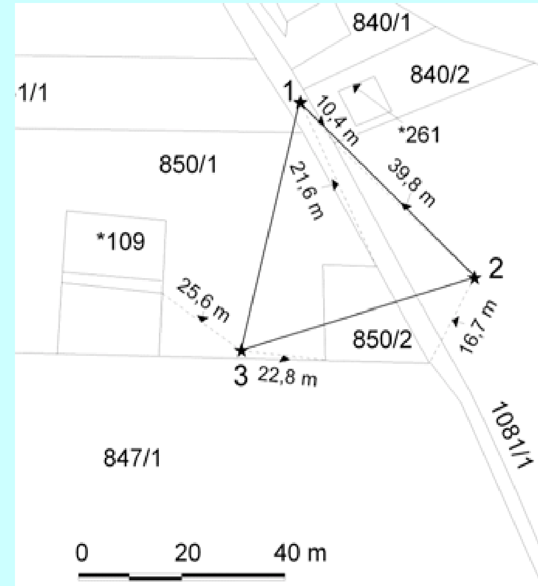
Seismic measurements

- Small aperture array Ostaš (OST) situated 10 km NE of the surface trace of the HPFZ

Small aperture seismic array Ostaš

Small-aperture array configuration

- Equiangular triangle of 50 m side length
- **Triaxial sensors:**
  - 3 × SM-6b 28.8×91 = 2621V/(m/s)
  - 1 × Guralp CMG-40T   800V/(m/s)
  - 1× LE-3D (backup) 400V/(m/s)
  - Sampling frequency = **100 Hz**, **continuous mode**.



Seismic activity

Most important recent seismic events

•**December 2003**

•15 events between Dec-2 and Dec-5, strongest event: **M = 1.7**

•**August 2005**

•24 events on Aug-10, strongest event: **M = 2.4**, I = 2°

•**October 2005**

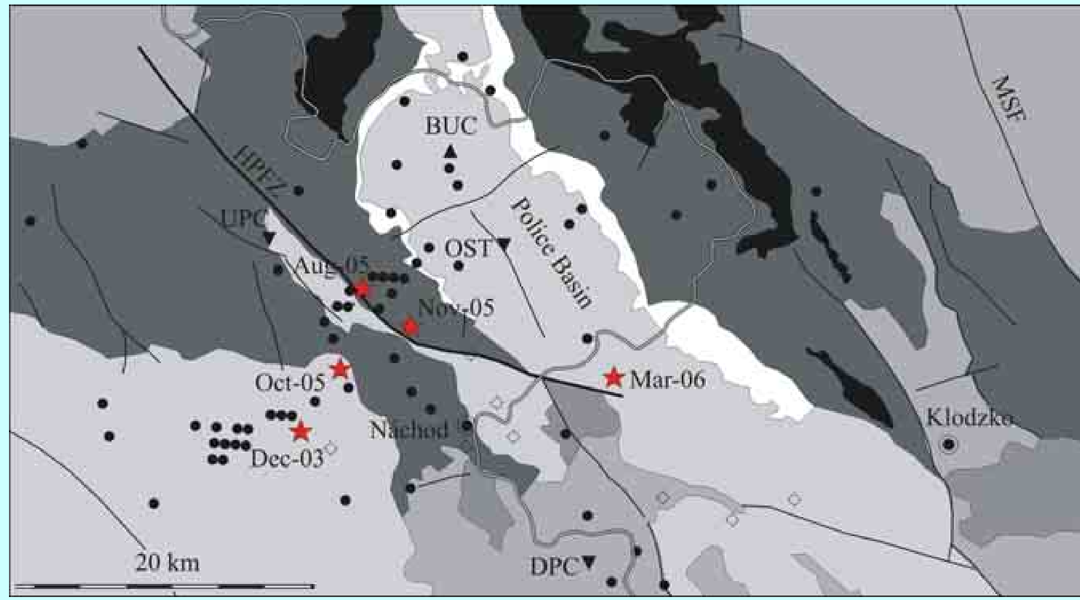
•6 events on Oct-25, strongest event: **M = 3.3**, I = 5°

•**November 2005**

•1 event on Nov-7, **M = 1.3**

•**March 2006**

•4 events on Mar-20, strongest event: **M = 0.3**



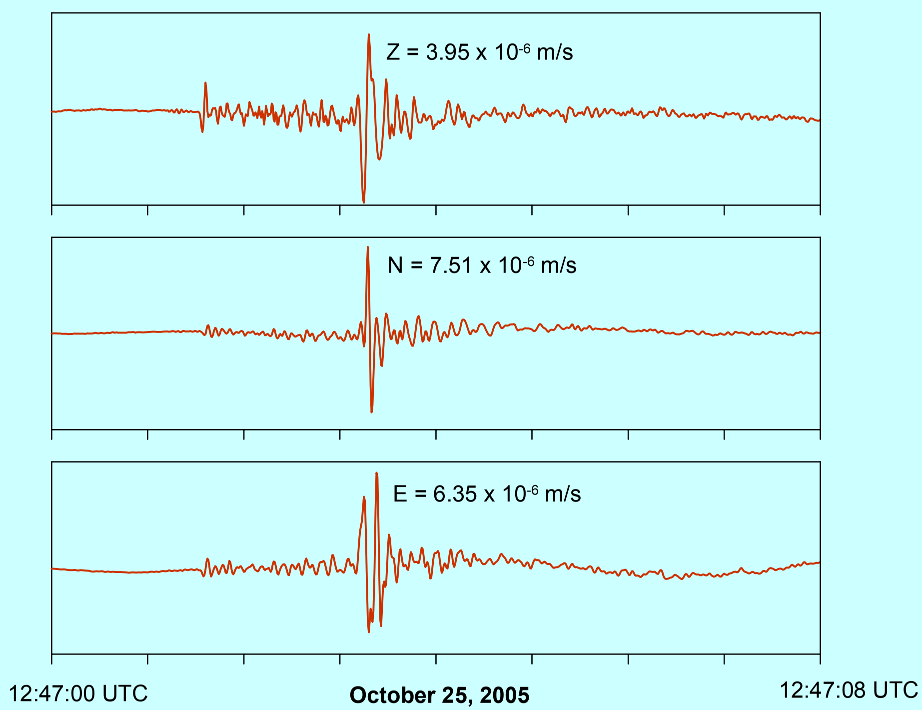
Weak local shocks in 2006 (unconfirmed):

•February 12, June 20, June 24, August 24.

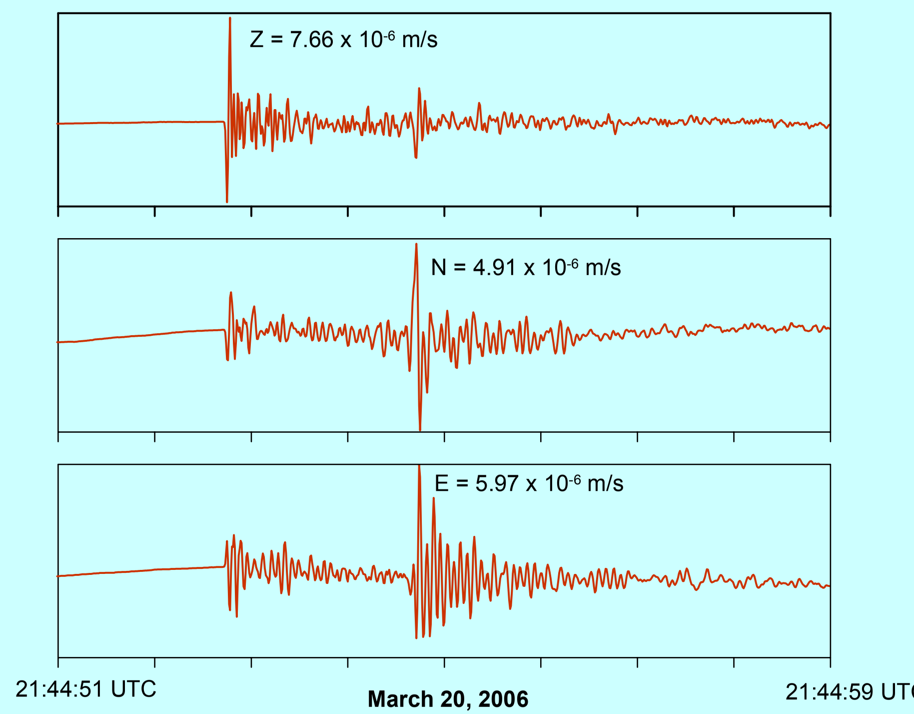
Recorded seismograms

Central station Guralp CMG-40T

October 25, 2005



March 20, 2006



Methods of hydrological monitoring

Water level measurements

- Automatic water level data-loggers
- Accuracy of measurements 0.1 %
- Resolution 1 mm
- Sampling period 10 minutes.

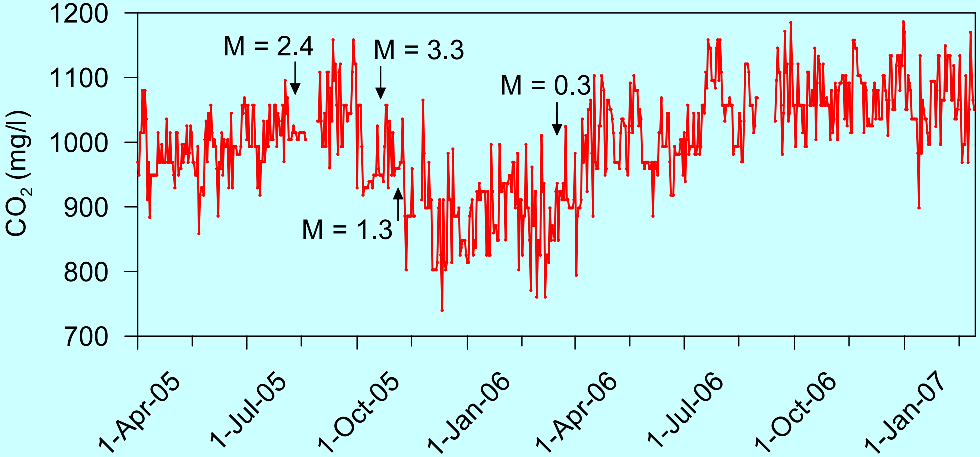
Air pressure measurements

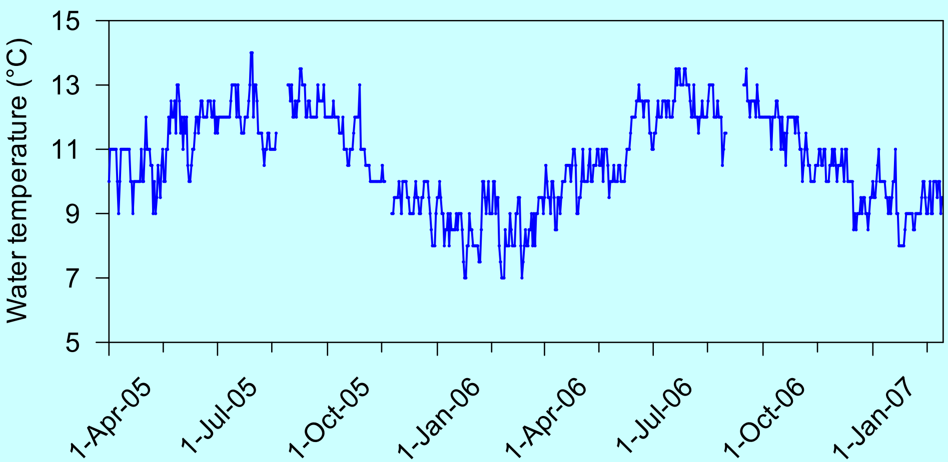
- Sampling period 10 min
- Resolution 0.001 hPa.

CO_2 observations

- Manual measurements with use of Haertl's instrument
- Accuracy 10 – 15%
- Sampling period 1 day

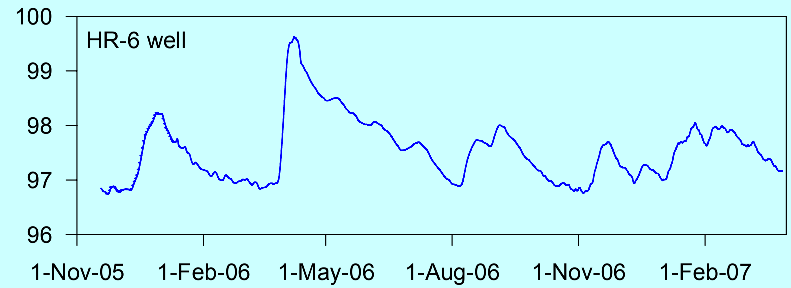
Carbon dioxide measurements

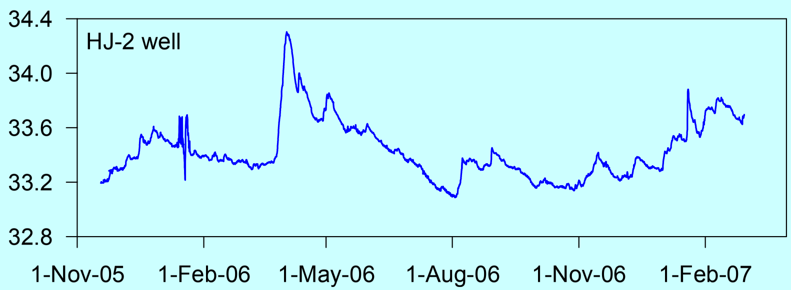


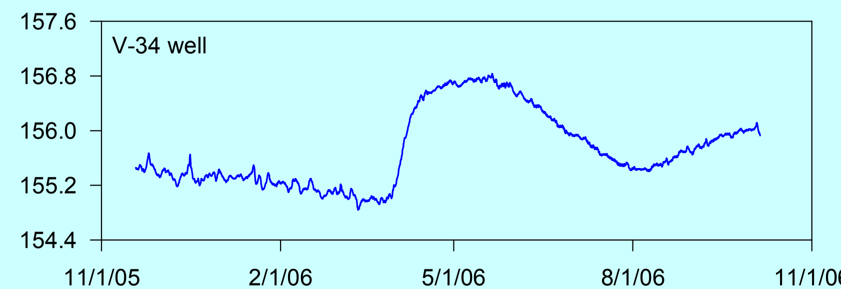


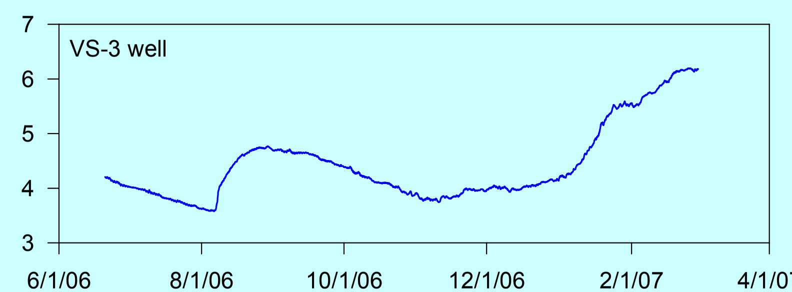
Mineral water spring Třtice

Groundwater level measurements



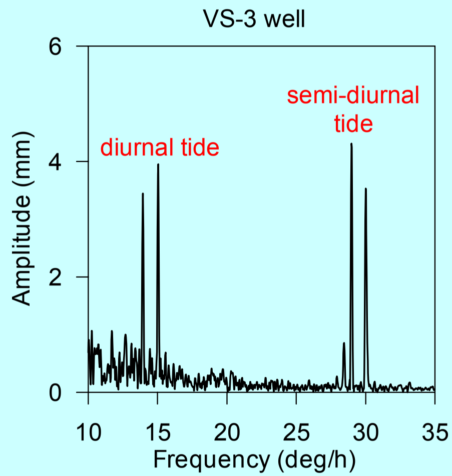


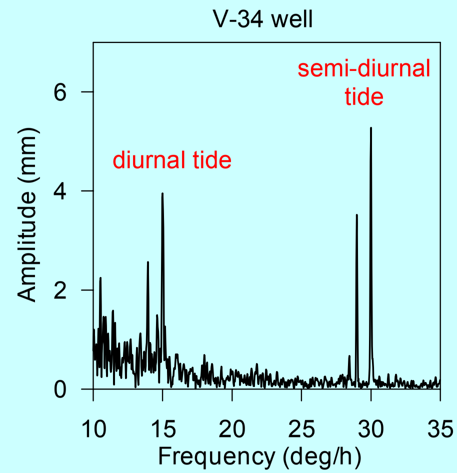


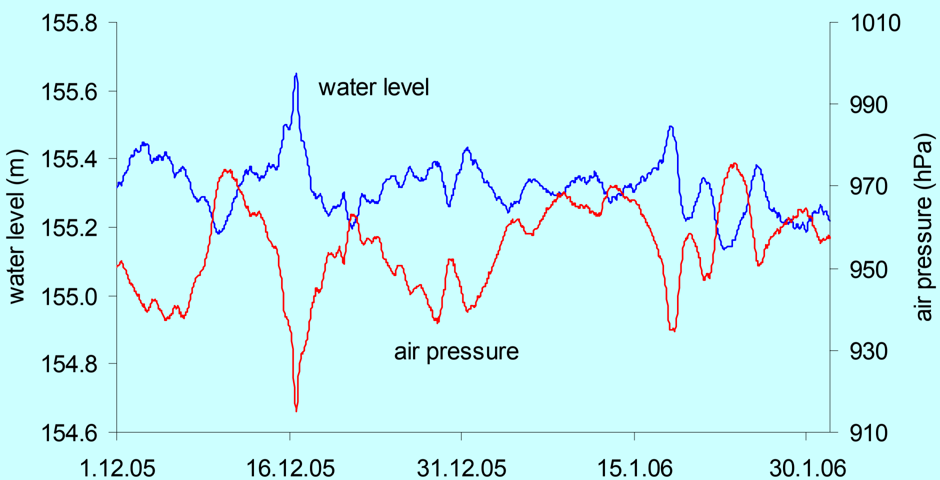


Barometric and tidal response of the groundwater level

Fourier amplitude spectra





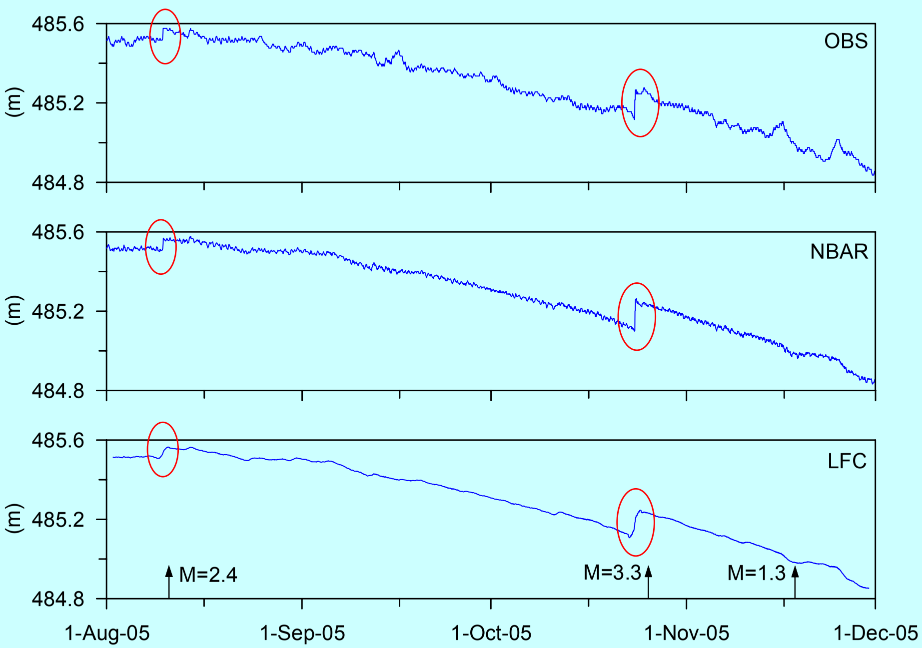


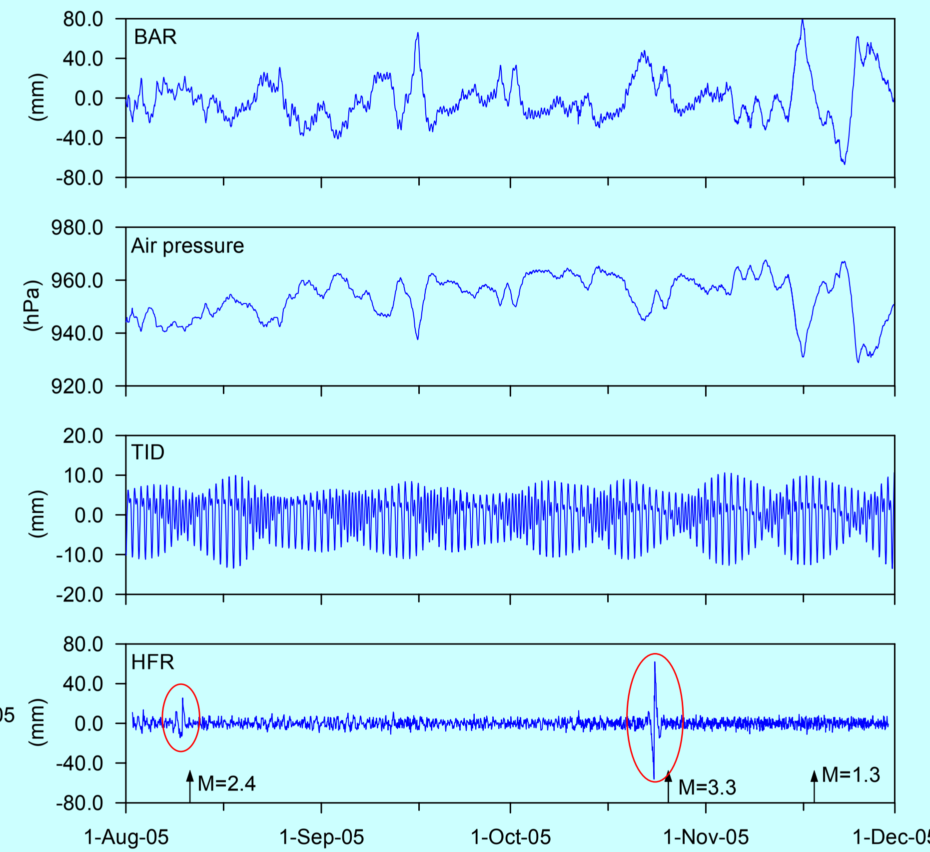
- Observed groundwater level exhibits well apparent response to surface loading due to **air pressure variations** and **solid Earth tidal strain.**

- Water level variations reflect volume tidal strain of the Earth's crust in order of $\mathbf{10^{-9}}$.

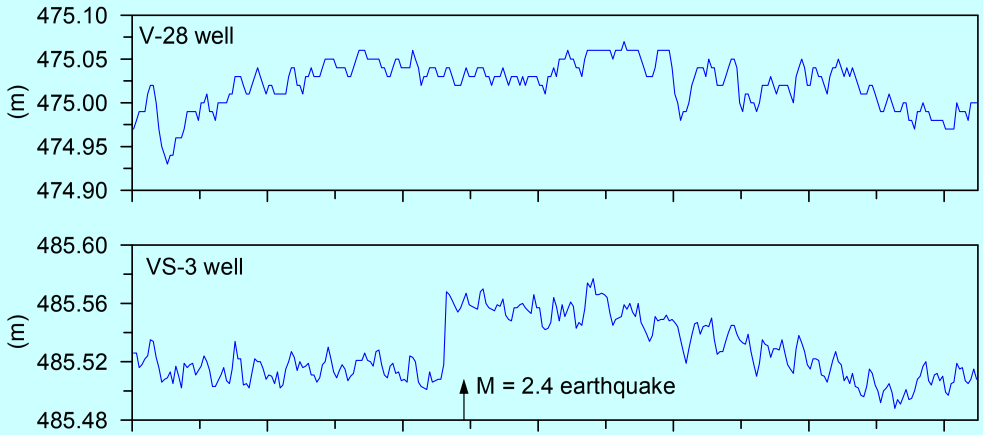
- *Dobrovolsky et al. (1979):* Earthquake precursor manifestation zone – precursory phenomena appear to be observed up to the distance from earthquake epicenter where deformation $\boldsymbol{\varepsilon = 10^{-8}}$. Thus the water well level variations can reflect potential earthquake induced crustal deformations.

Precursory events related to August 2005 and October 2005 earthquakes



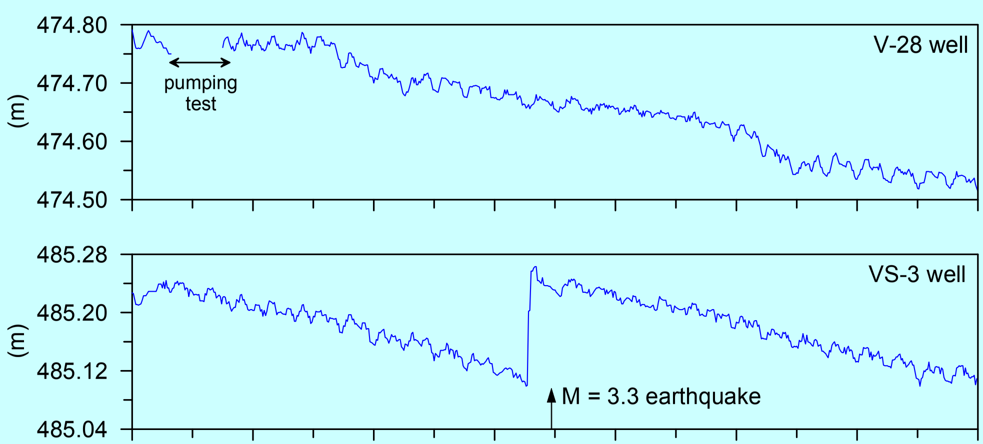


Precursory events – close up shots



- **August 2005 earthquake: 10.8. 2005 18:54:34 UTC, M = 2.4**

Sudden groundwater level rise (+6 cm) was observed on Aug-10 between 02:00 UTC and 06:00 UTC, i. e. 17 – 13 hours prior to the seismic event.

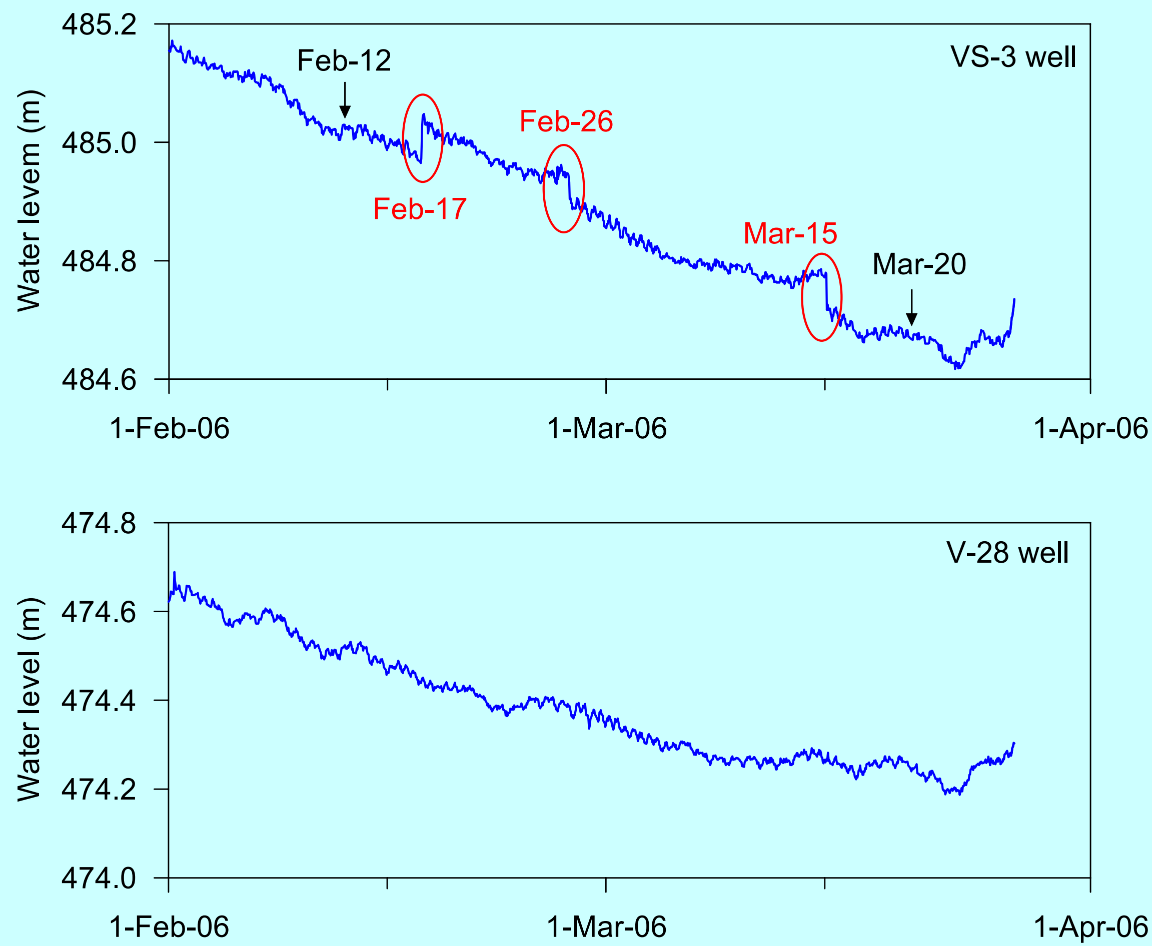


- **October 2005 earthquake: 25.10. 2005 10:51:57 UTC, M = 3.3**

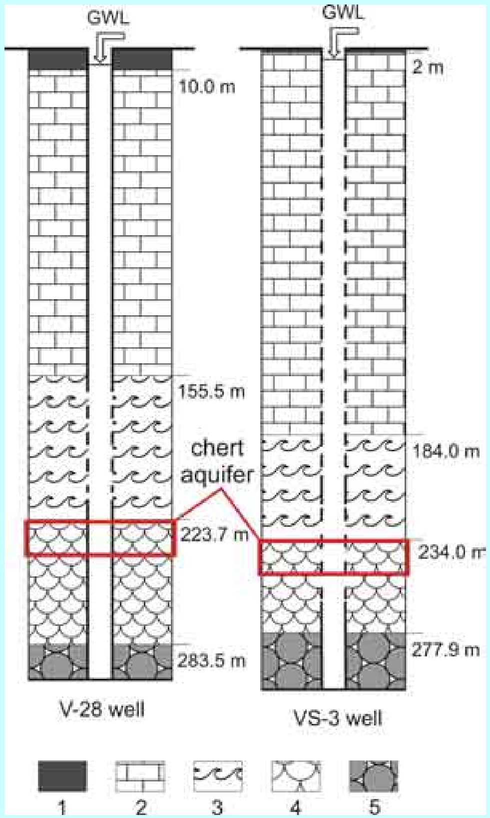
Sudden groundwater level rise (+15 cm) was observed on Oct-24 between 01:00 UTC and 04:00 UTC, i. e. 34 – 31 hours prior to the seismic event.

Further results

- February – March 2006



Preliminary interpretation and discussion



1 - Quaternary alluvial deposits. **2** - Middle Turonian marlstones and silty sandstones. **3** - Lower Turonian marlstones. **4** - Cenomanian silicites, marlstones and sandstones. **5** - Triasic sandstones. Broken line - open parts of the well casing.

Chert aquifer (Upper Cretaceous – Cenomanian)

•Most important water bearing sedimentary unit of the Police Basin.

•Fracture type permeability.

•Thickness up to 15 m.

•Hydraulic continuity over a large area of the northern part of the basin, proved by pumping tests (*Kněžek and Krásný 1995*).

•Presence of preferential zones of the groundwater flow (dense systems of highly permeable fissures – *Krásný et al. 2002*) with transport velocity up to 15 m/day.

Preliminary interpretation and discussion

- The existence of **sensitive sites** where are observed unexpectedly high amplitudes of earthquake-related water level changes is supposed by e.g. *King et al. (2006)*, *Kissin et al. (1996)* or *Kümpel (1992).* The **sensitive sites** are characterised as structurally weak zones surrounded by the relatively more stiff material, which are often situated near tectonic faults.
- VS-3 well as a **sensitive site** – connection with preferential zones of groundwater flow in the chert aquifer.

Groundwater level anomalies as a result of deformation of the preferential zones

compression ⇒ lowering of the volume of fluid filled fractures ⇒ water level rise

dilatation ⇒ expansion of fluid filled fractures ⇒ water level drop

- Regional continuity of the chert aquifer ⇒ hydraulic interference over long distances ⇒ transfer of effects of larger deformations taking place closely to the seismogenic fault.

- We cannot expect the presence of seismic/tectonic creep induced groundwater level changes related to the weak seismo-tectonic activity unless the observation well is drilled in a sensitive zone. Thus the V-28 well, which is not opened to the chert formation, can be used as a suitable reference object for identification of anomalous groundwater level changes induced by the local tectonic activity in the area of the Hronov-Poříčí Fault Zone.

Preliminary interpretation and discussion

- Relatively rare for the precursory groundwater level changes is the **sharp step-like character** of the observed anomalies.

- Some examples of the step-like precursory groundwater level changes are reported by *Kissin et al. (1996)*. The authors explain these changes by the **aseismic movements** in the near fault zone as well.

- As a reason of this type of short-time precursory phenomena recorded within a time span of hours before an earthquake are often considered **aseismic creep-like movements** (cf. e.g. *Rikitake 1975*). Similarly *Lorenzetti and Tulis (1989)* anticipate that the pre-seismic strain increases sharp within a few minutes to a month before the earthquake, which is caused by **accelerating aseismic slip**.

- In agreement with the above mentioned opinions, we regard the **pre-seismic creep-like movements** in the fracture system of the HPFZ as the primary cause of the precursory groundwater level changes recorded in the VS-3 well. Nevertheless we do not dispose of any direct evidence of the creep movements along the HPFZ. To confirm the above proposed conception of the origin of the hydrologic earthquake precursors it would be necessary to correlate the water level records with the data providing direct information on fault displacement (cf. e.g. *Roeloffs et al. 1989, Rudnicki et al. 1993*).

Conclusions

•The area of the Hronov-Poříčí Fault Zone represents the most important seismoactive region of the Sudetes.

•Spatial distribution of seismic events is not restricted only to the HPFZ and it reflects complicated and not fully known tectonic settings of the broader region.

•We found distinct relations between groundwater level variations and local seismo-tectonic processes, which are restricted only to the particular sensitive site.

•The anomalous groundwater level changes seems to reflect both seismic and creep-like tectonic events.

Thank you for your attention