GROUNDWATER LEVEL VARIATIONS IN THE SEISMO-ACTIVE REGION OF WESTERN BOHEMIA IN THE YEARS 2005–2010

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ABSTRACT

The western part of the Bohemian Massif (Vogtland/West-Bohemia region at the Czech-German border) is characterized by relatively frequent intraplate earthquake swarms and by other manifestations of present-day geodynamic activity. In this study we analyze variations in the groundwater level in four hydrological wells in the region during the years 2005–2010. The monitoring during the previous time interval 2000–2004 is also mentioned and used for comparison. Two of the wells were located in the epicentral region of Nový Kostel, the other wells were distant. The time interval included the 2008 earthquake swarm when all the wells displayed a noticeable drop in the water level. This effect was observed up to epicentral distances of nearly 30 km, which exceeds the distances where hydrological changes were observed during previous earthquake swarms. Moreover, it seems that a small rise in the water level preceded the intervals of increased seismic activity, which could represent a certain precursory phenomenon. On the other hand, the hydrological changes in the Nový Kostel area were relatively small, indicating that this epicentral area is not hydrologically linked with the seismo-active fault at depth. Consequently, we do not recommend drilling a deep borehole here for scientific or geothermal purposes, although such plans have been discussed recently. First of all, more suitable localities should be sought in a broader vicinity of Nový Kostel.

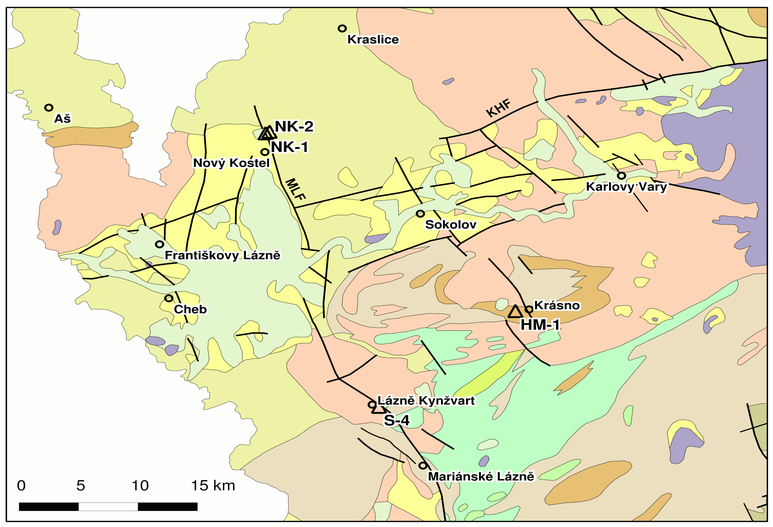
Code	Locality	Latitude	Longitude	h (m)	d (m)	r (km)	Measured since
NK-1	Nový Kostel	50.2299	12.4430	535	23	0.0	June 2000
NK-2	Nový Kostel	50.2318	12.4472	595	23	0.4	June 2000
HM-1	Krásno	50.1067	12.7721	805	23	27.2	June 2000
S-4	Lázně Kynžvart	50.0077	12.6346	718	97	28.3	November 2006

Parameters of the wells: code, locality, northern latitude and eastern longitude in degrees, altitude *h* in metres, depth *d* of the well in metres, *r* is a distance from the well NK-1 in kilometres.

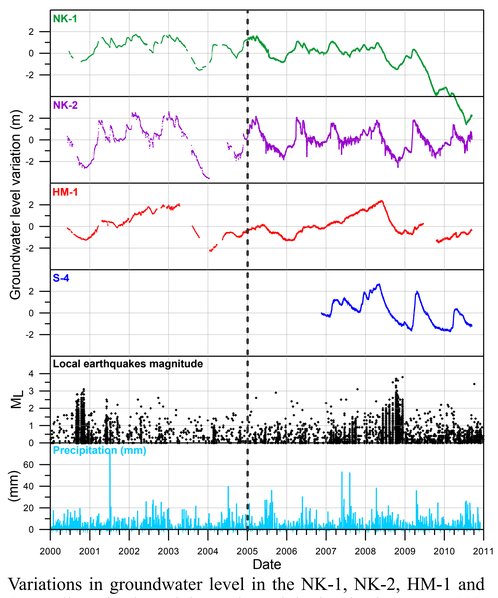
The groundwater level is recorded by means of the DCP-PLI03 pressure sensors produced by the company DataCon Co. Ltd., Prague. The sensors are connected to digital data loggers with a capacity of 32 000 measured values. The data were recorded with a sampling interval of 6 minutes until November 2006. Afterwards the sampling interval was set to 10 min. The accuracy of the measured values is 0.1% with the immersion depth of the sensor amounting to 10 metres. The deduction step is 1 mm. The recorded data are regularly downloaded using a laptop linked with a RS232 serial port.

Date	Time	Latitude	Longitude	h (km)	M_L	Locality
9.10.2008	22:20:37.91	50.215	12.445	9.63	3.5	N. Kostel
10.10.2008	03:22:05.26	50.213	12.446	9.44	3.6	N. Kostel
10.10.2008	03:22:06.88	50.209	12.442	9.20	3.2	Lesná
10.10.2008	08:08:46.24	50.213	12.444	9.68	3.3	N. Kostel
10.10.2008	08:08:46.40	50.214	12.443	9.70	3.7	N. Kostel
10.10.2008	11:18:41.62	50.221	12.443	9.60	3.3	N. Kostel
12.10.2008	07:44:56.31	50.213	12.447	9.38	3.8	N. Kostel
14.10.2008	04:01:36.31	50.217	12.444	9.64	3.0	N. Kostel
14.10.2008	19:00:33.10	50.213	12.448	8.85	3.7	N. Kostel
28.10.2008	08:30:11.39	50.425	12.452	8.03	3.6	N. Kostel

The strongest earthquakes during the 2008 earthquake swarm: date, origin time (UTC, hour:minute:second), northern latitude and eastern longitude in degrees, focal depth *h* in kilometres, local magnitude (only the events with are included), epicentral region. This table is taken from the WEBNET Catalogues of Local Earthquakes, produced by the Institute of Geophysics of the Academy of Sciences of the Czech Republic.

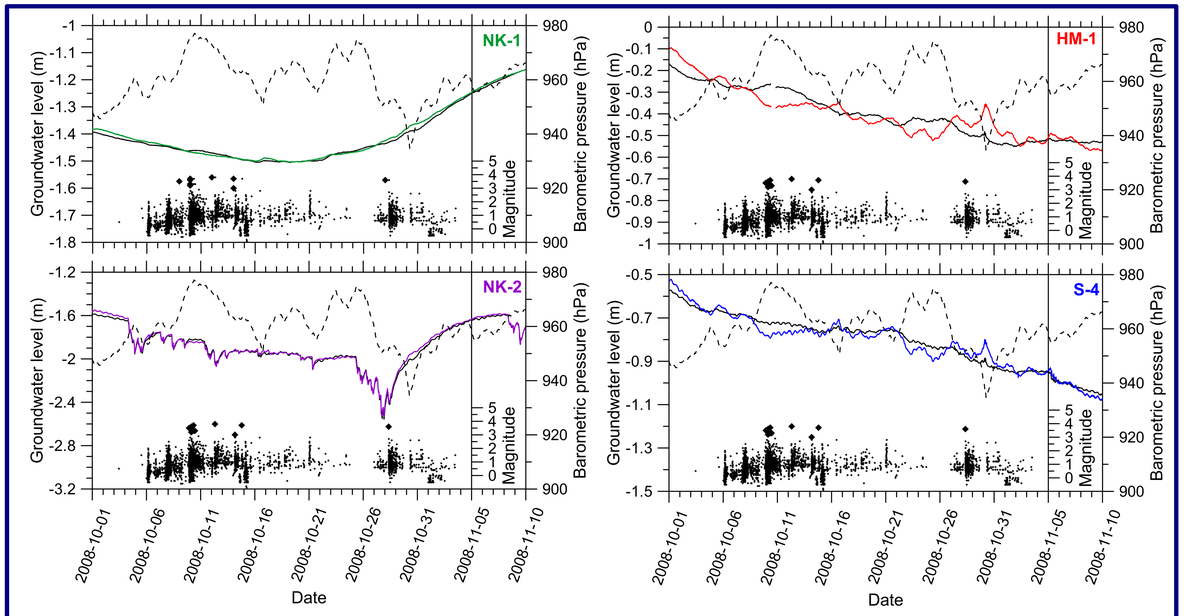


Simplified geological map of Western Bohemia (adapted after Kodym, 1998). The circles show the major towns in the region, triangles denote the wells, MLF and KHF are the Mariánské Lázně and Krušné hory faults, respectively. Wells NK-1 and NK-2 are situated at the NW margin of the Svatava crystalline block, which is a part of the Krušné hory (Erzgebirge) crystalline unit. Well HM-1 is located at the southern margin of the Slavkov complex. Well S-4 is situated within the Lesný-Lysina Massif in the SW part of the Western Krušné Hory Mts. composite pluton.



Variations in groundwater level in the NK-1, NK-2, HM-1 and S-4 wells, seismic activity and precipitation in the years 2000–2010. The groundwater levels are given in metres, relative to their long-term means. M_L means the local magnitude, derived from the WEBNET Catalogues of Local Earthquakes.

Two earthquake swarms with macroseismic effects occurred in the region during the monitoring period, the first one in August – December 2000 and the other in October – November 2008. During the earthquake swarms, the groundwater level dropped remarkably in all wells. We interpret this anomaly as a co-seismic phenomenon. The decrease was distinct even in the distant wells HM-1 and S-4.



Variations in the wells during the 2008 earthquake swarm: relative groundwater level (bold colour lines), air pressure from the Cheb meteorological station (dashed lines), groundwater level corrected for the air pressure (thin solid lines) and seismic magnitudes of the individual earthquakes (dots for magnitudes less than 3.0 and diamonds for higher magnitudes). The pressure corrections were computed using the regression deconvolution implemented in the program BETCO (Toll and Rasmussen, 2007).

Variations of the groundwater level in the NK-1 well are moderate and relatively smooth, without short-term effects and without noticeable relations to variations in seismic activity. The level in the NK-2 well varies more. Several drops in the water level can even be observed prior to the intervals of increased seismic activity, in particular before October 6, 12 and 28. Nevertheless, the measurements in the NK-2 are disturbed by pumping of water in a nearby house. The variations in the groundwater level in the distant wells HM-1 and S-4 are surprisingly similar. Small rises can be observed before some periods of increased seismic activity, e.g., before October 6, 8 and 28. We interpret this behaviour as a possible precursory phenomenon. Attention should also be paid to the "oscillatory" pattern during the main phase of the earthquake swarm between October 6 and 14.

CONCLUSIONS

The Institute of Rock Structure and Mechanics of the Academy of Sciences of the Czech Republic started monitoring the groundwater level in Western Bohemia in three observation wells in June 2000. Two of the wells, NK-1 and NK-2, are located in the epicentral area of Nový Kostel at the margin of the Oloví crystalline unit and close to the Mariánské Lázně fault. The third well, HM-1, is located near the town of Krásno in the Slavkov crystalline complex. Monitoring in the fourth well, S-4, started in November 2006. The latter well is located at the spa of Lázně Kynžvart in the Western Ore Mts. pluton.

Wells NK-1, NK-2 and S-4 display distinct seasonal variations in the groundwater level. The highest water levels are usually observed in spring, which is associated with the seasonal thaw. The seasonal variations in the HM-1 well are less obvious. The variations caused by barometric and tidal effects are significantly smaller and we have not studied them in detail. They were systematically analyzed by Stejskal et al. (2005). During the monitoring period of 2000–2010, two earthquake swarms with macroseismic effects occurred in the region, the first one in autumn 2000 and the other in autumn 2008

During the earthquake swarms, the groundwater level in all wells dropped remarkably, which we interpret as a co-seismic phenomenon. This decrease was distinct even in wells HM-1 and S-4, whose distance from the epicentral area is nearly 30 km. Note that the hydrological and geochemical changes during the previous earthquake swarms were observed only to epicentral distances less than 20 km. Moreover, during the 2008 earthquake swarm a small rise in the water level preceded the intervals of increased seismic activity, which could represent a certain precursory phenomenon.

Seismic monitoring around Nový Kostel is absolutely indispensable as this locality lies in the epicentral region. However, the hydrological changes in wells NK-1 and NK-2 during the earthquake swarms were relatively small in comparison with the changes in the distant wells. This probably indicates that the NK-1 and NK-2 wells are not hydrologically linked with the seismically active fault at depth, i.e. they are not close to the outcrop of the fault. For more details see Gaždová et al. (2011).

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