Acta Geodyn. Geomater., Vol. 10, No. 1 (169), 41–45, 2013
DOI: 10.13168/AGG.2013.0003

# REPLY TO THE OPEN LETTER

## TO CRUSTAL DEFORMATION MODELING OF THE WEST BOHEMIA SWARM AREA, CENTRAL EUROPE

**Vladimír SCHENK [1,2)]* and Zdeňka SCHENKOVÁ [2)]**

[1)] *Geo-Service Praha, Dürerova 2176/16, CZ – 100 00 Prague 10, Czech Republic*
[2)] *Institute of Rock Structure and Mechanics, Academy of Sciences of the Czech Republic V Holešovičkách 41, CZ – 182 09 Prague 8, Czech Republic*
**Corresponding author's e-mail:* vschenk@seznam.cz, schenk@irsm.cas.cz

(*Received* December 2012*, accepted* February 2013)

**ABSTRACT**
In this article we solve the non-standard situation that arose after publishing our paper "Crustal deformations in the epicentral area of the West Bohemia 2008 earthquake swarm in central Europe" (Schenk et al., 2012). Horálek and Fischer wrote a statement regarding our publication, sent it to specialists interested in research in the West Bohemia swarm area, and questioned the reliability of the seismic data used in our work. Since the statement regarding the reliability of our work was not directly sent to us we are using this journal to return to professional discussion regarding our results. In this paper we review scientific arguments made in their statement and provide review of various studies on West Bohemia tectonics and related seismicity.

**KEYWORDS:** satellite geodesy, crustal deformation, seismic cycle, West Bohemia

### INTRODUCTION

Two months after issuing our paper "Crustal deformations in the epicentral area of the West Bohemia 2008 earthquake swarm in central Europe", Horálek, the head of the West Bohemia network (WEBNET) group of the Institute of Geophysics (IG) at the Academy of Sciences of the Czech Republic; and Fischer, the head of the Institute of Hydrogeology, Engineering Geology and Applied Geophysics of the Faculty of Science, Charles University at Prague, sent a statement to researchers interested in studies of West Bohemian swarms (see Appendix).

In their statement, Horálek and Fischer declared that our work was based on data that they know is *clearly wrong*. With respect to this fact Horálek and Fischer consequently stated that our paper used *wrong earthquake locations … not suitable for any detailed analyses*, and that the crustal deformations and stress fields presented must also be wrong. Our forward modeling for the deformation and stress fields were only based on GPS data and not on the positions of swarm shocks, hence it is evident from their statement that they did not thoroughly read our work. Therefore we decided to provide here additional information regarding the problem.

### THE SEISMIC DATA AND THE NOVÝ KOSTEL ZONE

At first we are going to turn an attention to a nature of earthquake swarm origins in West Bohemia and their occurrence on single and/or multiple faults in the area of Nový Kostel. Jánský and Málek (2004) localized swarms originated near Lazy, Plesná, and Klingenthal using the master-event method. They determined that swarms in the Lazy region are linked to two parallel zones and that some swarms within the Klingenthal region also originate outside of a seismoactive structure.

Nehybka and Tilšarová (2007) investigated swarm positions along the Nový Kostel ─ Potůčky belt during the 2001-2006 period and used data recorded by the seismic network KRASNET which is independent of the WEBNET network. They studied the swarms located within the belt of the N 9º W azimuth and found that individual clusters observed along seismoactive faults declined from the belt direction to the east, up to the N10-20ºE azimuth. Thus their positions demonstrate that the belt consists of more seismoactive faults.

Our paper (Schenk et al., 2012) dealt with changes in crustal rock deformations during the 2008 earthquake swarm as assessed from GPS observations. To demonstrate high rate of geologic environment disruption of tectonic or magmatic origins within the seismoactive Nový Kostel zone, seismic data as found in the IG, http://www.ig.cas.cz, were utilized. Catalogued seismic data are continuously updated by the WEBNET group and the position of every observed shock is determined from the P and S wave onset and the 1D velocity gradient model for West Bohemia (Málek et al., 2000). The 3D image of

the shock positions in the 2008 swarm, as presented in our paper in Figure 6, indicated two parallel clusters. Based on the above mentioned papers and due to the strong swarm with events ML>3.0÷3.5 releasing relatively high amount of energy we did not see a reason to reject a probability that more faults at the zone can be seismoactive.

Fischer et al. (2010) relocalized the shocks of the 2008 swarm using the master event method suggesting only single fault plane is responsible for all earthquakes. For the master event they used the event of Oct 14, ML1.5, because it was recorded during the full operation of the WEBNET network. Using this approach the clustering of all 2008 shocks formed one zone 250 m thick; see Figures 5 to 9 in Fischer et al. (2010).

Relocations for the Nový Kostel 1991-2011 swarm events were also determined by Bouchaala (personal communication, September 25, 2012) who compared the locations obtained using the master event method and the double difference method (Waldhauser and Ellsworth, 2000). He utilized all available data for West Bohemia that occurred within the Nový Kostel zone over the last two decades and showed that the double difference locations are more reliable than the master event locations because the double difference method does not depend on subjectively selected number of master events. Moreover, the double difference locations indicated that the zone consisted of several faults where the seismoactivity related to different swarms originated at various times.

Vavryčuk et al. (2012) focused on the double difference (DD) method relative to the re-localization of 2008 swarm shocks in order to retrieve high-resolution locations. The locations exhibited complexity within the seismogenic zone Nový Kostel. Vavryčuk et al. (2012) studied the hypocenter distribution in the depth range from 7 to 11 km (Fig. 1) and indicated a coexistence of 169° strikes (red dots; the principle direction within the zone), with additional strikes related to several differently oriented faults (blue dots in 304º and black dots in 359º azimuths), demonstrating that the Nový Kostel zone consists of several faults since earthquake shocks occurring along the faults correspond to various focal mechanisms. Moreover, a number of hypocenters originated approximately at 0.5 km distance parallel to the principal direction of the zone (Fig. 1b).

A satisfactory explanation as to why one swarm cluster was largely concentrated to one fault plane or its segments has not, to date, been submitted. In general, it is accepted that the initiation of individual earthquakes largely depends on PT conditions and the position of structural elements, such as tectonic faults. As a result of this fact we deduced that the fault irregularity in swarm clustering within West Bohemia could be joined with short-run changes in the stress field. The presence of such changes has previously been explained using forward modeling for the *pre-, co-*, and *post-seismic phases* of the 2008 swarm (Schenk et al., 2012). Using this view we concluded that swarm origins depend on the momentary orientation and the size of the local stress field that naturally impacts the site displacements that are recorded at the surface (see below).

## CRUSTAL DEFORMATION MODELING

Horálek and Fischer brought into their statement a premise that the existence of two parallel seismoactive planes within the Nový Kostel zone (Schenk et al., 2012; Figures 5 and 6) could affect our deformation modeling. As mentioned above, our forward modeling was based on the GPS displacements observed in the *pre-, co-* and *post-seismic phases* of the 2008 swarm, not on the observed 2008 swarm shocks, or on the number of seismoactive faults within the Nový Kostel zone. Hence their reservations regarding impact of two active fault planes are not substantiated.

*The scheme of the fault sets applied during modeling* (Schenk et al., 2012; Fig. 12) was compiled from all available geological materials and geophysical data. A seismicity pattern of the West Bohemia area, involving the shocks observed during the 1994-2008 period, was taken as synoptic regional information. In the scheme, the dynamically active Nový Kostel zone was marked as fault set #2; another fault set numbered as #3 was the fault zone related to the outcrop presented in Figure 8d near Kopanina, etc. Generally speaking, all of the fault sets in the scheme were assumed to contain the sets of a few faults. Therefore, in our concluding remarks we wrote that the *data were numerically modeled by taking into account the local stress field, and the tectonic structural and seismicity patterns, especially for the 2008 swarm*.

The reliability of the crustal deformations detected by GPS measurements performed during the 2008 swarm supports the fact that similar reverse displacements were observed earlier. For the 2000 swarm, Mrlina et al. (2003) found that GPS site displacements in the *pre-* (1998–1999) and *co-seismic* (1999–2000) *phases* had opposite movement trends (Fig. 2). Simultaneously, Wendt and Dietrich (2003) observed comparable reverse displacements for the same swarm phases on the “a” site of their GPS network located within the West Bohemia region.

The short-running changes in GPS displacements observed during the 2000 and 2008 swarms in size and orientation were manifest in the dynamic instability of the area. Even if some irregularities in GPS vectors can be linked with the measurement technology, it is evident that their general pattern depends on changes in the local stress and the crustal deformation fields. To prove this fact, in the future it would be convenient to increase the number of network sites and to perform GPS campaigns several times per year.

## CONCLUSION

The article provided here delivers our reaction to the Horálek and Fischer statement, and informs researchers to whom the statement was delivered and other readers to whom the statement was additionally distributed. Even if Horálek and Fischer did not understand the subject of our paper, they asked readers to ignore our results. We have not commented on their statement here because it fully depends on the decision of those interested in the problem. Through this article we are hopeful that readers will understand our results and will choose to accept or reject our findings based on facts. The results presented in our publication are in a good agreement with foregoing investigations performed in West Bohemia, and we are sure that our seismo-geodetic approach substantially contributes and extends the work of this area.

## ACKNOWLEDGEMENT

We sincerely thank all of our friends who informed us of the Horálek and Fischer statement. We are grateful to our friends for their friendly actions and will never forget their helpful attitudes.

## REFERENCES

Fischer, T., Horálek, J., Michálek, J. and Boušková, A.: 2010, The 2008 West Bohemia earthquake swarm in the light of the WEBNET network, J. Seismol., 14, 665–682. DOI:10.1007/ s10950-010-9189-4.

Jánský, J. and Málek, J.: 2004, Relocation of earthquakes in West Bohemian/Vogtland subregions Lazy, Klingenthal and Plesná using the master event metod, Acta Geodyn. Geomater., 1, 73–83.

Málek, J., Jánský, J. and Horálek, J.: 2000, Layered velocity models of the western Bohemia region, Studia Geoph. Geod., 44, 475–490. DOI: 10.1023/A:1021859516682

Mrlina, J., Špičák, A. and Skalský, L.: 2003, Non-seismological indications of recent tectonic activity in the West Bohemia earthquake swarm region, J. Geodyn., 35, 231-234, PII: S0264-3707(02)00064-9. DOI: 10.1016/S0264-3707(02)00064-9

Nehybka, V. and Tilšarová, R.: 2007, Seismic activity in West Bohemia from 2001 – 2006, Acta Geodyn. Geomater., 4, 51–57.

Schenk, V., Schenková, Z., Jechumtálová, Z. and Pichl, R.: 2012, Crustal deformations in the epicentral area of the West Bohemia 2008 earthquake swarm in central Europe, J. Geophys. Res., 117, B07408. DOI:10.1029/2011JB009053

Vavryčuk, V., Bouchaala, F. and Fischer, T.: 2012, High-resolution fault tomography from accurate locations and focal mechanisms of swarm earthquakes, Poster presentation, ECGS Workshop "Earthquake source physics on various scales", Luxembourg, October 3-5, 2012.

Waldhauser, F. and Ellsworth, W.L.: 2000, A double-difference earthquake location algorithm: method and application to the Hayward fault. Bull. Seism. Soc. Am., 90, 1175–1189. DOI: 10.1785/0120000006

Wendt, J. and Dietrich, R.: 2003, Determination of recent crustal deformations based on precise GPS measurements in the Vogtland earthquake area, J. Geodyn., 35, 235–246, PII: S0264-3707(02)00065-0. DOI: 10.1016/S0264-3707(02)00065-0

## APPENDIX

The following statement by Horálek and Fischer was sent on 14 September 2012, at 13:15:37 UT by email to specialists interested in studies of West Bohemia dynamics (Figure 3). In the statement the specialists were asked *to distribute this letter to all the potentially interested colleagues.* Since we do not know to whom this open letter has been delivered we use this forum to discuss the reservations of *Horálek* and *Fischer* regarding our results.

The note to our application of *some very early version of our* (understand Horálek's and Fischer's) *routine absolute locations of the swarm events* we specify that the utilized seismic data were downloaded in October 2011, three years after the 2008 swarm.

Dear colleagues,

we are writing to those of you who are interested in the earthquake swarm activity in the area of Nový Kostel and are aware of the new paper of Schenk et al. (2012) published in JGR 117, B07408 that gives an extensive interpretation of the seismic activity during the swarm 2008.

The main point of our message is to tell you that the interpretation is based on wrong earthquake locations that split into two parallel clusters. Thus, all the results based on seismicity are wrong.

It is a regrettable circumstance that the authors did not inform us about their ongoing study, nor about the submitted paper. We learned that the paper has been published only one week ago from the email that Vladimir Schenk sent to some of you.

The discrepancy is clearly seen from the comparison of Fig. 6 in their paper with Figs. 5 and 9 in our detailed study about the 2008 swarm (Fischer et al., Journal of Seismology, 2010). As follows from the precise master-event locations of the 2008 swarm, the hypocenters have activated a single fault plane of the width about 100m and no parallel clusters have developed. The fine width of the fault zone have been recently verified by HypoDD locations as well (Fateh et al., submitted to Computers and Geoscience). Schenk et al. (2012) have probably used some very early version of our routine absolute locations of the swarm events that are not suitable for any detailed analysis. Unfortunately, they did not consult with us whether these incorrect locations can be used for this type of study.

We are sorry that we were not able to prevent this regrettable situation and in the future we will have to protect our data more carefully.

We expect that Schenk et al. will make all the necessary steps to take back their paper. Depending on that we will consider further actions to protect the honesty of scientific research in the West Bohemia/Vogtland area.

Finally we would like to ask you to ignore the interpretation presented in the paper. We have the exclusive right for this request because the paper is based on our data and we know that these data are clearly wrong. Schenk et al have no independent seismic data that would support their speculations.

Please distribute this letter to all the potentially interested colleagues.

Prague, September 14, 2012

Yours sincerely

Josef Horálek and Tomáš Fischer

**Fig. 3** The statement by Horálek and Fischer.

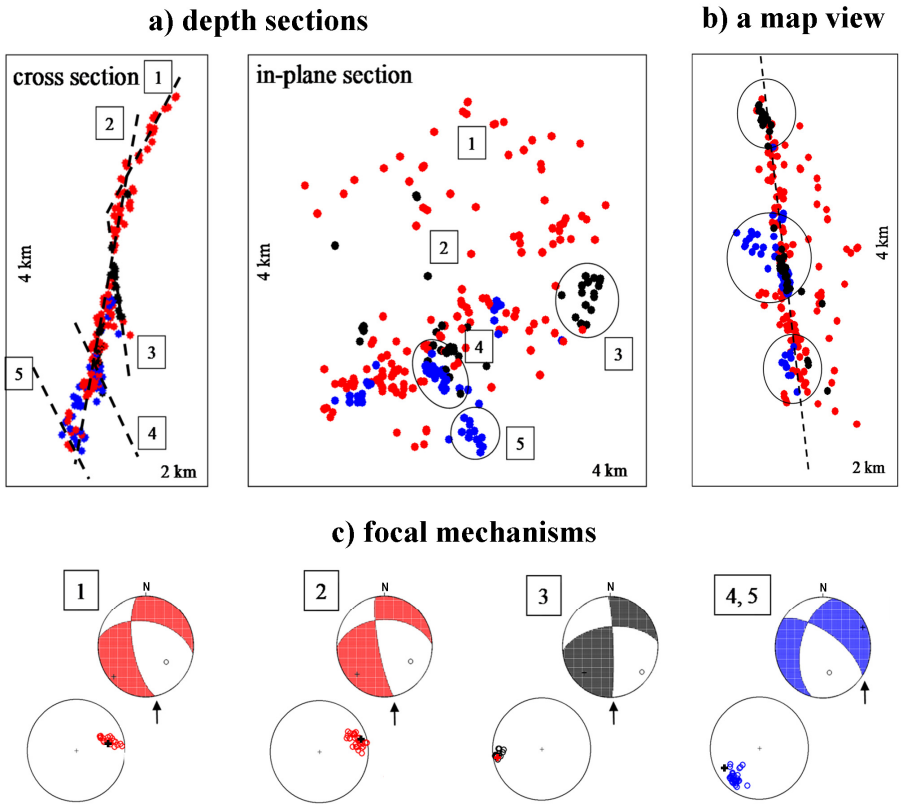


**Fig. 1** The re-located shocks of the 2008 swarm and the fault segments determined from the foci interpolation and focal mechanisms (Vavryčuk et al., 2012); **a)** the red, blue, and black dots are shocks separated according to focal mechanisms; the framed numbers mark individual shock groups; and dashed lines indicate the orientations of the faults; **b)** the dashed line indicates the direction of the active fault zone; colored dots represent the re-located epicenters; **c)** the focal mechanisms of the colored shock groups; the open circles in the focal spheres indicate the fault normals computed from the focal mechanisms, and the crosses mark the fault normals using the foci interpolation.

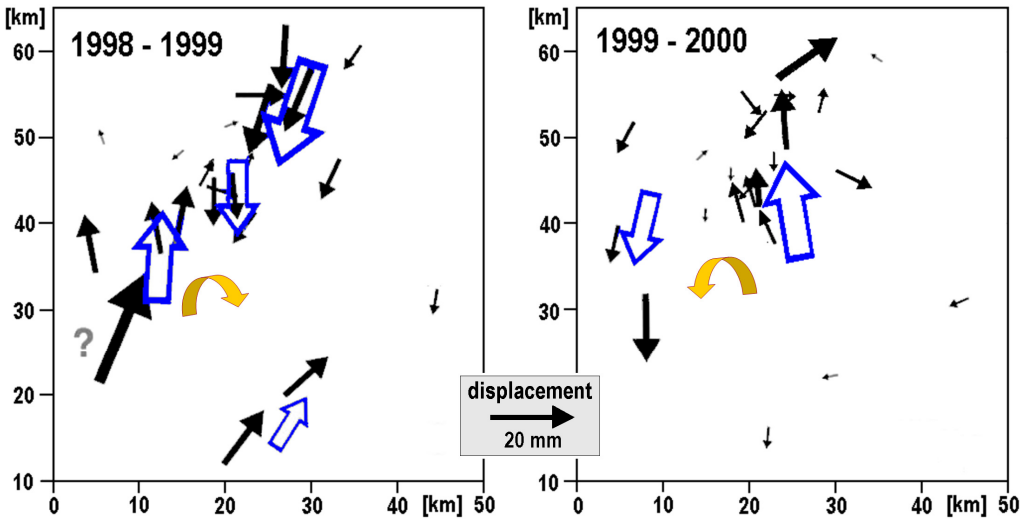


**Fig. 2** GPS annual 1998–1999 and 1999–2000 horizontal displacements with error estimations < 5 mm; blue empty arrows – predominant displacements (Mrlina et al., 2003);
yellow arrows – "quasi-rotation movement" trends of the structure elements (added by us).