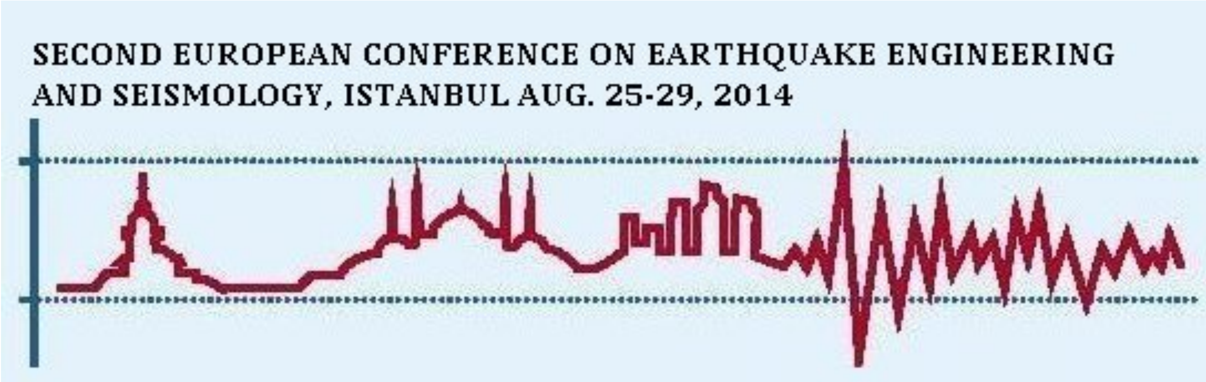

SUBSURFACE STRUCTURES AND THEIR RELATIONSHIP TO EARTHQUAKE SWARMS: A JOINT INTERPRETATION OF HIGH-RESOLUTION SEISMIC IMAGING AND EARTHQUAKE TOMOGRAPHY

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The West Bohemia/Vogtland area is a tectonically complex region. Throughout the region, several areas experience recurring swarm seismicity. An earthquake swarm is a rapid succession of earthquakes in a single area with no distinct main shock. The main West Bohemia/Vogtland swarm area is located under the Czech village Nový Kostel. This location coincides with the junction of two major fault zones and the edge of the Cheb Basin and Eger Rift (Figure 1). The seismic activity in this region is probably connected to young Quaternary volcanism manifested by numerous mineral water springs with a high content of carbon dioxide (Bräuer et al., 2005).

Nový Kostel is monitored by a dedicated seismic network called the West Bohemia Network (WEBNET; Fischer et al., 2010). A continuous catalog of earthquake recordings exists since the early 1990s. The station locations and detailed waveform analysis has resulted in several studies of past swarms. In particular, the 1992, 1997 and 2008 swarms have been extensively studied in terms of earthquake source locations, active fault planes, focal mechanisms, principle stresses and earthquake migration patterns (e.g. Bouchaala et al., 2013; Fischer et al., 2010; Vavryčuk, 2011). These studies have revealed that the swarms occur in the same location, however the active fault plane and dominant focal mechanism is not always the same. This indicates that the stress conditions in the earthquake zone change between the swarms. In addition, isotope analysis (mainly He^3/He^4) from the local springs and gas exhalation sites indicates the fluids are magmatic in nature. This has led to the hypothesis that fluids may have a major roll in the swarm activity (Bräuer et al., 2005; Hainzl et al., 2012; Weise et al., 2001).

Several studies have produced models of the subsurface structure using a variety of geophysical methods including gravity, seismology and seismics (Hrubcová et al., 2005; Karousová et al., 2012; Švancara et al., 2008). These studies aimed at investigating the deep crust and therefore did not resolve the focal zone. In the mid-1990s the reflection seismic profile 9HR/91 was acquired several kilometres to the east of Nový Kostel (Tomek et al., 1997). This profile was recently reprocessed using a more modern migration approach. Now, areas of high reflectivity, or ‘bright spots’ are clearly visible

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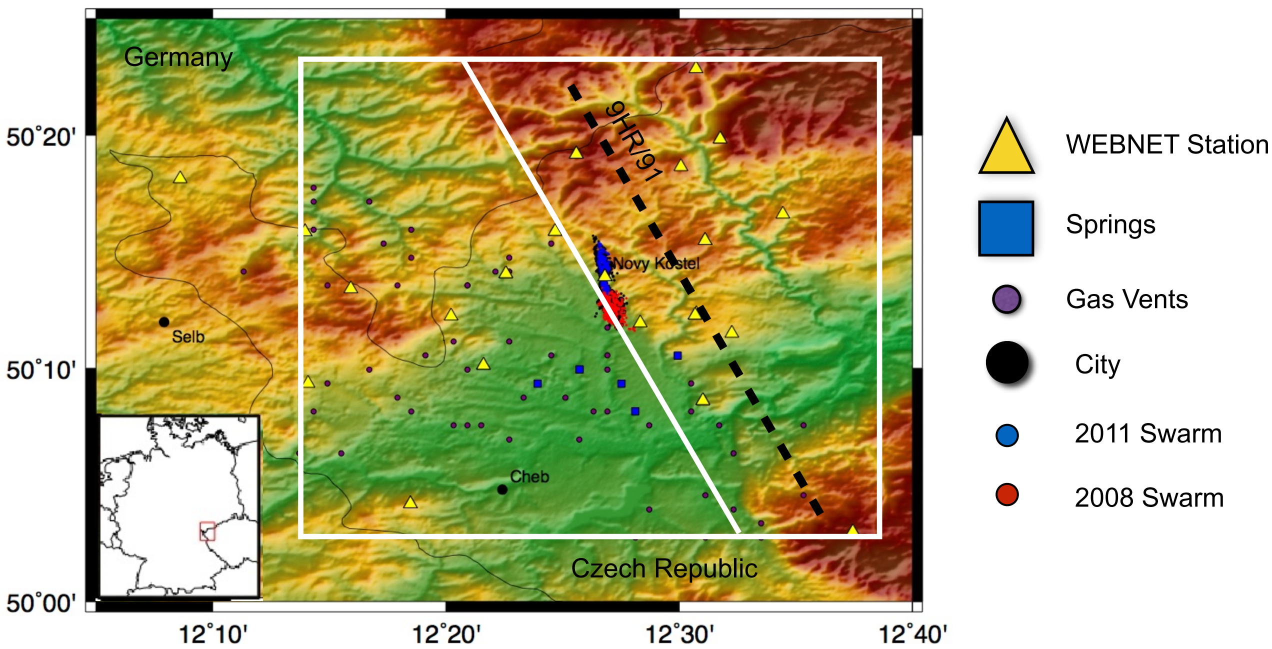

Figure 1. Map of the Nový Kostel Seismic Zone showing the recent seismicity, gas vents, mineral springs, seismic stations and profiles shown in Figure 2

in the shallow crust (< 10 km depth). These bright spots are spatially correlated with the areas of high seismicity, such as the Nový Kostel seismic zone (Mullick et al., 2013).

The 9HR/91 profile (Tomek et al., 1997) is approximately 200 km long, starting at the Czech-German border in the north-west and running to southern Bohemia in the south-east. It passes by the Nový Kostel swarm zone at a distance of about 4 km. The reflection seismic profile was reprocessed using Kirchhoff pre stack depth migration (Buske, 1999). Figure 2a shows the resulting migrated seismic section near Nový Kostel. Two distinct and slightly dipping reflectors (bright spots A and B) are visible at a depth of about 7 km. However, the main faults are not identifiable due to the survey location and design.

Recently, several independently conducted velocity tomography studies attempted to image the shallower structures (e.g. Alexandrakis et al., 2014; Růžek and Horálek, 2013). As a proof of concept, Alexandrakis et al. (2014) used double-difference tomography (Zhang and Thurber, 2003) in combination with Weighted Average Model post-processing to calculate the velocity structure within and around the focal zone using a subset of the 2008 Nový Kostel swarm data. The resulting model

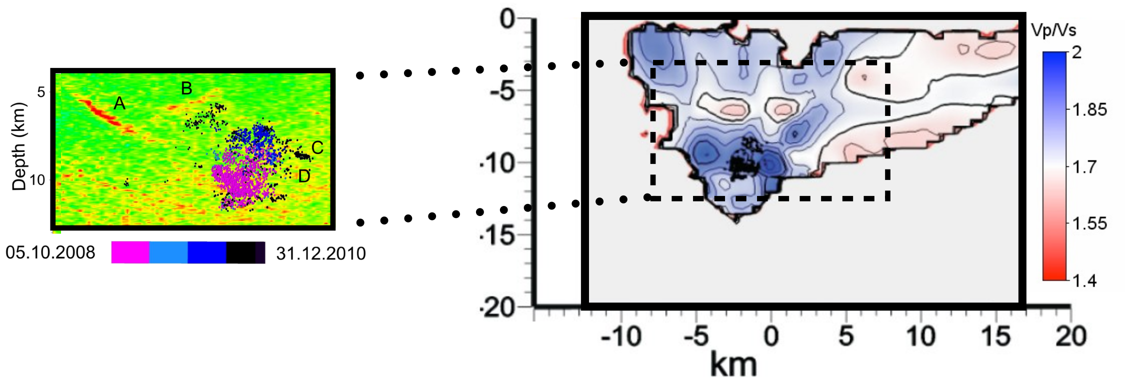

Figure 2. Comparison of Vp/Vs ratio model with a section of the reprocessed 9HR/91 profile. Note the seismicity occurs below the bright spots and the layer of low Vp/Vs ratio

showed that the compressional-to-shear wave velocity ratio (Vp/Vs) is high in the focal zone. Directly overlaying the focal zone is a layer of low Vp/Vs values.

The transition between low- and high-Vp/Vs ratio correlates with the shallowest swarm seismicity and with areas of high reflectivity in the 9HR/91 profile. The results of these two studies, along with tomography models calculated from the larger swarm catalog, are jointly interpreted in terms of the local geology, fluid saturation, rock properties and the overall seismic swarm cycle.

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