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Intraplate seismicity in the western Bohemian Massif (central Europe): A possible correlation with a paleoplate junction

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Abstract

Locations of the Eger Rift, Cheb Basin, Quaternary volcanoes, crustal earthquake swarms and exhalation centers of CO_2 and ^3He of mantle origin correlate with the tectonic fabric of the mantle lithosphere modelled from seismic anisotropy. We suggest that positions of the seismic and volcanic phenomena, as well as of the Cenozoic sedimentary basins, correlate with a "triple junction" of three mantle lithospheres distinguished by different orientations of their tectonic fabric consistent within each unit. The three mantle domains most probably belong to the originally separated microcontinents – the Saxothuringian, Teplá-Barrandian and Moldanubian – assembled during the Variscan orogeny. Cenozoic extension reactivated the junction and locally thinned the crust and mantle lithosphere. The rigid part of the crust, characterized by the presence of earthquake foci, decoupled near the junction from the mantle probably during the Variscan. The boundaries (transitions) of three mantle domains provided open pathways for Quaternary volcanism and the ascent of ^3He- and CO_2-rich fluids released from the asthenosphere. The deepest earthquakes, interpreted as an upper limit of the brittle–ductile transition in the crust, are shallower above the junction of the mantle blocks (at about 12 km) than above the more stable Saxothuringian mantle lithosphere (at about 20 km), probably due to a higher heat flow and presence of fluids.

Keywords: Bohemian Massif; Junction of paleoplates; Intraplate earthquake swarms; Brittle–ductile transition

1. Introduction

The Bohemian Massif (BM), the largest coherent surface exposure of basement rocks in central Europe, is a part of the Variscan orogenic belt representing a collage of magmatic arcs and microcontinents caused by the collision of Laurussia (Laurentia-Baltica) and Africa (Gondwana). The western BM represents a junction of three first-order tectonometamorphic units (Franke, 2000): Saxothuringian (ST), Teplá-Barrandian (TBU) and Moldanubian (MD, Fig. 1a and b). The Tertiary Eger (Ohře) Rift (ER), a 300 km long ENE–WSW striking structure characterized by high heat flow and Cenozoic volcanism is part of the European Cenozoic Rift System (ECRIS; Prodehl et al., 1995) and its formation is thought to be related to Alpine collision (Ziegler, 1992; see also review of the ER development in Geissler et al., 2005). Active tectonics is primarily manifested by frequent weak to moderate earthquake swarms (Horálek et al., 2000), emanations of CO_2 dominated gases of mantle origin (Weinlich et al., 1999; Bräuer et al., 2003), and by neotectonic crustal movements (Bankwitz et al., 2003). The post-rift uplift of the Krušné hory Mts. (Erzgebirge),

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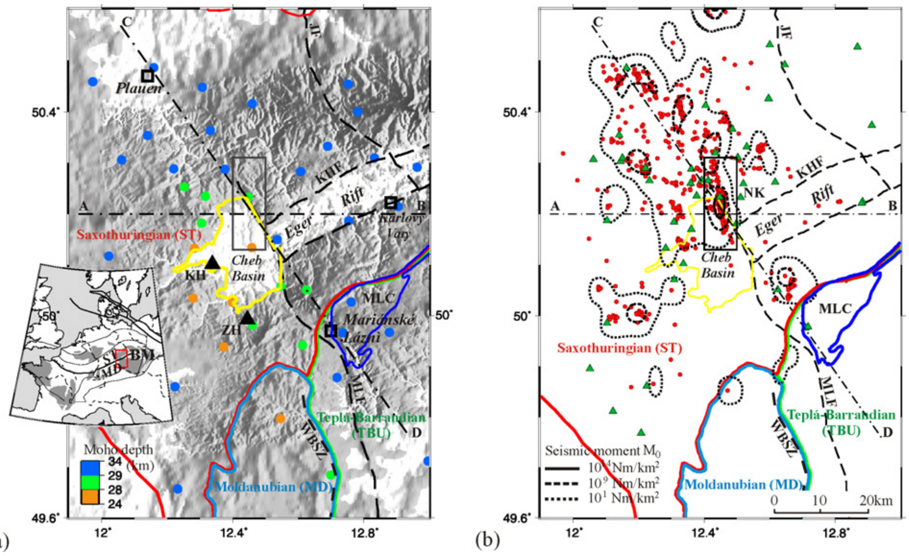

Fig. 1. (a) Topographic map of the western Bohemian Massif (BM) and its position within the European Variscides (inset). Simplified boundaries of the crystalline basement of tectonic units (ST, MD, TBU) are according to Kachlík (1997), Zulauf et al. (2002) and Mlčoch (2003). MLC—Mariánské Lázně Complex (contoured dark blue), MLF—Mariánské Lázně Fault, WBSZ—West Bohemian Shear Zone, KHF—Krušné Hory (Erzgebirge) Fault, JF—Jáchymov Fault. Triangles labeled KH and ZH represent the Komorní and Železná Hůrka Quaternary volcanoes. Circles denote crustal thickness from receiver function method according to Heuer et al. (2006). Dot-and-dash lines AB, CD locate cross-sections of Fig. 3. (b) Epicenters of 6262 events with $M_L > 0$ (red dots) that occurred from 1991 to 2004 and isolines of density of released seismic moment M_0. The rectangle shows the most seismoactive area of Nový Kostel (NK). Green triangles—stations used for event relocations.

involving the NW margin of the ER (Rajchl et al., 2003), represents one of the largest neotectonic uplifts in the Alpine foreland. The ER axis parallels a major mantle boundary separating the ST mantle lithosphere in the north from the TBU mantle lithosphere in the south (Babuška and Plomerová, 2000; Plomerová et al., 2005).

An explanation to the concentration of the geodynamic phenomena in this small region is still undefined. Most authors relate this seismic activity to the upper-crustal structures, to intersecting crustal faults (e.g., Bankwitz et al., 2003) and the regional stress field. However, recent investigations of fluids of mantle origin (e.g., Bräuer et al., 2005; Geissler et al., 2005) showed a possible link between the upper mantle and the earthquake swarm activity. Tertiary to Quaternary volcanism and the present-day escape of fluids of mantle origin around the major upper crustal fault zones may suggest that these faults can be linked with the upper mantle.

Our motivation was to study the links between the spatial distribution of the earthquake foci, as well as other geodynamic phenomena in the western BM, such as the Quaternary volcanoes and the gas escape centers, and the structure of the mantle lithosphere. Therefore, we have firstly relocated the earthquakes that occurred in the region during 1991–2004. Based on teleseismic tomography and seismic anisotropy, we have studied in detail the lithosphere–asthenosphere system beneath the western BM especially boundaries of the three mantle units, already located in a companion paper by Plomerová et al. (2007). The aim of this paper is to discuss the causes of the earthquake swarms in the western BM (e.g., Neunhöfer and Hemmann, 2005). We show that the Variscan collision of three microcontinents created a predisposition to the present-day intraplate geodynamic activity. Complex boundaries (transitions) of the originally separated lithospheric domains were reactivated in consequence of the Alpine collision and probably predetermined a later lithosphere/crust thinning, formation of the Cheb Basin (Fig. 1) and the seismic activity. The deep-seated boundaries also became preferential paths of magmas feeding the Cenozoic volcanism and open channels to the present-day escape of mantle gases and fluids.

2. Seismic activity and lithosphere structure

2.1. Distribution of earthquakes

Horálek et al. (2000) presented the first comprehensive earthquake distribution from local seismic network data for the period 1991–1999. More recent studies focused on seismicity in the most active Nový Kostel area (NK,