Variscan odyssey of the Bohemian Massif and the related plutonic activity

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Abstract: The voluminous Variscan granitic plutonism in the heart of the Bohemian Massif (Teplá–Barrandian and Moldanubian domains) episodically accompanied the complete orogenic cycle from the Late Devonian Andean-type subduction, through Early Carboniferous collision, deep subduction and relamination of the Saxothuringian continental crust and massive late syn-/post-collisional anatexis of the Moldanubian crust to the Late Carboniferous orogenic collapse. The granites were generated both from crustal sources, dominated by fertile metasediments with much Neoproterozoic arc-derived and Eburnean-age detritus, and mantle, variably contaminated by oceanic subduction-related fluids and deeply subducted felsic crustal material. The latter process finally resulted in the unusual and eye-catching spatial–temporal association of ultrapotassic intrusions and high-pressure, felsic Grt–Ky granulites.

Variscan Bohemian Massif — a deeply dissected 'hot' orogen

The Variscan Bohemian Massif, an archetypal example of a large hot orogen in Central Europe, was intruded by voluminous and compositionally diverse, mostly broadly granitic plutons. They yield unique insight into the composition of the orogenic lower/middle crust and its development in both space and time (Žák et al. 2014 for review).

From the NW to the SE, the Variscan tectonic sequence in the core of the Bohemian Massif is as follows (Franke 2000; Schulmann et al. 2009): Saxothuringian Neoproterozoic basement with Palaeozoic metasedimentary/metaigneous cover, the Teplá suture and the supra-crustal Teplá–Barrandian Unit (TBU). Crossing the Central Bohemian Plutonic Complex (CBPC), the Moldanubian Zone represents the orogen's 'root' locally containing, besides mid-crustal units, abundant lower crustal or upper mantle bodies. It suffered a strong anatexis, producing the enormous Moldanubian Plutonic Complex (MPC). To the E the Moldanubian Zone is bounded by Brunia microplate, little affected by the Variscan tectonometamorphism.

Many authors (but for alternative views see e.g., Franke 2000, Finger et al. 2007 or Kroner & Romer 2013) assumed that the Variscan Orogeny in the Bohemian Massif was driven by oceanic subduction passing into deep underthrusting of the attenuated Saxothuringian continental crust (O'Brien 2000; Janoušek et al. 2004b; Schulmann et al. 2009, 2014). This is in line with the occurrence of Variscan blueschists (Faryad & Kachlík 2013), diamond- and/or coesite-bearing gneisses, high-pressure (HP) granulites, eclogites, garnet pyroxenites and mantle peridotites in the Saxothuringian Zone (e.g., Massonne 2001; O'Brien & Rötzler 2003; Schmädicke et al. 2010; Kotková et al. 2011).

These observations, together with geochemical affinity and matching protolith ages between Saxothuringian orthogneisses and felsic Moldanubian granulites (Janoušek et al. 2004b; Janoušek & Holub 2007) with HP–HT metamorphic imprint: (>2 GPa and >1000 °C: O'Brien & Rötzler 2003; Kotková & Harley 2010; Vrána et al. 2013; Perraki & Faryad 2014) led to the model of relamination of felsic Saxothuringian crust under the Moldanubian back-arc (Schulmann et al. 2014; Maierová et al. 2014; Kusbach et al. 2015). If true, this model would have grave consequences for mechanism and magmatic evolution of the whole orogen, as examined below.

Variscan plutonic activity

This contribution does not aim to paint a complete picture of evolving Variscan magmatism over the entire Bohemian Massif. Instead it focusses on the key region of the TBU, Moldanubian Zone and the CBPC in between — interpreted as the forearc, backarc (future orogenic root) and magmatic arc, respectively (Schulmann et al. 2009). In the following text, when useful, petrology and geochemistry of granitoids is characterized in terms of the I/S-type classification (Chappell & White 1974) or the synthetic Barbarin (1999) scheme.

I — Normal-K calc–alkaline suite (I, ACG)

Initial stage of arc-related magmatism in the TBU marked minor **Čistá** and **Štěnovice plutons** (~375 Ma: Venera et al. 2000; Žák et al. 2011a). Chemically similar was contemporaneous protolith to the tonalite–granodiorite **Staré Sedlo** and **Mirotice orthogneisses** in the roof of the CBPC (Košler et al. 1993). In the CBPC itself, the unmetamorphosed Amp-bearing gabbros and quartz diorites–trondhjemites of the c. 355 Ma **Sázava suite** (Janoušek et al. 2004a) were emplaced during regional transpression (Žák et al. 2005). Characteristic is a metaluminous chemistry, CHUR-like Sr–Nd isotopic composition, subduction-related LILE/HFSE enrichment and ample evidence for magma hybridization (Janoušek et al. 1995, 2004a).

II — High-K calc–alkaline suite (I/S, KCG)

The mainly (Amp) Bt granodioritic c. 345 Ma **Blatná suite** (Dörr & Zulauf 2010; Janoušek et al. 2010) recorded a transpression along the NW contact of the CBPC, while the southern margin was pervasively overprinted by deformation marking the onset of the Moldanubian exhumation (Žák et al. 2012). The felsic magmas originated by melting of greywackes rich in Neoproterozoic to Early Palaeozoic volcanogenic detritus (Janoušek et al. 2010). The granitoids enclose numerous mafic enclaves or qtz monzonitic bodies with evidence for interaction with moderately enriched mantle melts (ε^{Nd}_{i}~−3) (Janoušek et al. 2000).

III — (Ultra-) potassic suite (ultra-K)

Characteristic Moldanubian feature are ~343–335 Ma syn- or post-tectonic ultra-K intrusions and dyke swarms (Holub 1997; Kotková et al. 2010; Kubínová et al. 2017). Strongly Kfs-phyric **durbachite suite** of Amph–Bt quartz syenitic–melagranitic plutons (e.g., Milevsko, Třebíč) is rich in mafic enclaves. Equigranular **Bt–two-Px syenitoids** of the late (337–335 Ma) Tábor and Jihlava plutons are less voluminous (Janoušek et al. 2019).

Both suites are characterized by high Cr, Ni and Mg# as well as low HFSE and high Pb, LREE, LILE, U and Th (Holub 1997; Becker et al. 1999; Janoušek & Holub 2007). The crust-like isotopic compositions ($^{87}Sr/^{86}Sr_{i}$ ~0.713, ε^{Nd}_{i}~−8) of the basic members cannot reflect shallow-level assimilation of the local crust (Janoušek et al. 1995). Instead, the spatial/temporal association with felsic HP granulites and complementary geochemical signatures suggest that primary ultra-K magmas came from mantle contaminated by felsic crust during the ~340 Ma HP metamorphism (Janoušek & Holub 2007; Schulmann et al. 2014). The compositional range reflects ensuing mixing with leucogranitic melts (Holub 1997; Wenzel et al. 1997; Gerdes et al. 2000). The cessation of ductile deformation along the TBU/Moldanubian boundary is bracketed by c. 338–337 Ma Tábor syenite and reversely-zoned Říčany granite (Trubač et al. 2017).

IV — Porphyritic biotite granite suite (I/S)

In southern part of MPC dominate ~331–323 Ma strongly Kfs-megacrystic **Weinsberg-type** biotite granites probably generated by partial melting of heterogeneous lower crust (Liew et al. 1989; Friedl et al. 1993; Gerdes 2001; Gerdes et al. 2003).

V — Peraluminous two-mica granites (S, MPG/CPG)

Two-mica granites, some with Crd or magmatic And, are the main component of the MPC. The main types include Eisgarn, Číměř, Lipnice, Kouty–Světlá or Deštná (see Matějka & Janoušek 1998; Breiter 2010 for details). U–Pb ages on monazite cluster at c. 328–326 Ma (Friedl et al. 1996; Gerdes et al. 2003; Žák et al. 2011b; Janoušek et al. 2015). All are peraluminous, having originated by the biotite (±muscovite) dehydration melting of metasediments (René et al. 2008). The eastern branch of the MPC occurs in the middle of a large elongated migmatitic complex that probably formed during diapir-like upwelling in the front of the underthrusting Brunia indentor (Verner et al. 2014).

VI — Post-tectonic tonalite–granite plutons (I)

The late medium-grained (Amp–) Bt tonalites to granites (e.g., ~316–315 Ma Altenberg and Mauthausen, ~310–300 Ma Freistadt — Gerdes et al. 2003) intruded mostly the older granitoids of the Weinsberg suite in the southern MPC. These are metaluminous, high-K calc–alkaline rocks with CHUR-like Sr–Nd isotopic signatures that were interpreted in terms of partial melting of metatonalitic lower crust (Gerdes 1997).

Concluding remarks

The so-far available Nd model ages and (scarce) U–Pb ages of inherited zircons indicate that the bulk of the Variscan granitoids in the Moldanubian Zone and at its contact with TBU were generated from fertile Cadomian to Early Palaeozoic metasediments dominated by the Neoproterozoic arc and Eburnean (~2.1 Ga) basement-derived detritus. Variably important was a contribution from mantle, at the arc stage characterized by an evolution from CHUR-like to strongly enriched (yielding ultrapotassic magmas). This reflected probably the progressive contamination of the orogenic mantle by deeply subducted felsic crust of presumed Saxothuringian provenance.

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