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Bohemian Microdiamonds: Diamond-forming Media and Carbon Source

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The Variscan Bohemian Massif in Central Europe, resulting from continent-continent collision, was long considered a potential UHP terrain due to numerous occurrences of high-pressure granulites, eclogites and ultramafic rocks. This was confirmed by recent discovery of diamond, and coesite, in rocks with high-pressure granulite-facies assemblages in the North Bohemian Massif (Eger Crystalline Complex and České středohoří Mts. basement; Kotková et al., 2011). Similar to the diamondiferous garnet-phengite gneiss from the Saidenbach reservoir in Central Erzgebirge (Massonne, 2001), which represents unusual, exotic rock type in contrast to the common high-pressure granulites, the two areas belong to the Saxothuringian Zone of the European Variscan belt (Fig. 1).

In the North Bohemia, perfectly preserved diamonds reaching 5 - 30 μm in size are enclosed in major phases (garnet, kyanite) and in zircon in both acid, quartzofeldspathic (garnet-kyanite-feldspar-quartz) and intermediate garnet-clinopyroxene (garnet-clinopyroxene-feldspar-quartz) rocks (see Fig. 2). The diamond-bearing UHP rocks form discrete layers within diamond-free rocks equilibrated under high-pressure granulite-facies conditions, which suggests internal carbon source.

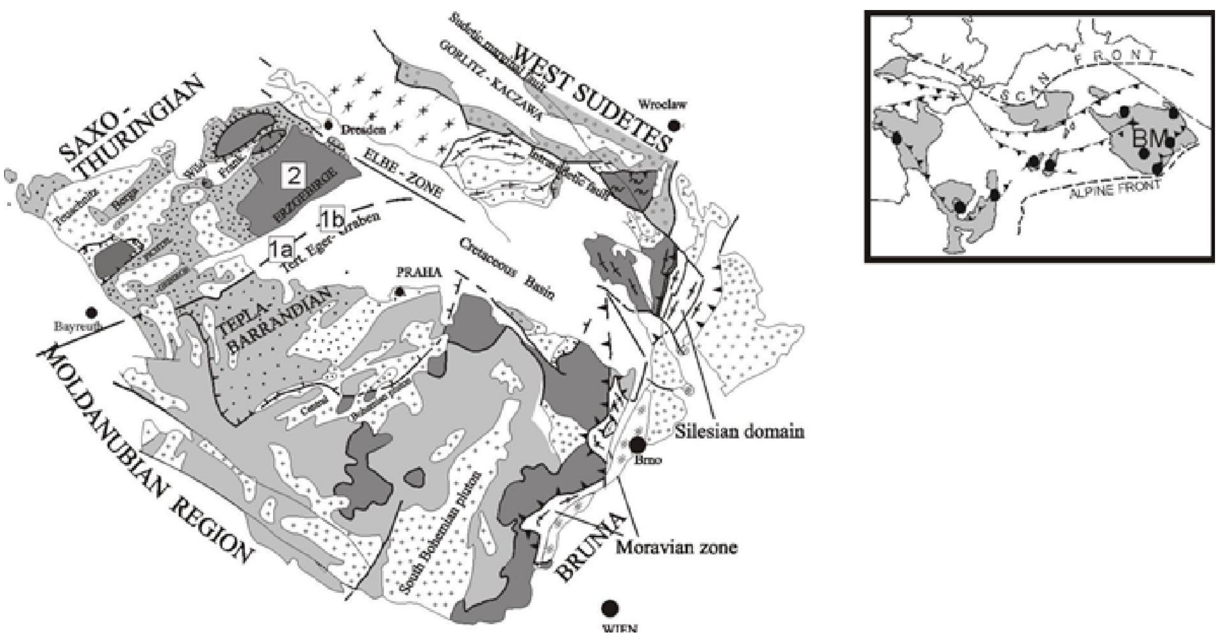

Fig.1 Geological sketch map of the Bohemian Massif (BM) with location of the diamond-bearing UHP rocks: 1a – Eger Crystalline Complex, 1b – České středohoří Mts. basement, 2 – Saidenbachtal in Erzgebirge. Adapted from Kotková et al. (2011).

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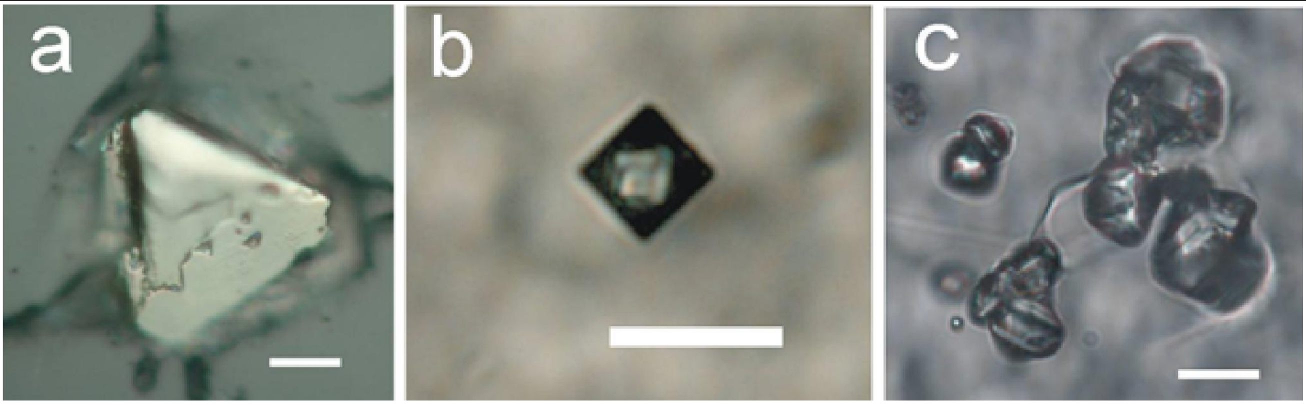

Fig.2 (a) and (b) shows single octahedral diamonds enclosed in kyanite in acid UHP gneisses, (c) depicts a cluster of cuboids enclosed in garnet in UHP garnet-clinopyroxene rock from North Bohemia. Scale corresponds to 10 μm. Adapted from Kotková et al. (2011).

Information on diamond-forming media and conditions can be thus obtained both from diamonds themselves and from their host rocks.

Character of diamond-forming media can be determined from diamond morphology, composition of inclusions in diamonds, and chemical composition of phases associated with diamond within the host. Due to small diamond size, micro- and nano-techniques such as SEM (morphology), AFM (character of crystal faces), FIB-TEM (diamond-host interface, diamond internal structure, presence and composition of inclusions, associated phases) and micro-Raman (associated phases) have been used. Diamond morphology in the two different rock compositions is contrasting. The acid garnet-kyanite UHP gneiss contains exclusively octahedral microdiamonds with well-developed smooth faces enclosed in kyanite and garnet (Fig. 2a, b). On the other hand, clusters of diamond cuboids with rough surfaces occur within garnet and zircon of the intermediate garnet-clinopyroxene UHP rock (Fig. 2c). In addition, octahedral diamonds are single crystals with regular interface towards the host phase, whereas cuboids are polycrystalline and the diamond-host interface is irregular (FIB-TEM). Striking feature of all microdiamonds analyzed is absence of any inclusions in their interior. The diamonds also lack any deformation-related dislocations: only dislocations related to Dia growth such as low-angle grain boundaries and long curved dislocations radiating from the diamond core were observed. In gemological terms, the north Bohemian diamonds are therefore internally flawless, which – along with their colourless nature – would make them a highly valued and priced diamonds if not for the low carat weight. Diamonds enclosed in anisotropic kyanite are an exception, as they contain numerous straight dislocation lines which reflect Ky deformation via a dislocation glide mechanism upon cooling. Importantly, this feature suggests short residence at high temperatures.

Diamond resorption resulted in a zig-zag character of the interface between cuboid diamond and its host, and single symmetric pointed-bottom negatively oriented trigonal etch pits on the crystal faces of diamond octahedra (FIB-TEM, AFM). Such a resorption requires high temperatures, and the dissolving agent has to represent the residual fluid after diamond crystallization also because it is enclosed in a host phase. Trigons of similar shape and distribution form during HP-HT experiments using fluid/melt with $H_2O/CO_2 \geq 50:50$ mol. %. An amorphous quenched fluid/melt phase occurs in rare cavities located close to the diamond surface, at the diamond-host interface and in interstitial spaces of polycrystalline diamond. This fluid/melt phase has similar composition in both rock types, containing Ca, K, Al, Fe, Mg, Cl and S. Last but not least, close association of microdiamond with quartz, rutile, apatite and carbonate has been documented by micro-Raman and FIB-TEM. The data suggest that both diamond types formed from high-density hydrous fluid/melt containing carbonatitic, silicic, saline, sulphate and phosphate components, without any obvious mantle component. They also show, that diamond morphology is controlled rather by driving force i.e. degree of supersaturation of the fluid/melt than present impurities.

Carbon source is constrained by carbon isotope composition of diamond. SIMS-determined δ13C values of -22‰ to - 33‰ correspond to those typical of organic carbon, thus providing an independent proof of crustal source of diamond-forming fluids.

Internal structure and trace element chemistry of zircon which encloses microdiamond (Fig. 3a, b) provides evidence for melting at UHP-UHT conditions, producing low-volume water-undersaturated partial melt. The diamond-bearing zircon domain shows relic oscillatory zoning, preserves steep HREE patterns, and contains up to 190 ppm Ti. This allows constraining peak UHP-UHT conditions of c. 1100°C and 4.5 GPa, and – along with thermodynamic modelling - suggests that the host zircon

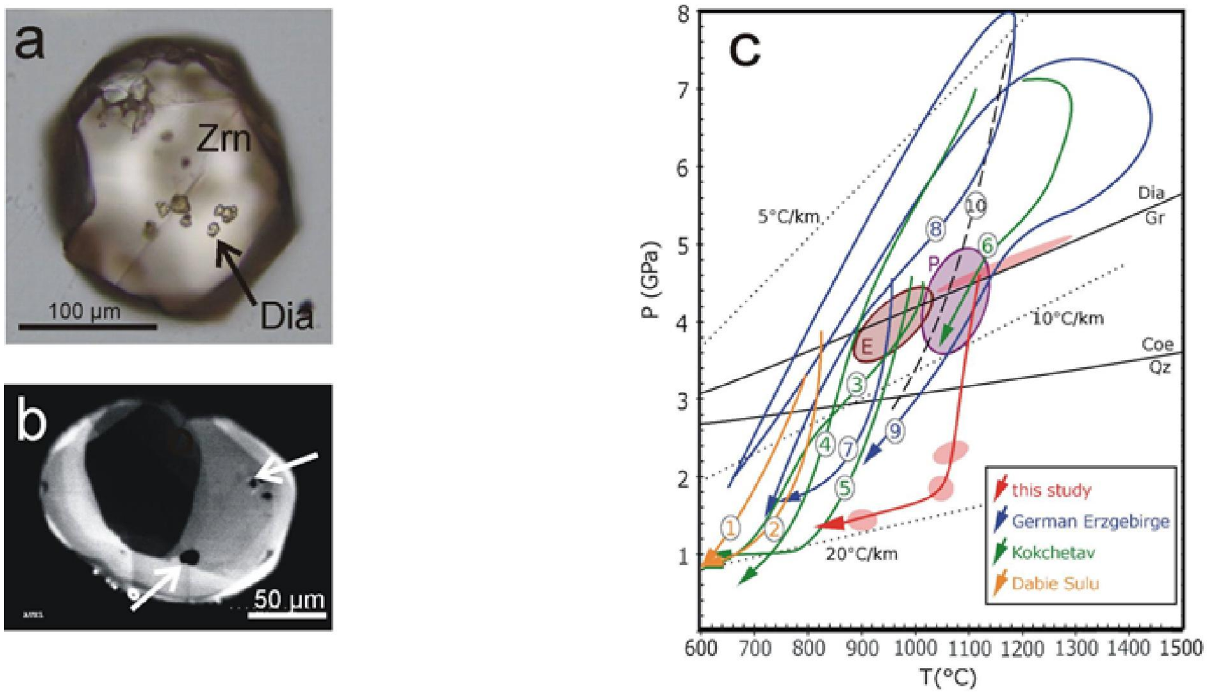

Fig.3 (a) P-T paths of the UHP rocks from North Bohemia ("this study", in red; P and E mark the peak P-T conditions determined for the associated peridotites and eclogites) and from Dabie–Sulu (paths 1–2), Kokchetav Massif (3–6) and German Erzgebirge (7–9). From Haifler & Kotková (2016). (b) diamonds enclosed in zircon and (c) CL image showing the dark core, diamond-bearing mantle and CL-bright rim of zircon from the North Bohemian UHP garnet-clinopyroxene rock. Diamond indicated by arrows (from Kotková et al., submitted).

crystallized at UHP-UHT conditions from the melt, i.e. supercritical fluid/melt due to high water solubility in the silicic melt under such extreme conditions (Haifler and Kotková, 2016; Kotková et al., submitted).

The peak P-T conditions determined for the North Bohemian UHP rocks are similar to those calculated for the associated garnet peridotites and kyanite eclogites, corresponding to 1030-1150°C and 3.6-4.8 GPa and 900-1050°C and 3.5-4.5 GPa, respectively (Medaris et al., 2015; Kotková and Janák, 2015). This clearly shows that the mantle rocks have been juxtaposed with the UHP crustal ones at mantle depth, as proposed by Kotková et al. (2011). Importantly, the high-pressure granulite – peridotite association, with granulites petrographically and geochemically similar to the North Bohemian rocks, are distributed throughout the European Variscan belt: it may thus represent a very large UHP terrain.

The diamond-bearing garnet-clinopyroxene rocks from North Bohemia were exhumed extremely rapidly, as shown by the near-to-adiabatic exhumation path (Fig. 3c) and overlapping U-Pb SIMS data for the diamond-bearing zircon interior and lower-pressure zircon rim, respectively (Haifler and Kotková, 2016; Kotková et al., submitted). This rapid exhumation could have contributed to diamond preservation in the rocks.

References

Haifler J. & Kotková J. (2016): UHP-UHT peak conditions and near-adiabatic exhumation path of diamond-bearing garnet-clinopyroxene rocks from the Eger Crystalline Complex, North Bohemian Massif. Lithos, 248-251, 366-381.

Kotková J. & Janák M. (2015): UHP kyanite eclogite associated with garnet peridotite and diamond-bearing granulite, northern Bohemian Massif. Lithos, 226, 255-264.

Kotková J., O´Brien P.J. & Ziemann M. (2011): Diamond and coesite discovered in Saxony-type granulite: Solution to the Variscan garnet peridotite enigma. Geology, 39, 667-670.

Kotková J., Whitehouse M., Schaltegger U. & D'Abzac F.-X. (submitted – pending revision): The fate of zircon during UHT-UHP metamorphism: isotopic (U/Pb, δ18O, Hf) and trace element constraints. J. Metamorph. Geol.

Massonne H.-J. (2001): Origin of microdiamond-bearing quartzofeldspathic rocks (saidenbachites) from the Erzgebirge, Germany: A progress report. In UHPM workshop 2001, Fluid/slab/mantle interactions and ultrahigh-P minerals, Tokyo, Abstr.Vol., 11-15.

Medaris G., Ackerman L., Jelínek E., Michels Z., Erban V. & Kotková J. (2015): Depletion, cryptic metasomatism, and modal mesatomatism (refertilization) of Variscan lithospheric mantle: Evidence from major elements, trace elements, and Sr-Nd-Os isotopes in a Saxothuringian garnet peridotite. Lithos, 226, 81-97.