FROM A GARNET INCLUSION TO THE VARISCAN EVOLUTION: IMPLICATIONS FOR THE POLYMETAMORPHIC HISTORY OF THE BOHEMIAN MASSIF

Sorger, D.[1,2], Hauzenberger, C.A.[1], Finger, F.[3], Linner, M.[4], Fritz, H.[5], Sizova, E.[1], Skrzypek, E.[1], Iglseder, C.[4], Schorn, S.[1]

[1]NAWI Graz Geocenter, University of Graz, Universitätsplatz 2, 8010 Graz, Austria
[2]Present address: Geoscience Center, Georg-August-University Göttingen, Goldschmidtstraße 1, 37077 Göttingen, Germany
[3]Department of Geography and Geology, University of Salzburg, Hellbrunnerstraße 34, 5020 Salzburg, Austria
[4]Department of Hard Rock Geology, Geological Survey of Austria, Neulinggasse 38, 1030 Vienna, Austria
[5]NAWI Graz Geocenter, University of Graz, Heinrichstraße 26, 8010 Graz, Austria
e-mail: dominik.sorger@uni-goettingen.de

The Central European Variscan orogen consists of a mosaic of various peri-Gondwana terranes, which separated from Gondwana at various times during the Cambrian to Devonian. Later, during the Devonian-Carboniferous they were between the converging continents of Gondwana and Laurussia as the Rheic ocean closed. While the major part of the Bohemian Massif belongs to the so-called Armorican terrane, some eastern parts are assigned to the Avalonian terrane, which amalgamated with the southern margin of Laurussia in the Silurian. The major phase of the regional metamorphism affected the rocks of the Bohemian Massif in the Visean at ~340 Ma and is thought to correspond to the final collision of Avalonia/Laurussia and Armorica/Gondwana (FINGER & STEYRER, 1995; KRONER & ROMER, 2013). Evidence of this predominant metamorphism is typically observed in the Bohemian Massif, while some rocks have remnants of an older metamorphism and/or were affected by a younger metamorphic overprint. The investigated part of the Bohemian Massif can be assigned to the high-grade Moldanubian zone, which is traditionally assigned to the Armorican terrane and is subdivided into several tectonostratigraphic subunits that were juxtaposed into their present relative positions during the Variscan orogeny. The high-grade Gföhl unit overlies both, the Drosendorf and Ostrong units. Although the Drosendorf unit was traditionally assigned to be part of the Armorican terrane, a detrital zircon study revealed zircon ages at ~1.2 Ga, ~1.5 Ga and ~1.8 Ga, which confirms an Avalonian affinity of the Drosendorf unit (SORGER et al., 2020). The youngest detrital zircon generation suggests a Neoproterozoic deposition age of the precursor siliciclastic sediment. These findings are in good agreement with recent zircon studies of orthogneisses from the Drosendorf unit (LINDNER et al., 2020). The area in the south-western part of the Moldanubian zone, which is characterized by a low-pressure–high-temperature (LP–HT) metamorphism associated with granitic plutonism, is referred to as the Bavarian unit. Polyphase garnet growth, remnant mineral inclusions and textural relations in samples from three prominent localities located in the Austrian part of the Bohemian Massif allowed us to decipher three different Variscan metamorphic events: an early Variscan event in the Devonian (event1, ~370 Ma), the predominant metamorphism in the Visean (event2, ~340 Ma), both with collisional P–T characteristics and a Pennsylvanian LP–HT overprint (event3, ~315 Ma).
The Devonian event1 can be observed in metapelitic paragneiss from the southern Drosendorf unit, which exhibit two chemically and texturally different garnet generations that provide

evidence of a polymetamorphic evolution. Both garnet generations carry abundant inclusions, the most important are monazite, rutile, kyanite, staurolite (limited to the second garnet generation) and crystallized melt droplets. The latter is indicating a peritectic growth of the host garnet in the presence of a melt phase. Thermodynamic modelling combined with various geothermo- and barometers allow the reconstruction of the complex evolution of two garnet-forming metamorphic events (SORGER et al., 2020). The metamorphic conditions for the first stage of garnet growth are estimated with 0.7–0.8 GPa at 680–700 °C and 0.95–1.10 GPa at 745–785 °C (Fig. 1). A Late Devonian age (373 ± 9 Ma) for this first metamorphic event (event1) was obtained from chemical dating of monazite inclusions in grt1. Generally, monazite has Y- and U-rich core domains that were overgrown by Th enriched domains. The latter may contain inclusions of crystallized melt droplets indicating a peritectic growth of monazite contemporaneous with garnet. Additionally, a significantly older monazite generation (654 ± 17 Ma) enriched in U and Y appears as inclusions in grt1 and can be interpreted as inherited grains of a Cadomian metamorphic event.

Subsequent exhumation after event1 placed these rocks in a shallower position. A second garnet (grt2) started growing in the amphibolite facies reaching peak conditions in the granulite facies with 0.95–1.10 GPa at 745–785 °C (Fig. 1), which are similar to those of the first garnet forming event. Subsequently, the rocks experienced a near isothermal decompression to 0.5–0.8 GPa accompanied by sillimanite and ilmenite growth in the matrix. A Visean age (343 ± 3 Ma) of monazite inclusions in grt2 and matrix grains correlates the second garnet forming event with the predominant metamorphism in the Bohemian Massif (event2). Similar ages are known for the metamorphic peak conditions of the rocks from the adjacent Gföhl unit, which includes high-pressure–ultra-high-temperature (HP–UHT) felsic granulite, orthogneiss and paragneiss.

Aluminous paragneiss from the Loosdorf complex (south-eastern Gföhl unit), which constitutes the hangingwall part of the large granulite bodies, provide some new insights on the exhumation history of these high-grade rocks at the end of the Visean metamorphic event (event2). The paragneiss commonly show reaction coronas of complementary cordierite moats and cordierite + spinel symplectites located at former garnet-sillimanite interfaces. Garnets and embedded rutile ± kyanite are relics of the previous peak assemblage and record the metamorphic conditions of 0.8–1.1 GPa and 770–820 °C. The reaction textures formed in the course of a nearly isothermal decompression (ITD) path at LP–HT of ~0.5 GPa and ~750 °C. The inferred P–T evolution suggests prograde metamorphism reaching granulite facies metamorphism at lower crustal depth of ~35 km subsequently followed by the ITD to the upper/middle crustal level (~15 km depth). The P–T evolution emphasizes rapid exhumation of the Loosdorf complex at the hangingwall position of the felsic granulite, which was most likely triggered by the exhumation of the HP–UHT granulite itself. Monazite inclusions in garnet and matrix grains yielded a slightly younger age of ~335 Ma. Although ages are overlapping within errors they may indicate the age of the retrograde LP–HT overprint during the exhumation subsequently after the metamorphic peak of event2 at ~340 Ma.

The Bavarian unit in the south-western part of the Bohemian Massif is characterized by strong, late-Variscan, LP–HT metamorphism. Rare migmatite varieties hosting garnets record detailed information regarding the regional P–T–t evolution. The garnet porphyroblasts preserve complex three-phase growth zoning and variable mineral inclusions indicative of a polymetamorphic history (Sorger et al., 2018). Garnet cores (grt1) and related inclusions yielded a medium-pressure–medium-temperature (MP–MT) metamorphic peak of 0.85–1.10 GPa at 720–780 °C (Fig. 1). Monazite inclusions in grt1 reveals an age of 340 ± 7 Ma indicating that the garnet cores are remnants of the predominant regional metamorphism (event2).

This first metamorphic stage was followed by a stage of decompression and cooling resulting in a partial resorption of grt1. A second prograde metamorphic stage then caused additional garnet growth, starting at 0.45–0.60 GPa at 580–630 °C (grt2 and inclusions) and leading to

LP–HT peak conditions of 0.55–0.65 GPa and 830–900 °C (grt3 and matrix). Monazite inclusion in grt2 yielded an age of 319 ± 6 Ma, matrix monazite and inclusions in grt3 produced an age of 312 ± 5 Ma, which dates the pervasive LP–HT overprint (event3).

Our petrological and geochronological data suggest that Avalonian and Armorican terranes had already collided in the late Devonian (event1), as proposed by KRONER & ROMER (2013). However, this is important from the viewpoint of global plate tectonics, as it marks the closure of the Rheic ocean. The final architecture of the Variscan orogen was established considerably later following a further strong collisional phase with regional high-grade metamorphism at ~340 Ma (event2). This was most likely a short-lived tectonic event with HT–HP granulite formation and a rapid exhumation thereafter. In the final stage of the Variscan orogeny some parts of the Moldanubian zone (Bavarian unit) were selectively reheated (event3). The isobaric heating to granulite facies conditions at the middle crustal level point to a significant external heat influx into the middle crust at this stage (e.g. mantle delamination).

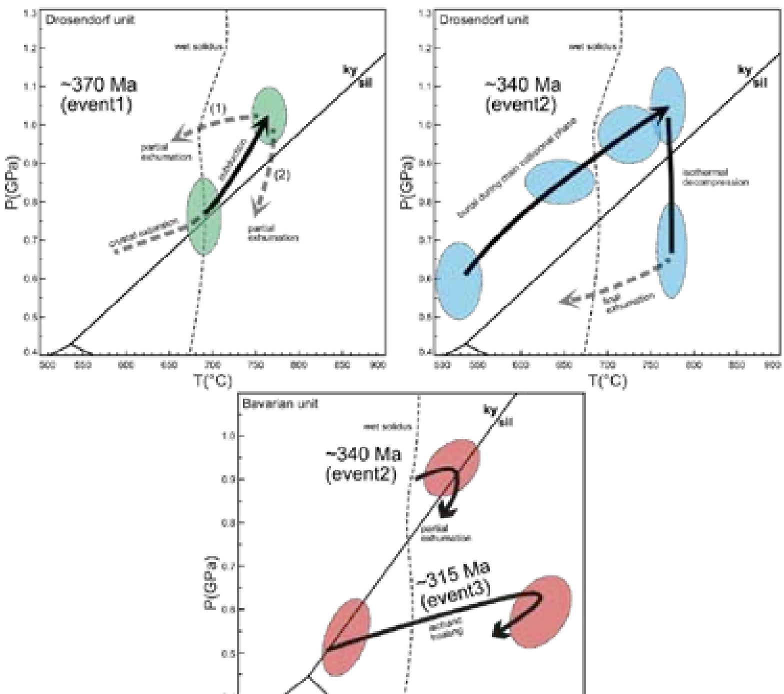

Figure 1: Proposed P–T–t paths for the Late Devonian (event1), the Visean (event2) and the Pennsylvanian (event3) metamorphic events, modified after SORGER et al., 2018, 2020.

FINGER, F., STEYRER, H. P. (1995): Geol. Carpathica, 46, 137–150.
KRONER, U., ROMER, R. L. (2013): Gondwana Res., 24, 298–329.
LINDNER, M., DÖRR, W., REITHER, D., FINGER, F. (2020): Geol. Soc., London, Special Publ., SP503-2019-232.
SORGER, D., HAUZENBERGER, C.A., FINGER, F., LINNER, M. (2020): Gondwana Res., 85, 124–148.
SORGER, D., HAUZENBERGER, C.A., LINNER, M., IGLSEDER, C., FINGER, F. (2018): J. Petrol., 59, 1359–1382.