High-resolution geochronology of Variscan granite emplacement – the South Bohemian Batholith

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Information on precise timing of magma emplacement and regional metamorphism is crucial for understanding the process of, and evaluating models for, granite generation in the Variscan belt. For many areas, however, geochronological data are still scarce, not reliable or controversial.

A resolution of 2–3 Ma or less is needed to resolve and thus fully understand the evolution of high temperature metamorphism and granite generation. Otherwise distinct short-lived events, spatial variations and the interaction of different processes might not be identified. Such precision can be achieved by dating of carefully selected, preferably single grains of zircon and monazite using the conventional U-Pb method (ID-TIMS).

The South Bohemian Batholith (around 10,000 km^2 of granite) represents one of the large Variscan composite plutonic complexes in the internal zone of the Variscan belt. Our results give new insight in the relative order of magma emplacement and the identification and duration of distinct magmatic events. In recent years there has been an intense discussion about the absolute age of magmatism in South Bohemia, e.g. of the Weinsberg Granite. This coarse-grained porphyritic granite type represents c. 50 % of the entire batholith. Finger – Von Quadt (1991), Friedl et al. (1996) and Gerdes (2001) proposed an intrusion age of about 328 Ma, based on U-Pb monazite and Rb-Sr isochron dating. However, in a recent study (Klötzli et al. 2001), mainly based on zircon evaporation ages, it is suggested that the Weinsberg granite formed much earlier around 345–355 Ma. This would imply that major parts of the batholith formed prior to regional metamorphism in the surrounding Moldanubian country rocks (c. 345–330 Ma), which is in contradiction to field evidence (Fuchs – Thiele 1968, Büttner – Kruhl 1997).

Our new U-Pb (ID-TIMS) ages from different localities and types of the Weinsberg granite vary from 323 to 331 Ma and thus clearly are at variance with the results of Klötzli et al. (2001). A precision for the single-grain ages of around 1–2 Myrs allows the temporal distinction of the three types of Weinsberg intrusion (WbG Ia: 330.7, WbG II: 326.0 and WbG Ib: 322.6 Ma) earlier characterised by having different $^{87}Sr/^{86}Sr$ initials (Gerdes 2001).

The two-mica granites of the Eisgarn type, which represent the northern part of the batholith, were generally seen as belonging to the younger South Bohemian intrusions. However our U-Pb ID-TIMS monazite and single zircon data indicate a crystallisation history even older than some Weinsberg granites. Interestingly the fine-grained varieties from northern Upper Austria (Sulzberg granite) are with 326 Ma only slightly younger than the medium- to coarse-grained granites from the type locality of the main Eisgarn granite in Lower Austria (327–328 Ma). From this main type and from the different Weinsberg granites we have analysed single zircon and monazite grains. In all cases the ages of the different minerals were identical or within error of the analyses.

Different diorites form small isolated bodies within the large granite area of South Bohemia. Their relations to the granites and often also their relative age are somewhat unclear. We have analysed zircon fractions (1–3 grains) from 4 diorites from different localities. In the NE of the batholith the medium-grained Eisgarn granite intruded the Gebharts Diorite. The U-Pb age of this diorite is 327.4 ± 0.8 Ma and thus indicates a contemporaneous history with the Eigarn granite. Diorites of the Mühlviertel in the W of the batholith, however, show younger crystallisation ages. A diorite from the northern Mühlviertel has a U-Pb age of 323 ± 1 Ma, which is identical to the age of the Weinsberg granite of this area (WbG 1b). Zircon grains from diorites of the Pfahl, an important NW-SE stretching fault, crystallised at about 318 ± 2 Ma (upper intercept). For a diorite of the Sauwald, in the southwest of the batholith, two concordant single zircon analyses suggest emplacement at 316 ± 1 Ma. Similar U-Pb ages (316–319 Ma) show monazite fractions from the Peuerbach and Schärding granites of the Sauwald.

Various fine-grained granites intruded into the older granites, e.g. the Weinsberg granite. Their absolute age and the relative age variation between them are still controversial. All fine-grained granites have a high amount of inherited zircon in common. Thus we analysed manly single monazites, which give us in difference to the zircons of these granites precise and reliable crystallisation ages. Most monazite analyses were concordant indicating no later disturbance of the U-Pb system. Four U-Pb monazite analyses from the fine-grained two-mica granites of the Altenberg pluton north of Linz give an age of 315 ± 1 Ma. A very similar U-Pb age of 316 ± 1 Ma have monazites from the fine-grained, I-type, Mauthausen granite. However, the Freistadt granodiorite pluton, previously considered as closely related to the Mauthausen granite, contains monazite that crystallized at c. 300–310 Ma and, in addition, some inherited 331 Ma old monazites.

All together our U-Pb data indicate magmatic activity in South Bohemia over a period of 30 Ma. Each intrusion marks a relative short-lived magmatic pulse within two main magmatic events. At 331–323 Ma about 80 % of the batholith were formed. Various fine-grained granites associated with some diorites represent the second less important episode at 319–315 Ma. The Freistadt granodiorite probably correspond to an independent, younger magmatic activity.

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The Golfo Aranci (Sardinia, Italy) metamorphic basement: from the Southern Variscan realm a look towards the North

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The Golfo Aranci metamorphic basement (NE Sardinia, Italy) is considered a fragment of the southern European Variscan belt. It is made up essentially by migmatitic paragneisses and slightly deformed orthogneisses, the latter of Ordovician age (P. India, Mt Alvu orthogneiss). Scattered lenses of mafic rocks (amphibolites s.s., garnet amphibolites and eclogites) crop out within the migmatitic gneisses and are concordant with the main regional foliation of the migmatites. The metamorphic basement is intruded by several late- to post tectonic Variscan shallow-level plutons: high-K calc-alkaline tonalitic to granitic intrusions (P. to Rotondo tonalite, Mt. Cannareddu granodiorite, Sa Curi granite) and peraluminous leucogranites (Rio Maronzu two-mica leucogranite).

The migmatitic gneisses are monotonous qtz, kfs, pl, bt, ± ms ± grt ± sil stromatic migmatites. Kyanite is commonly found as small relict inclusions within plagioclase or muscovite grains. The amphibolites s.s. are pl-hbl–qtz ± cpx banded amphibolites with granoblastic texture and in one case (Morongiu Nieddu outcrop) are closely associated with mafic and ultramafic cumulates with relic magmatic textures (Franceschelli et al., 2002). Eclogites and garnet amphibolites are generally associated and are easily distinguishable from the amphibolite s.s. by the occurrence of garnet porphyroblasts. Eclogites are commonly banded rocks, displaying grt rich and grt poor domains and are commonly strongly recrystallised. In a few samples they still display relics of a typical high-pressure paragenesis with low jadeite omphacite ($Jd_{31–36}$), grt, rt, qtz, ky, zo. Plagioclase–diopside symplectites on former omphacite, plagioclase–hornblende coronitic symplectites around garnet are the most common features of the retrogressed eclogites. Two eclogite samples display sapphirine – corundum – spinel – anorthite coronitic symplectites around kyanite and scarce opx occurrences within the di–pl symplectites on former omphacite. Garnet amphibolites are mainly constituted by plagioclase, brown amphibole, garnet and quartz. Relics of plagioclase–diopside symplectites are present and, together with the corroded garnet porphyroblasts, are rimmed by brown amphibole-plagioclase symplectites.

The textures and mineral parageneses in the migmatitic gneisses and in the mafic rocks point to a complex metamorphic history, which started with a high-pressure (up to 14–16 kbar) and medium temperature (600–650 °C) metamorphism related to the Variscan collisional event and recorded by the mafic eclogites. This event was then followed by an early decompression (8–10 kbar) accompanied by a possible increase of temperature (700–750 °C) up to the granulite facies (pl–di over omp and spr–crn–spl–pl over ky). The final step is recorded by the pervasive re-equilibration at lower pressure and temperature (P <8 kbar, T = 550–600 °C) within the amphibolite facies (amp–pl symplectites, banded amphibolites, migmatitic gneisses): this was probably related to the late Variscan transpressive- to extensional stage (Carosi – Palmeri 2002), which triggered the emplacement of large granitic masses within the crust.

Sapphirine-bearing rims around ky were never found till now in the Sardinian eclogites, whereas several occurrences are reported from the Central European Variscides from the Bohemian to the Armorican Massifs (O'Brien, 1997; Godard – Mabit, 1998). The proposed metamorphic history for the NE Sardinian basement is generally similar to those proposed for Central European Variscides, so adding new important data for the deciphering of the Variscan orogenic belt.

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