How gabbro zircons contain more U than zircons from the co-mingled granodiorite: Lessons from U-Pb and Hf-zircon isotope investigations

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Mantle derived magmas in convergent tectonic zones experience a complex evolution from their generation to the crystallisation in the upper crust. They commonly display large compositional variations due to the enrichment with incompatible chemical elements that are introduced into the upper mantle by slab-derived fluids or melts. This effect is strongly overprinted by the mantle-crust interaction. U-Pb and Hf- zircon isotope-geochronological and geochenmical investigations are crucial to evaluate the role of both processes as well as the kinematics of the mixing between mantle and crustal derived magmas.

The present study is focused on Upper Cretaceous plutons from Central Srednogorie Zone, Bulgaria. Sheet-like gabbro or gabbro-diorite bodies are intruded into magma chambers containing coeval felsic upper parts and lower parts of crystal rich porphyry granodiorites. Granodiorite: concordant zircons, U content range from 70 to 161 ppm. Three of them determine a mean $^{206}Pb/^{238}U$ age of 84.6 ± 0.3 Ma. Inherited zircons are also present. The calculated initial ($^{87}Sr/^{86}Sr$) ratio of 0.70492 and ε-Hf-zircon values of +4.7 to +8.7 argue for mixed crust-mantle origin. The gabbro contains three types of zircon: (i) brown zircons are U-rich (600-4400 ppm), two of them lying concordant at 82.16 ± 0.10 Ma; ε-Hf-zircon values are mantle dominated +7.6 to +10.5; (ii) milky zircons are less rich in U (270-350 ppm) and define a mean $^{206}Pb/^{238}U$ age of 85.0 ± 0.5 Ma; (iii) colorless zircons of mixed origin and an age of 442.7 ± 8.3 Ma are sparse. The initial strontium ratio of the gabbro is 0.70401. Transparent and milky prismatic zircons prevail in the mixed layers. Five of them yield a concordant age of 84.87 ± 0.13 Ma. All Upper Cretaceous zircons reveal similar REE distributions with positive Ce and weak or absent negative Eu anomalies. Brown gabbroic zircons are slightly richer in the REE compared to the zircons from intermediate rocks.

Mixing of the mantle magma (additional to the mingling) with crustal melt at mid- to upper crustal level is proposed to explain the change of the magma chemistry leading to zircon saturation and fast crystallisation of U- and REE-rich zircons.

Element partitioning between ferrobasalt-rhyolite immiscible liquids

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Evidence from natural rocks show that liquid immiscibility can be encountered by common basalts at advanced stages of crystallization. However, the partitioning of trace elements between the immiscible liquids are still poorly constrained therefore we have carried out a comprehensive study of liquid-liquid element partitioning. In contrast to similar previous experimental studies, we employed high temperature centrifuge phase separation, in order to get a better spatial separation of immiscible liquids. Three thermocouples and two independent heaters were used to minimize temperature gradients. Two starting compositions were prepared from synthetic silicate glass and reagent-grade FeO. The first being rich in FeO (24 wt. %) and SiO_2 (57 wt. %) in order to ensure liquid immiscibility to take place, the second starting composition had 50 % wt. SiO_2 and 22 wt. % FeO close to liquid compositions suggested for the Skaergaard magma where liquid immiscibility has been speculated. These mixtures were doped with 33 trace elements. Runs were carried out at 1050-1150 °C in sealed Fe containers at 1 atm. Quenched products were analyzed by electron microprobe and LA ICP-MS. Two immiscible liquids are present in all the products separated by sharp meniscuses. One of these is rich in SiO_2 (65 wt. %) whereas the other is having a moderate SiO_2 content (48 wt. %) but is rich in FeO (32 wt. %). Even at the highest rotation speeds, the centrifuge phase separation after 3 hours was incomplete, mostly because of the high viscosity of the silica-rich immiscible liquids. Partition coefficients show that all the elements analyzed, except K, Na, Rb, Al and Si, concentrate in the Fe-rich immiscible liquid. The ferrobasalt/rhyolite Nernst partition coefficients (D) are the highest for Zn (3.3) and Fe (2.6) and the lowest for Rb and K (0.4-0.5). The D values against ionic potential shows in general a convex upward trend that closely resembles the liquid-liquid partitioning of trace elements by Soret diffusion. Complementary Soret diffusion experiments are underway to further explore bulk compositions controls on immiscibility in Skaergaard-like magma compositions.