



DISTRIBUTION AND STABILITY OF REE ACCESSORY MINERALS IN THE WEST-CARPATHIANS GRANITES: SOME TECTONIC IMPLICATIONS

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The allanite - monazite stability relationship in granites is important for the recognition of the S / I-type granite suites and is very distinctly developed in the West-Carpathian granites. The presence of monazite or allanite is explained by different solubilities of these minerals in relation to the aluminium saturation index of the host granite, as well as to its fO_2 . Allanite precipitates preferentially in metaluminous (or slightly peraluminous), rather than in peraluminous granitic rocks with higher fO_2 or water contents. A higher proportion of allanite is typical for the early magmatic differentiated I-type granites; fractionated granites contain also monazite. High concentrations of monazite are present in early differentiations of the S-type granite suite, sometimes accompanied by primary allanite. Generally, the precipitation of allanite and monazite effectively decreases the bulk REE concentrations in the residual melt. But the REE contents of the various granite types can also be a function of other factors. A decrease in Ce within the S-type granite suite relates to the available P content in the melt. P is incorporated early into the feldspar structure in form of the berlinite molecule, and is effectively unavailable for precipitation of monazite. The increase of Ce in the I-type differentiates has a different explanation. Here allanite becomes unstable in the residual melt (with higher ACNK index) and monazite crystallizes instead of allanite when sufficient P and Ce are available.

Other important hosts for the REEs include apatite, titanite, xenotime and zircon. The REE content in apatite is relatively low, with Σ REE oxides typically <0.5 wt.% . In the

I- and S-type granites, apatite is light-REE enriched, whereas in the A-type granites, apatite is relatively enriched in heavy-REE (including Y). In the granitic rocks of the Western Carpathians, xenotime-(Y) is present both as a late-stage magmatic mineral, and as a secondary post-magmatic phase. Magmatic xenotime occurs with monazite mostly in the S and A-type granites and displays minor compositional zonation involving Si, Th and U. The source of elements for the formation of secondary xenotime-(Y) in the granitic rocks results from leaching of P and (Y + REE), mainly from zircon and apatite. Primary titanite, present only in the early differentiates of the I-type suite, indicates an increase in oxygen fugacity of the primary melt ($\log fO_2 \sim -12$). The low REE content in titanite is similar to apatite with also a similar chondrite-normalized pattern.

The REE-bearing accessory minerals have restricted stabilities in the fluid regime, so that during post-magmatic alteration of these phases, they undergo significant composition changes and even break down. Alteration of monazite is already possible from subsolidus magmatic fluids at relatively low temperatures. Under such conditions monazite breaks down and LREE-enriched apatite crystallizes on the monazite grains. Other transitions possible from the mobility of the actinide elements (U and Th), is the formation of huttonite or other Th- U-rich phases. Monazite that has been overprinted in the amphibolite facies breaks down to allanite via an intermediate zone of apatite (Finger et al. 1998, Broska and Siman, 1998). This apatite, in monazite-allanite-epidote coronas usually has low concentrations of the REEs. Xenotime (in a similar manner to monazite) is also unstable during overprinting in the amphibolite metamorphic facies. Xenotime alteration results in the formation of Y-rich epidote as coronas around the xenotime grains, and can also contain Y-rich apatite in an intermediate zone. Allanite breakdown is common with usually a REE-rich epidote as an alteration product. Titanite can break down to form allanite and REE epidote and these occur as small patches within the titanite grains.

By their presence or absence, or their physico-chemical character, REE-bearing accessory minerals can discriminate not only orogenic S and I type granites but also post-orogenic A- and specialized S-type granite. In I-type granites, REE-bearing accessory minerals are mainly apatite, titanite and zircon (S_{12} subtypes), a typical suite of these accessory minerals in S-type granites is monazite, apatite, xenotime, garnet and zircon with low subtype (subtypes S_{2-3}). Specialized S-type granites developed in the Upper Alpine tectonic unit - in Gemericum – consist of tourmaline then apatite, monazite, xenotime, and zircon (mainly subtype S_8), and in the most evolved granites, additional REE, U, Th mineral phases. The A-type granites are characterised by the presence of allanite ($\pm$ monazite), xenotime and zircon with P and D morphological subtypes being dominant.