# Accessory minerals as petrogenetic markers: A few applications

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Accessory minerals, besides containing a significant fraction of the PGE, REE, Y, Th, U, Zr, Hf, Nb, Ta, Sr, Ba, Pb, etc. have proved their value as petrogenetic markers in the following fields:

*Mantle-crust interaction.* Accessories are far more abundant in crustal than in mantle rocks. When a mafic magma gets contaminated with crustal materials, chances are for crustal accessories to survive in the magma if they are included in early-crystallizing minerals. In this talk I shall describe two examples: (1) the dunites of Kytlym, an Alaskan-type body of the Platinum-Bearing Belt of the Urals, which contains zircons derived from subducted sediments (2) the cortlandites and high-Mg gabbros of central Iberia, which contain numerous crystals of Th-rich monazite, thorite, uraninite, xenotime, wolframite, scheelite and arsenopyrite of indisputable crustal origin.

*Magmatic differentiation.* The wide compositional spectrum of the Variscan batholiths of the Urals ($SiO_2 \approx 50 – 75$ wt.%) was produced by crystal fractionation, but the physical mechanisms involved in formation of the bodies remained obscure until the Stepninsk pluton was studied in detail. A key observation was that primary titanite, the most abundant accessory, has very similar REE, Th, U, Zr, Hf, Nb, Ta, Y and V concentration in all members of the series, from gabbrodiorites to leucogranites. This is not consistent with a sequential process of fractional crystallization, in which increasingly silicic rocks precipitated from progressively differentiated residual melts, and leaded us to propose a model of deformation-driven filter-pressing differentiation.

*Mass-balancing mineral reactions.* Mineral reactions that consume mayor minerals with high Zr, Y, REE, Th, U, etc. to produce other major minerals with low concentrations of these elements may lead to the formation of zircon, xenotime, monazite, etc. as mass-balancing accessories which, if datable, permit high-resolution geochronology. In metamorphic systems, zircon and xenotime have been found as products of the retrogression of garnet. In magmatic and late-magmatic systems the most promising (Zr, REE, Th, U, Y)- liberating reactions are the transformation of early amphibole to biotite, titanite to ilmenite + plagioclase and, probably, the recrystallization of Zr-bearing feldspars into Zr-free feldspars plus zircon.

# Chemistry and textures of magmatic epidote and muscovite in a tonalite pegmatite, North Cascades, USA

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Rare tonalite pegmatites (~90 Ma) in the North Cascade Mountains contain magmatic epidote, typically in the assemblage pla + qtz + ms + czoi/epi, with trace biotite, Fe oxide, and rare garnet. Multiple generations of muscovite and epidote are present. Large epidote crystals are typically rimmed by more Fe-rich epidote, and partly replaced by medium grained muscovite.

The largest epidote crystals are ~13 cm long. Some are boudinaged and twinned, with euhedral oscillatory zoning, and compositions close to the clinozoisite-epidote boundary. Rims of these epidote crystals are partially coated by 0.1 mm-scale Fe-richer epidote. Clinozoisite and/or zoisite is also present as extremely fine-grained replacement of plagioclase. Trace element work using LA-ICP-MS is in progress.

Muscovite shows at least 5 textural groups and complex chemistry correlated to these groups. These textural groups include (1) cm-scale grains, (2) smaller grains replacing epidote, (3) mm-scale groundmass grains, (4) small groundmass grains, and (5) small grains after plagioclase. Chemical variations in the largest grains are evident in SEM BSE imagery as bright inner rims. Plots using $Al^{vi}$ versus Si almost completely discriminate the muscovite groups.

Early magmatic Fe-poor epidote apparently became unstable, and was replaced by Fe-richer epidote and muscovite, followed by later muscovite and epidote generations. These observations illustrate complexities that can be recorded by ‘simple’ pegmatites, and the dangers of geochronology and geothermobarometry conducted using averaged analyses or when textural complexities are ignored.