Zircon geochemistry records magmatic volatile evolution

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Pegmatitic segregations in hypabyssal tinguaites from the Alpine Dike Swarm lamprophyre-carbonatite complex (New Zealand) contain zircon that record volatile-driven igneous differentiation in a closed system.

Mineralogically, the segregations contain sodalite-cancrinite-carbonate-phyllosilicate-albite-niobian-rutile-ilmenite-zircon and represent the crystallized product of a volatile-rich residual melt. Zircon displays intensely recrystallized cores (Z1), syntaxial cathodoluminescence-dark mantles (Z2), and oscillatory zoned rims (Z3). Geochemically, Z1 and Z3 are similar with U = 150 ppm, extremely high Th/U ratios (~10 – 100) and chrondrite-normalized rare earth element (REE) profiles typical of magmatic zircon. In contrast, Z2 has high U (~500-1000 ppm), Nb, Ta, Ti, and Ca; low Th/U ratios (4-7), and LREE's comprise 50 wt.% of total REE's (~2.5 wt.% in Z3). We interpret these unusual patterns in geochemistry and zonation to be a result of progressive volatile saturation of a residual melt. Z1 grew from the volatile-undersaturated phonolitic melt. Upon volatile saturation Z2 precipitated from the fluid phase with low Th/U ratios and LREE enrichment, while Z1, in disequilibrium, was replaced via fluid-mediated dissolution-reprecipitation processes. LREE enrichment in Z2 occurred by fluid-melt fractionation of the REE's by REE-F and REE-Cl complexes, and/or REE^{3+} incorporation via non-xenotime-type substitutions involving H, Cl, F, or Nb+Ta. Z2 growth ceased with the sequestration of H, Cl, F, U^{5+}, U^{6+} and LREE in sodalite-cancrinite-carbonates-phyllosilicates, resulting in high Th/U, low LREE Z3. The availability of volatiles as complexing ligands is the primary control on the distribution of REE in minerals precipitating from evolved alkaline and carbonatitic systems.

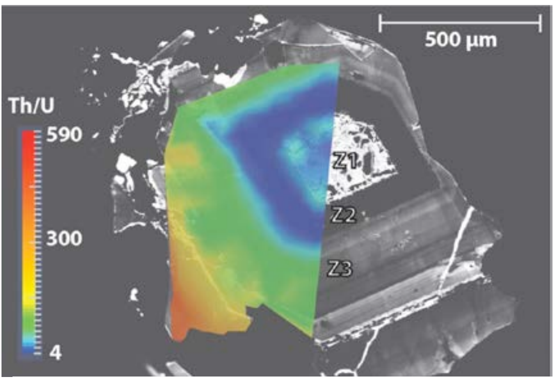

Figure 1: Cathodoluminescence image of zircon overlain by Th/U map