Exploring fundamental assumptions of He thermochronometry

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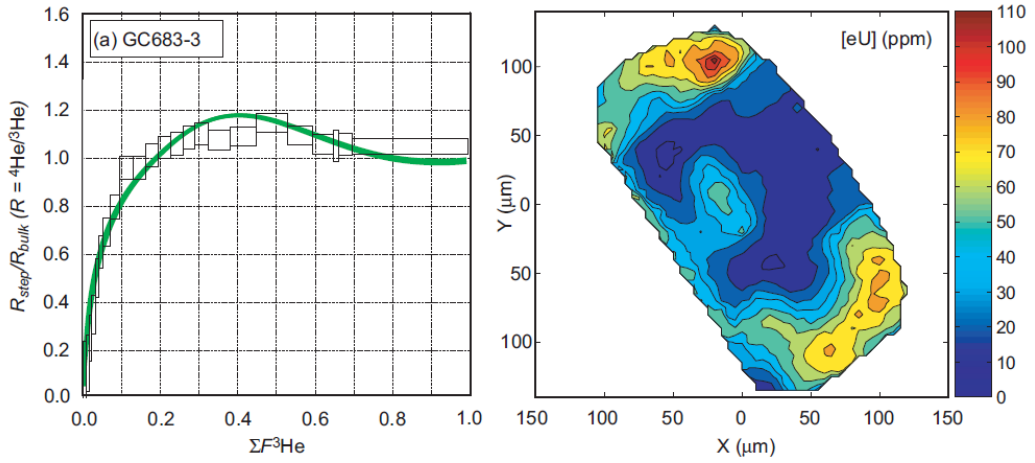
Whole-grain (U-Th)/He thermochronometry relies on several assumptions with only limited observational support. ^{4}He/^{3}He thermochronometry, which derives additional cooling history information from the ^{4}He concentration distribution, relies on the same assumptions but is often much more sensitive, and thus provides new insights to the validity of the assumptions.

Anisotropy: laboratory experiments suggest that He diffusion in zircon is faster in the axial than in the radial direction, but this may vary with radiation damage accumulation. In contrast, such experiments suggest little or no anisotropy in apatite. Quickly cooled samples subjected to ^{4}He/^{3}He analysis reveal the extent to which alpha-ejection penetrates into the diffusion domain. Thus in a typical elongate crystal the ^{4}He/^{3}He spectrum can distinguish strongly axial diffusion from radial or uniform diffusivity. Our ^{4}He/^{3}He experiments strongly support isotropic diffusion from apatite, and suggest the same for zircons with moderate amounts of radiation damage. If both the laboratory data and the latter observation are true, the degree of anisotropy may evolve in time in zircon.

Zonation: the sensitivity of the alpha ejection correction to zonation in U and Th (combined as effective U, eU) is well known. Because the ^{4}He profile reflects diffusion operating on the production profile (a function of the eU distribution), the ^{4}He/^{3}He method is directly influenced by eU zonation. For example, the ^{4}He/^{3}He spectrum shown below plots in the "forbidden zone" for diffusive ^{4}He loss from a uniform eU apatite, suggesting enrichment of eU on the rim. LA-ICPMS experiments on this sample confirm this sense of zonation; indeed we can model the spectrum rather well given the observed zonation.



Data are available on eU zonation in zircon, but little is known of eU zonation in apatite (FT mapping lacks the necessary spatial resolution-precision and is insensitive to Th). This absence of data has motivated us to undertake a large scale effort to characterize eU zonation in apatites.