Tracking contamination in felsic magma chambers with $\delta^{18}O$ of magmatic garnet and zircon

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Magmatic garnet (Grt) and zircon (Zrc) often coexist in peraluminous (A/CNK >1) granitoids. Grt and Zrc are ideal for oxygen isotope studies because their slow oxygen diffusion rates "quench in" magmatic $\delta^{18}O$ values at the time of crystallization. Thus Grt and Zrc potentially record a continuous record of evolving magma $\delta^{18}O$.

The utility of Grt and Zrc to monitor contamination has been explored by analysis of Grt-Zrc pairs from several plutons in the Sierra Nevada, CA, USA. Petrography shows earliest Zrc grew before garnet, because it commonly occurs as inclusions in garnet phenocrysts. Values of $\delta^{18}O$(Zrc) are 7.15–8.97‰. Grt may have multiple populations and $\delta^{18}O$(Grt) is more variable: 6.77–10.65‰. Three plutons (Fig.

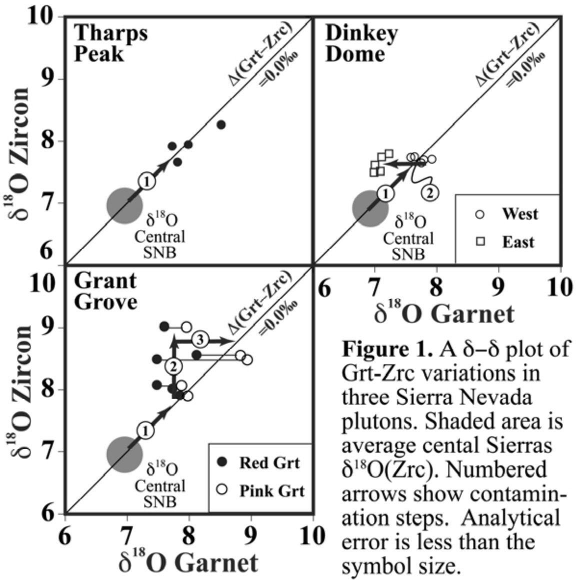

Figure 1. A δ–δ plot of Grt-Zrc variations in three Sierra Nevada plutons. Shaded area is average cental Sierras $\delta^{18}O$(Zrc). Numbered arrows show contamination steps. Analytical error is less than the symbol size.

1) illustrate our overall findings. The average $\Delta^{18}O$(Grt-Zrc) of 0‰ for the Tharps Peak pluton indicates a single contamination event (step 1) at depth before Grt or Zrc crystallized. The Dinkey Dome pluton is bimodal: its west side records a single contamination event (path 1), whereas the east side exchanged with low-$\delta^{18}O$ material after Zrc growth, but before Grt growth (step 2). Finally, in the Grant Grove pluton, early Grt (red) crystallized (step 1), followed by Zrc (step 2), and then a late Grt (pink) population (step 3). The three different growth episodes record complex contamination of the magma by wallrocks.

These findings confirm the potential of $\delta^{18}O$ of Grt and Zrc for deciphering progressive contamination in felsic magmas world-wide.

Underground cosmic ray geophysics: the new expanding frontier

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It is now apparent that in the coming decades, one would see increasing applications of cosmic ray nuclear interactions for studying the geological histories of underground materials. This may be called the new frontier of applications of cosmic rays in geophysics, beyond studies of geomorphic processes in the past decades, based on nuclear interactions of cosmic rays with surficial materials. The latter studies had to await developments in techniques to measure the feeble isotopic changes produced by cosmic rays at sea level and at mountain altitudes. The task is apparently harder for studying induced isotopic changes in deep seated underground rocks for a number of reasons: first, the flux of secondary cosmic ray particles decreases at greater depths due to degradation of cosmic ray energy, and second, the character of the secondary particles changes from a primarily *nucleonic* component to a weakly interacting *leptonic* component. However, there exist compensating factors, which should allow easy study of the exposure histories of underground rocks down to depths of (3-4) x 10^2 meters underground, and in favorable cases to an order of magnitude greater depths. Note that since the average nuclear excitation of leptonic component is much smaller than for the nucleonic component, underground isotopic changes are limited to production of isotopes close to the mass number of the target nuclei.

Composition and fluxes of the secondary cosmic ray beam underground are reviewed; expected rates of nuclear interactions in common target nuclei are presented (Lal, 1987; Stone et al 1998; Heissinger and Nolte, 2000). Some examples of applications of the cosmogenic isotopic changes are presented, as a case for the expected new frontier.

References

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