

Slow oxygen diffusion rates in igneous zircons from metamorphic rocks

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ABSTRACT

Empirical tests of oxygen exchange rate in zircon crystals from amphibolite- and granulite-facies metamorphic rocks of the Grenville Province demonstrate preservation of igneous $\delta^{18}\text{O}$ through protracted igneous and metamorphic histories, forming the basis of quantitative estimates of diffusion rate. Granitic orthogneisses, which cooled slowly after granulite-facies metamorphism, show no consistent relationship between zircon size and $\delta^{18}\text{O}$, indicating slow oxygen diffusion. Detrital zircon crystals from granulite-facies quartzites are out of equilibrium with their host rocks, and no consistent correlation is seen between $\delta^{18}\text{O}$ and grain size in high-precision analyses by laser fluorination of multiple grains, sieved for size. In a single sample, individual detrital zircon crystals preserve grain-to-grain variability in $\delta^{18}\text{O}$ (determined by ion microprobe), ranging from 5.0 to 9.5‰. The inherited cores of some zircon crystals are up to 5.6‰ lower than igneous overgrowths, showing that gradients of 5.6‰ can be preserved over 50 μm even at magmatic conditions. All of these lines of evidence show that oxygen diffusion in zircon in these rocks was slow both during metamorphism and during slow cooling of 1–3 °/m.y. Calculations based on the measurements indicate that the oxygen diffusion rate in zircon (D) must be $\geq 10^{-22} \text{ cm}^2/\text{s}$ at 600 °C to explain $\delta^{18}\text{O}$ (zircon) values measured from Grenville quartzite and orthogneiss. This value is consistent with the experimentally determined value of $D = 2 \times 10^{-27} \text{ cm}^2/\text{s}$ for dry diffusion experiments extrapolated to 600 °C (Watson and Cherniak 1997). These results indicate that oxygen-isotope analysis of zircon may be used to see through granulite-facies metamorphism and anatexis, and to unravel crustal recycling processes in igneous rocks.