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Comparative chemical versus isotopic dating of monazites

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Background

Monazites are widely used for U-Pb dating of igneous and metamorphic rocks and events. Monazite (mnz) U-Th-Pb dating that does not require isotopic data has recently been successfully utilized to characterize metamorphic events. In this “chemical” dating method, high-precision electron microprobe analyses with a significant spatial-resolution advantage over isotopic methods have been used to date *in situ* zones in partially recrystallized mnz grains that record timing of partial recrystallization events. This technique can produce a relatively complete picture of multiple tectono-thermal events in a metamorphic terrane or be used to decipher xenocryst-magmatic overgrowth relations in granitic plutons. The chemical method, however, remains controversial and in this presentation we report direct comparative results of *in situ* isotopic (SIMS, SHRIMP), bulk isotopic (ID-TIMS), and chemical (EMP) dating of the same mnz grains in rocks ranging from 2850 to about 300 Ma. We present analysis of uncertainties in chemical dating, including analytical errors and effects of common-lead correction.

Results

Case studies include (1) Archean and Paleoproterozoic mnz from the Tobacco Root Mountains, MT, (2) Mesoproterozoic mnz from a shear zone in NC, (3) Devonian mnz from granite, VT, and (4) Mississippian mnz from pegmatite, MA. In each case, dates are comparable within uncertainty, except where isotopic ages reflect mixing of two age zones.

Experimental calibration of zircon-quartz oxygen isotope fractionation

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Zircon is a common accessory phase occurring in many crustal rocks, and is often found with quartz. The $\delta^{18}\text{O}$ values of both minerals have been used to understand petrogenesis, and to constrain the provenance of grains no longer associated with their host rocks. In order to explore these minerals further, we report the first direct experimental characterization of oxygen isotope equilibrium fractionation.

Experiments (700-950°C; 10-20 kbar; 50-600 hrs.) were designed so that both phases would crystallize in chemical communication, but would be easily separable for isotope analysis. Zircon and quartz fractions were cleaned, and oxygen isotope analyses were performed on a Finnigan MAT 253 mass spectrometer by reacting zircon and quartz with BrF_3 using a 25W CO_2 laser line. Thus far, our data suggest an A-value which is in better agreement with empirical results [1] than with the indirect experimental calibration derived from zircon-water fractionation experiments [2].

A robust calibration would provide a new tool for mineral thermometry, and would have direct application to characterizing oxygen equilibrium/disequilibrium processes in petrological systems. In addition, because zircon is resistant to chemical alteration and physical breakdown during weathering, it is often used to constrain protolith origin(s). Our data provide an indirect means to determine $\delta^{18}\text{O}$ quartz values of the host rock – an important characterizing feature – provided zircon crystallization temperatures [3] and $\delta^{18}\text{O}$ zircon values are determined, and can be assumed not to have been compromised by post-crystallization diffusive exchange. The above methodology could also be applied to quartz inclusions in zircon which may be inaccessible to isotope analysis because of size, or altered by subsequent overprinting.

[1] Valley *et al.* (2003) *Geochim. Cosmochim. Acta.* **67**, 3257-3266. [2] Krylov *et al.* (2002) *European Journal of Mineralogy* **14**, 849-853. [3] Watson *et al.* (2006) *Contrib. Mineral. Petrol.* **151**, 413-433.