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LETTER

In situ ^{238}U-^{230}Th disequilibrium dating of pyrochlore at sub-millennial precision

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ABSTRACT

We report the application of high-resolution in situ ^{238}U-^{230}Th disequilibrium dating to pyrochlore [$(Ca,Na,REE,Th,U)_2(Nb,Ti,Ta,Zr)_2O_6(OH,F)$]. Compositionally zoned pyrochlore is an accessory phase in intrusive carbonatitic syenites, which were ejected as cognate clasts during the eruption of the phonolitic Laacher See volcano, East Eifel, Germany, 12.9 ka ago. Separated individual pyrochlore crystals were analyzed for U-Th isotopes and elemental abundances at high spatial resolution (~25 µm) using secondary ion mass spectrometry (SIMS) with an internal precision for the ^{238}U-^{230}Th isochron of ~700 a (2σ). U and Th were also analyzed by electron microprobe in SIMS spots. Instrumental mass fractionation for Th/U was corrected using an EMP vs. SIMS calibration curve, and the resulting pyrochlore isochron age of 26.1 ± 1.4 ka (including external calibration uncertainty) is concordant with the 23 +7/–6 ka U-Th zircon ages for the same sample. By contrast, AM206 pyrochlore from a Cretaceous alkali granite shows significant disequilibrium with $(^{230}Th)/(^{238}U) = 0.90 \pm 0.04$. The tightly defined isochron implies that U-Th in Laacher See pyrochlore remained a closed decay system during protracted residence in the magma chamber carapace, and was unaffected by hydrothermal alteration or post-eruptive weathering over time scales of tens of thousands of years. By contrast, disequilibrium in AM206 pyrochlore indicates U-Th mobilization during protracted near-surface residence.

Keywords: Pyrochlore, U-Th disequilibrium, carbonatite, radiation damage, nuclear waste