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Dating kimberlite emplacement with zircon and perovskite (U-Th)/He geochronology

Jessica Stanley (1,2) and Rebecca Flowers (2)

(1) GFZ-German Research Centre for Geosceinces, Potsdam, Germany (jstanley@gfz-potsdam.de), (2) Dept. of Geological Sciences, University of Colorado, Boulder, Colorado, USA

Kimberlites provide rich information about the composition and evolution of cratonic lithosphere. They can entrain xenoliths and xenocrysts from the entire lithospheric column as they transit rapidly to the surface, providing information on the state of the deep lithosphere as well as any sedimentary units covering the craton at the time of eruption. Accurate geochronology of these eruptions is key for interpreting this information and discerning spatiotemporal trends in lithospheric evolution, but kimberlites can sometimes be difficult to date with available methods. Here we explore whether (U-Th)/He dating of zircon and perovskite can serve as reliable techniques for determining kimberlite emplacement ages by dating a suite of sixteen southern African kimberlites by zircon and/or perovskite (U-Th)/He (ZHe, PHe). Most samples with abundant zircon yielded ZHe dates reproducible to $\leq$15% dispersion that are in good agreement with published eruption ages, though there were several samples that were more scattered. Since the majority of dated zircon were xenocrystic, zircon with reproducible dates were fully reset during eruption or resided at temperatures above the ZHe closure temperature ($\sim$180 °C) prior to entrainment in the kimberlite magma. We attribute scattered ZHe dates to shallowly sourced zircon that underwent incomplete damage annealing and/or partial He loss during the eruptive process. All seven kimberlites dated with PHe yielded dates reproducible to $\leq$15% dispersion and reasonable results. As perovskite has not previously been used as a (U-Th)/He chronometer, we conducted two preliminary perovskite 4He diffusion experiments to obtain initial estimates of its temperature sensitivity. These experiments suggest a PHe closure temperature of >300 °C. Perovskite in kimberlites is unlikely to be xenocrystic and its relatively high temperature sensitivity suggests that PHe dates will typically record emplacement rather than post-emplacement processes. ZHe and PHe geochronology can effectively date kimberlite emplacement and provide useful complements to existing techniques.