Dating young basalt eruptions by (U-Th)/He on xenolithic zircons

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Accurate ages for young (e.g., Pleistocene) volcanic eruptions are important for geomorphic, tectonic, climatic, and hazard studies. Existing techniques can be time-consuming and expensive when many ages are needed, and in the case of K/Ar and $^{40}Ar/^{39}Ar$ dating, extraneous Ar often can limit precision, especially for continental basalts erupted through old lithosphere. We present a new technique for dating young basaltic eruptions by (U-Th)/He dating of zircons (ZHe) from crustal xenoliths. Single-crystal ZHe dates generally have lower precision than typical $^{40}Ar/^{39}Ar$ dates, but can be determined on multiple replicate grain aliquots relatively easily.

We dated zircons from xenoliths from four volcanic centers in western North America: Little Bear Mountain, BC (157±3.5 [2.2%] 95% conf, MSWD=1.7) and Prindle Volcano, AK (176±16 [8.9%], MSWD=13) , in the northern Cordilleran volcanic province, and Fish Springs (273±23 [8.6%], MSWD=43) and Oak Creek (179±8.1 [4.5%], MSWD=12), in the Big Pine Volcanic Field, CA. All ZHe ages are either equivalent to or younger than previously determined K-Ar or $^{40}Ar/^{39}Ar$ ages, indicating the possibility of inherited ^{40}Ar in some of the previous measurements. Zircons from upper crustal xenoliths in the Oak Creek and Fish Springs vents show poorer reproducibility and multiple apparent age distribution peaks, consistent with either intracrystalline U-Th zonation or <99.99% He degassing (assuming ~100-Ma pre-entrainment ZHe ages) of some zircons during magmatic entrainment. Removal of clear outliers in the older age-distribution peaks of the upper crustal xenoliths, most of which have extremely high U compared to other zircons of the same xenolith, improve the reproducibilities of Fish Springs to 4.7% (95% conf., MSWD=4.8) and Oak Creek to 3.4% (95% conf., MSWD=6.2). Coupled thermal and He diffusion modeling using appropriate xenolith sizes and magma temperatures and assuming published diffusion kinetics for zircon indicates that incomplete He degassing would require entrainment times less than one hour. However, the observation of extremely high U in most zircons with older ages raises the possibility that zircons with high radiation dosages and significant pre-eruptive He may have more retentive He diffusion characteristics.