

## (U-Th)/He dating and calibration of low-*T* thermochronometry

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The prized fruits of thermochronometry and those most useful in studying shallow crustal processes are time-temperature (*t-T*) paths over wide temperature ranges. Obtaining these requires either combining results from complementary chronometers with disparate systematics, or modeling track-lengths, crystal-size-age correlations, or multi-domain diffusion. Confidence in resulting *t-T* histories relies on both independent calibration and concordant results of each technique. Addition of (U-Th)/He dating to the thermochronometric repertoire offers opportunities to both expand and fill in gaps in *t-T* paths. But as the density and overlap of *t-T* constraints increase, so does the need for accurate calibration of all systems.

Thermochronometric calibrations ideally begin with independent and mechanistic understanding of controls on diffusion and annealing. Direct experimental calibrations are limited however, in part because of the need for large extrapolations and because it is not possible to anticipate all important controls on diffusion/annealing. Inevitably, much of the credibility of thermochronometry will rely on concordant multimethod thermochronologies from well-constrained geologic settings (i.e., empirical intercalibration).

While intercalibration from natural settings can provide important benchmarks, especially for new systems like (U-Th)/He, its utility may also be limited unless discrepancies are carefully considered and even sought. Concordant results from atypically perfect specimens or conditions may have little relevance to the majority of natural cases in which important and common complications are present. For example, zircon He ages and K-spar Ar cooling models agree well in many slowly cooled rocks, except where zircons show strong intracrystalline U zonation. We are developing a routine technique for characterizing crystal-specific U zonation prior to analysis that significantly improves both accuracy and precision on zircon He ages.

Empirical intercalibration is also complicated by uncertainty in thermal histories of natural settings, especially if we are to avoid charges of circularity. As more and different thermochronometric results are obtained in "well-constrained" settings, it is at least as common that the thermal history of a setting, rather than the thermal sensitivity of the chronometer, is revised. Detailed He and fission-track ages from both apatite and zircon in a 100-m transect perpendicular to a 10-m basaltic dike demonstrate this. Ages show clear and concordant resetting profiles, but also clearly require heating outside the plane of exposure, precluding simple 1-D model predictions with which to "intercalibrate" the systems. In this and other cases, intercalibration from natural settings is not a panacea to limitations of independent and mechanistically based calibrations.

## Geochemical study of tholeiitic lavas from the submarine Hana Ridge, Haleakala volcano, Hawaii

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Hana Ridge is the longest submarine rift zone in the Hawaiian Island chain, which extends from the tip of Maui, 140 km to the east-southeast and has developed a complex morphology compared to other Hawaiian rift zones. In order to investigate the petrological and geochemical evolution of Haleakala shield, 108 rock specimens have been collected from the submarine Hana Ridge through three ROV Kaiko dives and three dives by Shinkai 6500 submersibles, during joint Japan-US Hawaiian cruises in 2001 and 2002 by JAMSTEC. All of the rocks (76 bulk rocks analyzed) from the six dives are tholeiitic basalts or picrites, and their MgO contents range from 6.55 to 28.88 wt.%, and SiO<sub>2</sub> contents vary from 43.3 to 50.37 wt.%, similar to those of lavas forming Kilauea shield building stages. The Sr/Nb, Zr/Nb, and Ba/Nb ratios show Kilauea-like compositions (e.g. lower Sr/Nb, Ba/Nb, and Zr/Nb) in the submarine lavas. However, those ratios of the subaerial Honomanu shield lavas show intermediate fields between Kilauea and Mauna Loa (Frey and Rhodes, 1993). The Sr, Nd, and Pb isotope compositions of submarine Hana Ridge lavas are similar to those of Kilauea compositions, whereas those ratios from subaerial Honomanu also overlap with Kilauea-Mauna Loa fields (Lassiter et al., 1996). The systematic variation of Pb, Sr, and Nd isotopes and trace elements ratios in lavas erupted at Haleakala shield volcano require chemically heterogeneous source for the volcano's parental magma. The submarine Hana Ridge lavas derived from a source with Kea-like component and subaerial Honomanu tholeiitic lavas derived from a source with Mauna Loa-like component. The Sr, Nd, Pb isotopic compositions of Hawaiian tholeiitic lavas show elongated array which extends between FOZO and EM1 components. Combining previously published Os and He isotopic data, we infer that the Hawaiian tholeiitic lavas derived from melting of a heterogeneous source consisting of recycled ancient oceanic crust with pelagic sediments, and FOZO (material from deep lower mantle or core mantle boundary) components.