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Lu-Hf geochronology constrains slow burial of crust in active orogens: the Pamir gneiss domes

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Since the ca. 55-Ma onset of the India-Asia collision, the deep crust of Asia accommodated high strain due to >2,000 km of intra-continental convergence. Giant metamorphic domes along the collision zone best manifest this extensive, mid-lower crustal strain. Where analyzed so far, high-grade rocks in these domes clearly record Miocene exhumation; their burial history, on the other hand, is still enigmatic and forms a major hiatus in our understanding of the initial, and most crucial, stages of crustal shortening and orogenesis. The gneiss domes in the Pamir of Tajikistan and Afghanistan expose widely migmatitic rocks that represent some of the highest-grade rocks in the interior of the India–Asia collision zone. We investigated the burial history of deep-crustal rocks in four domes through a combination of petrological techniques and Lu-Hf garnet geochronology.

Ten garnet-bearing metapelite samples, recording peak conditions in the range of 700-750 °C and 6-9 kb, were selected. Garnet formation is texturally related to the breakdown of staurolite, relics of which still occur in the samples that have not undergone widespread muscovite dehydration melting. The Lu-Hf garnet ages for the highest-grade, muscovite-absent samples cluster tightly in the Late Eocene (37.9 $\pm$ 1.1 Ma; 2 s.d.). Samples of lower metamorphic grade systematically yielded younger results. The youngest Lu-Hf garnet age (23.9 $\pm$ 0.6 Ma; 2 s.d.) was acquired from the sample having the highest modal abundance of muscovite and relict staurolite.

The samples represent a ca. 11-km thick section of crust that took ca. 13 Myr to fully progress beyond the conditions of the staurolite-to-garnet reaction. Because this time span greatly exceeds our analytical uncertainty, as well as the duration of garnet growth, we can discern that burial of the Pamir gneiss complexes 1) was a protracted and apparently continuous process, 2) continued until at least 30 Myr after the onset of India-Asia collision, and 3) occurred at an average rate of 0.8 $\pm$ 0.2 mm/yr.

The combination of petrological analysis and high-resolution Lu-Hf garnet geochronology provides a powerful way of quantitatively evaluating prograde histories and burial rates, parameters that are crucially important to geodynamic models of suturing and orogenesis. In the case of the Pamir, these pieces of information clearly demonstrate that burial of crust in response to India-Asia collision was accommodated by the viscous flow of rocks, rather than by tectonic underplating and rapid vertical movement along major thrust faults.