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Recording time: what starts and stops the metamorphic clock in deep orogenic crust?

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During continental collision, crustal rocks are buried, deformed, transformed and exhumed. The rates and timescales of these processes can be constrained by linking geochemical and geochronological data in metamorphic rock-forming and accessory minerals. Many studies of metamorphic timescales focus on single lithologies to shed light on particular stages of the terrane evolution. Mafic rocks typically only record geochronological evidence for their high-grade history. Felsic rocks, on the other hand, tend to yield ages of exhumation processes.

In NW Bhutan, eastern Himalaya, metabasaltic layers and boudins record a complex history involving an early high pressure (eclogite facies, ca 600C, >1.6 GPa) stage, a later high temperature (granulite facies, 800C, ∼1 GPa) stage and a final amphibolite facies (∼600C, 0.7-0.8 GPa) overprint. In their metasedimentary hosts, rock-forming mineral assemblages record granulite facies metamorphism, exhumation, and anatexis, with little to no evidence for high-pressure prograde metamorphism. This terrane provides a rare glimpse into the evolution and exhumation of the deep eastern Himalayan crust, and a detailed case study for deciphering the rates and timescales of deep-crustal processes in orogenic settings.

Our new petrochronological dataset suggests that the metabasites and their host metasediments record different and conflicting tectonic evolutions. Monazite in the metasediments yields 20-15 Ma ages, with trace element chemistry suggesting crystallisation during anatexis and exhumation. Rare hints of an earlier prograde history up to ∼34 Ma old are also preserved. On the other hand, allanite and zircon in the metabasites suggests that eclogite facies conditions still prevailed at ∼ 15 Ma, well after their host metasediments were apparently melting and decompressing. The age of the granulite facies overprint is still unclear in both lithologies. Detailed interrogation of conventional assumptions about how to link 'isotopic age' and 'trace-element-fingerprint stage' in different chronometers is therefore necessary to reconcile the two records.

The dataset highlights the importance of collecting evidence from a variety of different geochronometers in different lithologies in order to provide the most detailed picture of the evolution and exhumation of deep orogenic crust.