Storing metamorphic time: ages, stages, dates and rates

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The identification of the mechanisms by which crust is buried, deformed, transformed and exhumed is aided by the determination of tectonic rates and timescales. Precise and accurate measurement of radiogenic isotope ratios in minerals used as geological clocks is now routine, providing tightly constrained mineral ages. As spatial precision has increased and the requirement for larger analytical volumes has decreased, protracted geochronometer mineral growth has progressively been shown to be the norm in metamorphic rocks. However it is still unclear whether the yielded protracted range of dates is due to protracted crystallization of the geochronometer minerals over a range of PT conditions, an artefact due to analytical sampling of multiple growth zones or due to some other cause. We have analysed U-Th-Pb monazite dates in six samples collected within a few metres of each other from a layered Grt-Bt-Plag-Qtz±St±Ky±Sill gneiss outcrop in central Bhutan. Taken together, the samples yield dates range from ~32-16 Ma. However monazites in only one of the samples yield dates that span the whole range; other samples contain monazites that yield a much more constricted range of dates. The differences in recorded age could be due to bulk composition (same reaction at different times or different monazite-forming reactions), reaction kinetics, and/or the effects of fluid circulation. Our dataset show that minor variations in sampling strategy from a single outcrop can have a major effect on the interpreted age and geological evolution of that outcrop which in turn can have major implications for the tectonic interpretation(s) arising from that dataset. In young orogens such as the Himalaya where events occurring 0.5 Ma apart can now be separated by modern geochronological analyses, it is critical that the geochronometer-forming reactions are tightly tied to the pressure-temperature-deformation evolution of the bulk rock in order to provide a firmer platform for age interpretations.