Constraining the cooling history of the Greater Himalayan Sequence in NW Bhutan

Clare J. Warren[1], Djordje Grujic[2], John M. Cottle[3], N.W. Rogers[1]

[1] Department of Earth and Environmental Sciences, The Open University, Milton Keynes, MK76AA, UK, c.warren@open.ac.uk
[2] Department of Earth Sciences, Dalhousie University, Halifax, Canada, BH3 4R2
[3] Department of Earth Science, University of California, Santa Barbara, CA 93106-9630, USA

Rutile from a mafic granulite, intermediate granulite and mafic amphibolite within juxtaposed litho/tectonostratigraphic units in the Greater Himalayan Sequence (GHS) of NW Bhutan yield overlapping laser ablation multi-collector inductively-coupled plasma mass spectrometry (LA-MC-ICPMS) U-Pb lower intercept cooling ages of 10.1 ± 0.4 Ma, 10.8 ± 0.1 Ma and 10.0 ± 0.1 Ma, respectively. Titanite that grew during an exhumation-related amphibolite-facies overprint on an eclogite-facies mineral assemblage from the neighbouring Jomolhari Massif yields a U-Pb lower intercept cooling age of 14.6 ± 1.2 Ma. The interpretation of cooling rate by linking thermochronometer ages to a single closure temperature, T_C (Dodson, 1973), is shown to not provide as useful insight into cooling rates as matching analysed ages with those calculated from diffusion models. Certain assumptions made in calculating T_C, specifically the assumption of high starting temperature and cooling rate proportional to 1/time, are not applicable to Himalayan timescales and temperature paths. Additionally, T_C requires knowledge of the cooling rate, commonly the unknown parameter of interest. Given the increasing precision of available geochronological data and the computationally undemanding nature of simple diffusion models, there is now little reason not to progress beyond Dodson's 1973 T_C formulation in the quest for determining cooling rates. Numerical diffusion models constrained by previously published temperature-time (Warren et al. 2011) and Pb-diffusion data (Cherniak 2000) suggest that the rutile ages from NW Bhutan may be explained by rapid cooling (>50 °C/Ma) from peak P-T conditions of ca. 800 °C and 1.0 GPa at 14 Ma in the granulite-bearing unit and ca. 650 °C at 12 Ma in the amphibolite-bearing unit. The good fit between the model and analysed ages confirms the relatively high retentivity of Pb in rutile suggested by experimental data (Cherniak 2000). Diffusion modelling additionally suggests that the titanite age is too old to be consistent with the temperature-time paths inferred for the other analysed samples. Instead, the titanite data suggest that the Jomolhari Massif cooled at a rate of ca. 40 °C/Ma from ca. 650 °C at an earlier time of 17-15 Ma. This suggests that the high-grade rocks in the Jomolhari Massif experienced a different cooling history from the rest of the GHS in NW Bhutan. Together these data show that high-grade rocks from three apparently different structural levels of the GHS in NW Bhutan experienced rapid cooling following high temperature metamorphism, but at different times. The highest grade granulite-facies rocks were exhumed from deeper structural levels that are not exposed, preserved, or remain unrecognized west of eastern Nepal. A progressive eastwards change in tectonic regime, metamorphic history and/or exhumation mechanism across the orogen is implied by these thermochronologic data.

References

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