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Two-stage cooling and exhumation of deeply-subducted continents from U-Pb rutile thermochronology

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The deep burial and exhumation of continental crust in collisonal orogens such as the Himalaya and Caledonides exert a strong control on the dynamics of these regions. Cooling age trends from archetypal buried terranes such as the Western Gneiss Complex (WGC) in the Scandinavian Caledonides are key datasets for constructing accurate and comprehensive exhumation models for high- and ultrahigh-pressure rocks. However, despite a large multi-disciplinary research effort, the rates and style of exhumation of such terranes still remains difficult to reliably constrain. This is largely due to complexities in local geology and in the thermochronometric methods that are typically used (e.g., 40Ar/39Ar on mica or hornblende, U-Pb titanite). The U-Pb rutile thermo-chronometer provides a powerful approach to progress in this field, because, unlike many thermochronometers, its closure temperature systematics is relatively well-constrained. In this study, we used LA-ICP-MS trace-element and U-Pb analyses of rutile from eclogite and amphibolite samples from across the WGC. Samples were collected along a subduction- and exhumation-parallel vector and the variability in peak temperature and timing of mid-crustal cooling was constrained by Zr-in-rutile thermometry and U-Pb rutile chronology, respectively. Thermometry results show a stepwise peak temperature profile that decreases from c. 830°C in the UHP domain to 730°C at the UHP-HP transition, remains constant at ∼730°C across most of the terrane, and decreases again to 620°C beyond the eclogite-out boundary. In contrast, U-Pb cooling ages corresponding to temperatures of 500 °C are 380-375 Ma across the terrane up until the region of the eclogite-out boundary, where they increase to c. 400 Ma. The results suggest that exhumation of the WGC was a two stage process involving 1) exhumation by flexural bending at depth and lateral extrusion of shallow rocks towards the foreland, followed by 2) synchronous cooling below 500 °C across the bulk of the terrane. The latter indicates relatively homogeneous mass removal across a large area, which could indicate erosion of a paleo-plateau in the upper plate, similar to the Tibetan Plateau in the India-Asia collisional zone. The Caledonian Orogen developed at near-equatorial latitudes and, thus, the formation of a sustained orogenic plateau could have strongly impacted local and global climate during the Devonian and Carboniferous.