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Double dating (U–Pb and (U–Th)/He) of detrital zircon from the Gonfolite Group (European Alps) and implications for the lag-time approach to detrital thermochronology

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Detrital thermochronologic analyses are increasingly employed to develop quantitative models of landscape evolution and constrain rates of exhumation due to erosion. Crucial for this kind of application is a correct discrimination between thermochronologic ages that record cooling due to exhumation, i.e., the motion of parent rocks towards Earth's surface, and thermochronologic ages that record cooling independent from exhumation, as expected for example in volcanic and shallow-level plutonic rocks. A suitable approach for the identification of magmatic crystallization ages is provided by double dating, which combines for example U–Pb and (U–Th)/He analyses of the same mineral grain. Magmatic zircon crystallized from volcanic or shallow-level plutonic rocks should display identical U–Pb and (U–Th)/He (ZHe) ages within error, because of rapid magma crystallization in the upper crust where country rocks are at temperatures cooler than the partial retention zone of the ZHe system. Conversely, zircon grains crystallized at greater depth and recording cooling during exhumation should display ZHe ages younger than the corresponding U–Pb ages. These latter ZHe ages may constrain the long-term exhumation history of the source rocks according to the lag-time approach, provided that a range of assumptions are properly evaluated (e.g., Malusà and Fitzgerald 2020). Here, we explore the possibility that detrital zircon grains yielding ZHe ages younger than the corresponding U–Pb ages may record country-rock cooling within a contact aureole rather than exhumation. To tackle this issue, we applied a double-dating approach including U-Pb and ZHe analyses to samples of the Gonfolite Group exposed south of the European Alps. The Gonfolite Group largely derives from erosion of the Bergell volcano-plutonic complex and adjacent country rocks, and its mineral-age stratigraphy is extremely well constrained (Malusà et al. 2011, 2016). Analyses were performed in the UTChron Geochronology Facility at University of Texas at Austin. For U-Pb LA-ICPMS depth-profile analysis, all detrital zircon grains were mounted without polishing, which allowed for subsequent ZHe analysis on the same grains. Zircon for ZHe analyses were selected among those not derived from the Bergell complex or other Periadriatic magmatic rocks, as constrained by their U-Pb age. We found that ca 40% of double-dated grains, despite yielding a ZHe age younger than their U-Pb age, likely record cooling within the Bergell contact aureole, not exhumation. These findings have major implications for a correct application of the lag-time approach to detrital thermochronology

and underline the importance of a well-constrained mineral-age stratigraphy for a reliable geologic interpretation.

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