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Extracting quantitative information on denudation and relief history from thermochronological age-elevation profiles: an example from the French Western Alps

P.A. van der Beek (1), P.G. Valla (1), F. Herman (2), J. Braun (3), C. Persano (4), E. Labrin (1), K.J. Dobson (4), and F. Stuart (5)

(1) Laboratoire de Geodynamique des Chaînes Alpines, Université Joseph Fourier, Grenoble, France (pvdbeek@ujf-grenoble.fr, +33-476-51 40 58), (2) Geologisches Institut, ETH Zürich, Zürich, Switzerland, (3) Géosciences Rennes, Université de Rennes 1, Rennes, France, (4) Department of Geographical and Earth Sciences, University of Glasgow, Glasgow, United Kingdom, (5) Scottish Universities Environmental Research Centre, East Kilbride, United Kingdom

Constraining landscape evolution from thermochronological data remains challenging because topography impacts the underlying isotherms and thus disturbs the thermochronometric record. 2D numerical modeling is needed to avoid this pitfall and may allow quantitative estimates on both denudation and relief histories from low temperature thermochronology.

We test this hypothesis in the Ecrins-Pelvoux massif, French Western Alps, a region that has experienced modest tectonic activity but intense glaciation during the last few Myr and that is thus suitable to test the ability of thermochronology to provide independent constraints on denudation rates and relief development. We present new zircon and apatite fission-track and (U-Th)/He data collected along a roughly north-south elevation profile up the north-western flank of La Meije peak (between 1310 and 3215 m elevation). Age-elevation relationships can be interpreted to first order as reflecting a history of continuously increasing regional denudation rates through time from ∼0.16 km/Myr between 27 and 13 Myr ago (recorded by ZFT data) to ∼0.55 km/Myr between 13 and 8 Myr ago (recorded by AFT data). Rapid final cooling to surface temperatures between ∼6 and 4 Myr ago is suggested by partially overlapping AFT and AHe ages. However, the above interpretation is qualitative, one-dimensional and neglects the possible effects of surface topography and its evolution on thermochronometers.

We thus use a 3D thermal-kinematic model (*Pecube*) that enables predictions of thermal histories and thermochronological ages from input exhumation and relief histories; we combine this model with an inversion method based on the neighbourhood algorithm (*NA*) to extract quantitative information on both exhumation rates and relief change from our thermochonological dataset. Our numerical results with all the combined data suggest that exhumation of the Ecrins-Pelvoux massif was episodic and can be divided into at least 3 stages of exhumation during the last 30 Myr: two phases of slow exhumation (0.2 to 0.5 km/Myr) before ∼8 Myr and after ∼5 Myr ago, punctuated by a short phase of rapid exhumation (1.5 to 2.5 km/Myr) between 8 and 5 Myr ago. This rapid exhumation event has recently also been documented around the same period in other external alpine massifs like the Mont Blanc or the Aar.

Concerning landscape evolution, our results suggest that relief carving was significant during the last ∼8 Myr; however, our data cannot resolve whether this topographic change occurred between 8 and 5 Myr ago or later, and thus are unable to relate relief production directly to Quaternary glaciations.