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Deciphering rock cooling histories in the European Alps using ESR and OSL thermochronometry

xiaoxia wen, Melanie Bartz, Leif Anderson, and Georgina King
University of Lausanne, Institute of Earth Surface Dynamics, Faculty of Geosciences and the Environment, Switzerland
(xiaoxia.wen@unil.ch)

The impact of Quaternary glaciation on rates of erosion and the timing of Alpine valley incision remains disputed. This is mainly due to a lack of geochronological methods that cover the timespan of 10^3-10^6 years. While conventional thermochronometers like (U-Th-He) in apatite can constrain timescales of 10^6 years, and cosmogenic nuclide (CN) dating timescales of 10^1-10^3 years, it remains difficult to resolve changes in erosion rates at the timescale of glacial/interglacial cycles. To fill this temporal gap, we develop electron spin resonance (ESR) thermochronometry using both the Al and Ti centres in quartz. The combination of ESR and optically stimulated luminescence (OSL) thermochronometry, as well as numerical modelling approaches, will allow the development of a multi-thermochronometric system to understand rock cooling histories, enabling changes in erosion rates to be related to glacial advance and retreat.

In this study, we focus on the western European Alps, which were intensively glaciated during the Quaternary. Three vertical transects are targeted in the Rhône valley, which is thought to have substantially deepened around 1 million years ago[1]. The first transect consists of seven quartz samples, which were used for (i) optimizing the measurement protocols (i.e., preheat conditions, dose recovery), (ii) analyzing ESR signal growth and thermal stability of the Al and Ti signals to estimate kinetic trap parameters; and (iii) inverting the ESR data to constrain rock cooling histories.

A series of laboratory experiments show the potential of the single aliquot regenerative dose protocol. The Al and Ti signals show similar thermal stability between different samples in the same transect and yield mid-Pleistocene ages. Preliminary inversion of the data shows that the low closure temperatures of the Al and Ti signals in quartz allow the Late Quaternary exhumation of the Alpine valleys to be resolved. Our new ESR thermochronometry results will be supported by OSL thermochronometry measurements, CN dating and also the high density of existing thermochronometric data [e.g. 1] providing new insights into the glacial incision history during the Quaternary and especially how erosion rates varied temporally under a changing climate.

Keywords glacial erosion; landscape evolution; ESR; European Alps

Reference:

[1] Valla, P.G., D.L. Shuster, and P.A. van der Beek. 2011. Significant increase in relief of the European Alps during mid-Pleistocene glaciations, Nature Geoscience. 4(10): p. 688-692.