Geophysical Research Abstracts
Vol. 14, EGU2012-1902, 2012
EGU General Assembly 2012

Extracting denudation and relief histories from thermochronology data: rethinking sampling strategies?

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Thermochronological age-elevation profiles have been widely used to infer exhumation histories of mountain belts. However, recent studies have shown that this sampling strategy may not be the most pertinent for quantitatively inferring landscape evolution, in particular potential Neogene-Quaternary relief development in response to climate change.

Here, we investigate the ability of combining different thermochronology data sampling schemes with numerical modeling to better constrain both denudation rates and relief changes. We first produce synthetic thermochronology datasets for a real Alpine topography under a specific exhumation and relief scenario, using the thermal-kinematic model Pecube. We then adopt an inverse approach based on the Neighborhood Algorithm to quantitatively assess the resolution of different thermochronology datasets collected following steep elevation profiles, long transects and/or valley bottom sampling. We also test the effect of the modeling approach on denudation and relief predictions, in particular the influence of the topographic grid resolution.

Our results show that sampling along a single steep (short-wavelength) elevation profile does not allow to quantitatively constrain both denudation and relief histories. Numerical outputs evidence tradeoffs that clearly limit the capacity of simultaneously resolving denudation rates and relief change. Quantitative predictions are only slightly different when combining steep elevation profiles along different valleys, but are highly improved when using long transects or valley-bottom samples combined with an elevation profile. More importantly, output resolution on relief-change predictions may be increased by a factor of 2 when using spatially distributed datasets. Simulations with different model topography resolutions show that degrading the resolution for computational efficiency may result in a loss of quantitative information on denudation rates and relief history.

Finally, we apply the above methodology to two real datasets within the Western Alps, and compare the output predictions concerning exhumation and relief evolution. In summary, we highlight that both thermochronological sampling and modeling strategies can have a significant influence on predicted denudation and relief histories; thus collecting and interpreting thermochronology data may require a-priori sensitivity tests to design the optimal strategy. This presentation was supported by the EUROCORES programme TOPO-EUROPE of the European Science Foundation.