Geophysical Research Abstracts,
Vol. 11, EGU2009-3394, 2009
EGU General Assembly 2009

Inversion of thermochronological data to extract independent constraints on denudation and relief evolution

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We explore the capacity of low temperature thermochronological data, in particular age-elevation profiles, to provide independent constraints on both the exhumation and relief history of mountain belts. Age-elevation relationships (AER) have been widely used to provide information about orogen exhumation but the analyses of AER generally remain qualitative and limited to the identification of breaks or changes in slope. Although numerical models are now used to address these issues, most of these are 1D simulations; moreover they are generally only based on a single or perhaps two thermocronometers and thus only capture the denudation history for a short period of time regarding the whole evolution of the studied area. These investigations miss crucial information contained in the data, especially concerning the evolution of the topography and the 2D effects of topography on the underlying isotherms.

We aim to establish what quantitative estimates on relief evolution can be extracted from thermochronological data. To address this issue, we use a three dimensional thermal evolution 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 inverse synthetic data and eventually extract quantitative information on exhumation and relief change. We first explore two end-member scenarios with varying denudation rates or topography. We run several inversions adding progressively different thermochronometers to examine which kind of thermochronological dataset provides best estimates on denudation, relief evolution and timing for each end-member scenario. We then test various denudation histories and amplitude of relief changes to determine in which settings quantitative information on landscape evolution can be extracted from thermochronological data. In a separate contribution, we apply this approach to a "real-world" dataset.

Our results on synthetic data suggest that multiple thermochronometers are required to discriminate between different exhumation and relief history scenarios. However, in low denudation settings, moderate relief changes appear difficult to quantify using these datasets and we suggest that these thermochronometers may not be the most suitable for recording recent relief changes during their cooling. Using new thermochronometers (for instance 4He/3He on apatite), as well as improving the ways relief changes are included in numerical models, may be powerful tools for extracting relief history and thus better constraining the impact of climate change on orogen development.