Geophysical Research Abstracts
Vol. 14, EGU2012-1128, 2012
EGU General Assembly 2012

How to extract thermal structure and erosional denudation of batholiths from low-temperature thermochronology

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A growing body of evidence indicates that many igneous bodies result from the agglomeration of discrete smaller intrusions. Repeated injection of small magma intrusions in the crust results in a temperature structure that is fundamentally different from that resulting from the quasi-instantaneous emplacement of a single large magma body and could significantly perturb cooling and exhumation histories derived from low-temperature thermochronology in continental magmatic arc. Here, we present a new method integrating low-temperature thermochronology with numerical thermo-kinematic models to study the relative effects of magmatic and surface processes on the thermal evolution of the crust around the well-studied Chilliwack batholith in the Cenozoic North Cascades arc (Washington State, USA). Apatite and zircon (U-Th)/He and apatite fission-track data from two age-elevation profiles that are located 5-7 km south of the Chilliwack batholith show that spatial and temporal variability in geothermal gradients linked to magma emplacement can be constrained and separated from exhumation processes. During emplacement of the Chilliwack batholith at ∼35-20 Ma, the geothermal gradient of the country rocks increased to a very high steady-state value (∼45°C/km), which is likely a function of magma flux and the distance from the magma source area. Including temporally varying geothermal gradients in the analysis allows quantifying the thermal perturbation associated with magmatic intrusions and retrieving a relatively simple denudation history from the data, which is consistent with independent evidence for the uplift and erosional evolution of the North Cascades. More generally, this study highlights that a combined approach including thermo-kinematic modelling and low-temperature thermochronology opens new opportunities to study the thermal structure and its evolution in magmatic arc systems.