Constraining denudation in Scotland by using a combination of low temperature thermochronometers

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Mantle plumes may influence patterns of denudation of the crust underneath which they impinge. In Scotland the offshore record indicates that sedimentation was enhanced in several pulses at around 60 Ma. The correspondence of these pulses with volcanic activity related to the ancenstral Icelandic plume has been taken to indicate that erosion and hence sedimentation in the Palaeogene was dominated by the mantle plume activity.

Here we present new apatite fission track and (U-Th)/He data from two vertical profiles and one about 1300 m deep borehole from the Scottish Highlands and the outer Hebrides. Both apatite (U-Th)/He and fission track ages from the vertical profiles are at least 30 Myr older than the Tertiary magmatic activity. We have combined the two thermochronometers in a novel way that provides a precise estimates of the palaeotemperatures experienced by the samples at the time of the plume activity. Exploiting the fact that the samples lie on vertical profiles we are able to constrain the palaeogeothermal gradient and, thus, to calculate the amount of denudation since the Tertiary. Also by modelling apatite fission track and (U-Th)/He together we have constrained timing, amount and rates of denudation in Scotland through time. We conclude that the Scottish Highlands have experienced a period of rapid denudation between 80 and 40 Ma during which between 1.3 and 1.8 km of crust were removed.

The low temperature thermochronological data do not show a Neogene rapid denudational event, suggested by geomorphological and sedimentological records in other areas of the North Atlantic. We conclude that either northern Britain was not affected by this event, or its magnitude was not enough (less than 1 km) to affect the fission track and/or the (U-Th)/He systematic.

Timing of accelerated glacial denudation constrained by $^{4}He/^{3}He$ thermochronometry

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The thermal structure of the uppermost few kilometers beneath the surface responds to major changes in the topographic relief of mountain ranges. A record of this thermal structure through time permits testing of tectonic and geomorphic hypotheses, and quantification of rates of topographic evolution. $^{4}He/^{3}He$ thermochronometry of apatite constrains the set of possible time-temperature (*t-T*) histories that individual samples experienced between ~80°C and ~20°C. Unlike conventional "(U-Th)/He age-elevation" relationships, the *t-T* paths do not depend on the He ages or relative positions of other samples; each sample provides independent information on its own thermal history. By combining the *t-T* paths of multiple samples (e.g., along a vertical or horizontal transect), the evolving subsurface thermal structure is revealed. For instance, a vertically stacked set of *t-T* paths reveals the near-surface geothermal gradient through time. Likewise, major changes in the thermal field should be recorded in proximate samples.

We present the application of this approach to test a hypothesis recently proposed by Ehlers et al. (*Nature* in review) on the southern Coast Mountains in British Columbia, Canada. Using conventional (U-Th)/He ages and a thermal-kinematic model, they concluded that 1.0 to 2.2 km of exhumation occurred along the western flank of present day Mt. Waddington sometime since ~7.5 Ma. Our results independently corroborate their hypothesis and constrain the onset of accelerated denudation at the present location of the Klinaklina river valley to have initiated at ~1.8 ± 0.2 Ma. At least 2 km must have been removed from that location at a rate of > 5 mm/yr. The timing of this accelerated denudation correlates with enhanced Pleistocene glaciation in the region.