Patterns of relief development in a glacial landscape constrained by apatite $^4He/^3He$ thermochronometry

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Apatite $^4He/^3He$ thermochronometry of bedrock samples collected from high-relief and heavily glaciated terrain near Milford Sound in Fiordland, New Zealand reveals clear differences between the cooling histories of high- and low-elevation samples. Across a ~21 km by ~38 km region including 33 sample sites, the youngest observed apatite (U-Th)/He ages ~1 Ma generally occur at cirque floor elevations (~500-700 m elevation) rather than at sea level where (U-Th)/He ages approach ~2 Ma; the oldest ages approach ~3.0 Ma at ~1900 m. This general age-elevation relationship is remarkably consistent across the region which includes multiple valley systems draining towards both the NW and SE from the main divide. Thermal histories constrained by $^4He/^3He$ thermochronometry of three vertically oriented samples from one of these valleys collected along the headwall of a ~1100 meter deep cirque indicate that since ~1 Ma: (i) rocks presently located near the cirque rim (~1720 m elevation) have resided at temperatures <25 ^oC, while (ii) rocks at the floor of the cirque (~575 m elevation) continuously cooled from ~75-110 ^oC to the present surface temperature. These thermal histories indicate that most of the cirque relief developed over the last ~1 Ma and/or the sub-surface thermal field was highly perturbed during that time interval over an ~1 km horizontal scale. We interpret sample cooling histories and (U-Th)/He ages in conjunction with a 3-D thermo-kinematic model of subsurface temperature evolution [1] in response to arbitrary changes in topography. The dataset constrains local rates and patterns of glacial valley development superimposed on high rock uplift rates while clearly excluding "steady-state" relief and uniform deepening along valley longitudinal axes over the Quaternary. We find that the dataset is best explained by models involving headward propagation of incision along the longitudinal axis of a particular valley system.

References

[1] J. Braun, Pecube: a new finite-element code to solve the 3D heat transport equation including the effects of a time-varying, finite amplitude surface topography, Computers & Geosciences 29(2003) 787-794.