Tectonically-Controlled Exhumation versus Climatically Driven Relief Development in the Valais Area (Western European Alps) Revealed by Apatite (U-Th-Sm)/He and $^4He/^3He$ Thermochronometry.

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The Neogene evolution of the European Alps and potential climatic and/or tectonic controls on denudation rates and relief development remain debated. Pliocene-Quaternary increases in both *in-situ* denudation rates and sediment flux to surrounding basins are suggested to have been caused by climatically-induced relief amplification (in particular glacial valley incision). However, geomorphologic and sedimentologic studies suggests the transition from fluvial to oscillations between glacial/fluvial conditions only occurred at ~1 Ma and there is no direct quantitative constraint on topographic change during Pliocene-Quaternary times.

Here we present new apatite (U-Th-Sm)/He data from 2 vertical transects along the Rhône valley (Valais area, Swiss Alps). Previous thermochronology studies, employing apatite fission-track and (U-Th)/He data, have reported an increase in denudation rates ~5 Ma ago in this area; however the very recent (i.e. last 2-3 Ma) evolution of topography and potential valley incision is not constrained by these data. We also selected a subset of key samples from these two profiles for which we applied a novel method based on $^4He/^3He$ thermochronometry and a random search algorithm to identify permissible thermal histories below ~80 °C. These thermal histories are compared to denudation and relief scenarios obtained from numerical inversion of our (U-Th-Sm)/He ages and literature data using the 3D thermo-kinematic model *Pecube*.

Our $^4He/^3He$ results show rapid cooling before ~5-4 Ma followed by a quiescent phase with little cooling. This early cooling, mainly shown by top-profile samples, may be due to tectonically-controlled exhumation of the External Crystalline Massifs. Mid-profile samples (~1000 m elevation) reveal subsequent rapid cooling around 3-2 Ma while bottom samples (500 m elevation) only show very recent major cooling (~1 Ma). Onset of rapid cooling since 3-2 Ma is contemporaneous with major climate change in the Northern Hemisphere, i.e., the onset of glaciations in the Northern Hemisphere. We thus suggest this late-stage cooling to be due to the onset of glacial erosion and associated valley deepening in the European Alps.

$^4He/^3He$ thermochronometry provides data that support conventional apatite fission-track and (U-Th)/He ages, and constrains each sample's continuous cooling history below ~80 °C. This method enables us to precisely quantify the final cooling that we relate to recent valley deepening in the Swiss Alps. Further investigations in mountain belts may use $^4He/^3He$ thermochronometry to more precisely constrain climatically-driven topography evolution.