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Intra-catchment variability and significance of catchment-averaged denudation rates from ^{10}Be concentrations in stream sediments: a ^{10}Be-budget of the Etages catchment, French Western Alps

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As most of the European Alps, The Ecrins-Pelvoux massif (French Western Alps) was extensively glaciated during Quaternary glaciations, leading to strong rejuvenation of its morphology. The massif therefore provides a suitable area to study the efficiency of erosion processes in relief evolution on postglacial timescales. Denudation rates inferred from in-situ produced ^{10}Be concentrations in stream sediments, obtained from 12 catchments throughout the Ecrins-Pelvoux massif, have been recently shown to correlate with mean catchment elevation in the absence of significant relationships with other morphometric parameters (Delunel et al., in press). We have proposed that the present-day denudation of Ecrins-Pelvoux massif climatically driven trough increasing frost-controlled processes with elevation, providing a mechanistic link for the inferred feedback between uplift, elevation and denudation rates observed in the European Alps (Wittmann et al., 2007; Champagnac et al., 2009). However, cosmogenic isotope measurements of stream sediments do not allow distinguishing the intrinsic spatial variability of denudation within a catchment. Therefore, we have sought to verify our previous conclusions on a smaller scale within a single catchment, from exhaustive measurements of ^{10}Be concentrations carried by quartz fraction of different sources feeding the high-altitude stream sediment routing system.

We focus our current study on the Etages catchment, a high-elevation hanging tributary of the Vénéon valley (western part of the Ecrins-Pelvoux massif) underlain by homogenous granitic bedrock. This 14 km^2 catchment presents elevations ranging from 1600 m to ∼3600 m (mean catchment elevation ∼2700 m), within the altitudinal range where frost-controlled processes are most efficient in the Western Alps (Delunel et al., in press). This catchment also hosts a small cirque-glacier, remaining from the Little Ice Age glacial advance. We have collected 19 samples on the most representative morphologic features resulting from active high-altitude erosion processes, in order to extract their in-situ produced ^{10}Be signatures.

^{10}Be concentrations measured from these samples vary strongly from 0.1×10^5 to 6.3×10^5 atoms g^{-1}. Beryllium content of glacial materials varies from 0 (i.e. undistinguishable from procedural blanks) close to the present-day glacier position to 0.8×10^5 atoms g^{-1} toward the LIA moraines. Scree-slope materials collected at different levels within the catchment have slightly higher ^{10}Be concentrations (0.4 to 0.7×10^5 atoms g^{-1}). Regolith material collected close to the highest crests carries much higher concentrations (1.4 to 4.2×10^5 atoms g^{-1}). Bare rocks that deliver the material to form regolith are also characterized by relatively high ^{10}Be concentrations, ranging from 4.2 to 6.3×10^5 atoms g^{-1}. Finally, stream sediments collected at the outlet of the Etages catchment carry a ^{10}Be concentration of only 0.2×10^5 atoms g^{-1}. These ^{10}Be concentration measurements at a single catchment scale thus suggest the processes within a catchment to be more complex than our initial interpretation based on catchment-wide erosion rates on the massif scale.

Therefore, we performed numerical modelling based on the spatial variability of erosion rates within this catchment in order to explain how the wide range of initial ^{10}Be concentrations evolves toward those measured within downstream sediments. Although glacial material with low ^{10}Be content cannot be rejected as contributing to the stream sediment signature, results obtained from this model suggest the significant role of bedrock gorges that rapidly incise the area between hanging tributaries and main trunk valleys (Valla et al., 2010) in the ^{10}Be signature carried by stream sediments. Our study hence shows that combining cosmogenic isotope measurements with

numerical modelling may help to significantly improve our understanding of which processes govern the relief evolution in high elevation areas on post-glacial timescales.