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# Geomorphological response of a landscape to long-term tectonic and glacial processes: the upper Rhône basin, Central Swiss Alps

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The Rhône River in the Central Swiss Alps drains a 5380 km$^2$ large basin that shows a high spatial variability of bedrock lithology, exhumation rate, glacial conditioning and climate. All of these factors were recently discussed to control erosion rates in orogenic settings in general, and particularly in the Alps (e.g. Wittmann et al. 2007, Vernon et al. 2008, Norton et al. 2010a). Thanks to various and densely distributed data, the upper Rhône basin located between the Aar massif and Lake Geneva is a suitable natural laboratory to analyze the landscape's geomorphological state and controlling factors at a basin-scale.
In this study, we extract geomorphological parameters along the channels of ca. 50 tributary basins of various sizes that contribute to the sediment budget of the Rhône River either through sediment supply by torrents or debris flows. Their catchments are located in either granitic basement rocks (External Massifs), oceanic meta-sedimentary and ophiolitic rocks (Penninic nappes) or fine-grained continental-margin sediments (Helvetic nappes). The analysis of longitudinal river profiles from DEMs and slope/area relationships show that all tributary rivers within the Rhône basin are in topographic transient state that is expressed by mainly convex or concave-convex channel shapes with several knickpoints of either tectonic-lithological or glacial origin. Furthermore, the frequency distribution of elevations (hypsometry) along the river channel allows identifying glacially inherited morphologies and the recent erosional front. The combination of those different geomorphological data yields to a categorization of the tributary rivers into three endmember groups: (1) streams with highly convex profiles, testifying to a strong glacial inheritance, (2) concave-convex channels with several knickzones and inherited morphologies of past glaciations, (3) predominantly concave, relatively steep rivers with minor knickpoints and inner gorges. Assuming that increasing concavity is an expression of advancing topographic equilibration (Wobus et al. 2006, and others), tributaries within the Rhône basin are in different states of equilibrium. Interestingly, the three groups correspond with distinct litho-tectonic units: Tributaries of group 1 are frequently found in the External Massifs, whereas channels of group 2 and 3 are located in the Penninic and Helvetic nappes, respectively. Fission-track data from the Alps (Vernon et al. 2008) also suggest a spatially variable exhumation history closely related to the different litho-tectonic units, ranging from youngest exhumation in the External Massifs, intermediate in the Helvetic units and oldest in the Penninic units.
Non-equilibrated river profiles in the External Massifs can be explained by a combination of recent glaciation and exhumation. In contrast, river profiles in the Helvetic nappes appear to be closer to topographic steady state. Rivers located in the Penninic nappes, which show much older exhumation ages, were probably perturbed mainly by multiple glaciations and have not equilibrated yet. These observations suggest that differences in response times of river channels are probably conditioned by the differences in lithologies and tectonic histories of the three litho-tectonic domains.

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