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Landscape resistance: using drainage networks as deformation markers

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Fluvial networks determine to a large extent the structure and geometry of erosive landscapes in mountain ranges. As a consequence it is fundamental to understand how they develop and evolve in order to reconstruct and predict landscape evolution in orogens. A particularly important problem is the degree to which fluvial networks and basin boundaries evolve and change through their existence.

Two end members may be invoked. On one hand, river networks are rather dynamic, changing and reorganizing frequently during orogen evolution. In this view, landscapes mostly reflect the present stage of the tectonic forcing, with a minor component of "memory". On the other hand, river networks may also be largely static in the landscape, resistant to deformation, thus acting as potentially useful passive markers of the crustal strain. In this view, networks develop in the foreland, and are then passively advected into the relief by outward growth of the orogen [1]. The "dynamic" view has long found support in a variety of observations evoking river captures and drainage network changes (wind gaps, some hanging valleys, sinuous shape of water divides, inferred changes of detrital sources), and is reproduced in some analogue and numerical models [2]. However, there are also a large number of observations which support a contrary view according which drainage network are resistant to deformation. Some notorious examples are antecedent rivers and drainage systems cutting through lithological and geological structures (folds and faults), drainage systems extending behind the main drainage divide in large mountain ranges, and preservation of superficial cover rocks adjacent to valleys deeply incised into the basement. Some spectacular plane deformation of large river basins also points to the large resistance of river networks to plane deformation and their difficulty to reorganize [3].

We present a novel conceptual framework that allows distinguishing the different cases of landscape reaction to tectonic forcing. We study the effect of end-members horizontal versus vertical and discrete versus continuous deformation on drainage networks.

We develop a method for quantitatively assessing the degree of drainage basin deformation based on the flowing angles of transverse rivers. Application to the Western European Alps shows a set of rivers that deviate from their "natural" azimuth. These rivers all cut through zones of right lateral slip related to rotation of Apulia with respect to stable Europe, with deformation focused on faults [4] with a potential internal deformation of surrounding blocks. We test the variation of local drainage direction vs. the general slope of the belt and compare this against structural and GPS data of the strain field [5].

[1]Castelltort, S. & Simpson, G. (2006). [2]Hasbargen, L.E. & Paola, C. (2000). [3]Hallet, B. & Molnar, P. (2001). [4]Hubbard, M. & Mancktelow, N.S. (1992). [5]Delacou, B. et al. (2008).