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Sediment budgets by detrital geochronology and new perspectives in understanding orogenic erosion (solicited)

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Low-temperature thermochronological data provide an estimate of the average exhumation rate from the partial retention zone to the surface. The timescale the rate is referred to largely depends on the distribution of thermochronological ages in the study area, which may be inadequate to constrain fast orogenic processes. New perspectives to investigate orogenic erosion and its linkage with climate and tectonics are provided by quantitative sediment budgets based on detrital geochronological analyses, which allows a much greater time resolution chiefly depending on available biostratigraphic constraints.

Detrital samples derived from the mixing of geochronologically distinguishable detrital sources are expected to yield polymodal grain-age distributions that include different grain-age populations. The relative size between populations depends on (i) the relative size of the catchment areas, (ii) the mineral fertility of the parent bedrock, and (iii) the erosion rate in each catchment. If we know two of these factors, then we can calculate the third (Resentini & Malusà, 2012). A reliable approach to mineral fertility quantification thus represents a fundamental prerequisite for any sediment budget based on single-mineral data. In a temperate/cold climate where chemical weathering is minor, mineral fertility in the source rocks can be effectively determined by measuring the mineral concentration in the sediment they produce, provided that a range of potential sources of bias are properly accounted for and minimized (Malusà et al., 2013). Specifically, this approach requires that no significant modification has been induced by hydrodynamic processes in the natural environment (as tested by basic principles of hydraulic sorting), and that no bias is later introduced during mineral separation. Orogen-scale fertility maps are thus easily produced for different minerals thanks to the analysis of a reasonably low number of modern sand samples.

Potentials and pitfalls of the method are illustrated with examples from the European Alps, also including preliminary applications to fossil sedimentary successions. In the Alps, both apatite and zircon concentrations span over two orders of magnitude in different subcatchments, with a major impact on sediment budgets that cannot be easily dismissed by untenable constant-fertility assumptions. Mineral fertility estimates are consistent with predictions based on geochemical analyses of bulk sediment, and poorly affected by variability in replicate samples and by minor selective-entrainment effects in alpine valleys (Malusà et al., submitted). Moreover, single-mineral analyses minimize the bias introduced by hydraulic sorting and by the differential stability of mineral species during weathering and diagenesis. The spatial resolution of the inferred erosion patterns can be easily increased by using different minerals or different geochronometers on the same mineral, and additionally cross-checked by other independent methods.

References

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