COMMENT: doi: 10.1130/G24664C.1

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Champagnac et al. (2007) deduced that rock uplift in the western Alps is occurring mainly as the isostatic response to erosion and is thus being largely driven by climate rather than by other potential causes such as plate motions. They reported that spatial average erosion rates within the Alps increased from ~0.15 to ~0.3 mm yr⁻¹ around ~6–5 Ma (a probable effect of aridification and base-level lowering during the Messinian salinity crisis; cf. Bridgland and Westaway, 2008), then increased progressively to a value, typical since ~1 Ma, of ~0.48 mm yr⁻¹. Using flexural isostatic modeling, they showed that this erosion history can account for ~500 m of rock uplift since ~1 Ma, at ~0.5 mm yr⁻¹. They compared this rate with a geodetic measurement of ~1.1 mm yr⁻¹, and thus concluded that the isostatic response to erosion is the principal mechanism causing uplift in the Alps.

The idea that rates of rock uplift in upland and mountain regions of central Europe increased around the early-middle Pleistocene boundary is not new; it was first suggested by Kukla (1975). It has also long been appreciated that this event corresponds to the mid-Pleistocene revolution (MPR) in climate (i.e., the switch from ~40 ka to ~100 ka cyclicity), suggesting a cause-and-effect relationship. The literature includes many descriptions of mechanisms whereby the climate cyclicity has influenced rates of surface processes and has thus controlled fluvial sediment fluxes (e.g., Zeuner, 1945; Vandenberghe, 1995, 2008; Bridgland, 2000). On the basis of many analyses, it has therefore been argued that the rock uplift observed across most of Europe (and, indeed, in other regions worldwide, typically revealed by flights of fluvial terraces) is being driven by the effect of climate on surface processes (e.g., Westaway, 2002a; Bridgland and Westaway, 2008). There is no reason why the Alps should differ from the rest of the continent; the difficulty has concerned proving it, because the relatively rapid erosion has obliterated evidence that might otherwise exist. Champagnac et al. have now demonstrated that the Alps are consistent with the well-documented regional context, a significant achievement.

However, it has also long been realized that, in many parts of Europe and elsewhere, rates of rock uplift exceed spatially averaged erosion rates, in some cases dramatically so. This effect is not explicable using conventional isostatic modeling; the need to account for it has led to the development of new modeling software (e.g., Westway, 2002b; Westaway et al., 2002), the key feature of which is the incorporation into the isostatic response of flow in the mobile lower crust induced by the surface processes. The idea that lower-crustal flow is significant within the continental crust has its critics (e.g., McKenzie et al., 2000; Jackson, 2002), whose views have likewise been vigorously challenged (e.g., Handy and Brun, 2004; Morley and Westaway, 2006). Westaway et al. (2003) presented a simple test of the issue, noting that rates of Quaternary vertical crustal motion are orders-of-magnitude less in crustal regions, which lack mobile lower crust, than in regions of “normal” continental crust, thus indicating that the presence of this mobile layer is key to understanding the significant “epirogenic” vertical crustal motions observed in the latter class of region.

Modeling using these techniques, applied to many localities in Europe and elsewhere (e.g., Westaway, 2002a; Bridgland and Westaway, 2008), can account for the available evidence. A characteristic feature of such solutions is that, under the non-steady-state conditions that follow an increase in erosion rate, the spatially averaged influx of lower crust exceeds the spatially averaged loss of mass by erosion, causing net crustal thickening and surface uplift, with rock uplift faster than the erosion. The evidence from the Alps that erosion since the MPR, at a spatially averaged rate of ~0.48 mm yr⁻¹, has driven rock uplift at ~1.1 mm yr⁻¹ suggests this effect; this is entirely reasonable, as the thick crust (up to 56 km; Cloetingh et al., 2005) and resulting high Moho temperature (at least 900 °C, from the ~40 °C km⁻¹ near-surface geothermal gradient; e.g., Rybach and Finckh, 1979) imply highly mobile, lower crust beneath the Alps. Thus, rather than trying to explain away this difference in rates, Champagnac et al. should note that it is characteristic within continental crust under the non-steady-state conditions that result from the effect of climate change on rates of surface processes.

REFERENCES CITED


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