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Glacial isostatic uplift of the European Alps

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Present-day vertical movements of the Earth's surface are mostly due to tectonic deformation, volcanic processes, and crustal loading/unloading. In tectonically stable regions of North America and Scandinavia, vertical movements are almost entirely attributable to glacial isostatic rebound after the melting of the Laurentide and Fennoscandian ice sheets. In contrast, the Pleistocene Alpine icecap grew on a younger mountain belt that formed by collision of the European and African plates, still subject to shortening. Therefore, measured uplift is potentially a composite signal of tectonic shortening and unloading after deglaciation and concomitant erosion. Deciphering the contributions of tectonics and crustal unloading to present-day uplift rates in formerly-glaciated mountain belts is a prerequisite to using uplift data to estimate the viscosity structure of the Earth's mantle, a key variable in geodynamics. We evaluate the post-LGM glacial-isostatic rebound of the Alps following a 4-tiered procedure. First, we estimated the thickness distribution of sedimentary valley fills to create a bedrock map of the entire mountain belt. Second, this map was used as topographic basis for the reconstruction of the Alpine icecap using a numerical ice-flow model. Third, we estimated the equilibrium deflection of the Alpine lithosphere, using the combined loads of ice and sediments with a variable effective elastic thickness. Finally, we used an exponential decay function to infer the residual deflection and the present-day uplift rate for a range of upper mantle viscosities. Our analysis shows that virtually all of the geodetically measured surface uplift in the Swiss and the Austrian Alps can be attributed to glacial unloading and redistribution of sediments, assuming an upper-mantle viscosity lower than that inferred for an old craton (e.g., Fennoscandia), but higher than that for a region with recent crustal thinning (e.g., Basin and Range province).