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Exhumation in the Alps and relief adjustment by deep-seated gravitational slope deformation

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Although the relationships between tectonic and surface processes have been emphasized by several investigators, the impact of large deep-seated gravitational slope deformations (DSGSD) on orogenic landscapes is still poorly understood. In this perspective, we collected the first original orogen-scale DSGSD inventory, covering the entire European Alps (area > 90,000 km2) and including about 900 individual phenomena. DSGSD frequency and distribution were analysed with respect to a variety of descriptors, namely topographic (elevation, slope, relief), geological (lithology, seismicity, rock uplift, exhumation), and climatic (rainfall pattern, distribution of glacial features). Exhumation was constrained by a comprehensive dataset of published apatite and zircon fission-track ages. DSGSD spatial distribution has been evaluated along 30 swath profiles perpendicular to the belt axis and analysed using spatial statistics. Topographic characters of orogenic landscape (e.g. hypsography, fractal descriptors) revealed different signatures in areas with different exhumation patterns. Climate-driven fast exhumed areas (apatite ages < 10-15Ma, average annual rainfall > 1400mm, e.g. Lepontine) show low values of mean elevations and local relief, with fluvial processes and catastrophic landslides playing a major role on relief adjustment. Very low DSGSD density is observed in these areas, as well as in tectonically-driven fast exhumed areas (e.g. External Massifs, Tauern Window) and where very low rock uplift and slow exhumation occur (e.g. Southern Alps). Excluding local lithological and structural controls, DSGSDs cluster in slowly exhumed areas with moderate rock uplift rate (apatite ages > 15Ma, e.g. western axial belt, Austroalpine lid), with higher average elevations and high local relief values focused along large, formerly glaciated valleys incised down to the post-glacial base levels of the orogen. In these areas, DSGSDs play a significant role in adjusting post-glacial topography by reducing slope inclinations even down to threshold values typical of steady state topography.