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Deep-seated slope deformations, exhumation and relief in the Alps

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Deep-seated gravitational slope deformations (DSGSDs) are widespread in active collision orogens and influence landscape development. Nevertheless, their relationships with tectonic processes, climate, and relief evolution are still poorly understood. In order to gain new insights in this topic, we completed the first inventory of DSGSD at the scale of the whole Alps, extending over an area of ca. 90,000 km2. Mapping was performed in GoogleEarthTM and based on a variety of diagnostic criteria including morpho-structural evidence, amount of slope deformation, and relationship with drainage pattern, tectonic features, and Quaternary landforms and deposits. Mapping errors were also evaluated by comparison with existing local inventories compiled with different techniques and at various scales by different authors. Mapped features include DSGSDs (868) as well as large landslides (1220), rock avalanches (158), inferred active tectonic morpho-structures (125), as well as large sediment fans (425) and talus slopes (134) associated to DSGSDs.

The distribution of DSGSDs was analysed with respect to several factors including: lithology, major tectonic features, slope morphometry (i.e. local relief, elevation, slope gradient), seismicity, rate of rock uplift and exhumation, distribution of glacial features and rainfall patterns. To identify DSGSD effects on the general pattern of topography, slope morphometry was analysed both inside and outside DSGSD areas. Moreover, we analysed the distribution of DSGSDs, rate of rock uplift and fission track-derived exhumation, LGM glacier thickness, rainfall descriptors, topography, and their relationships along 30 orogen-perpendicular swath profiles characterized by different swath widths.

An area exceeding 5300 km2 is affected by DSGSDs, which occur in a variety of tectonic and geomorphological settings. Nevertheless, they cluster in areas where anisotropic and fractured rock masses and high local relief occur. Their onset is strongly controlled by slope-scale and major tectonic features, including regional tectonic boundaries as well as post-nappe brittle structures. Analyses along swath profiles show that DSGSDs are rare for very low or extremely high exhumation rates, and are mostly located in areas with intermediate-to-high long-term exhumation rates, and high rate of present-day rock uplift (where available). A significant positive correlation between DSGSD areal frequency and local relief is also outlined, with modal local relief values in DSGSD areas in the range 1500-2000 m, indicated in the literature as associated to a sudden increase in erosion rate by large landsliding. Values of slope inclination in DSGSD areas also point to threshold conditions typical of steady state topography. Consistent trends among the distribution of DSGSD and the patterns of exhumation, uplift and relief suggest that DSGSD may represent limiting processes to tectonically-induced relief and exhumation.