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Progress and challenges in the understanding of long term evolution of deep-seated gravitational slope deformations

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Deep-seated gravitational slope deformations (DSGSDs; Agliardi et al., 2001) is a generic term for slow moving (mm year^{-1}) rock-mass movements that encompass the entire mountain slopes or valley flanks occurring in a wide spectrum of terrestrial and extraterrestrial settings (Mège and Bourgeois, 2011). Current progress in mapping technologies, geophysics, modelling and monitoring has provided valuable insights into the distribution, internal structure, mechanics and recent movements of DSGSDs. However, amidst all this progress, long-term ($\geq$102 years) temporal dynamics remains one of the least explored aspects of DSGSDs (Pánek and Klimeš, 2016).
Based on both the in-depth review of published studies from all around the world and several detailed geochronological investigations in the Carpathians, the Crimean peninsula and the Taurus Mts, this paper accents recent progress in the understanding of the lifespan, long-term rates and potential catastrophic accelerations of DSGSDs. Major concern is paid to the differences between glaciated and non-glaciated mountain landscapes. Outcomes of this review can be summarized as follows: (i) DSGSDs occurring outside the limits of Quaternary glaciations reveal more complex and generally longer lifespans. (ii) Despite traditional views, the dating results show that immediate chronological response of DSGSDs to glacier withdrawal is rather rare. On the contrary, there tends to be a significant (millennial) time-lag due to a complex interaction of paraglacial processes. (iii) Some DSGSDs (or their parts) may originate episodically and relatively fast, which is in contradiction to traditional definitions. (iv) Recurrent catastrophic collapses of slopes (e.g. rock avalanches, rockfalls, earthflows) are frequently sourced within DSGSDs bodies, irrespective of whether localized within glaciated or non-glaciated areas.
Although a boom in geochronological methods has significantly improved our knowledge of the temporal dynamics of DSGSDs, it is important to stress that such conclusions rely largely on limited case studies obtained in geographically similar mountains, i.e. especially alpine landscapes. In order to fully resolve the temporal dynamics of DSGSDs, it will be necessary to (i) extend the focus of DSGSDs dating geographically, (ii) provide regional-scale DSGSDs dating, along with the correlation with high-resolution palaeo-proxies, (iii) combine the dating with monitoring, numerical modeling and geophysical investigation on the same DSGSDs, and (iv) develop new dating strategies allowing the evaluation of full lifespane of DSGSDs; i.e. determine the timing of their initiation, development and eventual catastrophic collapses.

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