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Structural geology of large (ancient) rockslides - an indicator for a seismic or climatic origin?

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The stability of rock slopes is often guided by the structural geology of the rocks composing the slope. Geological structures, such as ductile folds, discontinuities as well as brittle faults and fractures, are known factors contributing to a decrease in slope stability according to their orientation in space - with respect to the general orientation of the main slope and its (seismo-) tectonic damage history. Additionally, a rock slope may undergo many forms of gravitationallyinduced, erosional and/or weathering-induced destabilisation.

Rock slope failures may be classified and described according to several factors, such as their volume, displacement mechanisms and velocity. In this work, especially deep-seated and very large failures (with a volume of $>10^7$ m^3) are analyzed with regard to their structural characteristics.

Giant rockslides originate as planar, rotational, wedge, compound, or irregular slope failures. Most of them convert into flow-like rock avalanches during emplacement. Here, we will not detail the evolution of rock slope failures but rather focus on their origin. The main goal is to identify features allowing to distinguish seismic trigger modes from climatic ones, notably on the basis of the source zone rock structures. We will present examples of classical anti-dip slope (and along-strike) rock structures that hint at a seismic origin, but we will also consider a series of mixed structural types, which are more difficult to interprete. This morpho-structural study is supported by numerical modelling results showing that seismic shaking typically induces deeper seated deformation in initially 'stable' rockslopes.

For failures only partially triggered by dynamic shaking, these study results could help to identify the seismic factor in slope evolution. Especially in less seismically active mountain regions, such as the Alps and the Carpathian Mountains, these analyses can be used for paleoseismic studies – provided that dating the seismic initiation of mass movement is possible. For instance, we will show that the "Tamins" and the "Fernpass" rockslides in the Alps present structural and morphological features hinting at a partly seismic origin. Furthermore, we present study cases of ancient rockslides in the SE Carpathians ("Balta" and "Eagle's Lake"), where a pure seismic origin is most probable and currently under discussion (supported by numerical analyses).

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