Strong earthquakes as main trigger mechanism for large pre-historic rock slope failures in Western Tyrol (Austria, Eastern Alps): constraints from lacustrine paleoseismology

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Catastrophic, pre-historic rockslides are generally well studied in terms of geological controls on slope instabilities, dating of failure events and characterization of the transported mass. Regarding their triggering mechanism, however, either changing climatic forces or strong seismic shaking are discussed in literature, since such mechanisms cannot be unambiguously inferred by directly studying the transported mass or the failure scarp.

Here, we present two independent Holocene lacustrine archives in the Eastern Alps (Lake Plansee and Lake Piburger See), both situated within a spatial cluster of seven large and mostly well-dated rockslides that occurred between 4.2 to 3.0 ka cal BP, comprising the Tschirgant, Eibsee and Fernpass rockslides with up to 1 km³ rock mass volume.

To evaluate a potential seismic trigger for these rockslides, we investigated the lacustrine archives of Lake Plansee and Lake Piburgersee with multiple geophysical (multibeam bathymetric mapping, subbottom profiling) and sedimentological methods (e.g. XRF- & CT scanning) on up to 15m long sediment cores. In the deep Lake Plansee (2,87 km²; 77m deep), earthquakes are expressed by coeval, multiple subaqueous mass wasting deposits, while in the small and shallow Lake Piburger See (0,14 km²; 29 m deep), earthquakes have generated soft-sediment deformation structures such as intraclast breccias and folded strata.

The paleoseismic records derived from the investigated lakes contain 13 event deposits most likely induced by strong earthquakes in the Holocene. Comparison to seismic intensities of historical earthquakes reveals that the investigated lake sediments only record earthquakes exceeding the seismic intensity threshold of VI (EMS-98 scale) at the lake site. At least three earthquake-induced deposits at ~6.8, ~4.0 and ~3.0 ka cal BP are found in both lakes suggesting to be stronger than the region's maximum documented earthquake (1930 M5.3 in Namlos). Most of the 13 identified pre-historic earthquakes concentrate in the timeframe around 7.0 – 3.0 ka cal BP coinciding with the majority of rockslide events (6.5 – 3.0 ka cal BP). Conspicuously, two strong earthquakes coincide within age uncertainties with two (Tschirgant and Haiming rockslides; ~3.0 ka cal BP) and at least
three potentially simultaneous, large rockslides (Eibsee, Fernpass and Stötltbach rockslides; ~4.0 ka cal BP), respectively. Moreover, an extraordinarily large earthquake-related deposit at 4.0 ka cal BP in Plansee coincides with rockslides in the lake's vicinity. The same is true for the 3.0 ka cal BP event in Piburger See, pointing also at a spatial coincidence of rockslides and earthquakes.

Our new findings support the interpretation of earthquakes being the major triggering mechanism for large rock slope failures in the Eastern Alps such as e.g. the historically-known Dobratsch rockslide triggered by the AD 1348 Villach earthquake in Carinthia. Changing climatic forces during the Holocene such as heavy rainfall periods may play a significant role in pre-conditioning rock slopes for failure. However, the quiescence in rockslide activity despite a changing climate since 3.0 ka cal BP together with the striking coincidence of the rockslide cluster and the strong earthquakes corroborate the importance of earthquakes as ultimate trigger for large rockslides.