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Small-scale seismogenic soft sediment deformation (Hirlatzhöhle, Upper Austria)

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The Hirlatz Cave lies in the Dachstein Massif about 2 km SW of Hallstatt, in the Upper Austrian Salzkammergut. With a length of 101 km, this karst cave, located in the Dachstein nappe (Northern Calcareous Alps), is the second largest known cave system in Austria. Within the cave, in the so-called Lehmklamm, located 2.8 km southeast of the cave entrance, laminated (mm-scale) Quaternary clay-sized sediments with interbedded fine-grained sandy layers are preserved. In these layers, numerous soft sediment deformation structures are preserved in many layers. The unconsolidated sediments show rhythmic layering of brighter, carbonate and quartz rich, and darker, more clay mineral rich horizontal varve-like layers, that are assumed to be fluvio-lacustrine deposits.

The present study focuses on a very detailed documentation of an approximately 6.8 x 3 m vertical outcrop that was cut by a small brook. Centimeter to millimeter sized water escape structures (intruded cusps and flame structures), folds (detachment folds, fault bend folds) and faults (normal faults, fault propagation folds, bookshelf faults) are described. Because of the geometric analogy to seismogenic structures which have been described at two orders of magnitude larger scales from areas close to the Dead Sea Fault, we suggest that the formation of the investigated soft-sediment structures was also triggered by seismic events. The structures were mainly formed by three different mechanism: (i) North directed gravitational gliding near the sediment surface; (ii) Liquefaction resulting in a density discontinuity and decreasing in shear strength within in the stratified layers; (iii) Extensional faulting that cut through the stratified layers. Observations of coarsening upwards into sandy layers on the top of the outcrop and current ripple indicate a north-directed flow under phreatic conditions, which is opposite to the present flow direction of the vadose water in the cave.

The fact that deformation and erosion mostly occur in the uppermost meter of the outcrop wall suggests a higher seismic activity and at least periodically higher flow rates during sedimentation of the younger deposits. Since several extremely deformed layers occur between undeformed ones, we suggest that deformation of the layers occurred only in the uppermost highly water saturated sediments and that several seismic events lead to the formation of the observed structures. A possible source responsible for the seismic event is the Salzach-Ennstal-Mariazeller-Puchberger (SEMP) strike-slip fault, which accommodates the active extrusion of the Eastern Alps towards the Pannonian Basin.