



## **One hour of catastrophic landscape change in the upper Rhine River valley 9400 years ago**

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The Flims rockslide, which happened about 9400 years ago in the eastern Swiss Alps, is the largest postglacial terrestrial landslide in Europe. The landslide and the huge secondary mass flow it induced completely changed the floor and lower slopes of the Vorderrhein valley over a distance of several tens of kilometres, probably in one hour or less. The landslide began with the sudden detachment of 10-12 km<sup>3</sup> of Jurassic and Cretaceous limestone from the north wall of the Vorderrhein valley. The detached rock mass rapidly fragmented as it accelerated and then struck the Rhein valley floor and the opposing valley wall. Tongues of debris traveled up and down the Vorderrhein. The impact liquefied approximately 1 km<sup>3</sup> of valley-fill sediments, mainly fluvial and deltaic gravel and sand. The liquefied sediment moved as a slurry – the Bonaduz gravel – tens of kilometres downvalley from the impact site, carrying huge fragments of rockslide debris that became stranded on the valley floor, forming hills termed ‘tumas’. Part of the flow was deflected by a cross-valley barrier and flowed 16 km up the Hinterrhein valley (the main tributary of the Vorderrhein), carrying tumas with it. Bonaduz gravel is >65 m thick and fines upward from massive sandy cobble gravel at its base to silty sand at its top. Sedimentologic and geomorphic evidence indicates that the liquefied sediment was transported as a hyperconcentrated flow, possibly above a basal carpet of coarse diamictic sediment that behaved as a debris flow. The large amount of water involved in the Bonaduz flow indicates that at least part of the Flims rockslide entered a former lake in Vorderrhein valley. The rockslide debris impounded the Vorderrhein and formed Lake Ilanz, which persisted for decades or longer before the dam was breached in series of outburst floods. These floods further changed the valley floor below the downstream limit of the landslide. Today, Vorderrhein flows in a spectacular 8-km-long gorge incised up to 400 m in Flims rockslide debris; the river has yet to reach the base of the debris sheet.