New Pieces to the Flims-Tamins Rockslide Puzzle

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Abstract

The huge Flims rockslide in the Swiss Alps has been the focus of scientific study for over 100 years, whereas a nearby rockslide at Tamins that occurred only slightly earlier, is understudied. Field investigations of the Tamins rockslide has provided new insights in its history, as well as that of the Flims rockslide. These investigations, complemented by interpretation of LiDAR imagery, has allowed us to document the sequence of postglacial events in the Vorderrhein river valley. We confirm the hypothesis that the Flims rockslide induced a large debris stream that transported huge volumes of liquefied alluvium, as well as large rafts of rock slide debris (Toma hills), many kilometers both down the Vordderrhein and up the Hinterrhein, its major tributary. The older Tamins rockslide partially impeded and was overrun by the debris stream, dividing it into two lobes.

Keywords

Rockslide • Liquefaction • DGM • Toma hills

155.1 Introduction

Over a period of decades, understanding of the Flims rockslide had been repeatedly declared complete by scientists who have studied it. All questions supposedly were answered, and all processes understood. Such presumptuous declarations contradict Heim's humble remark (1883, p. 309) that every new finding gives rise to new questions. This remark has certainly been proven true for the huge Flims Tamins rockslide area. The Flims landslide is the largest rockslide in the Alps and is easily accessible; thus it has been the focus of substantial research since the days of Heim. In contrast, the nearby, smaller Tamins slide has been almost neglected, which is unfortunate given that it provides important insights into the Flims event.

155.2 The Flims Rockslide

The Flims deposit (Fig. 155.1) has a volume of 9–12 km^3 (Caprez 2008). It was dated to the early Holocene by Poschinger and Haas (1997), and more precisely to 9,480–9,430 cal yr BP by Deplazes et al. (2007). During the landslide, a thick package of Jurassic and Cretaceous limestone slid down inclined bedding planes into the Vorderrhein, smashed into the opposite valley wall, and blocked the Vorderrhein for months, if not years. Parts of the failed rock mass were locally crushed to particles down to the micrometer range (Pollet 2000), yet former rock structures are still partly preserved. Rounded river gravels were injected under high pressure into the slide deposit in several places, similar to magmatic intrusions, due to liquefaction of Quaternary sediments on the floor of the Vorderrhein.

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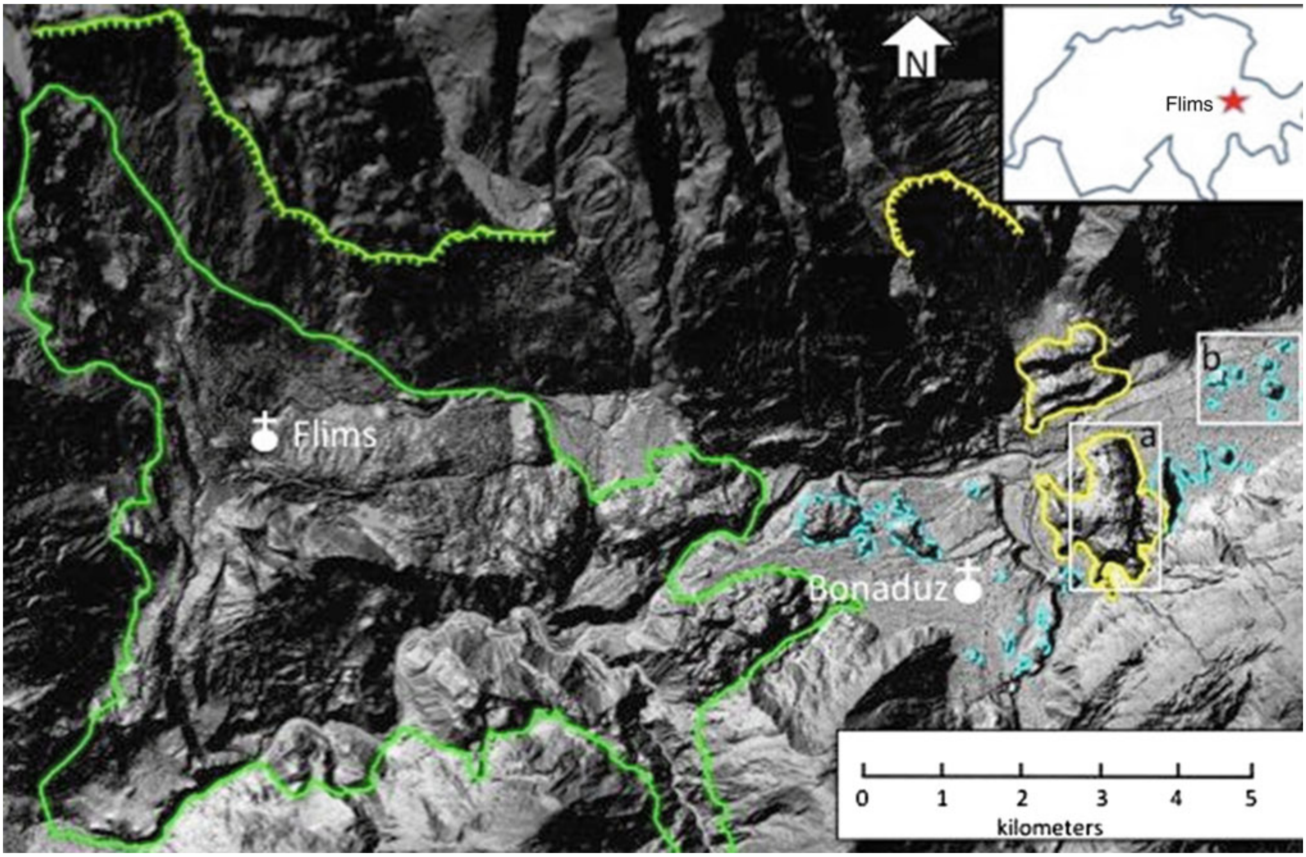

Fig. 155.1 LiDAR-derived hillshade map of the Vorderrhein river valley. To the west is the larger Flims landslide deposit (*green solid line*) and scarp (*green hachured solid line*). To the east is the smaller Tamins deposit (*yellow solid line*) and scarp (*yellow hachured line*). The *dashed lines* delineate Toma hills. The town of Bonaduz sits atop the Bonaduz gravel plain. **a** Figure 155.2. **b** Figure 155.4

155.3 The Tamins Rockslide

The neighbouring Tamins rockslide has a volume of 1.5 km^3 (Abele 1973) and thus is much smaller than the Flims rockslide. In spite of the difference in size, the internal fabric of the two landslides is similar. Field evidence confirms that the Tamins rockslide is older than the Flims event, yet still of postglacial age. It too blocked the Vorderrhein and impounded a lake into which part of the Flims rock slide entered. Part of the surface of the Tamins deposit is smooth, which is atypical of a rockslide, as seen in Fig. 155.2. Some liquefied alluvial and lacustrine deposits can be found on its surface. Because surface exposure dating by Ivy-Ochs et al. (2008) precludes a glacial age, the capping gravels, sands, and silts must have been brought there after the Tamins event and almost certainly during the Flims event.

155.4 The Bonaduz Sediments

A sheet of fining-upward, non-stratified gravel and sand up to 75 m thick underlies the Vorderrhein valley floor near the village of Bonaduz, downstream of the Flims rockslide (Fig. 155.3). Poschinger and Kippel (2009) attributed this sheet of 'Bonaduz sediments' to a giant mobilisation and resedimentation of alluvium triggered by the Flims rockslide. The Bonaduz sediments support isolated hills, without roots, of rockslide debris that still have well preserved internal structures (Fig. 155.4). Some of these so-called Toma hills are up to 50 m high and more than 100 m long. They occur in the Vorderrhein upstream of the Tamins landslide, in the Alpenrhein downstream of Tamins, and in the Hinterrhein. Only a huge stream of liquefied sediment could have carried them up to 10 km from their sources at

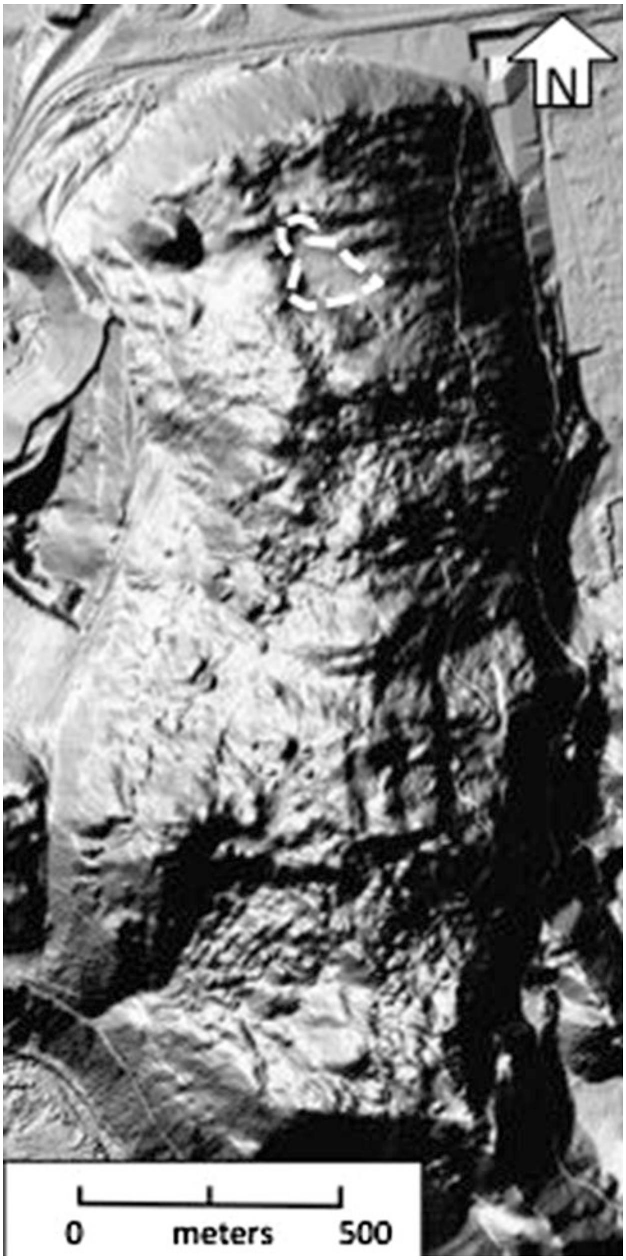

Fig. 155.2 The surface of the north side of the Tamins landslide is smooth and has a discontinuous cover of rounded gravels and sands, for example in the area delineated with the *dashed line*, indicating that it was overtopped during the Bonaduz gravel emplacement event. See Fig. 155.1 for location of image

the margins of the Tamins and Flims rockslides. The Bonaduz unit contains distorted clasts of lacustrine silt up to meters across (Fig. 155.5a). The clasts occur throughout the deposit, from its base to the top and from proximal to distal locations with respect to the Flims landslide. In contrast, the subrounded gravel component at all exposures fines upward, from cobble-size at the base to granules at the top. Subvertical "pipes" (Pavoni pipes) are ubiquitous in most exposures of the Bonaduz gravels. The pipes are elutriated of fine sand and silt, and are found from the base, within cobbly gravel, to the top of the deposit, within very coarse sand (Fig. 155.5b). They are dewatering features that formed when the mass flow came to rest. The sheet of Bonaduz gravels temporarily filled and clogged the confluence area of the Hinterrhein and Vorderrhein rivers. The establishment of a short-lived higher base level changed the regime and paths of these rivers, if only temporarily. Planar stratified sands gravel and rare imbricated cobble layers overlie the Bonaduz sediments and are remnants of this short period of elevated base level in the Hinterrhein-Vorderrhein confluence area. The Bonaduz sediments do not fit any current scheme of mass flow terminology. The term 'debris flow' is not accurate, as this is not a gravitationally driven process; 'gravel slurry' does not approach the scale of the event and is not well-defined; and a 'hyperconcentrated flow' does not produce the fining-upward sequence we observe.

Fig. 155.3 Exposure of typical Bonaduz gravel in a subvertical face; the deposit fines upward

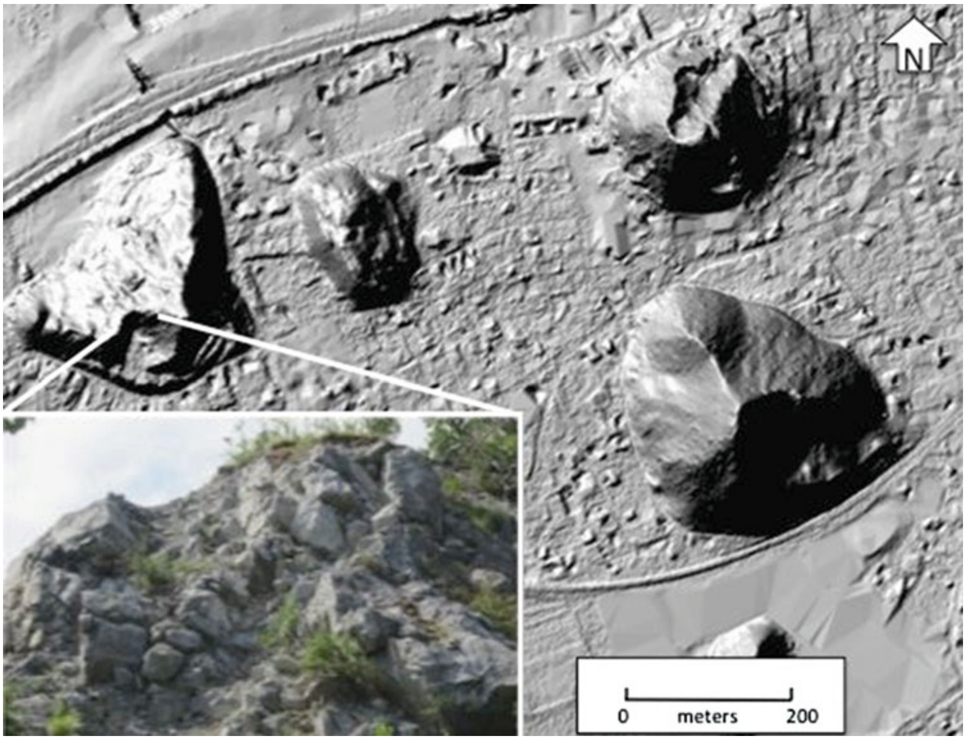

Fig. 155.4 A cluster of Toma hills approximately 8 km downstream (east) of the toe of the Flims rockslide, and 1 km downstream of the toe of the Tamins rockslide. The inset photo displays the typical blocky internal texture of a Toma hill. See Fig. 155.1 for location

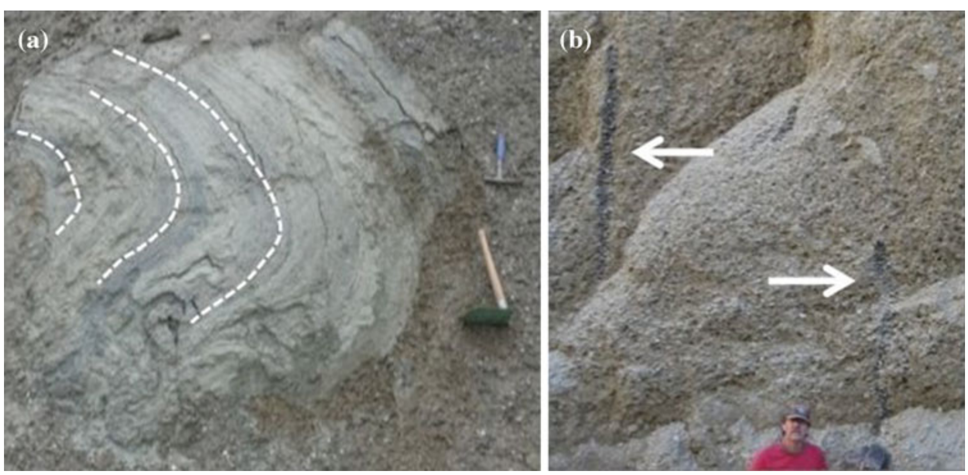

Fig. 155.5 **a** Laminated, clayey silt rip-up clast within Bonaduz gravel. *Dashed white lines* follow laminations within the clast; their *curvature* indicates that the clast was deformed, although not destroyed, during transport. **b** Subvertical, elutriated Pavoni pipes (*white arrows*) 55 m below the Bonaduz gravel plain surface within the cobble gravel facies of the Bonaduz sediments

155.5 New Investigations

LiDAR and geomatics tools have provided insights into the Tamins and Flims landslides. Bare-earth LiDAR imagery reveals, in new detail, relationships between the two landslides, the nature of the Bonaduz sediments, and the structure and origin of the Toma hills. The LiDAR imagery and derived 1-m contour maps, slope maps, and hillshade maps, coupled with the palm-PC hardware and software, have allowed us to map in a mobile GIS environment. We are building a GIS containing all the data collected in the field. Outcrop and landform information is precisely georeferenced and easily shared. We also have used laser scanning and photogrammetry techniques on key outcrops to build 2D panoramas and 3D models that provide high-resolution images of Toma hills and landslide deformational structures and sedimentological features. Coupled with field observations, these tools have enabled us to (1) map, with a high degree of accuracy, the three-dimensional distribution of the Bonaduz sediments, (2) demonstrate the effect of the Tamins landslide on the flow path of the Bonaduz sediments, (3) determine the provenance of the Toma hills, and (4) map the outburst flood deposits resulting from the breaching of the lake impounded behind the Flims landslide.

155.6 Conclusion

A giant rockslide is by itself a very complex phenomenon. Two separate giant landslides that are spatially and temporally related pose major problems of interpretation. Heim's remark mentioned in the introduction to this paper became evident during our recent field research on the Flims and Tamins landslides. Nevertheless, our research and the availability of LiDAR imagery provide some new insights and conclusions. We have benefited from local geologists who know when new, interesting exposures become available and who are interested in our research. We also have capitalized on an enthusiastic working group of diverse researchers from three countries who welcome new ideas from different geoscientific perspectives. Persistence is also important—more than 20 years of research in the Flims area has assembled many of the pieces of this huge puzzle. The puzzle itself probably will never be totally finished, but the picture that is emerging is helpful in better elucidating large and comparable rockslides elsewhere.

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