Geological Survey of Austria

The formation of rock glaciers from mass movements

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Introduction

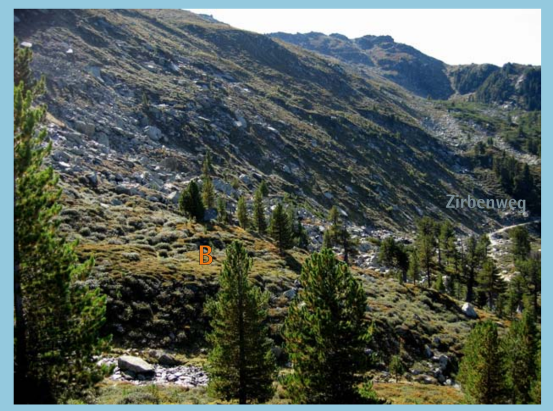
According to our present knowledge (BARSCH, 1996; HAEBERLI et al. 2006) the morphological and geological conditions for the formation of rock glaciers in Alpine environments seem to be clear. All known examples derive from porous more or less coarse grained sedimentary bodies, either from moraines or, in most cases, from talus fans. In the latter case the debris accumulation originates overwhelmingly from physical weathering, rock falls or rock avalanches in proximity to rockwalls.

Location of the study areas

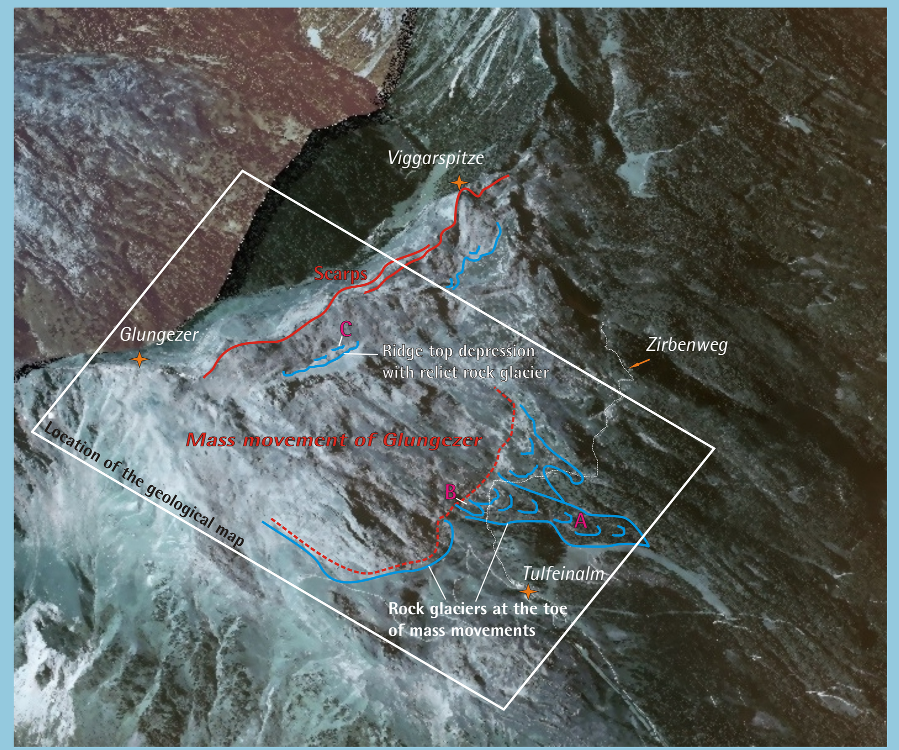
A - Patscherkofel and Glungezer south of Innsbruck

B - Schobergruppe north of Lienz

View of the toe of the mass movement at the northern flank of Mount Glungezer (see also geological map). Note the transistion of the disintegrated rock mass into the relict rock glacier (blue lines indicate ridges of the rock glacier, numbers indicate rock glaciers in the geological map).

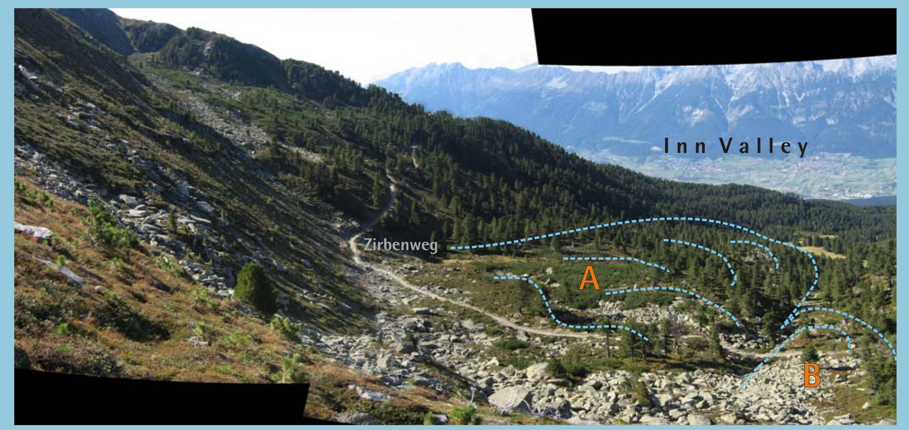


Detail of an tongue shaped small rock glacier (location B) at the steep toe of the vaste mass movement of Mount Glungezer.



Scene (3D-model) of the Glungezer area (SE of Innsbruck) with evidence of mass movements (red lines) and rock glaciers (blue lines).

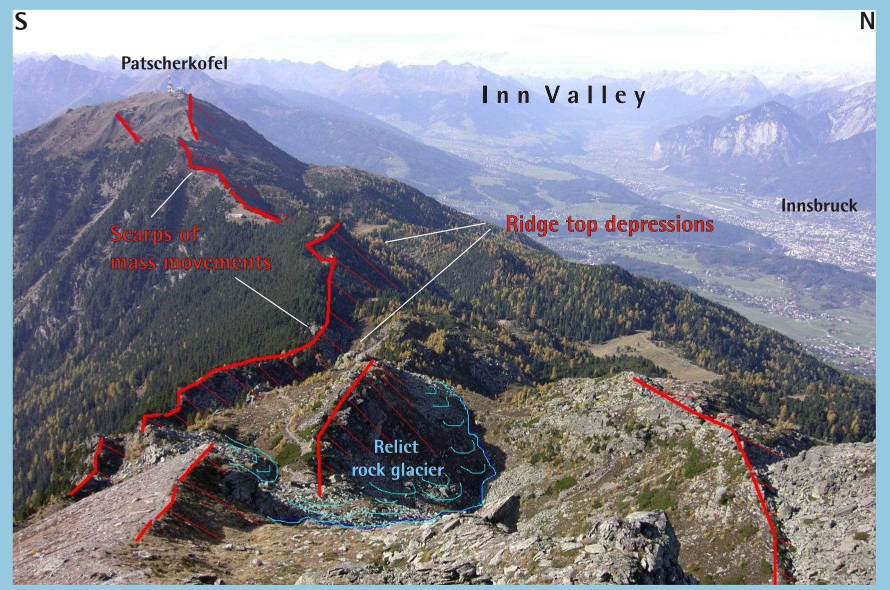
Geological map of the Glungezer - Tulfeinalm area (SE of Innsbruck) with evidence of till deposits of local glaciers (yellow), mass movements (red simbols) and rock glaciers (blue).



View from the mass movement (foreground) to the "root zone" of the rock glaciers in the cirque of Tulfein Alm

The geological/morphological setting of rock glaciers

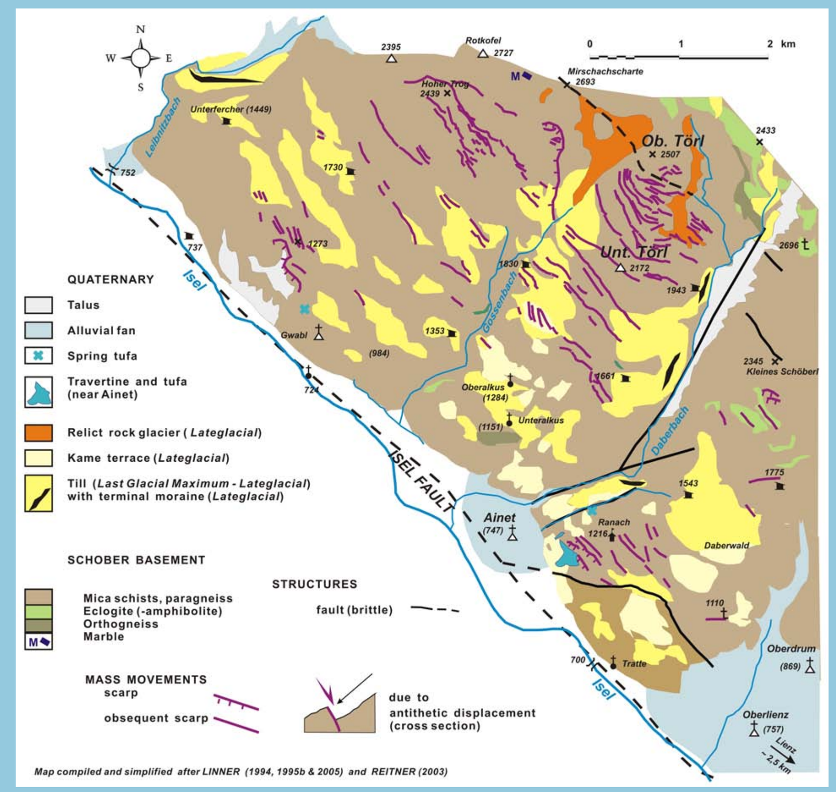
In the course of geological mapping in the crystalline areas of Eastern and Northern Tyrol (Schober Gruppe, Tuxer Alpen) we found a new setting of rock glacier formation. Some relict rock glaciers occur directly at the bulging toe of bedrock slopes, which had been affected by deep-seated gravitational slope deformations (REITNER, 2003; GRUBER, 2005). Furthermore rock glaciers are also present in ridge-top depressions and similar graben-like features that originated from gravitational processes in jointed bedrock. In all these cases talus fans with debris accumulation are missing in the source area of those rock glaciers.



View from the top of the Viggarspitze towards Patscherkofel: The scarps and the ridge-top depressions of the giant Sackung-type mass movements towards the north (Inn valley) are evident. The formation of thepresent relict rock glaciers in the foreground occured after the slope failure had started.

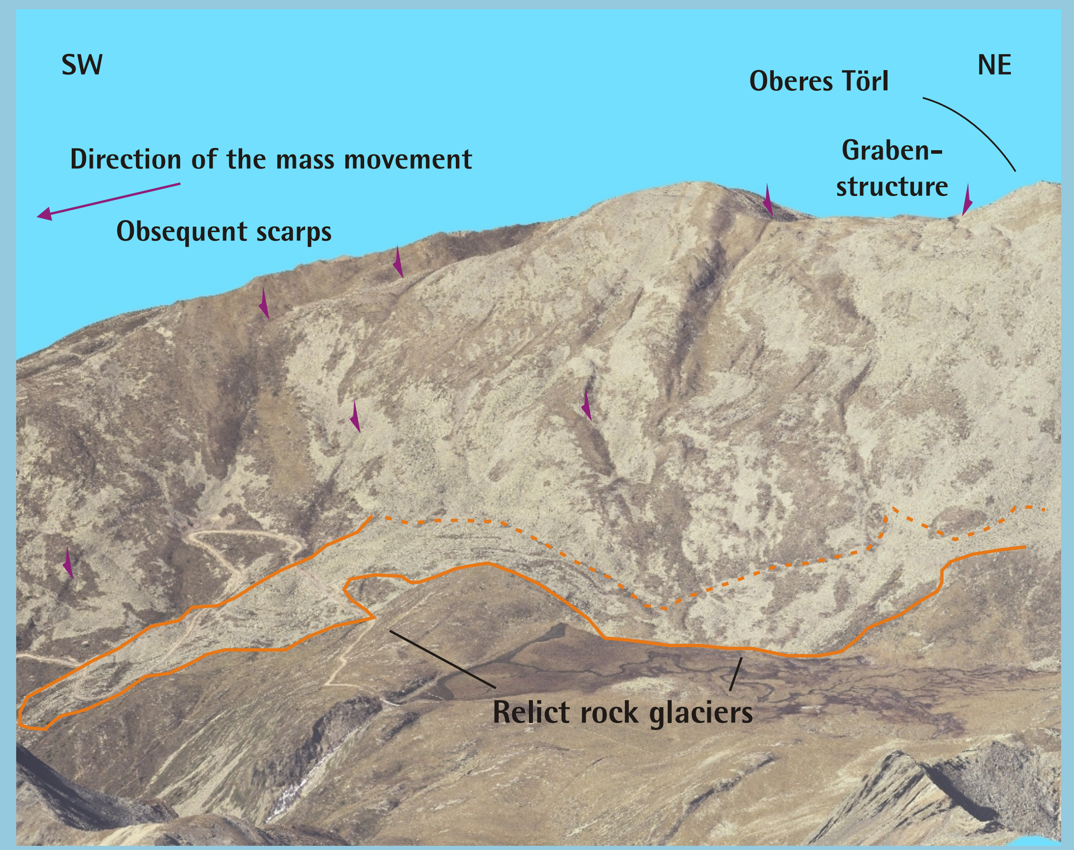
A new model of rock glacier formation

According to our model the disintegration of jointed rocks by creeping mass movements resulted in an increased volume of joint space. This enabled the formation of interstitial ice under permafrost conditions. Increased ice saturation led to the reduction of the angle of internal friction and finally to the initial formation of a rock glacier. Due to the previous and maybe still ongoing slope deformation abundant material was provided for the further movement and thus for formation of quite large rock glaciers. Most rock glaciers of this type originated from mass movements of sagging -type (Sackung sensu ZISCHINSKY, 1966), which illustrates the continuous transition from gravitational to periglacial creep



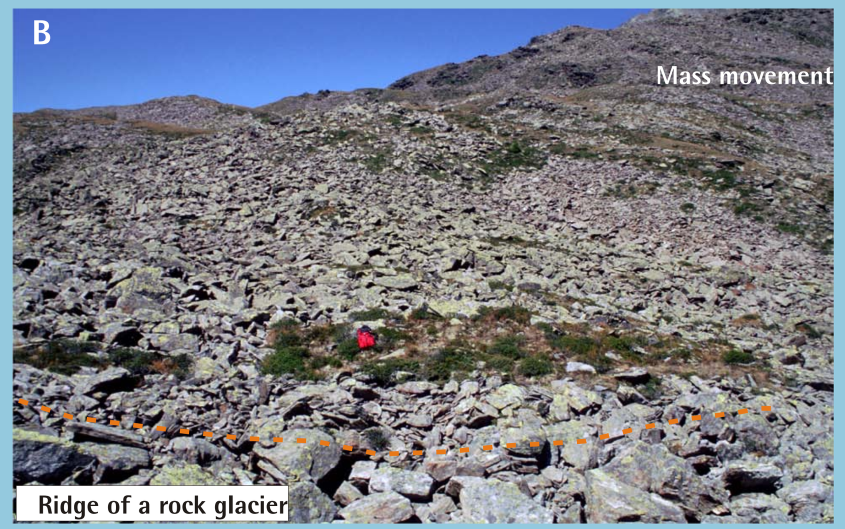
Simplified geological map of area of slope of Oberes Törl and surrounding area (NW of Lienz). The obsequent scarps indicate a deep-seated toppling slope failure along faults and joints striking parallel to the Isel strike-slip fault and dipping steeply into the slope.

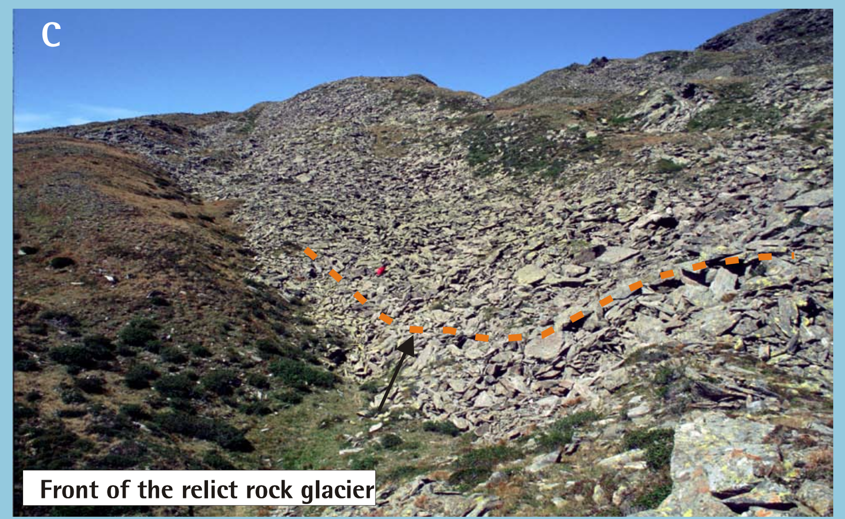
Outcrop at the rim of the relict rock glacier (locality 1): A layer of coarse fragments (thickness 1-1.5 m) overlays a matrix-supported diamictic material with a sandy and fine-gravelly matrix and clasts of gravel to cobble size (diameter mostly < 10 cm).



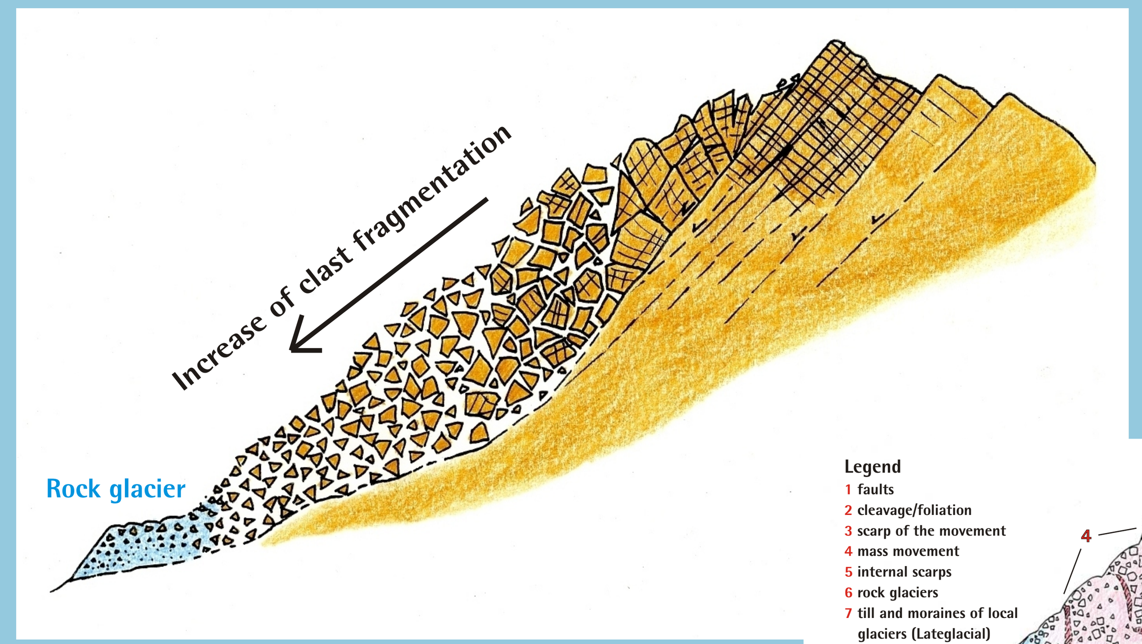
View of the SE-flank of the slope of Oberes Törl. The morphology is dominated by obsequent scarps and a graben structure generated by a toppling failure towards SW (Isel valley). The source area of the relict rock glaciers lies within the rock mass disintegrated due to the deep-seated toppling.

Detail of the tongue-shaped relict rock glacier in the southwestern part. The debris blanket in the hinterland of the rock glacier indicates the rock masses affected by the mass movement. (1 - locality of the outcrop image).

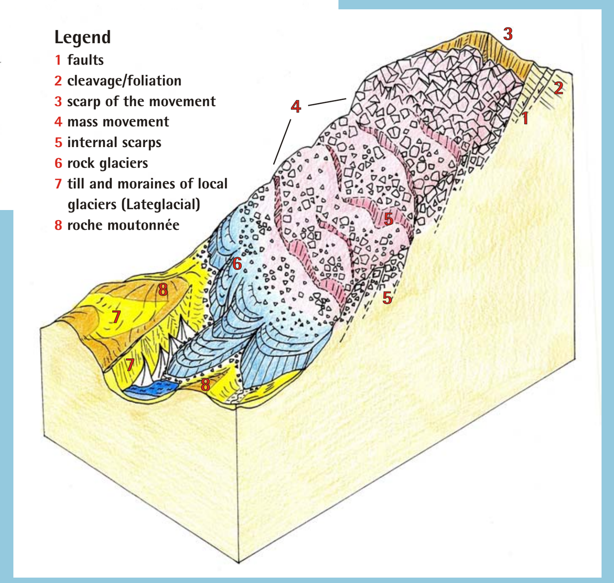




Development from the rock mass, with open joints (A) indicating disintegration caused by the mass movement, to a block field with angular boulders (B) merging into a rock glacier . Steep backwalls with talus fans are missing in the hinterland of such rock glaciers (C).



Schematic sketch of the evolution of rock glaciers from a mass movement. Note the transition from jointed rocks in the upper part through completely disintegrated toe of the mass movement to the rock glacier formation. The downwards fragmentation of clasts and a break of slope gradient indicates the presence of a rock glacier.



Block diagram showing the progressive deformation of the rock mass caused by deep-seated mass movement and the formation of rock glaciers at the toe of the slope.

Conclusions

According to the evidence in the field rock glaciers were formed from rock slopes, which were affected by deep seated mass movements.

Such (relict) rock glaciers (in our cases of Lateglacial age) postdate the formation of the mass movements. They enable a chronological constraint of this gravitational phenomenon on the base of our knowledge of climate history. In addition, those examples with rock glaciers linked at various altitudes with mass movements mirror as well former stepwise permafrost degradation, where rock glacier formation moved to higher altitudes. In this respect and envisaging a rising permafrost boundary, rock glacier formation at slopes affected by mass movements should be anticipated for the future.

References

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