Collapse of the Bérard Rock Glacier (Southern French Alps)

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Introduction

In the Mediterranean French Alps, the summer 2006 has been marked by the sudden collapse of the Bérard rock glacier (Parpaillon Range, Alpes de Haute Provence, France), a very rare event and exceptional by the amount of disturbed material estimated to be about 2 millions m^3 (Fig.1).

Located near the southern limits of the European Alpine permafrost, the Bérard rock glacier case is perhaps representative of the potential consequences of mountain permafrost degradation under present global warming, and raises questions about the evolution of ice-debris mixtures on steep slopes; for example, rock glacier under permafrost conditions. An atmospheric warming of 0.5 to 1°C between 1900 and 2000 is indeed currently observed in the Alps (Casty et al. 2005). In the same way, recent observations on thermal evolution of the ground in high mountains (Harris et al. 2003), as well as the occurrence of new and unexpected phenomena, for example, acceleration of rock glacier flow (Ikeda & Matsuoka 2002, Roer et al. 2005, Delaloye et al. 2006, Kääb et al. 2006, Delaloye et al. 2008) or rock glacier collapse (Evin et al. 2007), seem to indicate that mountain permafrost could respond much faster to global warming than expected, and that areas at its lower limits could experience a morphogenetic crisis.

Crucial questions in terms of natural hazards and associated dangers are being raised (Harris et al. 2000): the speed-up of creeping landforms (Kääb et al. 2006), the destabilisation of the frontal part of rock glaciers (Arenson 2002), and an increase of the rockfall activity (Haeberli et al. 1997, Noetzli et al. 2003) and of the frequency of debris flow have already been observed in mountain permafrost areas.

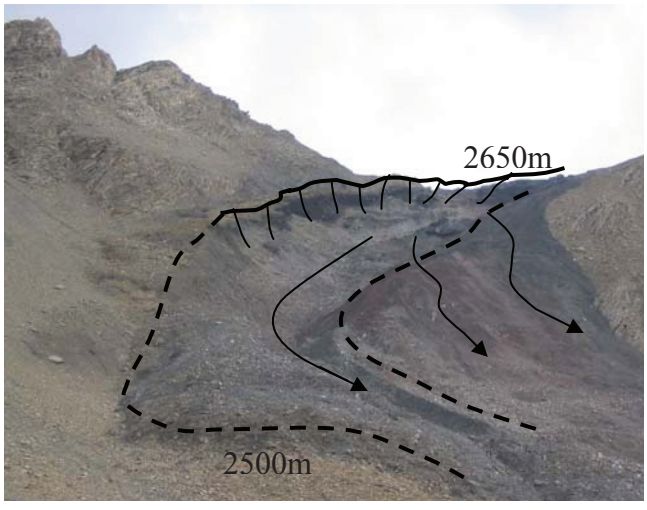

Figure 1. An upward-looking view of the collapsed Bérard rock glacier (July 2007).

In this context, the main objective of our study is to understand the mechanisms that triggered the Bérard rock glacier collapse, which could subsequently gain new insights into the destabilisation of ice-rich deposits on mountain catchments.

The Bérard Rock Glacier Situation

The Bérard rock glacier is located in the Parpaillon Range, one of the southernmost ranges of the European Alps, including the summits of Grand Bérard (3046 m) and La Chalanche (2984 m). Topoclimatic and geomorphological conditions are favorable to permafrost occurrence in this valley.

Methods

Within a larger research project intending to study the consequences of permafrost degradation in the French Alps, a complete monitoring of the site has hence been set up. This includes:

- the geodetic survey (Differential and Permanent GPS) of marked blocks during the summer, in order to quantify the velocity and the characteristics of the movement;
- the use of radar interferometry to reconstruct the history of the event during the previous years and to map the main destabilised areas;
- the interpretation of electrical resistivity and refraction seismic tomographies to assess the physical properties of the internal structure of the rock glacier;
- the analysis of the ice to determine its origin and its main physical properties;
- the survey of the climatic parameters (air temperature, solar radiation, wind speed and direction, snow height) with an automatic weather station; and
- the survey of the thermal state of the ground (with miniature temperature dataloggers) to allow the monitoring of pertinent indicators; for example, mean annual ground surface temperature (MAGST) or mean annual active layer temperature.

First Results

Among the above-mentioned methods, geomorphological study, DGPS results, and ice analyses have given first results.

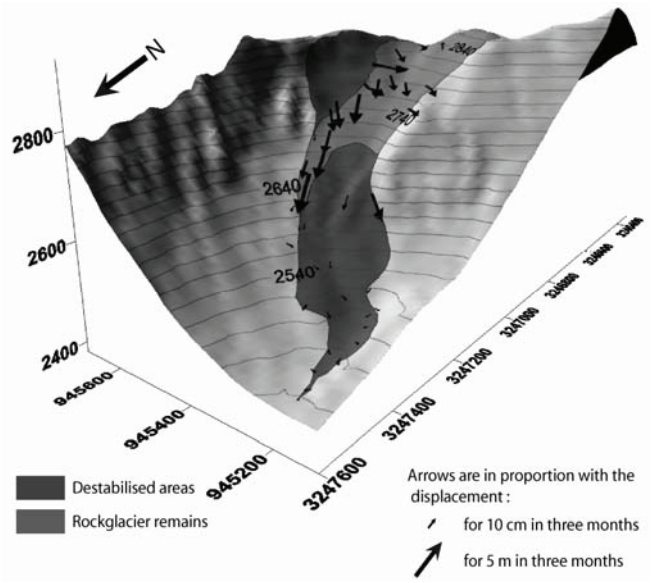

Figure 2. 3-D displacement of marked blocks on the Bérard rock glacier between June and September 2007.

The geomorphological study of the site has already revealed that the breaking of the rock glacier is probably partly related to an underlying rockslide in the schist series, which may have been activated by storms during summer 2006.

First results are DGPS measurements of more than 40 marked blocks on the Bérard rock glacier and the slided mass, in June and September 2007. The 3-D vectors map shows that the slided mass has not experienced important movements during the three surveyed months. *Z* values suggest a general settling (about 5–15 cm), certainly due to the ice melt in debris. Remains of the rock glacier, especially near the collapse area, are affected by large movements (more than 5 m in three months) and the destabilisation is effective as far as the saddle point (displacements are around 1 m in three months). Permanent GPS, located above the scar on a flat area, indicates a mean displacement of 6.4 $mm.day^{-1}$ in the north direction, corresponding to an annual displacement of more than 2 m, which fits with the surrounding DGPS measurements.

Stratigraphic observations on near-surface ice outcrops reveal that Bérard rock glacier has been affected by periglacial and glacial mechanisms. Preliminary analyses of ice structure have revealed the sample to be similar to glacier ice (Vallon, pers. com.). Little Ice Age period is suspected in this mechanism change, but other analyses have to confirm that.

Our study, thanks to the various monitoring devices, has already clarified the respective roles of the meteorological conditions, the recent climatic warming, and the geological settings in the collapse of the Bérard rock glacier. Most of the results are coming during the summer 2008 and will bring new precision on the Bérard rock glacier event.

References

Arenson, L.U. 2002. *Unstable Alpine permafrost: A potential important natural hazard – Variations of geotechnical behaviour with time and temperature.* PhD Thesis, ETH Zurich.

Casty, C. et al. 2005. Temperature and precipitation variability in the European Alps since 1500. *International Journal of Climatology* 25: 1855-1880.

Delaloye, R. et al. 2006. ERS InSAR for detecting slope movement in a periglacial mountain environment (western Valais Alps, Switzerland). *Ninth International Symposium on High Mountain Remote Sensing Cartography* (HMRSC-IX), Graz, Austria.

Delaloye, R. et al. 2008. Recent interannual variations of rock glacier creep in the European Alps. *Proceedings of the Ninth International Conference on Permafrost, Fairbanks, Alaska, 29 June–3 July 2008*.

Evin, M. et al. 2007. Rupture et glissement en masse d'un glacier rocheux dans le vallon du Bérard (Massif du Parpaillon, Alpes du Sud, France) au cours de l'été 2006, Grenoble, *SHF - Section Glaciologie/ Nivologie*.

Gruber, S. et al. 2004. Interpretation of geothermal profiles perturbed by topography: the Alpine permafrost boreholes at Stockhorn Plateau, Switzerland. *Permafrost and Periglacial Processes* 15(4).

Haeberli, W. et al. 1997. Slope stability problems related to glacier shrinkage and permafrost degradation in the Alps. *Eclogae Geol. Helv*. 90: 407-414.

Ikeda, A. & Matsuoka, N. 2002. Degradation of talus-derived rock glacier in the Upper Engadin, Swiss Alps. *Permafrost and Periglacial Processes* 13: 145-161.

Kääb A. et al. 2006. On the response of rockglacier creep to surface temperature increase. *Global and Planetary Change* 56(1–2): 172-187, doi:10.1016/j.gloplacha.2006.07.005.

Noetzli, J. et al. 2003. Mountain permafrost and recent Alpine rock-fall events: A GIS-based approach to determine critical factors. *Proceedings of the Eighth International Conference on Permafrost, Zürich. Swets & Zeitlinger, Lisse.*

Roer, I. et al. 2005. Rockglacier "speed-up" throughout European Alps: A climatic signal? *Second European Conference on Permafrost*, Potsdam, Alfred-Wegener-Stiftung.