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Discussions

Interactive comment on "Glacier ice in rock glaciers: a case study in the Vanoise Massif, Northern French Alps" *by* S. Monnier et al.

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Comments by Wilfried Haeberli on

Glacier ice in rock glaciers: a case study in the Vanoise Massif, Northern French Alps

submitted to the Cryosphere by S. Monnier, C. Camerlynck, F. Rejiba, C. Kinnard and P.-Y. Galibert

General: The submitted paper presents interesting GPR soundings on a creeping alpine permafrost body; this precise evidence is worth publishing. The temperature and movement determinations have a lower quality level; they are nevertheless helpful and could be improved, especially by making better use of information from the existing literature. The geomorphological interpretation is difficult to follow: The "push moraine" used for ELA reconstructions is a problematic feature, which cannot be interpreted in a simple or straightforward way, and the term “glacier” as used already in the title of the paper may be inappropriate in view of the minimal size of the envisaged surface ice body (« 0.1 km2). The paper could be improved by upgrading the temperature and movement data/interpretation, by sticking to the observed facts rather than speculating about vague geomorphogenetic ideas, and especially by applying correct and precise terminology/phenomenology with respect to the investigated surface/subsurface ice. The authors may use the following general comments and suggestions. Many references can be found in the overview paper on mountain permafrost in No. 200 (special issue, pp. 1043-1058) of the Journal of Glaciology, in the IPA/ICSI task force report by Haeberli and others (2006) as contained in the reference list of the submitted paper, or in Harris, C. & Murton, J. B. (eds): Cryospheric Systems: Glaciers and Permafrost, The Geological Society of London, Special Publication 242.

GPR soundings and rock glacier geophysics: Ice-rich material and lenses of massive ice are no exception but characteristic in creeping permafrost on mountain slopes, especially under conditions of compressing flow as in the investigated case. Complementary resistivity or seismic soundings could strongly improve the interpretation of the so far done GPR soundings. Comparison should at least be made with long-existing results from core drilling, borehole measurements and geophysical soundings reported from other rock glaciers. This type of information documents a typically layered vertical structure with large blocks at the surface (no or little ice in the pore volume), finer (silty/sandy) material with excess ice underneath, and a blocky layer at depth (from surface blocks which fell over the front of the creeping ice/rock-mixture and were subsequently overridden by it). The interpretation of the presented GPR soundings could make strong profit from such existing information about the internal structure of rock glaciers.

Thermal conditions and movements: Why were the temperature records interrupted in summertime? Completely measured annual cycles would provide important information about mean subsurface temperatures and the thickness of the investigated permafrost. Furthermore, information about energy fluxes through the surface could be obtained from more complete and systematically analysed records (thermal offsets, zero curtain, snow-cover duration, microclimate of the coarse blocks at the surface, etc.). Even with the presented incomplete records, better interpretation is possible: the recorded low temperatures during February and March reflect BTS-values (Bottom Temperature of the Winter Snow Cover – an often used method to map permafrost distribution in complex mountain topography), which clearly indicate permafrost conditions. The uncertainty of 0.6 m/y in the movement determination for slowly creeping permafrost on slopes is very high, provides an extremely coarse image of the flow field, which probably exists in reality, and strongly limits possible interpretations. Much more sophisticated and detailed flow determinations have been accomplished on other rock glaciers. Such detailed flow measurements enable flow trajectories to be constructed, patterns of surface age to be estimated and relations between surface structures and extending/compressing flow to be analysed. The authors should at least refer to the corresponding studies, results and understanding. Even the limited information presented here appears to indicate that there is a transverse flow component in the upper and orographic left part of the feature from thick frozen debris underneath large rock walls to the west, while movement is weaker in the upper and orographic right (eastern) part with much smaller rock faces and thinner debris. This asymmetry may be related to the transverse deformational structure visible in the GPR soundings.

Geomorphology/paleoglaciology: The geomorphological interpretation should be essentially reconsidered with respect to (a) the highly questionable “push moraine” and its use for ELA reconstructions, (b) various possible origins of ice-rich frozen ground and subsurface massive ice, and (c) a correct use of the term “glacier” and an adequate physical understanding of minimal-size surface ice. The feature called “push moraine” is outside the investigated rock glacier and roughly parallel to its flow direction. It could represent a lateral moraine of a long vanished lateglacial ice body in the cirque or possibly even be part of a separate and now inactive flow feature from the separate talus in

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the east of the rock glacier. Its use for paleoclimatic reconstructions and ELA estimates is highly questionable and should better be avoided. The speculative and vague age constraint envisaged is of limited interest anyway (cf. the much more informative direct age determinations for other rock glaciers in the Alps). Deformational structures in subsurface ice are deformational structures in subsurface ice and nothing more. There is no straightforward or unique relation between such deformational structures and a “true glacier” (what is a “true” glacier? – better use scientific language). Deformational structures in a creeping permafrost body can develop in subsurface ice of various origins (this was already misunderstood in the cited paper by Fukui et al. 2008). Massive subsurface ice can form by ice segregation at a stable freezing front in fine material, reflect injection ice or originate from burial of former surface ice (see below). Electrical resistivity provides the most reliable information about different formation processes (sedimentary, congelation and metamorphic ice with characteristic ion contents). Even buried ice, which originally built up at the surface, is not necessarily “glacier ice” (a term without precise scientific content anyway). The length of the investigated rock glacier is some 300 m and its width about half of this if not less. The dimension of the surface-ice feature inferred by the authors is thus « 0.1 km2. Because of this minimal size, the term “glacier” is inadequate and should be replaced by a term like “perennial snowbank” or “glacieret”. Such surface ice of minimal size can be a former avalanche cone, which formed at the foot of the steep slopes at the head of the rock glaciers (such snow patches are visible on Fig. 5 and high-resolution Google Earth images of the investigated rock glacier) and would probably not even be included into glacier inventories. Perennial surface ice bodies with the dimensions « 0.1 km2 are indeed often encountered near the head and on the surface of rock glaciers. They are usually thin (metres, cf. Fig. 4), predominantly consist of refrozen snow (superimposed ice) and do not really move from an accumulation (firn) area to an ablation (ice) area. Instead, they are ablation areas in some years and accumulation areas in others. Their ice is commonly cold and frozen to the underlying ground, because ice temperature cannot rise above zero during summer yet cool far below zero during winter. As a consequence,

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such small bodies of perennial surface ice from avalanche deposits, wind drift, etc., are – by definition – related to negative ground temperatures throughout the year (= permafrost); they often participate in the building-up of deeply frozen talus, which then starts creeping, and they are best preserved under conditions of compressing flow due to dynamic thickening of the insulating blocky surface layer.

Conclusion: The reported observations confirm our understanding of permafrost creep and periglacial rock glaciers. These observations are interesting but provide no evidence of anything extraordinary or unusual. It is unnecessary to warm up long outdated speculations about "glacial origins" of morphological features and occurrences of surface ice, which – for simple reasons of size – are not called glaciers in international programmes of glacier monitoring and inventory (cf. http://www.wgms.ch/ or Cogley, J. G., R. Hock, L. A. Rasmussen, A. A. Arendt, A. Bauder, R. J. Braithwaite, P. Jansson, G. Kaser, M. Möller, L. Nicholson, and M. Zemp (2011). Glossary of glacier mass balance and related terms. IHP-VII Technical Documents in Hydrology No. 86, IACS Contribution No. 2, UNESCO-IHP, Paris, 114 pp.). The authors may consider to either reduce their paper to an objective description of the measured information or to add further, complementary and better field measurements. With the latter, a much more solid paper on the internal structure, thermal condition and creep behaviour of mountain permafrost in the studied region could then be submitted.

Interactive comment on The Cryosphere Discuss., 5, 3597, 2011.