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The Cryosphere Discussions

Interactive comment on "Frozen debris lobe morphology and movement: an overview of eight dynamic features, southern Brooks Range, Alaska" *by* M. M. Darrow et al.

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General:

The authors present interesting materials and reflections about slope instability and creep phenomena in warm, ice-rich subarctic permafrost. The text is well written and has a logical structure. The illustrations are informative and the conclusions are clear and essential. The findings are innovative and significant as they document an end-member of permafrost-related landform evolution on steep slopes, which is still under-researched: the cumulative flow and deformation of deeply frozen fine-grained/organic materials in forested mountain permafrost. Similarities and contrasts with respect to other members of the envisaged landform evolution – the much better documented

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rock glaciers – are correctly mentioned but not really discussed. Here is the main possibility for further improving an already good and welcome contribution. The publications mentioned in the comments below and contained in the subsequent reference list provide important information.

An example is the recommendation by the authors at the end of the Conclusions to use geophysics and drilling in the future. This argument would become stronger if the corresponding possibilities were at least mentioned with reference to the rich experience in rock glacier research. Concerning drilling, for instance, Krainer et al. (2014) show with radiocarbon dating and measurements of borehole temperature and borehole deformation that creep of ice-rich frozen materials and rock glacier formation in warm permafrost in the Alps had taken place since the beginning of the Holocene. Geoelectrical resistivity soundings can provide some indication on the origin and characteristics of subsurface ice (Haeberli and Vonder Mühll, 1996) and in combination with seismic refraction even about ice and unfrozen water contents (Hauck, 2013).

Details:

Abstract, line 18: Information on rock strength is certainly interesting. In the present case more important, however, would be information on the strength and creep properties of the moving material. A recent review on such questions is provided by Arenson et al. (2014).

Abstract, line 26: True but acceleration seems to be predominant – a phenomenon which parallels the recent trend to increasing flow speeds observed on Alpine rock glaciers (see discussion in Deline et al., 2014). A completely synchronous development is hardly to be expected as thermal conditions are not the only factor influencing flow velocities.

Page 2, line 7: Better use "global warming", "atmospheric temperature rise" or so instead of "warming climate". The term "climate" is defined as a statistical average of meteorological conditions and as such cannot "warm" (the expression is popular but not really scientifically correct).

Page 2, lines 12-15: A more recent and excellent overview is given by Deline et al. (2014).

Page 2, line 30 to Page 3, line 1: The introduction of the term “frozen debris lobes” is an interesting step, especially as the term “rock glacier” has always been questionable (the corresponding phenomenon is neither a rock nor a glacier). In fact, the suggested new name could also be appropriate for what is usually called “rock glacier”. The aspect of movement should, however, also be expressed in the new nomenclature.

Page 3, lines 5 – 22: The high subsurface ice content enabling steady-state creep deformation should also be mentioned (cf. core drilling by Krainer et al., 2014 and discussion by Arenson et al., 2014). The term “glacier-cored” should be reconsidered carefully. It relates to a long-outdated geomorphogenetic speculation, which is hardly supported by adequate field measurements (geophysics, core drilling). Of course, buried massive ice can be preserved within permafrost. For simple size reasons, however, such buried ice is in most cases remains from ice patches, avalanche deposits or glacierets rather than real “glaciers”. Making a full stop after “Pleistocene glaciation” would help avoiding such discussions.

Page 4, lines 16-18: Where are the temperature data from? What depths and times do they cover? In which (lower, upper) parts of which FDL were they taken? And to what sites in the adjacent permafrost were they compared? This important information should be precise.

Page 8, line 32: Should the high frost susceptibility of such silty sand be mentioned here? It could be a key factor concerning subsurface ice content and creep mode.

Page 9, lines 6-7: Can more information be given on this drilling? How representative is the information on extremely small ice contents? How was this ice content determined? Was melting of core-ice during drilling prevented by cold-air cooling or so?

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Were temperatures at depth measured here? Where was the exact position of this drilling?

Page 10, line 16: This occurrence of massive ice and ice-rich soil here seems to be in strong contrast with the extremely low ice contents found in the drilling on FDL-A (cf. previous remark). Is this contrast real and, if yes, can it be explained?

Page 12, lines 17-27: Reference should be made to the dated permafrost core through an active rock glacier described by Krainer et al. (2014), which documents a similar evolution for rock glaciers in the Alps. The authors should also have a look at the concepts developed on the basis of core drilling and borehole measurements already in the late 1990s for rock glacier evolution over time (Haeberli et al., 1998). These concepts are comparable to the ideas presented here but provide more detail about flow physics and the internal layering of the creeping body. They especially also consider the phenomenon that material from the more rapidly moving surface falls down over the steep front and is then overridden by the more slowly advancing lower parts of the front.

Page 13, line 16: Again – compare with rock glacier datings (Krainer et al., 2014 and other references provided there).

Page 13, lines 28-30: The possibilities of geophysical soundings could be mentioned here and primary results from such measurements on rock glaciers could be summarised.

Page 14, lines 6-7: Why are the debris flows increasing the surface temperature? Provide a brief explanation of the physical process involved.

Page 14, lines 10-12: Ikeda et al. (2008) document and discuss detailed field evidence on this process chain from drilling and borehole measurements.

Page 15, line 16: Better write " . . . study of eight FDLs near the Dalton Highway in the Brooks Range, which . . ." for the readers who primarily look at the conclusions.

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Page 16, line 25: In view of the still strongly limited temperature data and the evolution in time, it could be more appropriate to write: " ... movement changes which may be tied to changes in air temperature." (The movement itself is not tied to air temperature in a straightforward way but rather via a complex process chain).

Page 16, lines 29-30: Concerning geophysical soundings and drilling refer to the general comments at the beginning of this review.

Caption of Figure 1: Is there only one blue rectangular inset in (a)?

Caption of Figure 5: What exactly is meant with the term "Deflation"? This term usually stands for erosion by wind. Is this meant here?

References:

Arenson, L., Colgan, W. and Marshall, H.P. (2014): Physical, thermal and mechanical properties of snow, ice and permafrost. In: Haeberli, W., Whiteman, C. (Eds.), Snow and Ice-related Hazards, Risks and Disasters. Elsevier, 35-75. Deline, P., Gruber, S., Delaloye, R., Fischer, L., Geertsema, M., Giardino, M., Hasler, A., Kirkbride, M., Krautblatter, M., Magnin, F., McColl, S., Ravanel, L. and Schoeneich, P. (2014). Ice loss and slope stability in high-mountain regions. In: Haeberli, W., Whiteman, C. (Eds.), Snow and Ice-related Hazards, Risks and Disasters. Elsevier, 303-344. Haeberli, W. and Vonder Mühll, D. (1996): On the characteristics and possible origins of ice in rock glacier permafrost. Zeitschrift für Geomorphologie N.F., 104, 43-57. Haeberli, W., Hoelzle, M. Kääb, A., Keller, F., Vonder Mühll, D. and Wagner, S. (1998): Ten years after drilling through the permafrost of the active rock glacier Murtèl, eastern Swiss Alps: answered questions and new perspectives. Proceedings of the Seventh International Conference on Permafrost, Yellowknife, Canada, Collection Nordicana, 57, 403-410. Hauck, C. (2013): New concepts in geophysical surveying and data interpretation for permafrost terrain. Permafrost and Periglacial Processes 24, 131-137. doi:10.1002/ppp.1774 Ikeda, A., Matsuoka, N., and Kääb, A. (2008): Fast deformation of perennially frozen debris in a warm rock glacier in the Swiss Alps: an effect of liquid

water. Journal of Geophysical Research 113, F01021. doi.org/10.1029/2007JF000859
Krainer, K., Bressan, D., Dietre, B., Haas, J.N., Hajdas, I., Lang, K.,Mair, V., Nickus, U., Reidl, D., Thies, H. and Tonidandel, D. (2014): A 10,300-year-old permafrost core from the active rock glacier Lazaun, southern Ötztal Alps (South Tyrol, northern Italy). Quaternary Research 83 (2), 324–335. doi:10.1016/j.yqres.2014.12.005

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