

Interactive comment on “Surface depressions (Lacunas) on Bering Glacier, Alaska: a product of downwasting through differential ablation” by P. J. Fleisher

P. J. F. Fleisher

fleishpj@oneonta.edu

Received and published: 3 July 2014

Referee Received and published: 5 June 2014 This paper addresses a little-known subject, a rare class of supraglacial hollows known as ‘lacunas’. It is potentially of some interest to those concerned with processes of ablation on surge-type glaciers.

Response Little known as lacunas may be, they are no less esoteric than dozens of other glacial features or topics that capture the interest for journal readers. However, in today’s global discussion of climate change and glacial retreat it is entirely appropriate to consider all aspects of ablation, especially those that are rather perplexing.

However, it is very poorly written (this is a matter of judgment and can be disputed) and

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



referenced

Response This manuscript was submitted to Cryosphere to take advantage of the open review process, which places the reviewer's comments in the same light as the manuscript. The only significant difference is that one of the authors is known. Indeed, the subject under consideration is not well known, which is clear justification for bringing it to the attention of those interested in all forms of ablation. Admittedly referencing is limited. However, it should be noted that the geologic literature makes virtually no reference to lacunas.,

Referee and the proposed mechanism of formation is unconvincing

Response the proposed mechanism of formation is certainly hypothetical, as it must be when considering the origin of features of such limited occurrence. The manuscript is intended to encourage discussion).

Referee The subject is probably worth pursuing, but this will require much more thought and study of the literature

Response more thought – yes, However, even an in depth study of the literature yielded no reference to a processes or mechanism specific to lacuna formation, which is why an attempt is made to combine processes known to exist.,

Referee and a thorough re-write of the paper

Response agreed, the discussion segment of paper should be rewritten and alternative ideas are proposed for discussion. I would contend that the entire paper does not require rewriting as implied by the term “thorough”).

Referee Here, I comment on some of the major misconceptions and weaknesses of the paper, as pointers on how the re-write could be approached. It may also be useful to team up with a co-author, to help with interpretations and writing

Response I would welcome a coauthor and all suggestions of who might be invited.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Referee Introduction: at the outset, it needs to be stated who introduced the term 'lacuna' into the glaciological literature, and how it was originally defined

Response Good point, but there is no formal introduction of the term, except for use when naming the Lacuna Glacier, Alaska. Because justification for use of the term or a definition does not appear in any reference literature, glossary or volume of geologic terms, the title of the article contains a succinct descriptor. Perhaps it would be helpful to point out that a search of the U.S. Board on Geographic Names indicates the Dictionary of Alaska Place Names (Donald P. Orth, USGS Professional Paper 567) contains the term "lacuna" as it was first used by mountain climbers in the late 1940's who made reference to the Lacuna Glacier (Alaska Range, Alaska), but not in a technical or formal sense as might be anticipated in the scientific literature. Austin Post (personal communication, 1995) applied the term lacuna to surface cavities on the Bering Glacier as reported in this manuscript, but no written record exists. It is interesting to note the use of the term in the literature of several other disciplines (i.e. music, literature, anatomy, law, history, etc.) to describe a void, pit or gap, as it used in this manuscript. Within the sciences, the term has been applied with taxonomic reference for an insect (*Arrhopalites lacuna*) found within the terrestrial cave environment (Christiansen and Bellinger, 1996) and for a subfamily of a marine Mollusca (Bouchet, et al., 2014, Sepkoski, 2002, Reid, D.G., 1989a), and Turgeon, et al., 1998).

Bouchet, P.; Reid, David G.; Gofas, S. (2014). Lacuna Turton, 1827. Accessed through: World Register of Marine Species at <http://www.marinespecies.org/aphia.php?p=taxdetails&id=138099>

Christiansen, Kenneth and Bellinger, Peter, 1996, Cave *Arrhopalites* New to Science., *Journal of Cave and Karst Studies* 5, 8(3):168-18

Reid, D.G. (1989a) The comparative morphology, phylogeny and evolution of the gastropod family Littorinidae. *Philosophical Transactions of the Royal Society of London, Series B* 324: 1-110.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



J. J. Sepkoski, Jr. 2002. A compendium of fossil marine animal genera. *Bulletins of American Paleontology* 363:1-560

Turgeon, D. D., J. F. Quinn, Jr., A. E. Bogan, E. V. Coan, F. G. Hochberg, W. G. Lyons, et al. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: Mollusks, 2nd ed. American Fisheries Society Special Publication 26. 526

U.S. Board on Geographic Names, U.S. Geological Survey, Reston, Virginia

However, referencing such literature was viewed too far a field to be included in this manuscript. Perhaps, more thorough references to literature dealing with the ablation process and/or glacier karst sink-holes would be warranted, as suggested by Anonymous Referee #1. The suggestion will be pursued.

Referee Section 3. Glacier karst. This section is not well written or referenced, and it is unclear what point is being made. Is the author suggesting that sink holes in glacier karst are not of collapse origin? Or to define some specific relationship between lacunas and sink holes? Response I am suggesting not all glacier karst sink holes are due to collapse and that some of what have been referred to as sink holes may be lacunas. The link between sink holes and lacunas is established to point out that both features form on and within ice that is either stagnant or passive to flow. Referee Clayton (1964) is of course the classic reference on glacier karst, but things have moved on since then. See references in Benn and Evans (2010), p.353, especially Kruger 1994, Kirkbride 1995, and Gulley and Benn 2007. The latter reference is especially relevant, since it reports observations within englacial conduits beneath stagnant ice, some of which had partially collapsed roofs. Response Point well taken, but I do not refute collapse occurs within conduits beneath glacier karst. What I have said is that collapse does not result in depressions with circular surface expression. I have presented evidence indicating lacunas do not form as a result of collapse (i.e. continuity of englacial structures within the walls and floors of lacunas). The references suggested will be

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



consulted further prior to rewriting this section of the manuscript and the link between sink hole and lacunas will be clarified. Referee line 89: this reference to saturation (and subsequent instances in Section 4) implies an incorrect conception of glacial drainage. The presence of englacial conduits does not imply 'saturation' of the surrounding ice any more than the presence of a system of pipes in a building implies saturation of the walls. The concept of an 'englacial water table' is incorrect, as almost all intact glacier ice is essentially impermeable. Consistent water levels in sink holes just imply that they are all connected via some open drainage system and have a common base level.

Response Agreed and understood – use of the water table concept to imply full saturated certainly was not the intent, no more than implying all parts of all rocks below a terrestrial water table are saturated. Of course, only the available spaces (cavities and conduits in ice) are saturated and not the tight fabric of actively flowing glacial ice. Perhaps this does need clarification. Referee line 112: these arguments about 'increased saturation of ice' are inconsistent with modern conceptions of glacier drainage (see Gulley et al., 2009: Quaternary Science Reviews, and Benn and Evans 2010, chapter 3). The data do appear to show that fractures in the 'lacuna band' are hydraulically connected to the bed, but this does not imply saturation of the ice

Section 5: the association of the lacuna band with the basal topography appears to be robust, although it could be stated more clearly and succinctly. There are a number of unsupported statements such as 'For all practical purposes [what does that mean?] ice held deep within the trough persisted in a passive and stagnant condition beneath overriding ice...'. Figure 6 illustrates the concept, but what is the evidence?

Response The evidence lies in the orientation of thrust surfaces relative the subglacial trough. Exposures of such thrusts formed during earlier surges are preserved within this segment of the piedmont and may be observed on the ablating surface of the post-surge ice. Perhaps this evidence should been more thoroughly introduced, illustrated, and discussed. However, there is not direct, observable evidence for stagnation within the trough. As Figure 6 suggests, horizontally oriented plates of ice thrust over the

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



trough would cause ice within the trough to remain passive or stagnant during post-surge ablation and retreat. Perhaps this should be more fully developed. However, there is not direct, observable evidence for stagnation within the trough. The potential for this to occur is what is being presented.

Post-surge ablation data presented indicate lacunas develop in ice trapped at depth within the subglacial trough. If this ice is indeed stagnant or passive, there is a link with glacier karst features such as sink holes.

Referee Section 6: The argument inferring ablation rates from the depth of debris in crevasses is not strong, and rests on a crevasse depth value plucked from a general textbook. (

Response There is no published reference to specific crevasse depths within a surging glacier, and as anyone who has attempted to make such measurement in the field would know, access precludes direct measurement. Therefore, a general figure taken (or "plucked") from a text reference is better than none. I would challenge anyone to find a published reference for the duration of time required for a debris band to reappear on the surface of glacier after it was lost to collapse during a surge. I would suggest the discussion utilizing this information is valid as it stands).

Referee The survey data referred to in Section 6.2 provide a firmer basis, and although it is probably correct that initial ablation rates on the crevassed surface were a bit higher, it is not possible to say by how much.

Response Agreed, but it is possible to make an estimate of ablation rate, which is what the author has done.

Referee Section 7: The discussion of the effects of stagnation on ice density and 'saturation' is mostly unsupported speculation. How can there be 'ongoing intracrystalline deformation' in stagnant ice? if the ice is stagnant, by definition it cannot be deforming.

Response This is exactly the point being made. Lack of ongoing intracrystalline defor-

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



mation would suggest the ice would not respond to infiltrating surface meltwater in the same way active ice does.

Referee And why should this 'compromise ice texture' and result in 'infiltration' and 'saturation'?

Response Are there subtle differences in density and/or rates of infiltration? Lacking such information, it is reasonable to assume that infiltrating meltwater would gain access to minute avenues between ice crystals of stagnant ice that would not occur if the ice was actively being deformed. Granted, much of what is being suggested is speculative, but at least it leads to open, interactive discussion. Certainly a more comprehensive approach would be to conduct additional field studies to determine if the ice within the lacuna band differs significantly from adjacent ice in which lacunas do not form.

Referee From the evidence presented, it can be said that there is a consistent association of the lacuna band with an area of fractured glacier ice likely occupying a transverse trough. It is possible that the fracturing influences patterns of surface ablation. Presumably, fractures allow drainage of meltwater into the ice, otherwise the lacunas would be full of water. How might the presence of open fractures encourage development of depressions?

Response Consideration is given to the asymmetric surface expression of lacunas, which is attributed to accelerated ablation along fractures and englacial structures. However, if open fractures were the only influencing factor, lacunas would appear elsewhere on the Bering piedmont lobe, but they don't.

Referee Does some kind of feedback process amplify ablation and lead to formation of the closed hollows?

Response Indeed, there must be some kind of feedback leading to lacuna formation, and their limited occurrence with a band of ice that occupied a subglacial trough across

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



which ice was thrust during a surge.

Referee Are there any systematic differences in the density or characteristics of fractures in ice with and without lacunas?

With a more thorough, critical approach, it is possible that a sound explanation can be found for these odd features.

Response Indeed, and this manuscript opens the door for discussion of features that have been entirely overlooked in the literature.

Interactive comment on The Cryosphere Discuss., 8, 2403, 2014.

Interactive comment on The Cryosphere Discuss., 8, 2403, 2014.

TCD

8, C1082–C1089, 2014

[Interactive
Comment](#)

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

