Review | Subglacial drainage patterns of Devon Island, Canada: detailed comparison of river and tunnel valleys. Galofre et al. (2017)

General Comments

This is an interesting paper that presents original research on a series of bedrock cut meltwater channels on Devon Island, Canadian Arctic Archipelago. A number of techniques including GPS, mobile LiDAR data and stereo imagery derived DSM are applied to investigate the difference between subglacial meltwater channels and rivers at high spatial resolution. There is a lack of high resolution morphological analysis of bedrock carved meltwater channels and this is therefore welcome work. The paper itself is generally well written and structured. However, I do have a number of general comments that I would like to see addressed before this paper is published, and some more specific comments below this.

1. *Use of the term tunnel valley*: The term tunnel valley is traditional used to refer to much larger features of the order of several kilometres wide and tens of kilometres long, that may be cut into sediment or bedrock. The features described here seem to be an order of magnitude smaller and I therefore suggest sticking to the term subglacial meltwater channel or N-channel throughout.
2. *Missing literature:* A large body of work on subglacial meltwater channels, including how to identify them in the geological record (e.g. Greenwood et al., 2007 and references therein) and their morphological properties and spatial distribution (e.g. Brennand & Shaw, 1994; Kristensen et al., 2007; Livingstone & Clark, 2016 to name but a few) seem to have been missed, with a lot of emphasis instead given to the Kehew et al. (2012) paper. In the discussion at least I was expecting the authors to refer back to previous work to put into context how these features are similar or different. Indeed, in the discussion, the text on the hydraulic potential equation is presented as original work, whilst it is actually well known (see Shreve, 1972), and their 'new' metric for tunnel valley identification on channel directionality is not really new (e.g. see Greenwood et al., 2007). The authors may also want to look at and compare their work to some of the recent modelling work that has tried to incorporate fluvial erosion into numerical ice models to investigate the formation of N-channels.
3. *Morphology of the subglacial meltwater features*: I believe this paper really undersells what is a fantastically high resolution study of the morphology of bedrock carved channels. I am not aware of such detailed work in such well preserved landforms and yet the results seem rather hidden away after the comparison of the different techniques. I would like to see more made (and example figures shown) of the channel morphologies, including further discussion of the headwalls, anabranching pattern, spacing, cross-sectional profiles and association with other bedforms, while a summary statistics table would also really help the reader. As currently written, it is the use of the different techniques which really comes out from this, not the morphology of the features. To broaden this work out it would have been nice to see how their dimensions compare with other studies of similar sized features (and then also the larger tunnel valleys) and to discuss what this means in terms of their formation (e.g. slow and steady vs catastrophic drainage).

Specific Comments

P1L1: Tunnel valleys can also be cut into sediment.

P1L6: should be “extent”

P2L28: I think there needs to be some recognition of the different scales here. N-channels are typically associated with much smaller channels cut specifically into bedrock. Tunnel valleys/channels may also be cut into sediment and are much large. In terms of the effect on ice dynamics – most of the work is associated with the evolution to channelized drainage and these channels are again envisaged to be an order of magnitude smaller than tunnel valleys/channels.

P2L10: “from” instead of “only with”.

P2L26: e.g. in wrong position in brackets beginning “Denton...”

P2L27: See also for a comprehensive mapping along a large portion of the southern sector of the Laurentide Ice Sheet: *Livingstone, S.J. and Clark, C.D., 2016. Morphological properties of tunnel valleys of the southern sector of the Laurentide Ice Sheet and implications for their formation. Earth Surface Dynamics, 4(3), p.567.* Indeed, there is a large body of work in this area, and also in the North Sea: see older papers in review by Kehew et al. (2012) – for completeness it would be good to reference some of the key work.

P2L34: This is conjecture – where is the evidence for temporal variability and large inputs?

P3L2: Although there has been a large body of work on the morphology of tunnel valleys (e.g. Livingstone & Clark, 2016).

P3L15: “ice sheet began retreating towards the current...”

P3L17: Capitalise Ice Sheet.

P5L11: This is not obvious from Fig. 1.

P5L25: What about figures 2 and 3?

P9L1-5: It would be useful for the reader if you included a schematic, perhaps on one of the profiles in Fig. 3 as it is not clear to me.

P9L19: “to have originated in a subglacial regime.”

P9L8: “tributaries have widths of...”

P9L8-10: I also found that apparent anabranching of the channels an interesting feature worth observing. In particular, can you tell from the DEM whether the channels were formed synchronously (same depth of channel bottom), or time-transgressively (which might manifest as different depths of anabranching channels).

P13L1-2: More details are needed here. How does the cross-sectional shape and depth change between recognised tunnel valleys and river channels? This is a key distinction that has been glossed over here.

P13L3: This is not clear to me as only a small portion of the image corresponds to tributaries that you pick out as having similar widths. Is there a better example?

P13L10: Braiding is the wrong term here I believe as this would refer to temporary islands as part of a dynamic sedimentary system. Anabranching is a more appropriate term

P13L8-11: Again, this seems very short on details. You state that you can pick out the key characteristics of tunnel valley networks but then seem to restrict this to a few choice observations.

P13L13: "criteria exposed before" is an odd phrase. Re-write.

P13L19: delete "targeted"

P13L21: "and approximately constant downstream from the origin until..."

P13L17: "tunnel valley widths are up to tens..."

Do these channels merge into the surrounding topography at their origin or do they have a clear amphitheatre-headed canyons? (e.g. see Lamb et al., 20016, 2014). This might give you some clues as to their origin.

P13L34: "Examples of this pattern are shown in..."

P14L1: "tree-like network typical of..."

P14L3: "tunnel valleys also have very few."

P14L8-21: This is nicely summarised, but not new. The hydraulic potential gradient has been widely used to infer channel direction and we know that the ice surface slope can drive water over topographic undulations.

P15L4: And critically, their morphology and association with other subglacial features like eskers, moraines, outwash fans.

P15L5: What is the example and how does that help? The text below does not mention other subglacial bedforms.

P15L10-12: I am not convinced this is a new metric for tunnel valley identification (e.g. see Greenwood et al., 2007; Livingstone & Clark, 2016 – section 3.1).

P15L11-12: I do not understand this final sentence. If the ice is cold based surely large meltwater channels are unlikely to form?

P16L5: How can you be so precise in stating the timing of these features?

<u>Figures:</u>

Figure 1: Can you distinguish, maybe with different colour arrows, between the river valleys and tunnel valleys. This would help the reader.

Figure 2: In the caption you refer to distinct groups but these are not clear from the figure. It would be useful to include these headings so the reader can easily distinguish. It is not that obvious from the profiles why some have been termed tunnel valleys and some rivers. For instance, most of group 4 and 5

tunnel valleys are relatively smooth with little in the way of reverse bed slops, and are therefore comparable to groups 2 and 3. What allowed you to distinguish these as tunnel valleys rather than river channels?

Figure 4: Missing a colour legend for panels (c) and (d).

Figure 5: What do the arrows refer to? More details on what is actually picked up in these images would be helpful to the reader.

References:

Beaud, F., Flowers, G.E. and Venditti, J.G., 2016. Efficacy of bedrock erosion by subglacial water flow. Earth Surface Dynamics, 4(1), pp.125-145.

Brennand, T.A. and Shaw, J., 1994. Tunnel channels and associated landforms, south-central Ontario: their implications for ice-sheet hydrology. Canadian Journal of Earth Sciences, 31(3), pp.505-522.

Greenwood, S.L., Clark, C.D. and Hughes, A.L., 2007. Formalising an inversion methodology for reconstructing ice-sheet retreat patterns from meltwater channels: application to the British Ice Sheet. Journal of Quaternary Science, 22(6), pp.637-645.

Kristensen, T.B., Huuse, M., Piotrowski, J.A. and Clausen, O.R., 2007. A morphometric analysis of tunnel valleys in the eastern North Sea based on 3D seismic data. Journal of Quaternary Science, 22(8), pp.801-815.

Lamb, M.P., Howard, A.D., Johnson, J., Whipple, K.X., Dietrich, W.E. and Perron, J.T., 2006. Can springs cut canyons into rock?. Journal of Geophysical Research: Planets, 111(E7).

Lamb, M.P., Mackey, B.H. and Farley, K.A., 2014. Amphitheater-headed canyons formed by megaflooding at Malad Gorge, Idaho. Proceedings of the National Academy of Sciences, 111(1), pp.57-62.

Livingstone, S.J. and Clark, C.D., 2016. Morphological properties of tunnel valleys of the southern sector of the Laurentide Ice Sheet and implications for their formation. Earth Surface Dynamics, 4(3), p.567.

Shreve, R.L., 1972. Movement of water in glaciers. Journal of Glaciology, 11(62), pp.205-214.

Stephen Livingstone