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A model for the interaction between conduits and the surrounding hydraulically-connected distributed drainage system based on geomorphological evidence from Keewatin, Canada.

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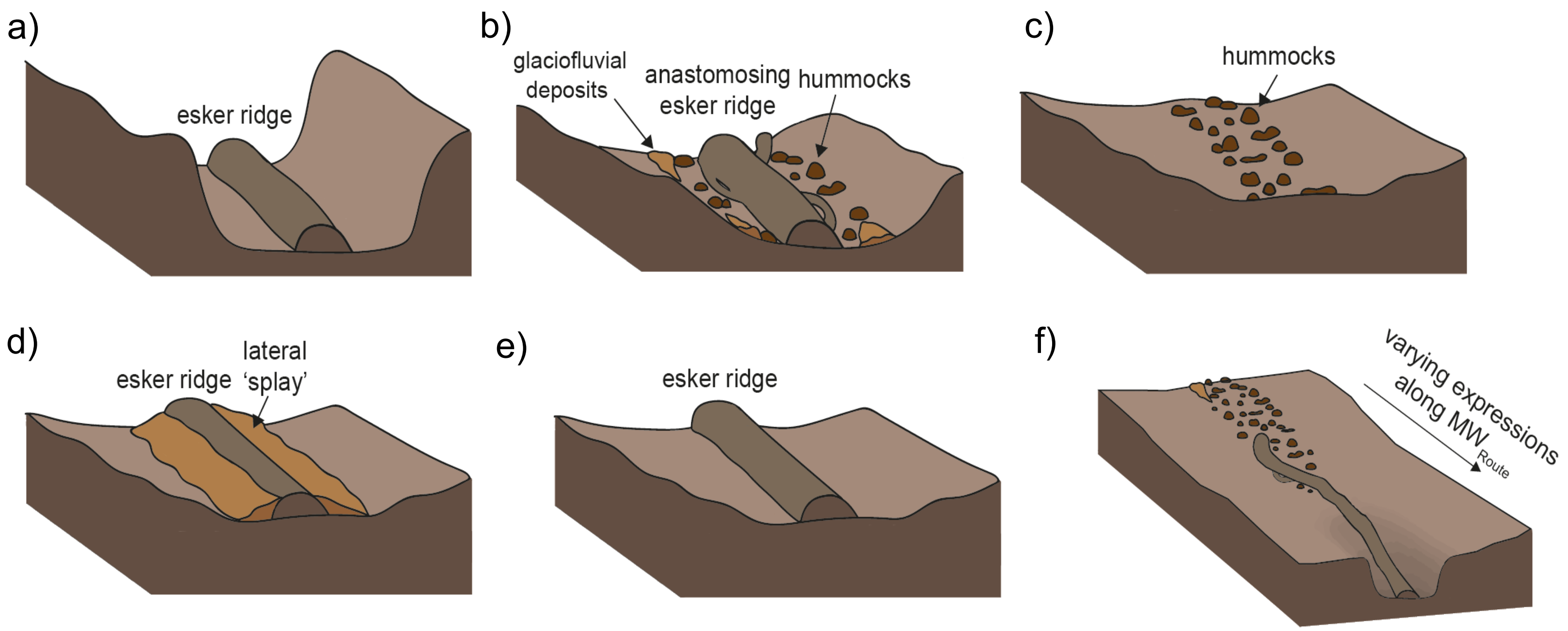
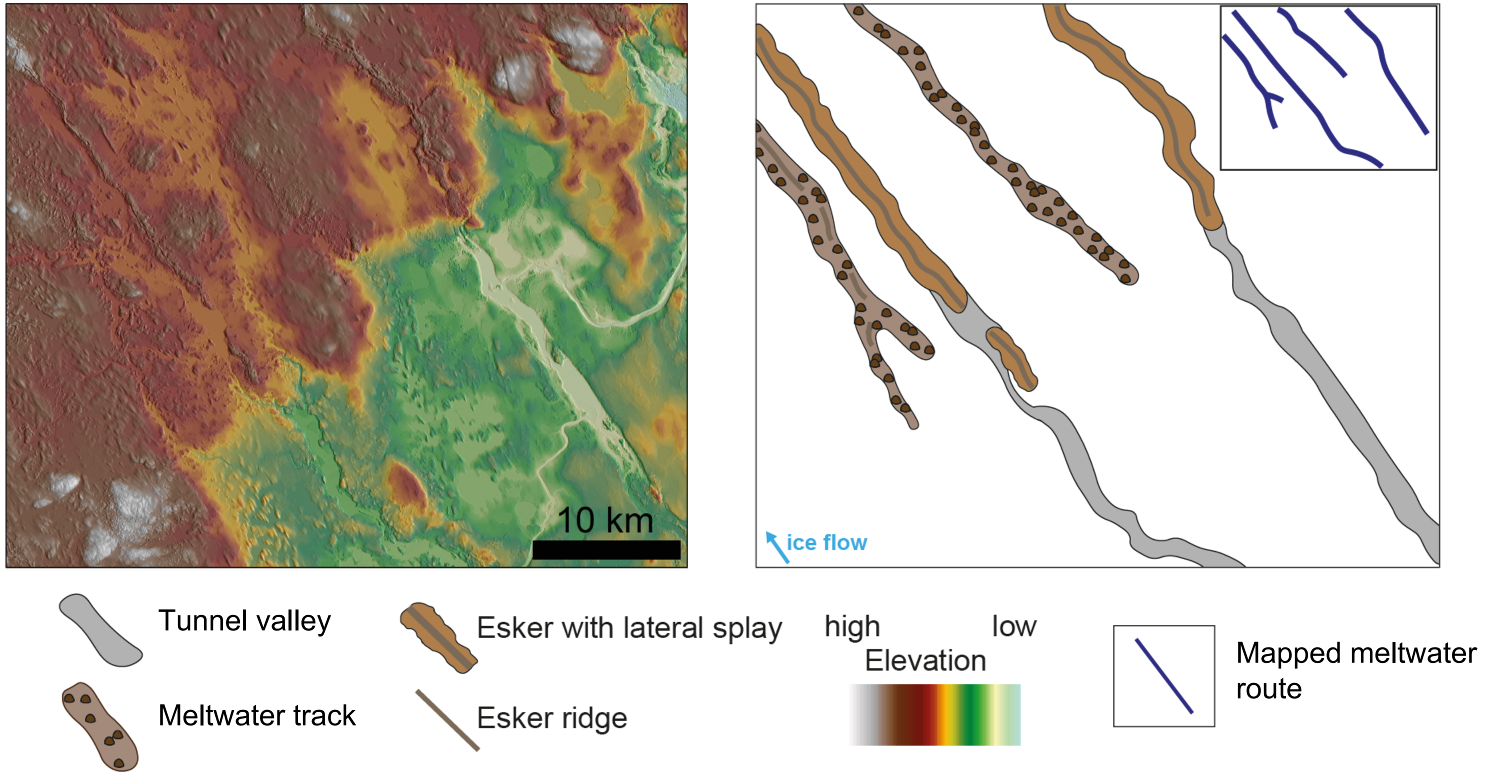
1. Motivation and Aim



Recently available high resolution ArcticDEM data allows us to view palaeo-ice sheet beds at unprecedented spatial scales and level of detail. This offers the potential to determine the spatial incidence of drainage, its different forms and its evolution.

A wide range of different meltwater landform expressions are found in the study area: (a) tunnel valley with esker; (b) meltwater track with esker, hummocks and glaciofluvial deposits; (c) hummocks organised in tracts; (d) esker surrounded by lateral deposits; (e) esker alone and; (f) frequent transitions along flow.

2. Methods



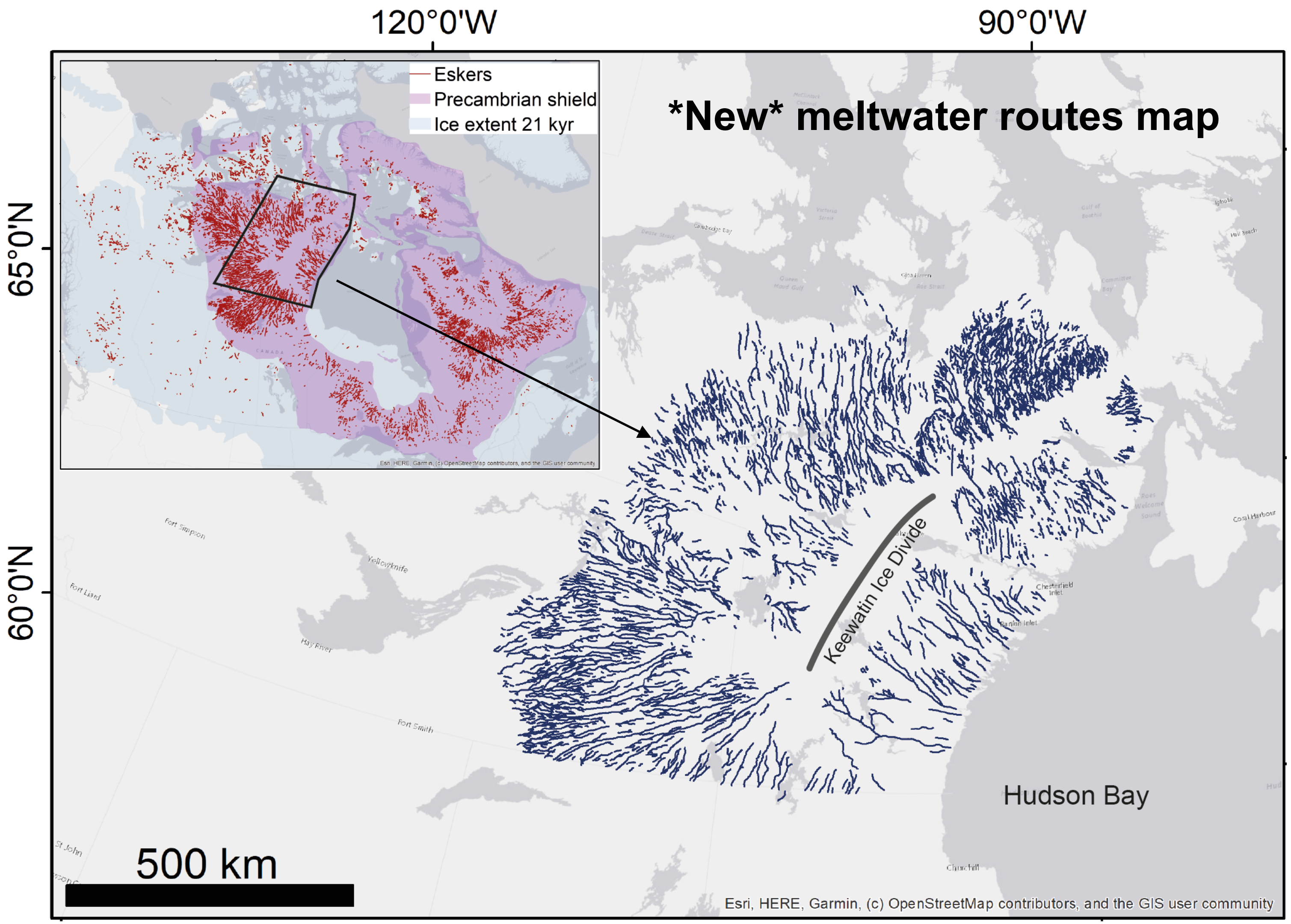
We map all visible traces of subglacial meltwater as meltwater routes (blue lines) across a large area of Keewatin, Northern Canada. We note multiple transitions along flow between different expressions of features traditionally mapped separately. Eskers are often situated within meltwater tracks or tunnel valleys.

2. Methods

The large-scale mapping (blue) is used to undertake an assessment of the distribution and variations in feature expression across the study area.

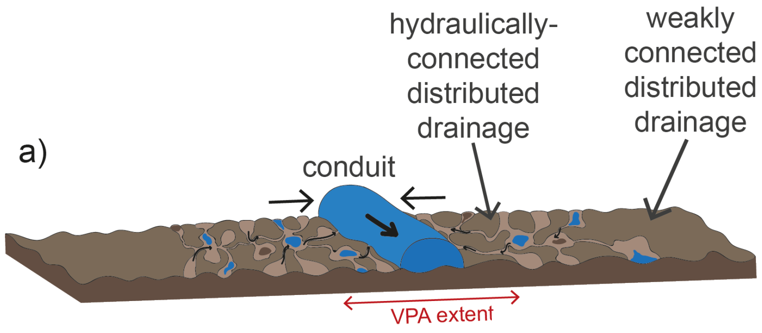
Similarities and associations between tunnel valleys, meltwater tracks and eskers, suggests that ‘different’ subglacial meltwater features could be different geomorphic expressions of the same system.

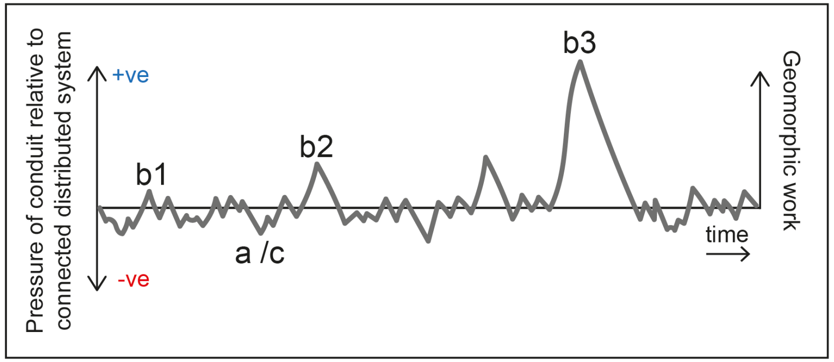
Based on these observations, we propose a new model….



Inset: Existing mapped eskers (Storrar et al., 2013), Laurentide ice sheet extent at the last glacial maximum (Dyke et al., 2003) and extent of the Precamrbian shield (Wheeler et al., 1996).

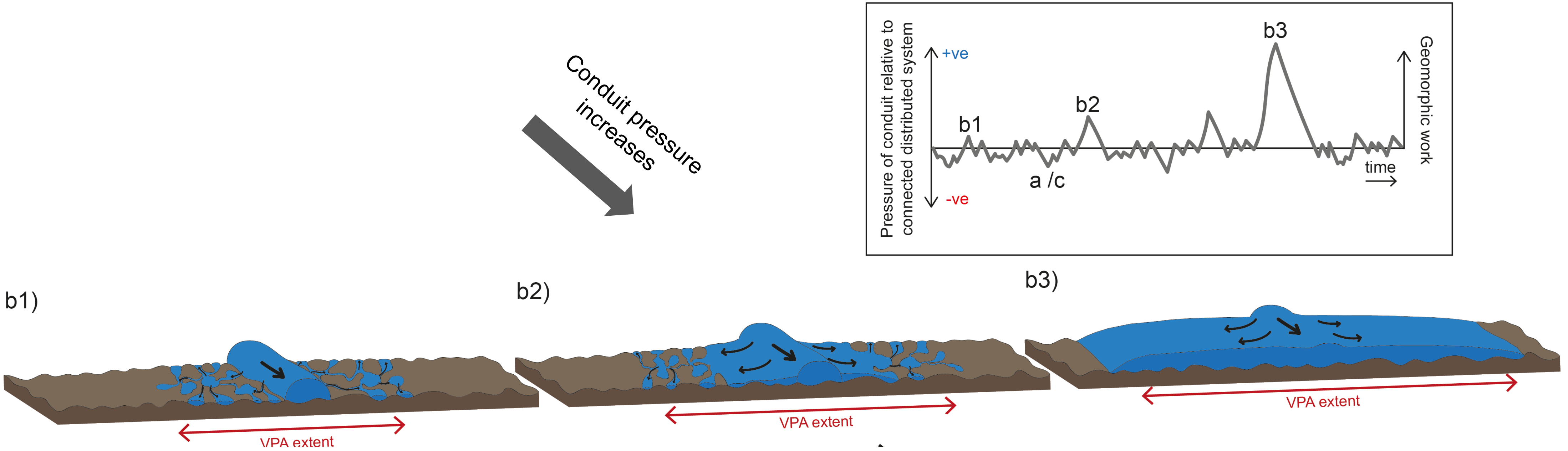
3. Proposed Model - A





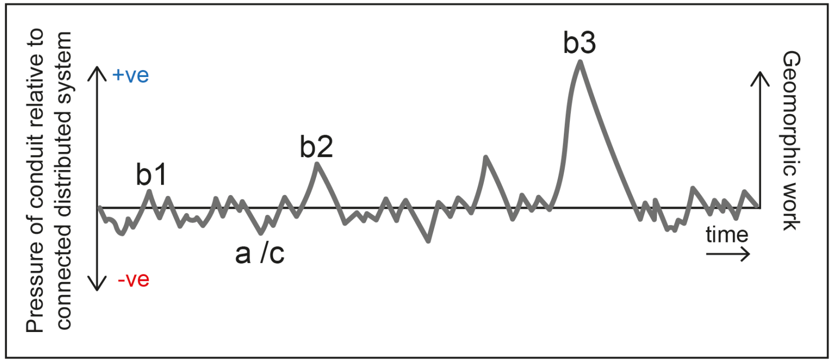
a) During steady state, the conduit is at lower pressure than its surroundings and thus drawing water in.

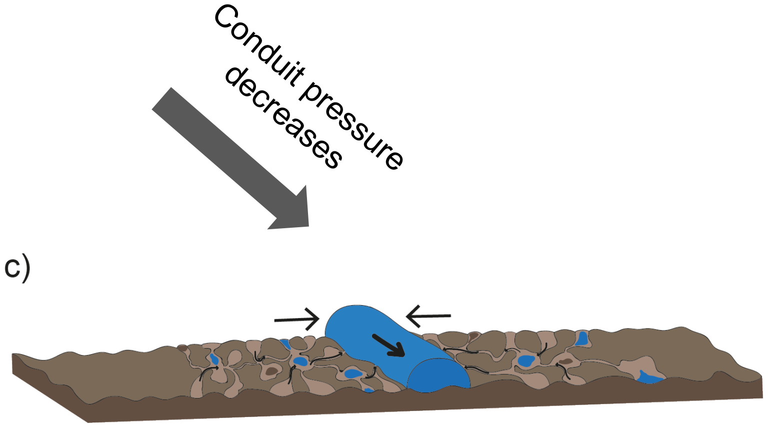
3. Proposed Model - B



b) A large and / or rapid meltwater input can cause a pressure spike within the conduit and reverse the pressure gradient (e.g. Hubbard et al., 1995; Bartholomaus et al., 2008; Werder et al., 2013; Tedstone et al., 2014), temporarily forcing water out and into the surrounding hydraulically-connected distributed drainage system across the variable pressure axis (VPA). The extent and geomorphic work of this (b1 -> b2 -> b3) likely depends on the magnitude of the pressure perturbation, basal sediments and antecedent conduit conditions.

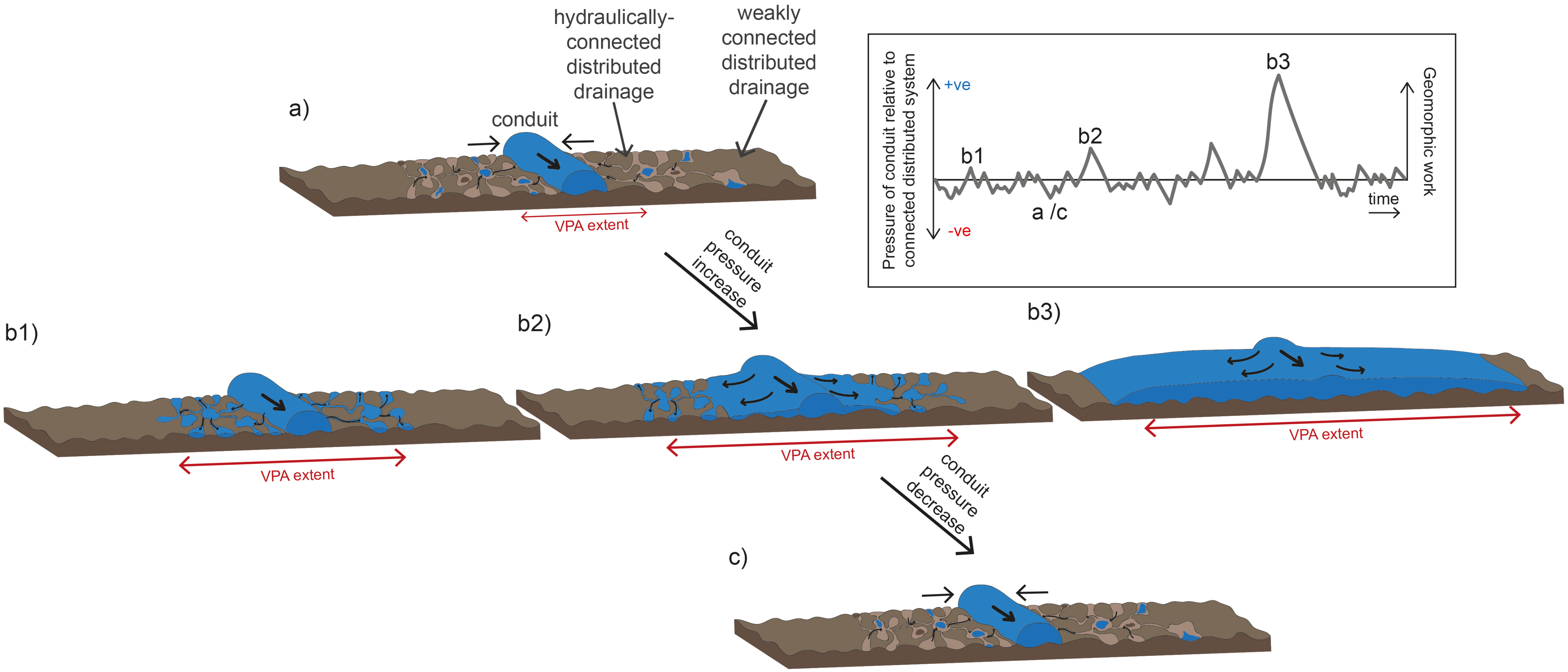
3. Proposed Model - C





c) The meltwater input decreases or the conduit adapts to a sustained increase in input and the pressure gradient is re-established.

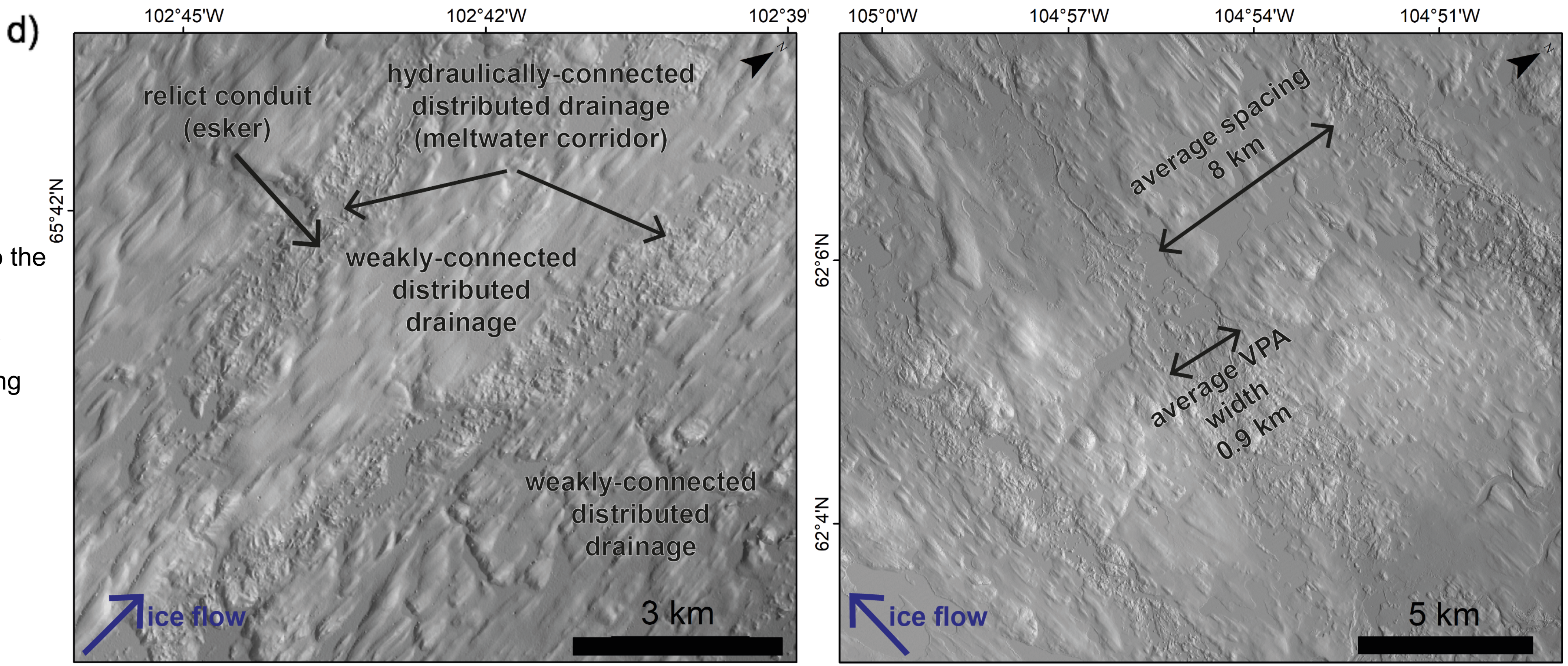
3. Proposed Model



Geomorphic signature??

3. Proposed Model - D

The proposed model links geomorphic observations to the components discussed in a contemporary / modelling setting (a-c)

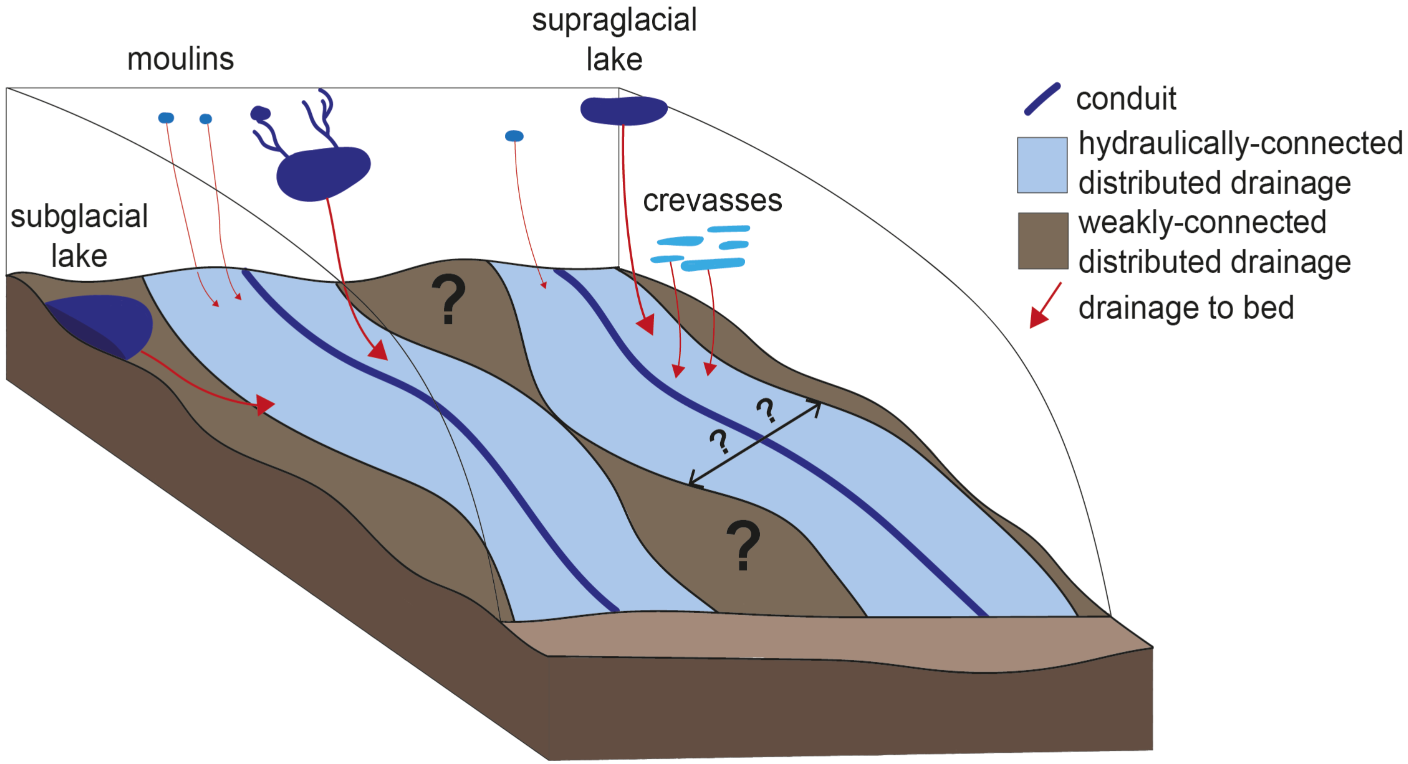


Note the contrast between the ‘rough’ meltwater corridors which are frequently connected to surface melt inputs and the surrounding ‘smooth’ bed where surface inputs rarely / never reach and where water remains in distributed drainage or in the till.

Meltwater corridors (meltwater tracks -> tunnel valleys) are composite features formed by the repeated connection of conduits with the surrounding hydraulically connected distributed drainage across the VPA over 10’s – 100’s years in the ablation zone. The generation of relief can be attributed to the conduit over-pressurisation (b1 - b3). Hummocks may be erosional – formed during the rising limb of flood events (b3); because of the removal of fines (all stages) or; the remnants of braided canals (e.g. Rampton, 2000; Peterson et al., 2018) – or depositional with sediment deposited in subglacial cavities (e.g. Brennand, 1994) or within cavities eroded up into the ice (Utting et al., 2009).

4. Implications

- Importance of considering a holistic subglacial drainage system – a three-system drainage model (e.g. Andrews et al., 2014; Hoffman et al., 2016) and traditionally 'different' geomorphic signatures.
- Quantification of the percentage of the bed influenced by surface meltwater inputs - meltwater corridors (and therefore the hydraulically-connected distributed drainage) covers somewhere between 5-36 % of the bed in Keewatin (x25 more than eskers alone).
- A mechanism for conduits to access and erode sediments at the bed (e.g. Swift et al., 2002; Alley et al., 2019) which may be used to build eskers. This could imply that the rate of subglacial fluvial erosion is dependent on meltwater fluctuations rather than total meltwater input.



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Thank you for reading!

If you have any comments or questions please do get in touch and if you would like to know more please see our paper under review in The Cryosphere Discussions: https://doi.org/10.5194/tc-2020-10

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