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Top-down or bottom-up? Assessing crevassing directions on surging glaciers and developments for physically testing glacier crevassing models.

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Networks of crevasse squeeze ridges (CSRs) preserved on the forelands of many surging glaciers attest to extensive full-depth crevassing. Full-depth connections have been inferred from turbid water up-welling in crevasses and the formation of concertina eskers however, it has not been clearly established if the crevasses formed from the top-down or the bottom-up. A Linear Elastic Fracture Mechanics (LEFM) approach is used to determine the likely propagation direction for Mode I crevasses on seven surging glaciers. Results indicate that, the high extensional surface strain rates are insufficient to promote top-down full-depth crevasses but have sufficient magnitude to penetrate to depths of 4–12 m, explaining the extensive surface breakup accompanying glacier surges. Top-down, full-depth crevassing is only possible when water depth approaches 97% of the crevasse depth. However, the provision of sufficient meltwater is problematic due to the aforementioned extensive shallow surface crevassing. Full-depth, bottom-up crevassing can occur provided basal water pressures are in excess of 80–90% of flotation which is the default for surging and on occasion water pressures may even become artesian. Therefore CSRs, found across many surging glacier forelands and ice margins most likely result from the infilling of basal crevasses formed, for the most part, by bottom-up hydrofracturing.

Despite the importance of crevassing for meltwater routing and calving dynamics physically testing numerical crevassing models remains problematic due to technological limitations, changing stress regimes and difficulties associated with working in crevasse zones on glaciers. Mapping of CSR spacing and matching to surface crevasse patterns can facilitate quantitative comparison between the LEFM model and observed basal crevasses provided ice dynamics are known. However, assessing full-depth top-down crevasse propagation is much harder to monitor in the field and no geomorphological record is preserved. An alternative approach is provided by geotechnical centrifuge modelling. By testing scaled models in an enhanced 'gravity' field real-world (prototype) stress conditions can be reproduced which is crucial for problems governed by self-weight stresses, of which glacier crevassing is one. Scaling relationships have been established for stress intensity factors - KI which are key to determining crevasse penetration such that $KIp = \sqrt{N}\, KIm$ (p = prototype and m = model). Operating specifications of the University of Dundee geotechnical centrifuge (100g) will allow the testing of scaled models equivalent to prototype glaciers of 50 m thickness in order to provide a physical test of the LEFM top-down crevassing model.