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Deep ice-filled crevasses at Store Glacier, Greenland, revealed by borehole optical televiewing

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Surface crevassing is common on most of Earth's glaciers and particularly prevalent on fast-moving outlet glaciers characterised by high surface strain rates. As well as having implications for the mechanics of ice deformation and net strength, crevasses represent a means of transferring surface-generated meltwater and associated heat into the interior, and ultimately possibly to the base, of ice masses. Theoretically, surface crevasses are restricted to the uppermost tens of metres of an ice mass, but this can be extended by hydrofracturing where crevasses are water-filled. However, details - such as the locations of hydrofracturing both within a crevasse field and more locally within individual crevasses - are poorly understood such that vertical crevasse extent remains largely unconstrained. This knowledge gap mainly reflects the challenges associated with obtaining measurements of crevasse depth at glaciers, in terms of both obtaining direct access and geophysical imaging, especially of water-filled crevasses.

Borehole optical televiewing (OPTV) records a high-resolution, geometrically-accurate image of the complete wall of any logged borehole, revealing the visible ice types and structures intercepted by that borehole. The technique therefore represents one means of investigating deep crevasses at ice masses, noting that such crevasses need to be inclined sufficiently to intersect an approximately vertical borehole. Here, we report evidence from a 325 m-long OPTV log of a borehole drilled ∼30 km upglacier of the terminus of Store Glacier, a fast-moving tidewater glacier in west Greenland. While most structural features in the OPTV log are low-angle alternating decimetre-scale layers of clear ice and bubble-rich ice, interpreted as stratification, several high-angle features were also imaged. These were present to a depth of ∼275 m and were typically centimetres to decimetres thick and composed of predominantly bubble-free ice. In one case, parallel crystal edges indicative of a directional freezing front were evident. Close inspection of the OPTV log also reveals that most of the high-angle layers enclosed one or more (and exceptionally, 11) structurally concordant millimetre-thick bubbly layers. We interpret the steeply-dipping layers as crevasses containing refrozen meltwater, and the fine bubbly layers as individual episodes of crevasse re-opening, refilling and refreezing – each expelling a new layer of gas as freezing completes. Implications for the transfer of mass and heat from the glacier's surface to its interior are explored by (i) comparing measured borehole temperatures with modelled englacial temperatures, and (ii) a spatial analysis of local surface crevassing.