What Basal Crevasses Reveal About Stress State at the Ice-Ocean Interface of Whillans Ice Stream

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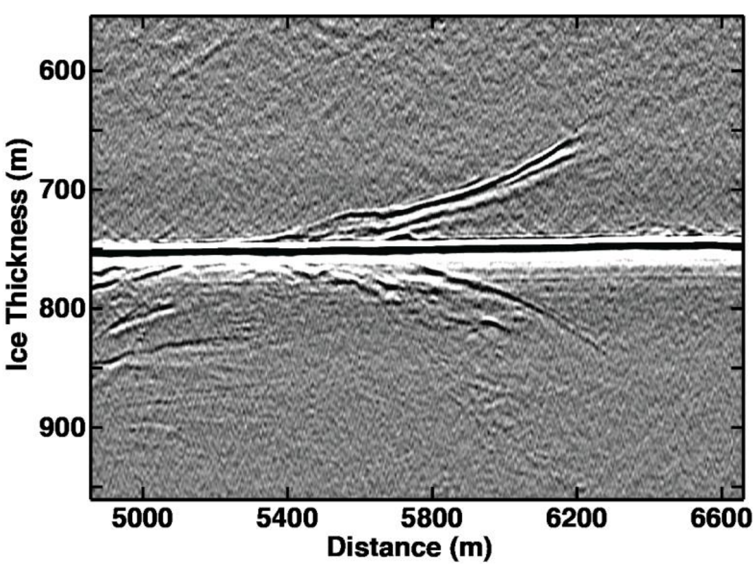
The transition from limited- or no-slip conditions at the base of grounded ice to free-slip conditions beneath floating ice occurs across the few-kilometers-wide grounding zone of ice sheets. This transition is either an elastic flexural transition from bedrock to hydrostatically supported elevations (often tidally influenced), or a transition from thicker to thinner ice over a flat bed, or some combination of these. In either case, ice must flow across a changing stress field, often resulting in brittle deformation manifested as basal crevassing at the ice sheet base and tidal strand cracking on the ice surface. Thus the position and morphology of basal crevasses reveal important information about the stress state across this transition where ice and ocean interact.

We acquired gridded ground-based radar surveys at two locations on the Whillans Ice Stream grounding zone, one over a subglacial peninsula where the transition to floatation is abrupt and the second over a subglacial embayment where several dynamic subglacial lakes drain to the ocean, likely resulting in episodic high sediment and water flux across the grounding line. Our surveys indicate a complex pattern of basal crevasses; some are related to basal topography, but others are more likely associated with ice flexure across the basal channel carrying water and sediment to the ocean. Due to the high reflectivity of seawater and the relatively shallow ice thickness, we image many off-nadir crevasses where the radar energy is first reflected from the ice-water interface and then from the crevasse, producing an echo signature with a delayed arrival time and reversed phase due to the second reflection. In several cases these crevasse echoes appear to mimic the geometry of a sub-ice "wedge" dipping into the sediment, while in reality the radar never penetrates below the basal interface. Elsewhere we image pairs of crevasses from either side of a channel incised into the bed that produce curious signatures in the radar profile showing a high degree of symmetry at both shorter and longer arrival times than the nadir bed echo (image). Our results indicate that basal crevasses offer a rich, but unexploited, dataset for diagnosing stress state and salient processes across grounding zones where ice and ocean interact, and that special care is needed when interpreting subglacial returns in radar data.



Symmetric crevasse signatures from the margins of a basal channel imaged simultaneously from fore and aft of the radar.