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Deep crescentic features caused by subglacial boulder point pressure on jointed rock; an example from Virkisjökull, SE Iceland

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A variety of subglacially formed, erosional crescentic features (e.g. crescentic gouges, lunate fractures) have been widely reported on deglaciated bedrock surfaces. They are characterised by a conchoidal fracture that dips in the same direction as the palaeo-ice flow direction, and a steeper fracture that faces against the ice flow. They are generally interpreted as being formed by point pressure exerted by large boulders entrained in basal ice. They are significant in that they record palaeo-ice flow even if shallower glacial striae are obliterated by post-glacial weathering [1, 2, 3].

This contribution reports on deep scallop-shaped, crescentic depressions observed on abraded surfaces of roche moutonnées and whalebacks recently (<10yrs) exposed beneath the actively retreating Virkisjökull, an outlet glacier of the Oraefajökull ice cap in southeast Iceland. The substrate comprises hard rhyolitic rock (relatively rare in Iceland compared to more common basalt and hyaloclastite) with polygonal, columnar jointing.

The crescentic depressions at Virkisjökull are cut into smoothed, abraded surfaces festooned with abundant glacial striae. Differences with previously reported crescentic features are:
• The scallop-shaped depressions are considerably deeper (5-20 cm);
• The steep fracture facing ice flow coincides in all cases with a pre-existing joint that cuts the entire whaleback. The steep joints developed thus before the conchoidal fracture, whilst in reported crescentic features they develop after the conchoidal fracture.

We suggest the following formation mechanism. A boulder encased in basal ice exerts continuous pressure on its contact point as it moves across the ice-bedrock contact. This sets up a stress field in the bedrock that does not necessarily exceed the intact rock strength (other crescentic features are rare to absent at Virkisjökull). However, as the stress field migrates (with the transported boulder) and encounters a subvertical, pre-existing joint, stress concentrations build up that do exceed the intact rock strength, resulting in a new (conchoidal) fracture, 'spalling' off a thick, scallop-shaped fragment.

The significance of the deep scallop-shaped crescentic depressions is that:
• in common with other crescentic features they appear to be robust ice-flow indicators and indicate that former basal ice was rich in coarse, cobble/boulder-sized debris;
• they are deeper and represent more significant erosion than previously reported crescentic features; during continuous subglacial erosion they thus (re)introduce a significant roughness on smoothed abraded surfaces, resulting in faster subglacial erosion;
• assuming our proposed formation mechanism is correct, they could develop at lower stress (?thinner ice, [3]) than other crescentic features, as they utilise pre-existing weaknesses in the rock.

The observations were made as part of the British Geological Survey's Virkisjökull Observatory Project.

[1] Gilbert, GK, 1906. Bull. Geo. Soc. Am, v. 17, 303-313.
[2] Harris, SE, 1943. J. Geology, v. 51, 244-258.
[3] Wintges, T. 1985. J. Glaciology, v. 31, 340-349.