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Characterising ice-magma interactions during a shallow subglacial fissure eruption: northern Laki, Iceland, a case study

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Iceland has the largest variety of subglacially formed volcanic edifices worldwide, given the extensive glacial cover during the Pleistocene and its frequent volcanic activity. As substantial parts of the volcanic zones are presently ice-covered, eruptions beneath glaciers are common.

Phreatomagmatic activity and flood deposits have been hypothesised for shallow subglacial fissure eruptions, at or within a glacial margin. However, to date, no historical examples that did not immediately break through the ice, resulting in dry magmatic activity, have been directly observed. Also, at dynamic ice-margin settings, no extensive resultant formations from shallow subglacial fissure eruptions formed in older historic eruptions have been studied until now.

The final fissure from the 1783–84 CE Laki basaltic flood lava event in the Síða highlands of Iceland, fissure 10, provides a perfect natural laboratory to understand the eruptive dynamics of a shallow subglacial or intraglacial fissure eruption. Fissure 10 is a 2.5 km long formation, which constitutes the final phase of activity on the 29 km long Laki crater row, formed as eruptive activity from the Laki eruption propagated under Síðujökull, an outlet glacier from the Vatnajökull ice-cap. The resultant eruptive sequences display evidence of the increasing influence of ice when traced along strike from SW to NE, with the eruption transitioning to a predominantly phreatomagmatic phase with increasing degrees of lateral confinement. The sequence is dominated by volcanoclastic units, formed by multiple phreatomagmatic and magmatic phases suggestive of fluctuating water levels, intercalated with hackly jointed intrusions, hackly jointed lobate lava flows and debris flows. Repeating units of agglutinated spatter and spatter-fed lava flows cap the sequence, suggesting decreasing influence of external water with stratigraphic height and towards the end of the

fissure's eruptive activity. A thin layer of glacial till coats the top of the fissure 10 sequences. The margin of Síðujökull has since fully receded from the formation.

Our model for the eruptive dynamics of the northern Laki fissure 10 formation is based on field mapping, a drone photogrammetry survey, petrological observations and EMP analysis of glassy tephra and lava selvages to gain a full understanding of the activity and how eruptive activity progressed. The Laki eruption benefits from a wealth of previous studies on the magmatic phases from the other 9 subaerially eruptive fissures, to the SW of fissure 10, allowing for the effects of the glacier on this fissure's activity to be isolated and defined.

Fissure 10 allows for an approximate reconstruction of the ice margin and glacier slope at the time of eruption, adding valuable information on the extent of the glaciers in SW-Vatnajökull in the late 18^{th} century, and during the Little Ice Age. These shallow subglacially erupted deposits are the only fully accessible intraglacial eruptive vents, from a known historical eruption, on Earth. Detailed mapping and petrological analysis of deposits like these is important for interpreting landforms in paleo-ice margins, where transitional activity occurs.