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Volcano-ice interaction: The empirical constraints derived from eruptions in Iceland in the period 1918-2015

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Eruptions where glacier ice has a significant effect on the style of activity occur in some parts of the world, notably the Andes, Alaska, parts of Antarctica and Iceland. Due to its northerly latitude and considerable ice cover within the volcanically active zones, about 50% of all eruptions in Iceland occur within glaciers, which is about 15 such eruptions per century. In the last 25 years, six such confirmed eruptions have taken place while only one minor confirmed eruption occurred in the period 1938-1996. This is due to the episodic nature of activity in the volcanoes covered by the 7900 km^2 Vatnajökull ice cap, with a new period of high activity starting with the Gjálp eruption of 1996. Contemporary observations have therefore provided considerable empirical data on these events. These data include glacier thickness prior to eruptions, ice cauldron development, glacier flow perturbations, melting rates and transitions from fully subglacial to explosive/partly subaerial eruptions. In addition, some data exist that constrains the volcano-ice interaction in the eruptions of Katla in 1918, Grímsvötn in 1934 and 1983, Gjálp in 1938 and Hekla in 1947. The majority of these events were basaltic. However, at least two eruptions that had an initial fully subglacial phase (Gjálp 1996, Eyjafjallajökull 2010) were of intermediate composition. The volume of subglacially-erupted magma ranged from a few million m^3 to 0.45 km^3 (DRE), initial ice thicknesses ranging from 50 to 750 m, and melted ice volumes between 0.01 km^3 to 4 km^3. Combined, the data from the eruptions of the last 100+ years, provides important constraints on heat transfer rates, the rate of penetration of eruptions through ice, glacier response to eruption, and the potential for generation of jökulhlaups and lahars. Post-eruption observations in Grímsvötn have revealed that craters formed in eruptions that break through the glacial cover can be partly built on ice. These tend to be highly transient features due subsequent melting and ice movement. Surface melting of ice by pyroclastic density currents has occurred in Iceland, but this type of activity has in the recent past mostly been confined to the occasional sub-Plinian to Plinian eruptions in e.g. Hekla volcano. However, there are indications that such activity has played an important role in some relatively rare large Plinian eruptions at ice covered volcanoes in Iceland, as observed in e.g. Alaska and the Andes.