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Magma storage before large and small explosive eruption at Grímsvötn volcano, Iceland, constrained by thermobarometry and volatiles in melt inclusions

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Basaltic eruptions at Grímsvötn occur every decade on average. These are normally phreatomagmatic of a low intensity whereas occasionally larger eruptions with an initial plinian phase take place. The last eruption in May 2011 reached into the stratosphere with heavy ash fall over south Iceland. What causes the difference in eruption intensity at Grímsvötn is not understood. In order to discuss this difference, the crystallization conditions of the eruptive magma were determined through thermobarometry and volatile concentration measured on melt inclusion (MI) and groundmass glasses. Tephra of the two largest historical eruptions (2011 and 1873) and two small eruptions (2004 and 1823) were investigated. Pressure and temperature estimates of crystallization are obtained through equilibrium clinopyroxene-glass (cpx-liq) pairs, where both adjacent groundmass glass and that of melt inclusions (MI) were measured. Most cpx-liq equilibria give pressure of 4 ±1 kbar corresponding to approximately 15 km depth. The cpx crystallization occurred over a considerable temperature range, 1065-1175 °C that correlates with the estimated pressure in products of the 19th century eruptions. Sulfur and chlorine concentrations are highest in MI of the larger eruptions (1974-1789 ppm and 339-266 ppm, respectively) together with lowest groundmass glass concentrations (908-766 ppm and 208-180 ppm, respectively). Quenching with glacial water explains higher groundmass values for the smaller phreatomagmatic eruptions. The differences in volatile concentrations between MI and groundmass glass ([U+F044] S) and the average sulfur concentration in the degassed groundmass correlate with known eruptive volume for the 21st century eruptions and that of the Laki eruption. This suggests water/magma ratio control of S degassing efficiency and allows crude estimates of unknown volumes for older eruptions. The higher volatile concentrations of MI in the larger eruptions are likely to reflect recharge of deep-derived and gas-rich magma and thus best explains the different eruption regimes at Grímsvötn. Similar crystallization depths of magma erupted in the four eruptions are comparable with cpx crystallization of basalt emitted during the 2014-2015 Bárðarbunga rifting event. This reveals identical depth of origin, supported by magnetotelluric surveys, and suggests an important magma storage at mid-crustal depth above the center of the Iceland mantle plume. The associated gas phase and its thermal expansion can be shown to account for the measured co-eruptive deformation.