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Explaining the Plinian-phreatoplinian shift during the 1875 Askja volcano eruption by coupling geological and numerical techniques

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The Askja Volcano is part of the larger Dyngjufjöll complex which is located in Central Iceland. During the 1874-76 a large volcano-tectonic episode took place on the Northern rift zone and the 1875 eruption of the Askja Volcano is part of it. The explosive rhyolite eruption of the Askja caldera, one of the very few eruptions showing both phreatoplinian and Plinian styles and the only well documented by eye witnesses, is the subject of this study. The eruption began the 28th of March (9 pm) with a subplinian event (phase B) which lasted for 1 hour. In the early morning of the 29th, after a pause of 6.5 hours, the eruption continued with a phreatoplinian phase (phase C1), which lasted 1 hour. This phase included emplacement of dilute density currents (phase C2), which became dryer with time. At 7 am the Plinian phase D commenced and lasted for about 5-6 hours. The vent position, which migrated throughout the eruption, has been constrained by previous studies. Aside from a small pond, no standing water which could have caused the phreatoplinian phase was present at that time in the caldera and therefore the source of external water driving the phreatoplinian phase is uncertain. We have undertaken a study to test if groundwater residing in the lava pile that partly fills the main Askja caldera could have been the provider of the external water involved in the phreatoplinian phase. The key questions are: Does the intra-caldera groundwater reservoir hold enough water? Can the water be transported fast enough to the vent site? The intra-caldera lava flows are strongly jointed and fractured and in order to quantify the fracture pattern and the permeability it provides we have measured and mapped out the fracture patterns of several lava flows. A discrete fracture modelling technique is used to compute the corresponding permeability and porosity. A 3D digital model of the Askja caldera that represents the pre-eruptive topography and hydrostratigraphy has been reconstructed. The calculated porosities and permeabilities provide factual data as model input parameters. Results show that the eruption resulted in ultra-fast radial flow of groundwater towards the conduit and provides sufficient water flux to drive the phreatoplinian phase of the 28-29 March Askja eruption. Furthermore, the model also produces rapid draw-down of the intra-caldera groundwater which explains the drying-out of the phreatoplinian phase depicted by the dilute density current deposits.