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Magma permeability and magma-slurry mingling during the 1963-67 eruption
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Processes observed during the extremely well documented eruption of Surtsey, Vestmanyaar, Iceland, 1963-67, highlighted the effects of interaction between erupting magma and abundant seawater on eruption dynamics. As the 50th anniversary of this canonical eruption approaches, however, many specific aspects of the eruption dynamics remain only qualitatively characterized. We present a detailed micro-cT 3D textural analysis of lapilli and ash from Surtsey, and use mingling and thermodynamic theory to quantitatively describe Surtseyan jets.

Fine lapilli (-2.0 phi) have total porosity ranging from 24 to 59 % (with one dense, impermeable outlier of 6 %), > 98 % of which is connected. Bubble number densities range from 4.05x105 to 8.30x106 cm-3, and are roughly inversely proportional to porosity. Darcian permeability ranges from 2.95x10-13 to 3.87x10-11 m2. Ash particles (3.0-3.5 phi) are generally blocky in outline, with surfaces often bounded by broken vesicles on one or more sides; however, blocky particles lacking any sign of vesiculation are also present. Groundmass textures vary from nearly holocrystalline tachylite to hypocrystalline sideromelane, with many larger clasts having a transitional texture characterized by patches of both.

Nearly all the lapilli have ash-packed vesicles around their exteriors. Such ash could easily have been entrained mechanically during transport, deposition and/or reworking, or drawn into the exterior vesicles by capillary action. More enigmatic, however, is when the vesicles deep within lapilli contain fine ash particles, ranging from a few grains adhering to vesicle walls, to cases where the vesicles are densely packed with poorly-sorted ash.

Based on careful examination of textures, we explore the hypothesis that a proportion of the ash in lapilli may in fact have been entrained during hydrodynamic mingling of magma erupting through a slurry of previously-erupted material in a flooded vent. We use such a scenario to explain the typical Surtseyan cypressoid jets of steam and pyroclasts. The slurry entrained into the newly erupted pyroclasts was vapourized to steam by magmatic heat, and then discharged from the same pyroclasts during dispersal.

Analyses based on thermodynamics and fragmentation criterion suggest that for a narrow but plausible range of magma porosity and magma-slurry mingling regimes, entrainment and vapourization of slurry may also have assisted in driving part of the fragmentation process. The hypothesis presented here is consistent with classical qualitative models of Surtseyan jet dynamics, and works toward explaining specific details about how magmatic and external factors contribute individually and cooperatively to shallow subaqueous eruption dynamics.

キーワード: magma, permeability, magma-water interaction, Surtsey, microtomography, mingling
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