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Observations on the Structure of Surtsey, Iceland, and its Basaltic Lapilli Tuff

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Comparison of the results of new investigations of the 1979 and 2017 cored boreholes coupled with observations of the dynamic surface of Surtsey have modified our concepts of the subsurface structure of the volcano, an oceanic island erupted from 1963–1967 on the insular shelf of the south coast of Iceland. The temperature anomalies in the 2017 vertical and inclined boreholes closely resembled each other in shape and magnitude even though they are 80 m apart horizontally. The peak temperature of the vertical hole anomaly immediately after drilling was 124 °C at 105 m below surface (m.b.s.) and the inclined hole anomaly 127 °C at 115 m.b.s. This temperature anomaly and the paucity of coherent basalt in the 2017 cores casts doubt on a previous concept — that the heat anomaly in the 1979 borehole, 141 °C at 100–106 m.b.s., was due to nearby intrusions. The new observations suggest instead that top-down heating from the subaerial lava shield may have contributed to the Surtsey thermal anomaly. In August 1966–June 1967, lava flows rapidly filled the Surtur vent crater to 80 m.b.s. and overflowed to the south and east. The conduction of heat from the cooling shield into the water-saturated substrate would have been influenced by the material characteristics of the underlying lapilli tuff, but the mechanisms of downwards heat transfer are not clear. In the zone of tidal flux centred at ~58 m.b.s., for example, the tuff was highly porous in 1979 and it remains porous and permeable 50 years after eruptions terminated. Boiling of interstitial water below sea level could have produced steam that rose and warmed the porous and permeable tephra adjacent to the lava shield, where it produced broad areas of palagonitized tuff. Other sources of heat are also under consideration. At 107 m.b.s., fresh glass in the lapilli tuff of the original 1979 thin sections contains abundant granular and microtubular structures. These resemble endolithic microborings, and they are perhaps indicative of an early, short-lived episode of cooler temperatures and functional microbial activity at <120 °C. A geometrical analysis of layering in unrolled digital scans of the 2017 cores indicates that the relation of the apparent dip to the true dip of layering in the core inclined 55° from horizontal is such that steep dips are more common in westerly true dips, and gentle dips are more common in easterly true dips. The measurements indicate that near-surface layering in both the vertical and inclined cores dips westerly, suggesting that the boreholes are located inside the Surtur crater. In this proximal setting, the section of lapilli tuff may be almost entirely composed of facies re-sedimented from unstable depositional sites and/or recycled through the vent perhaps multiple times. Sub-seafloor lapilli tuff samples with high porosity, high water

absorption and low unit weight may reflect these complex eruptive processes. The new observations support the hypothesis that broad conduit and vent filling deposits underlie the Surtur crater.