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ICDP SUSTAIN drilling at Surtsey Volcano: A time-lapse drill core record and hydrothermal borehole observatory in basalt 50 years after eruption

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Surtsey, a 50-year-old volcanic island in the southern offshore extension of the SE Icelandic rift zone, provides a uniquely well-documented record of the explosive eruption of basalt into seawater and the rapid alteration of basaltic glass and crystals in an active hydrothermal system. The SUSTAIN drilling project, sponsored in part by the International Continental Drilling Project (ICDP), builds on 1963–1967 observations of explosive and effusive eruption processes and investigations of hydrothermal processes in a 1979 181-m-deep cored drill hole (SE-01)[1]. SUSTAIN research provides precise time-lapse observations of the hydrothermal system, the mineralogical, geochemical, geomagnetic and microbiological processes that transform the subaerial tuff cone and submarine deposits, the changes in material properties that accompany these processes, and further insights into the eruption processes that produced the volcano.

2017 SUSTAIN drilling in the Surtsey Natural Reserve and UNESCO World Heritage site reoccupied the 1979 drill site, at 58 m a.s.l. on the eastern crater. It produced nearly 700 m of core using an Atlas-Copco CS-1000 rig mounted on a spinner base, through zero-impact protocols developed with the Iceland Environmental Agency. A vertical HQ (63.5 mm) cored hole (SE-02A) used filtered, doubly-sterilized seawater drilling fluid and no mud products, to minimize contamination, but collapsed at 152 m (93 m b.s.l.). Samples for geochemical and microbiological analyses from the core were immediately fixed and frozen on site. A second vertical, cored HQ hole contains the Surtsey Subsurface Observatory, a 183-m-deep, 47.6 mm diameter (NQ) chamber with T6061 anodized aluminum casing and 5 perforated sections at 38, 63, 106, 136, and 161 m below the wellhead. These flow-through chambers contain temperature loggers and perforated PEEK (polyetherketone) incubators, attached to Vectran rope hung from the well cap. A two-year experiment using basaltic glass granules melted from Surtsey lava and olivine (Fo90) was installed on September 6, 2017. Finally, a cored hole inclined 35° from vertical (SE-03) and directed S4°W provides a 354 m long window into the eruptive conduit, feeder dikes for lavas, sub-seafloor microbial habitats, and the deeper zones of Surtsey's hydrothermal system. Although challenges with obtaining a reliable sea water supply delayed drilling progress, these were resolved with construction of a 16,000 liter reservoir with submersible pump on the northern peninsula. Downhole logging in SE-02B indicates variations in material properties in porous tuff above sea level, clay-rich submarine tuff at hydrothermal temperature maxima, >120°C at 48 m b.s.l., and loosely consolidated tephra overlying coherent basalt. Temperature monitoring confirms gradual cooling from 1979 to 2017. Introductory comparisons of 1979 and 2017 tuff drill core indicate that ongoing alteration of glass, plagioclase, and olivine produced abundant additional smectitic clay mineral, principally nontronite, and authigenic zeolite and Al-tobermorite minerals.

The integrated results of the time-lapse drill core investigations and borehole incubation experiments will provide a foundational reference for the initiation of microbial life in a pristine basaltic habitat and the systematic, longitudinal characterization of water-microbial-basalt interactions in subaerial and submarine environments.

[1] Jakobsson, S., and Moore, J.G. (1986) GSA Bulletin, 97, 648–659.