THE HYDROTHERMAL SYSTEM OF THE 2014–2015 LAVA FLOWS AT HOLUHRAUN, ICELAND: AN ANALOG FOR MARTIAN LAVA–WATER INTERACTIONS. C. M. Dundas[1], L. Keszthelyi[1], C. W. Hamilton[2], L. E. Bonnefoy[2], S. P. Scheidt[2], E. Lev[3], M. E. Rumpf[3], T. Thordarson[4], Á. Höskuldsson[4], I. Jónsdóttir[4], A. L. Keske[5], M. M. Sori[2], [1]U.S. Geological Survey, Astrogeology Science Center, 2255 N. Gemini Dr., Flagstaff, AZ 86001, USA (cdundas@usgs.gov), [2]Lunar and Planetary Laboratory, University of Arizona, 1629 E. University Blvd., Tucson, AZ 85721, USA, [3]Lamont-Doherty Earth Observatory, Columbia University, 61 Route 9W, Palisades, NY 10964, USA, [4]Faculty and Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland, [5]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85281, USA.

Introduction: A major basaltic eruption occurred at Holuhraun, Iceland between 2014–2015 [1–3]. The resulting lava flow field is one of the largest and most rapidly emplaced subaerial lava flows erupted during recent times anywhere on Earth. As such, it is one of the best available analogs for the still-larger flows that dominate Martian volcanic provinces.

The substantial lava–water interactions are an especially interesting feature of this exceptional analog site. Numerous observations indicate various forms of lava–water (or lava–ice) interaction on Mars, producing landforms such as rootless cones and columnar jointing [e.g., 4–11]. On Mars, floods of lava and water appear to have erupted from the same vents, possibly as part of the same eruptions [11–12]. Lava heating could have provided habitable hydrothermal environments. Although short-lived, these could be excellent places to look for evidence of life brought up from the deep subsurface by contemporaneous eruptions of water and lava [13].

Hydrothermal System of the 2014–2015 Lava Flows: The fresh lava has been interacting with both groundwater and river water. Surface water and shallow groundwater reach the lava from several directions and flow beneath it. The lava–water interactions manifest in several ways: widespread steam plumes rise from the lava, warm springs emerge within an existing riverbed covered by the flow, and a river (part of the braided river system Jökulsá á Fjöllum) lines the southern and eastern edge of the lava flow field (Fig. 1). Despite this extensive interaction, rootless cones did not develop and/or were not preserved on the lava.

Parts of the system are dynamic on various timescales, even after the eruption ceased. During August 2015, the river disappeared beneath the lava flow several km from the end of the lava flows, at a point where it was impounded by the lava. The stream level was variable: on 8/23/15, the stream smoothly flowed into rubbly pahoehoe and vanished, although traces of a much higher water level were visible (Fig. 2). Twenty-four hours later, the water had risen and formed a substantial temporary lake (Fig. 3), presumably due to differences in stream flow since the lava dam had not changed. By the summer of 2016, the river had breached the blockage and flowed continuously along the southern margin of the lava.

The warm springs at the toe of the lava represent a significant source of advective heat loss and indicate water cooling of the lava. Temperatures and water flux measurements permit an estimate of this heat flux. The springs were as warm as 47°C in August 2015 but had cooled substantially one year later. However, temperatures up to 37°C were still present in places away from the toe along the northern edge of the lava, indicating that the hydrothermal system is likely to remain warm for several years. Algae was abundant in the warm springs.

Lessons for Mars: The Holuhraun hydrothermal system has several lessons applicable to Mars. Parts of the system are far more dynamic than current concepts of lava–water interaction, posing a challenge to deciphering the cooling history where substantial lava-water interaction occurred on Mars. There is a necessary feedback between studies of the surface morphology (and interior jointing, when possible) and of the cooling processes. For instance, formation of columnar joints by aqueous cooling [e.g., 14] will be influenced by the spatial and temporal variations of water flow. The 2014–2015 flow at Holuhraun demonstrates that lava-induced hydrothermal systems are favorable locations for life. Although life is unlikely to originate in such an ephemeral system, old Martian analogs could be good locations to look for biosignatures indicating a temporary blooming. Fluvial modification of the lava is likely to occur on short timescales; the flow of water beneath the lava is also intriguing and could produce misleading temporal relationships in satellite data. The lava flow field itself is an outstanding analog for Martian lavas and should provide insights into questions about rubbly pahoehoe formation, landscape evolution, and other processes.

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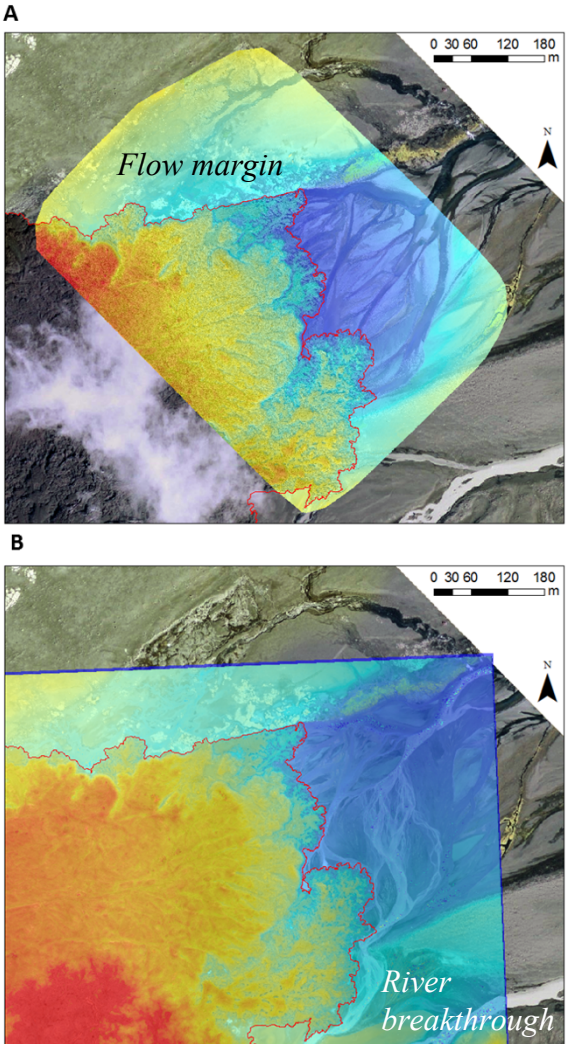

Figure 1: Aerial photos with overlain digital topography covering the spring outflows at the most distal point of the Holuhraun lava flow field, with overlain digital topography derived from unmanned aerial vehicle (UAV) imagery. Cool colors represented lower elevation while warm colors represent higher elevation. Panel A is from September 4, 2015 and panel B from July 28, 2016, showing the breakthrough of the river channel along the southeastern margin of the lava. The location of the stream and temporary lake shown in Figs. 2 and 3 is 3–4 km southwest of the hot springs region shown in this figure.

Figure 2: Location of stream draining into and beneath lava flow (August 23, 2015).

Figure 3: Temporary lake formed within 24 hours (August 24, 2015).