LAVA ERUPTION AND ENSHARMING: USING CLUES FROM HAWAI’I AND ICELAND TO PROBE THE LUNAR PAST. D. H. Needham¹, C. W. Hamilton², J. E. Bleacher¹, P. L. Whelley¹,³, K. E. Young¹,³, S. P. Scheidt², J. A. Richardson¹,³, S. S. Sutton². ¹NASA MSFC, 320 Sparkman Dr., Huntsville, AL 35805, debra.m.hurwitz@nasa.gov, ²LPL University of Arizona, ³NASA GSFC, ⁴USRA, ⁵UTEP/Jacobs JETS, NASA JSC.

Introduction: Investigating recent eruptions on Earth is crucial to improving understanding of relationships between eruption dynamics and final lava flow morphologies. In this study, we investigated eruptions in Holuhraun, Iceland, and Kīlauea, Hawai’i to gain insight into the lava dynamics near the source vent, the initiation of lava channels, and the origin of down-channel features. Insights are applied to Rima Bode on the lunar nearside to deduce the sequence of events that formed this lunar sinuous rille system.

The goal of this work is to precisely interpret whether the volcanic features associated with Rima Bode directly relate to eruption conditions at the vent and, thus, whether those features can help us understand associated eruption dynamics or, alternatively, whether the features formed as a result of more localized influences on lava flow dynamics. For example, if the lava channel developed early in the eruption and was linked to pulses in vent activity, its morphology can be analyzed to interpret the flux and duration of the eruption. Conversely, if the lava channel initiated late in the eruption as the result of a catastrophic breaching of lava that had previously pooled within the vent [e.g., 1], then the final channel morphology will not indicate eruption dynamics but rather local dynamics associated with that breach event. Distinguishing between these two scenarios is crucial for correctly interpreting the intensity and duration of volcanic activity on the Moon.

Geology of Rima Bode: Rima Bode (Fig. 1) is located in SE Sinus Aestuum on the lunar nearside and is characterized by an elongate source vent (Fig. 2a) and two channel segments separated by a smooth plain 266 km² in area (Fig. 3a). The channel segments are 109 and 139 km long, 870 and 670 m wide, and 100 and 75 m deep, respectively, measured using Lunar Reconnaissance Orbiter Wide Angle Camera (LRO WAC) images, Kaguya Terrain Camera (TC) images, and Lunar Orbiter Laser Altimeter (LOLA) topography tracks. Vent depth varies from 160 to 500 m and has a volume of ~6 km³, and the upper channel initiates at the northeastern rim of the vent (Fig. 2a). The down-channel smooth plain has a marginal ledge that encircles the entire feature (Fig. 3a, arrow). By studying recent terrestrial eruptions, we gain insight into (1) the origin of vent morphology with its variable depths, (2) the timing of initial channel formation, and (3) the origin of the down-channel plain.

Origin of the Vent and Channel: The 2014–2015 eruption at Holuhraun, Iceland provides an analog for the vent/channel system of Rima Bode. This widely documented fissure eruption initiated August 29, 2014, and over the ensuing 183 days deposited ~1.5 km³ of lava over an area of 83.5 km², with a mean eruption flux of 161 m³/s [2]. The fissure developed spatter cones around distinct centers of explosive eruptions, with the largest cone encircling the longest-lived, 0.5 km-long northeastern cluster of eruption centers (Fig. 2b,c). Other sites of effusive activity ended earlier in the eruption (left part of Fig. 2b), leaving behind smaller cones and shallower pits after the eruption ceased.

Lava channels formed throughout the eruption—some were cut off by spatter deposition (e.g., site of a once-active channel, white arrow in Fig. 2c) while others widened (e.g., site of developing channel, black arrow in Fig. 2c), possibly through small-scale local erosion as lava carried portions of the cone down-channel. One channel in particular formed at the northeastern rim of the long-lived cone about half-way through the eruption, before the spatter cone had developed, then widened to form a prominent channel that remained active for the duration of the eruption. This channel was directly linked to the vent and, thus, its morphology reflects the dynamics of this eruption.
This volume represents a mini-vent and flowed through the upper channel segment. The volume of lava that erupted from the Rima Bode set upon the Moon, though at a much larger scale. Similar ledges are observed around the smooth plain (Fig. 3b). These observations are consistent with the formation of a lava pond that subsequently drained [1].

Similar ledges are observed around the smooth plain associated with Rima Bode (Fig. 3a), though these lunar ledges are 60–80 m above the adjacent plain. This suggests a lava pond similar to that observed in Hawai‘i also formed on the Moon, though at a much larger scale. The volume of the lunar lava pond provides an estimate for the volume of lava that erupted from the Rima Bode vent and flowed through the upper channel segment. This volume represents a minimum estimate because the lava may not have completely drained out of the channel or the pond, as is observed in the Hawai‘ian and Iceland lava channels.

Implications for Rima Bode: Rima Bode likely developed analogously to the terrestrial cases. Observed variations in eruption intensity along the Holuhraun fissure resulted in a final vent morphology with varied cone heights and vent depths, much like that seen in the Holuhraun vent associated with Rima Bode. Additionally, observations of the well-developed lava channel that evolved over the duration of the Holuhraun eruption suggest that the Rima Bode channel likely was also directly linked to the eruption. Therefore, observed morphologies of the sinuous rille and the volume drained from the lava pond can be used to estimate the flux and duration of the Rima Bode eruption (Table 1).

Table 1: Flux and duration of three eruptions.

<table>
<thead>
<tr>
<th>Eruption</th>
<th>Duration</th>
<th>Volume (km$^3$)</th>
<th>Flux (m$^3$/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 1974</td>
<td>6 hours</td>
<td>0.014</td>
<td>662 (mean)</td>
</tr>
<tr>
<td>Holuhraun</td>
<td>183 days</td>
<td>1.6</td>
<td>161 (mean)</td>
</tr>
<tr>
<td>Rima Bode</td>
<td>10–22 days</td>
<td>14</td>
<td>7,000–16,000 (peak)</td>
</tr>
</tbody>
</table>

In conclusion, by studying analogous terrestrial eruptions, we gained confidence in our interpretation that morphologies of sinuous rilles lend insight into lunar eruption dynamics.