VENT MORPHOLOGY AT THE HOLUHRAUN LAVA FLOW (NORTHERN ICELAND) AS AN ANALOG FOR MARTIAN FISSURE VENTS.

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Introduction: Elongate volcanic vents are a common feature in volcanic fields on the Moon, Mars, and Earth and are generally the source for basaltic lava flows. On Mars, hundreds of these elongate fissure vents have constructed the current landscape within the Tharsis Volcanic Province [1].

Holuhraun Field Analog. The fissure vent system of the Holuhraun lava flow in central Iceland has an analogous morphology to the fissure vents in Tharsis. The main phase of the Holuhraun eruption began on August 31, 2014 and extruded ~1.4 km^3 of lava over 6 months, making it the largest subaerial flood lava on Earth since the 1783–1784 eruption of Laki [2,3]. The largest source vent constructed a 500-m long, 50-m deep crater named Baugur, which is similar in its morphology and size to vents cataloged on Mars [4].

Field methods: Volcanic materials outside and within the Baugur vent were described by our team during field expeditions to the region between 2015–2019 [5]. During these campaigns we performed lidar and aerial surveys to create digital elevation models (DEMs) of the vent surface.

Lidar surveys. Terrestrial lidar surveys were performed within the main Holuhraun vent and its proximal channel using a Riegl VZ-400 laser scanner. Scan positions were georeferenced and combined into vent-wide point clouds using RiSCAN Pro software. Vent point clouds cover >90% of the interior of the vent with a point-space resolution of 2 cm.

Aerial surveys. Stereophotogrammetric surveys were completed over the vent area to produce high-resolution orthoimages and elevation models of the vent and channel. Image data from a Trimble UX5 HP fixed wing drone with a 36 MP full-frame digital camera were used to produce DEMs at 12–20 cm/px and an orthoimage at 2.5–4 cm/px resolution.

Image analysis. Videos and images during the 2014–2015 eruption from tourists, park rangers, and scientists, as well as material provided by the Icelandic meteorological office in monthly reports enabled the production of a timeline of events. These events include the formation, destruction and evolution of vent features.

Construction of the Baugur Vent: *Spatter rampart.* Baugur was constructed as a 500 m long spatter rampart during the first half of the eruption, initiating as a fissure on August 31, 2014. Fire fountaining from the vent began emplacing spatter that agglutinated and built topography [4]. In mid-September, this fissure vent was initially constructed as three independent cones [6] about 50 m high [4]. Within weeks, these cones began coalescing into one elongate spatter rampart. Ultimately the dimensions of the Baugur vent were 500 m long by 50 m wide with the summit 50 m above the Holuhraun lava surface, though this friable edifice is now degrading [5].

Channels. Main lava channels developed for each cone during their construction with the largest two emanating from the north and south of the vent (Fig 1). In mid-September, the southern channel of the vent was

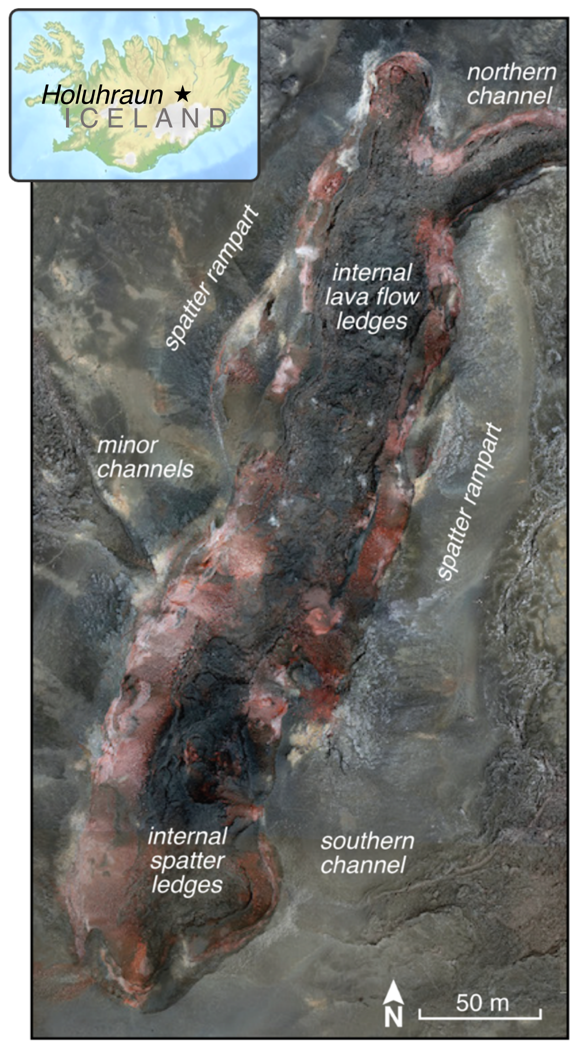

Figure 1. Aerial orthomosaic of Baugur, the largest vent of the Holuhraun flow in 2018.

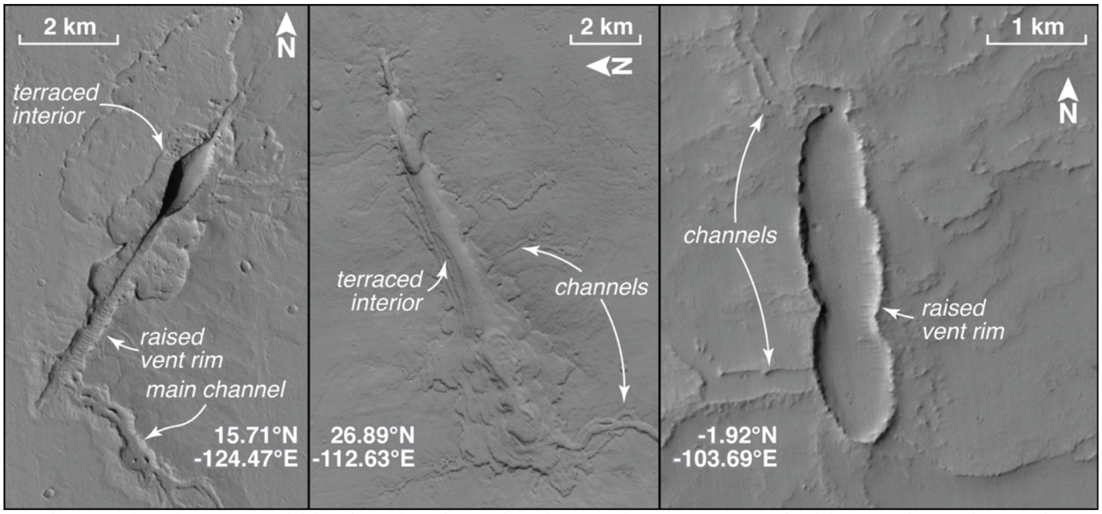

Figure 2. Three volcanic vents within the Tharsis Volcanic Province, Mars. *Left*, this vent has a large channel at its south end and a deep depocenter towards the north end. *Center*, this vent exhibits several channels and several layers of nested terraces within its depression. *Right*, This vent has a prominent rim that cuts off channels to the south but opens to a northern channel. Image source is the CTX global mosaic [9].

the main outlet of lava to the flow field, though by October 12, only the northern channel was active and it would remain the main channel until the end of the eruption at the end of February. While the southern channel is now buried in spatter, a minor channel is perched, unburied on the western flank of the vent. Video of the eruption in February suggests that this channel is adjacent to a location of active fountaining and might have been intermittently filled with molten material late in the eruption [7].

Interior terraces. We identified two types of terraces in the interior of Baugur. The first type have interior-facing cliff faces that expose welded spatter. Their top surfaces slope away from the axis of the vent. The second type have sub-horizontal surfaces and are made out of basalt lava. We have matched these lava terraces to the height of ponded lava in Baugur during February 2015, the final month of the active eruption. By comparing images of the lava pond within the vent to the lidar point cloud and aerial imagery, we have found that the level of lava within Baugur maintained a steady height of ~8 m above the currently preserved vent floor for at least 2 weeks at the beginning of February [6,7]. We interpret these terraces to be remnants of a cooled crust that formed at this elevation. At the end of the eruption, lava drained from the vent and this crust would have collapsed, creating the highly fractured basaltic lava floor within the vent today.

Application to fissure vents on Mars: The similarities of Tharsis fissure vents (Fig. 2)[1] to Holuhraun can enable the interpretation of these volcanic eruptions on Mars. The presence of many small channels at volcanic vents is similar to the early period of construction at Baugur when isolated fire fountains along the fissure each produced channels. Main channels develop after the vent system has matured and fire fountains feed a connected vent that drains from a single exit, and the presence of a main channel and buried channels suggests a sustained eruption lasting weeks or more instead of a single outburst of lava.

Systematically different morphology between Holuhraun and martian vents indicates differences in eruption dynamics on Mars. Raised rims on martian vents, for example are generally much thinner than the vent width, which is different from Baugur where the spatter rampart is about as wide as the vent interior. If these vents are not eroded, this implies that a smaller amount of fountained lava was able to weld together upon landing. One possible explanation is that fountaining more effectively fragments lava on Mars, causing clast size—clast temperature upon landing—to decrease. Evidence of this high level of fragmentation has also been seen on Tharsis cones [8].

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