THE GEOLOGY OF INFERNO CHASM, IDAHO: A TERRESTRIAL ANALOG FOR LUNAR RILLES

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Introduction: Lunar sinuous rilles are thought to have formed by thermal erosion, mechanical erosion, construction, or a combination of these processes via emplacement by lava tubes and/or lava channels **[1-4]**. The investigation of Hadley Rille by Apollo 15 provided the first field observations of a rille, including outcrops of stratigraphic layers within the far rille wall **[5]**. High-resolution remote sensing data sets from NASA's Lunar Reconnaissance Orbiter allow for the identification of smaller volcanic features, outcrops, layers, and detailed topographic measurements at the meter-scale **[6,7]**. Several questions relate to layers observed in the rille walls including: 1) What is their stratigraphic sequence and can individual flows be defined? 2) Are the layers a sequence of multiple, older eruptions that have been thermally eroded? 3) Which layers are related to the eruption that formed the rille? Each visible lineation that defines a layer, may not be a surface contact between individual flows, therefore 4) How can individual flows be distinguished within the stratigraphic sequence? and 5) What flow processes can be recognized based on characteristics of the wall rock (inflated pahoehoe) **[8]**?

Terrestrial volcanic features with similar morphologies to lunar rilles can provide insight into their formation on the Moon. While the scale of most lunar rilles are much larger than their terrestrial counterparts, there are several examples similar in scale to ones we have documented in Idaho. The SSERVI FINESSE team (Field Investigations to Enable Solar System Science and Exploration) **[9]** conducted field studies at Craters of the Moon National Monument and Preserve (COTM) in Idaho from July 28 – Aug. 8, 2014 to investigate terrestrial analogs for lunar volcanic and impact features **[10]**. Here, we compare field observations at Inferno Chasm **(Figs. 1,2)**, a rille-like channel in Idaho to Isis **(Fig. 3)**, a similar sized rille on the Moon.

Inferno Chasm (42°58'00"N, 113°11'25"W) is a basaltic low-shield with a vent and sinuous channel **(Fig. 1)**. The area is overgrown with sage and desert grasses, but it appears that the margins of the low shield have been embayed or buried by subsequent lava flows or loess making it difficult to define the true extent of this volcanic feature and locate lava deposits beyond the end of the channel.

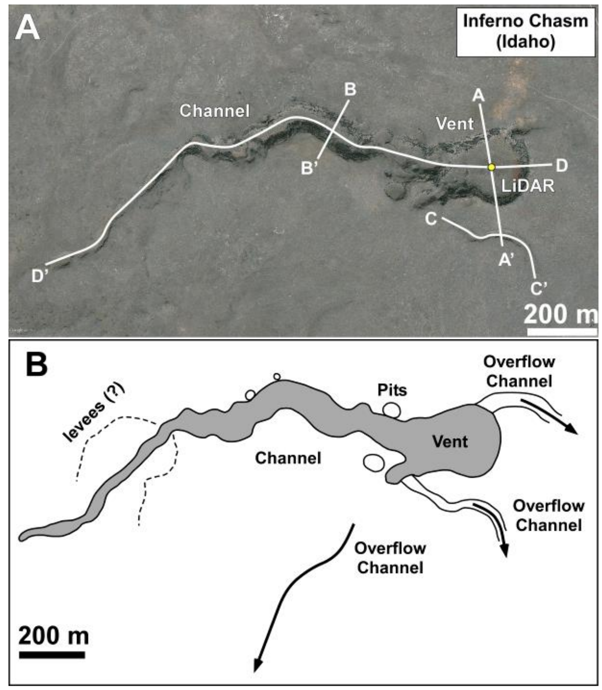

Figure 1. Inferno Chasm in Idaho. (A) Location of Differential GPS and LiDAR surveys [Google Earth]. (B) Morphologic sketch map of key flow features and structures.

We documented the geology and morphology of Inferno Chasm using a Riegl Vz-400 LiDAR, a Trimble R8 and TopCon Hiper II Differential Global Positioning Systems (DGPS) **(Fig. 2)**, Unmanned Aerial Vehicles (UAV), and sampling. The main vent crater is roughly circular and is ~200 m wide, ~20 m deep and has a small 2.5 m-high mound in the center **(Fig. 2)**. DGPS survey D-D' shows that the sinuous channel extends to the west while dropping ~10 m over ~1700 m, yielding a slope of -0.005° **(Fig. 2)**. Several overflow channels are also visible in the remote sensing images **(Fig. 1B)**, but are subtle in the field. For example, DGPS profile C-C' is 350 m long, 30 m wide, and 2-5 m deep. Outcrops of the vent walls expose massive layers 2-3 m thick with textures that suggest highly welded spatter overlain by a 1-2 m thick sequence of thinner layers (overspills, shelley, gaseous blisters) each 10s of cm thick. Field observations and samples collected indicate low-shield development typical of the Eastern Snake River Plains **[11]**.

Lunar Rilles: Isis, a rille in Serenitatis Basin (19°N, 27.5°E) **(Fig. 3)** has a similar morphology to Inferno Chasm. The feature is ~1.3 km wide and ~60-70 m high at the vent. The channel is ~3 km long, 283 m-wide, and 25 m deep **[7]**. The rille is located within high-Ti basalts and there are no identifiable deposits extending from the end of the channel. The vent is aligned with three other small cones along a north-west-southeast trending graben, possibly related to an intrusive dike. There are boulders present along the rim of the rille, but no distinct layers are visible in the images.

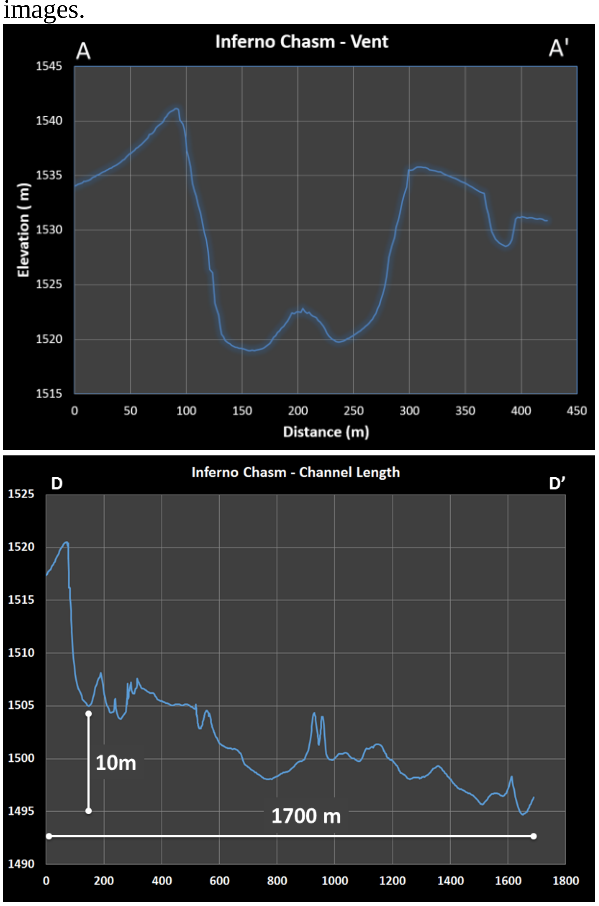

Figure 2. Differential GPS profiles A-A' across the vent (North to South) and D-D' along the channel floor (East to West) of Inferno Chasm (see Fig. 1A).

Discussion: Field observations of the wall material at Inferno Chasm suggest the feature was constructed through a combination of thin lava overflow, rheomorphic flow of congealed spatter, and intense welding of deeper parts, with or without additional lava injection, to form the thick, massive layers. Evidence of thermal erosion and/or lava tube collapse along the channel were not identified, but have not been ruled out. Distinct levees were not identified along the channel margin, but there are linear, topographic highs near the mouth of the channel **(Fig. 1B)**.

Isis has several similarities in both morphology and scale to Inferno Chasm. Both are topographic highs with a central channel ~2-3 km long. No distal deposits are identified beyond each channel. Isis is atypical compared to larger sinuous rilles, like the example in Marius Hills shown in **Fig. 3B.** Most lunar rilles appear to carve into the local terrain through thermal erosion **[7]**. We suggest Isis was formed by construction, from a highly gaseous, fire fountain eruption that created spatter that collected to form the cone and spatter-fed flows rather than by thermal erosion. Observations of flow textures in exposed layers and rocks can help interpret the flow processes that formed the rilles **[8]**. For example, the planar, vesicle horizons observed in rocks along the rim of Hadley Rille are consistent with inflated pahoehoe **[8]**, whereas the tumultuous textures observed in the boulders and wall rock at Inferno Chasm are consistent with welded spatter. However, given the much larger scale of most lunar rilles, construction may only be a minor component of their formation. Based on the depth of a rille, assumptions on how much the wall represents eroded substrate material and which layers formed via construction is important for determining parameters for thermal erosion models.

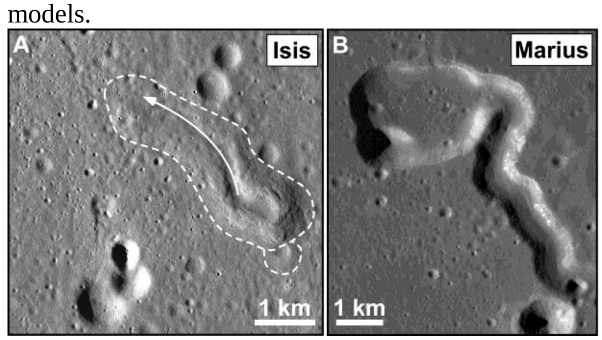

Figure 3. Lunar rilles: A) Isis appears to have formed by construction. LROC NAC M1126950375RE (1.2 m/pixel). B) A rille in Marius Hills has a similar morphology to Inferno Chasm, but appears to form by thermal erosion. LROC NAC M1096815341LE (1.25 m/px). [NASA/GSFC/ASU].

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