COMPARING VENT SURFACE GEOMETRY WITH ITS SUBSURFACE STRUCTURE. C. E. Parcheta[1*], A. Parness[1], J. Nash[1], N. Wiltsie[1], K. Carpenter[1], and K. L. Mitchell[1], [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA, 91204 (*carolyn.e.parcheta@jpl.nasa.gov)

Introduction: Documenting and understanding the realistic size and shape of volcanic conduits was proposed as a top priority for the next 100 years of volcanic research by over 200 volcanologist at a 2012 AGU Chapman conference [1]. Volcanic conduits are poorly understood because documentation, quantification, and investigation is almost impossible – most vents are destroyed or buried during syn- and post-eruptive processes. Our current understanding of eruption mechanisms on both terrestrial planets and icy satellites starts with first order geometric assumptions of the conduit shape – namely a cylindrical pipe or a rectilinear crack (Figure 1) [2-6]. This assumption directly affects our understanding of eruption dynamics (e.g., vent flaring, controls on volcanic jet behavior, pyroclastic/ballistic deposits, magmatic ascent rates, and subsurface magmatic transport). Since basaltic fissure eruptions are the most common type of volcanic eruption on Earth [7] and also appear to have dominated resurfacing on Moon and Mars [8], it is highly relevant to document fissure vents and conduits. Earth-based field geology can provide an improved, cm-m scale resolution, second order framework to our understanding of volcanic systems [9]. The Mauna Ulu eruption of Kilauea, Hawaii provides a unique opportunity for volcanic fissure conduit documentation because the conduit drained and remains preserved, making it an ideal field locality to start addressing this topic [9,10]. Here we present preliminary data on the shallow fissure conduit geometry and surface vent structure for 1 of the 54 Mauna Ulu fissure vents (from May 24, 1969, Figure 2), and discuss its implications for planetary and icy satellite volcanic vents.

Robotic data acquisition approach: We have designed and built a robot – VolcanoBot – to go inside the Mauna Ulu fissure (Figure 2) and image its vents and conduit using a PrimeSense Carmine 1.09 sensor [10]. The design phase created the payload harness and protective shell for robotic descent, constructed a circuit board and programmed it to communicate with the instruments and a surface-based computer, and prototyped wheels specific to volcanic vent and conduit rock textures [10]. The robot's mechanical parts were mostly built with 3d printers, but milling, casting, and laser cutting techniques were also employed [10]. The electronics and instruments were assembled from off-the-shelf components and electronically integrated together. Our field-test on 5 – 9 May 2014 involved lowering the robot into four vents and a non-eruptive crack via thin steel cable tether. Upon reaching our maximum depth of tether, we would retrieve the robot by pulling it out by lifting the tether [10]. Two of the

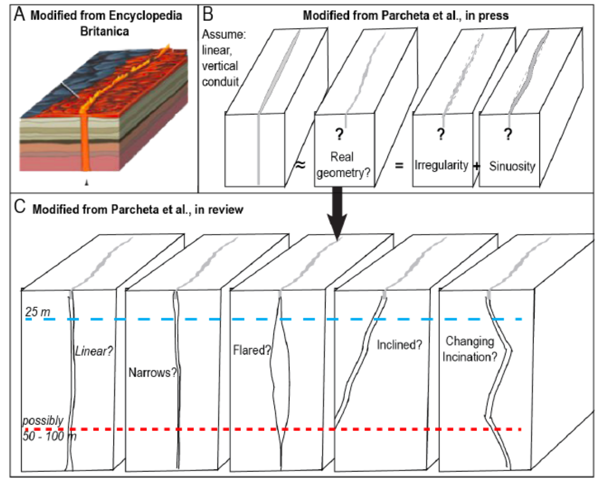

Figure 1 *A:* modified from [13], depicts the current state of knowledge about fissure conduits: they are linear and vertical. *B:* modified from Parcheta et al., [in press], depicts a more realistic fissure geometry. *C:* The blue dashed line in the lower panel indicates the 25 m depth that we have reached with VolcanoBot1. The red line in the lower panel indicates the lower range of depths to which we think the fissure is a subterranean void (50-100 m). Between them are possible geometries that could be present.

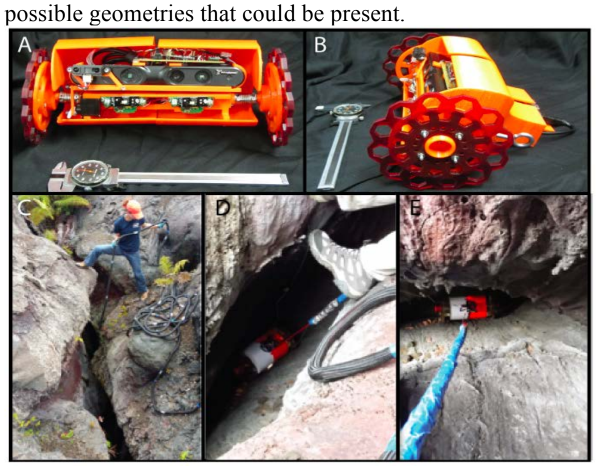

Figure 2 Photos showing VolcanoBot. *A, B:* Photograph of recently modified VolcanoBot2, a rotary microspine robot, with 12.5 cm diameter wheels and a 25 cm long body. *C-E:* Field-testing of VolcanoBot1, 20 cm diameter wheels and 35 cm long body. *C:* Lowering the robot into a volcanic fissure vent at Mauna Ulu. *D:* Foot for scale with VolcanoBot1 in the fissure. *E:* VolcanoBot1 beginning to map the fissure. The tether (blue) spans 30 m, and includes two power cables, a data cable, and a mechanical tether.

vents were imaged in detail through the first 20 m of the conduit. The other two vents and non-eruptive crack had small sections documented for future fieldwork reconnaissance. Our current data is from the eastern of the two detailed vents we documented.

Vent geometries: The Mauna Ulu fissure vent system is the first to be documented in detail (i.e., more than just summarized as a straight line on a map) [9]. Fissures have three types of variability [9]: cm-scale surface roughness due to lava drain-back, dm-m-scale irregularities due to the fracture mechanics of the host/wall rock, and Dm-hm sinuosities due to the local and regional stress regimes. The drain-back textures represent a 2-7 cm rind on short-lived (<1 day), basaltic fissures, and thus the vent shape is slightly larger (2*rind) than the measured shape [9]. Any flaring in short-lived vents is mechanical in nature [9].

Shallow conduit geometries and correlations: By mapping the fissure to 25 m depth at centimeter scale, we found that irregularities persist on the conduit walls in the shallow subsurface, supporting the hypothesis that they are likely a result of wall rock fracture mechanic behavior hypothesized by Parcheta et al. [8]. These irregularities are up to 50% of the fissure width, making them large enough to influence the fluid dynamical behavior [11] of Hawaiian style fissure eruptions. Roughness (i.e., drip/drain-back textures) also continued with depth into the fissure, but become less pronounced with depth. The presence of sinuosity could not be tested in the map view (x-y) plane because the vent is not long enough to host this wavelength feature, however it may be identified in the vertical (z) plane as we continue to process the data (Figure 3) and add deeper data with future field campaigns. It was anticipated that the conduits would pinch and close off within the first 30 m of depth, but we failed to observe the bottom of the fissure. Two previously shallow plumb bob measurements were documented by VolcanoBot to simply be minor talus clogs at narrow portions of the conduit, but the surrounding conduit remained opened at near constant width after accounting for the irregularities.

Planetary and icy satellite volcanism: If fissure vents [5, 12] can be clearly identified in the new high-resolution data from HiRISE and LROC datasets of Mars and Moon, then their surface vent geometry could be mapped to the resolution of the images. From the vent geometry, we could infer a general shallow conduit geometry given a known host rock (predetermined irregularity sizes). Should the vents be long enough to record a sinuosity, we would be able to back out knowledge of the local and or regional stress field that the fissure propagated through, providing insights into the local and or regional crustal environment. Additionally, the south polar cracks of Enceladus are an order of magnitude thinner than basaltic fissures [6, 16], but 2-3 orders of magnitude larger in length [6]. Naturally, their wall "rock" is ice, and we might expect to find irregularities along the vent surface that match the properties of extensional ice fractures. While further fieldwork is needed to verify crevasse geometries with VolcanoBot, it is anticipated that by knowing the surface irregularities, one would have a better understanding of similar features along the ice conduit walls. This would subsequently allow for a better understanding of cryovolcanic ascent and eruption mechanisms.

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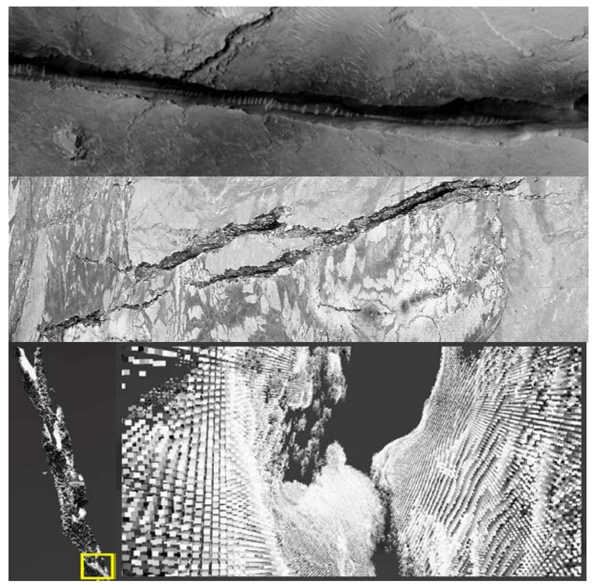

Figure 3 *Top:* Martian fissure from Cerberus Fossae [14]. *Middle:* Aerial Image of the 1971 eruptive fissure at Kilauea's summit [15] *Bottom Left*: Top 5 m of shallow conduit from a Mauna Ulu vent imaged with VolcanoBot. Yellow box denotes image on the right. *Bottom Right*: A look inside a fissure conduit. Two irregularities protrude into the fissure at the same depth – the right side is 0.5 m closer to the camera than the left. White boxes are individual data points.

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