

**MAPPING PLANETARY VOLCANIC DEPOSITS: IDENTIFYING VENTS AND DISTINGUISHING BETWEEN EFFECTS OF ERUPTION CONDITIONS AND LOCAL LAVA STORAGE AND RELEASE ON FLOW FIELD MORPHOLOGY.** J.E. Bleacher<sup>1</sup>, D.B. Eppler<sup>2</sup>, J.A. Skinner<sup>3</sup>, C.A. Evans<sup>2</sup>, W. Feng<sup>4</sup>, J.E. Gruener<sup>2</sup>, D.M. Hurwitz<sup>5</sup>, P. Whitson<sup>2</sup>, B. Janoiko<sup>2</sup>. <sup>1</sup>Planetary Geodynamics Laboratory, NASA GSFC, Greenbelt, MD, 20771, [Jacob.E.Bleacher@nasa.gov](mailto:Jacob.E.Bleacher@nasa.gov); <sup>2</sup>NASA Johnson Space Center, Houston, TX; <sup>3</sup>Astrogeology Team, U.S. Geological Survey, Flagstaff, AZ; <sup>4</sup>Departments of Geology and Astronomy, Smith College, Northampton, MA; <sup>5</sup>Lunar and Planetary Institute, Houston, TX 77058.

**Introduction:** Terrestrial geologic mapping techniques are regularly used for “photogeologic” mapping of other planets, but these approaches are complicated by the diverse type, areal coverage, and spatial resolution of available data sets. When available, spatially-limited in-situ human and/or robotic surface observations can sometimes introduce a level of detail that is difficult to integrate with regional or global interpretations. To assess best practices for utilizing observations acquired from orbit and on the surface, our team conducted a comparative study of geologic mapping and interpretation techniques. We compared maps generated for the same area in the San Francisco Volcanic Field (SFVF) in northern Arizona using 1) data collected for reconnaissance before and during the 2010 Desert Research And Technology Studies campaign, and 2) during a traditional, terrestrial field geology study. The operations, related results, and direct mapping comparisons are discussed in companion LPSC abstracts [1-3]. Here we present new geologic interpretations for a volcanic cone and related lava flows as derived from all approaches involved in this study. Mapping results indicate a need for caution when interpreting past eruption conditions on other planetary surfaces from orbital data alone.

**Study Area:** The SFVF includes > 600 volcanoes, with volcanism spanning ~ 6 Myrs [4]. Though each cone in SFVF has a broadly similar eruptive history, these histories vary subtly due to topographic, climatic, tectonic, and magmatic conditions at the time of eruption. Our study focused on the evolution of SFVF vent 7504 (V7504) [5] as well as the number and nature of the source vents and resultant flows. Crater V7504 was identified as a center of basaltic flows and pyroclastic deposits [6]. This is an ideal test site for NASA operations studies due to a combination of volcanic deposits with a range of ages and modification states coupled with older and younger sedimentary and aeolian deposits. This environment provides opportunity to conduct traverses across environments physically akin to regolith-covered surfaces. Additionally, the SFVF facilitates investigations of outcrops of competent rock we now know to be common on the Moon and Mars from high resolution camera observations [7,8].

**Results:** V7504 (Figure 1) includes a cone unit (Qc) and three lava flow units (Qb1-3). Samples from the V7504 lava flow units display millimeter-sized

phenocrysts of olivine and pyroxene in a finer-grained matrix, within which plagioclase is sometimes discernible. This mineralogy is unique among the lava flows within the study area and identifies outcrops as originating from V7504, which was often not readily apparent in remote sensing data. In some locations, larger (up to cm-sized) phenocrysts/xenoliths of olivine and pyroxene are present. Although not common, xenoliths of the Grand Canyon sequence of rocks can be found throughout V7504, as can other deeper igneous samples.

The V7504 cone unit is composed of interbedded cinders and bombs, welded spatter, and outcrop-forming, rheomorphic deposits. This combination suggests variations in the vent conditions throughout the eruption. V7504 displays a vent complex composed of 1) a nearly circular cone to the S that is open to the N and 2) an arcuate ridge to the NW that is concave to the SW and open to the W. The S cone rises to an elevation of ~ 2090 m along the SE and SW rims and 2030-2050 m along the E and W rims. The N ridge displays heights of ~ 2000 m on the W extent, climbing to ~ 2030 m on the S/SE extent.

Units Qb1-3 display comparable mineralogy distinguishable only by the abundance of centimeter-sized olivines and pyroxenes. However, the overall morphology of these flow units differs significantly. Qb1 forms a plateau-like unit that extends N from the N ridge. Due to burial by younger sediments, this unit does not display a clear contact with the N ridge but aligns with a set of small, N-trending ridges that form an alcove. Qb2 forms a deltaic deposit on the S side of the vent complex. The apex of this flow unit rises to ~ 2000 m forming a hummocky flow field to the S and W. Qb3 is the most rugged of the lava flows and forms a hilly deposit that extends to the NW. This flow appears to have been captured by a fault valley in the underlying Kaibab Limestone, thereby diverting the flow to the N/NE. Qb3 displays not only lava flow outcrops, but also localized cinder patches and outcrops of layered rheomorphic material and welded spatter. Most of these layered outcrops generally dip towards the vent complex.

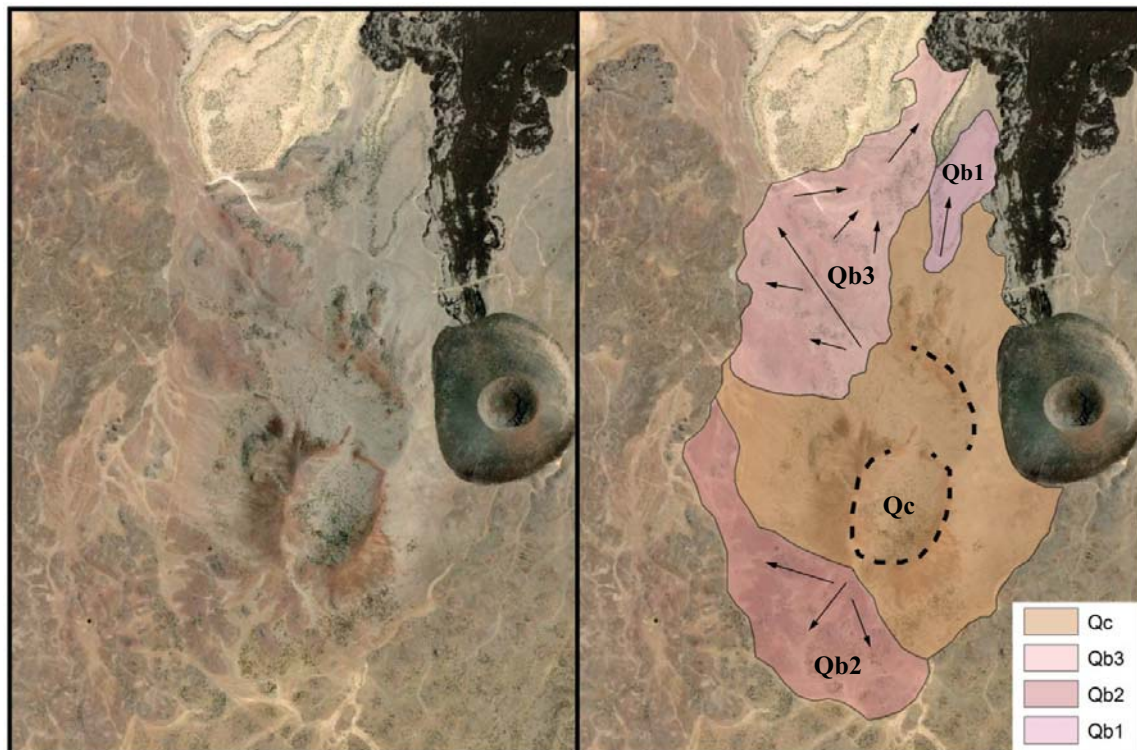
**Discussion:** We conclude that V7504 is a single vent complex that experienced multiple lava emplacement episodes interspersed with variable cone building episodes. The V7504 vent originally formed an elongate, N-trending cone. This feature might have

been preceded by a small N cone that breached and emplaced the Qb1 flow before significant accumulation along the N-trending structure. The second lava emplacement event occurred to the S where the Qb2 flow breached or overtopped a younger cone that was lower in topography, ~ 2000 m high as marked by the apex of the flow unit. Following additional cone building (to a height of 2000-2030 m) the vent complex experienced a breaching event to the NW. This flow event carried numerous cone segments, thereby producing a hilly terrain with rafted cone outcrops and isolated cinder-rich surfaces. This rafting process is comparable to the eruptive development of some cones in Crater Flat, NV [9]. Subsequent development of V7504 involved cone-building events increasingly focused to the south, building the south cone to elevations above 2050 m.

**Planetary Implications:** Flow morphology and length are, among other factors, controlled by eruption and emplacement conditions [10,11]. High effusion rate is commonly cited as evidence for long lava flows, especially on other planets. Harris and Rowland [11] define effusion rate (E) as the volume flux of erupted lava into a flow at any specific time. One might consider E at the vent for an entire eruption, or subdivide the total erupted volume into E for different lava flow units.

V7504 experienced at least three lava flow emplacement episodes that might have resulted from increases in E at the vent. It could be assumed that E at the vent was higher for Qb3 to produce a longer and rougher flow than for Qb1. However, the surge that produced Qb3 most likely involved storage of lava in the cone's caldera, abrupt release of that lava when the cone was breached, and different cooling conditions than experienced during emplacement of Qb1. In other words, E throughout the eruption of V7504 might have varied, thereby explaining the three episodes of lava emplacement, but a steady or declining E at the vent could also have resulted in lava flow emplacement if lava was stored at the cone and abruptly released. Such local storage and release events are critical to consider on planets when attempting to assess trends in eruption conditions at regional or planetary scales based on remote sensing characterizations of lava morphology.

**References:** [1] Eppler et al. (2014) LPSC. [2] Skinner et al., (2014) LPSC. [3] Feng et al. (2014) LPSC. [4] Priest et al. (2001) USGS Fact Sheet 017-01 (<http://geopubs.wr.usgs.gov/fact-sheet/fs017-01/>). [5] Ulrich and Bailey (1987) USGS Misc. Field Studies Map: 1956. [6] Billingsley et al. (2007) USGS Sci. Inv. Map 2977. [7] Zanetti et al. (2011) LPSC #2262. [8] Keszthelyi et al. (2008) JGR-E, doi:10.1029/2007JE002968 [9] Valentine et al. (2013) GSA Bulletin, doi:10.1130/B25956.1. [10] Walker (1973) Phil. Trans. Of Royal Society London, 274. [11] Harris and Rowland (2009) IAVCEI Sp. Pub., 2.



**Figure 1.** The study area (left) and V7504 vent complex map (right). Dashed lines mark ridge crests that represent the south cone (bottom) and north ridge (top). Arrows indicate inferred flow direction of each lava flow unit. All V7504 margins are buried by younger, unrelated lava flows to the west, east, and south, and overlie the lighter toned Kaibab limestone to the north.