THE ORIGIN OF LAVA PITS—INFLATION OR COLLAPSE? CONSTRAINTS FROM LIDAR AND DRONES AT BLACK BUTTE, IDAHO. L.J. De Crescenzo, E.H. Christiansen, J. Radebaugh, Dept. of Geological Sciences, Brigham Young University, Provo, UT 84602 (levi.decrescenzo@gmail.com).

Introduction: Basalt, particularly pahoehoe, is ubiquitous on Earth and throughout the solar system and the surface features of basaltic flows give clues to their modes of emplacement and eruption histories. Among these crucial features are pits in the lava crust that are easily observed via satellite imagery.

Inflation of Basalt Flows: A common phenomenon in basalt lavas is inflation, where magma is injected beneath the crust of cooling basaltic lava and exerts pressure causing the surface crust to “rise” or “inflate" [1, 2]. Inflated flows have a variety of structures depending on pre-flow topography and effusion rate, with higher effusion rates forming large, even sheet-flows and more moderate rates forming “hummocky” flows. Low rates of effusion may prevent inflation and lead to stacked lobes and surface breakouts [2].

Inflation can form tumuli, mounds of the lava’s crust with deep axial clefts [4]; pressure plateaus or lava-rises, which are “flat-surfaced uplifts, formed…by injection of lava under a surface crust” [5]; kipukas, high-standing features not covered by the flow remain as “islands” surrounded by lava; and pits, which can be formed by inflation or collapse of the crust.

A study of basalt lava flow in New Mexico concluded that pits form by inflation, as pre-existing topography may obstruct injected lava beneath newly cooled crust, causing the rigid crust to rise around—but not directly above—an obstacle [1]. These inflation pits may be distinguished from similar collapse features by a funnel shape with concentric fractures centered around the preexisting high topography—or more definitely by the presence of lava wedges in the pit’s walls. These wedges appear to be squeeze-out features formed when cooled viscous lava is forced from sub-horizontal fractures in at the inflating walls of a developing pit [1].

Originally, many pits were thought to have formed by collapse of rigid crust as liquid in the core moved [1,6]. As circular fractures, funnel shapes, and zones of extension and compression are also products of collapse [7], additional observations are necessary to establish a clear correlation between morphology and pit origin.

Black Butte: The Black Butte Crater lava field, the subject of this project, is a 56 km long basaltic lava flow. It lies on the northern margin of the Snake River Plain, Idaho (Fig. 1). Black Butte is a low-shield volcano 30 km north of Shoshone, Idaho, that is 2.5 km across and 45-60 m high (Fig 1) that erupted ~12,00 years ago [9]. Its vent is a complex network of several connected craters.

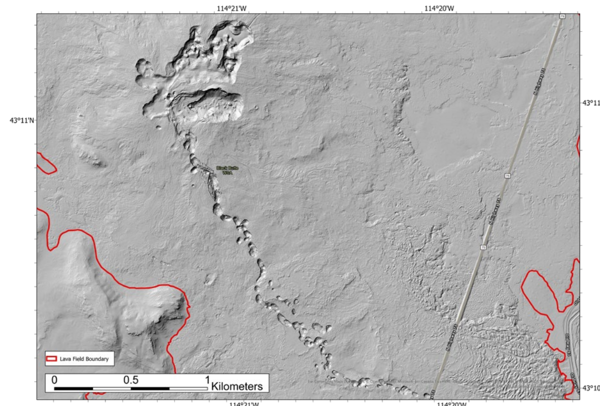

Fig. 1. Black Butte crater and a partially collapsed lava tube cap a low-shield volcano on the Snake River Plain, Idaho, as shown in this shaded relief map constructed with 1m lidar data [10].

Late in its eruption history, it produced a long, tube-fed flow extending SE. This crater is large for such a small shield—with a maximum diameter and depth of 650 m and a depth of 50 m.

Methods: DEMs from lidar produced by Boise State University and Quantum Spatial, with 1 m resolution [10] were used to map pits in ArcGIS and to calculate their shapes and sizes. Three-dimensional models, which we have constructed from drone images provide more detail and supplement our field observations.

Results and Discussion: The basalt of the Black Butte is a compound flow comprised of multiple adjacent and overlying lobes, along with plateaus of varying elevations. These plateaus are dotted with distinctive pits, the deepest of which appear to be associated with the highest plateaus and ridges (Fig. 2). The lava field has pits of two distinct morphologies: steep-sided pits with rubbly walls that are likely products of collapse, and subcircular pits with gradually sloping walls of tilted pahoehoe crust. The latter occur mostly in dramatically inflated areas and appear to be the result of rise of crust around a point where the rigid upper crust is attached to the pre-eruption surface.

The colored shaded relief map in Fig. 2 shows a variety of flow surface textures including: *(1)* A rugged surface dominated by short (<10 m) surface breakout flows and small pits. We interpret this to have formed during a period of low effusion rates in the tube-fed flow. *(2)* A large (1.7 km across) smooth-topped lava plateau with a cluster of small pits (4 m to 60 m across). These shallow pits are commonly floored by small post-

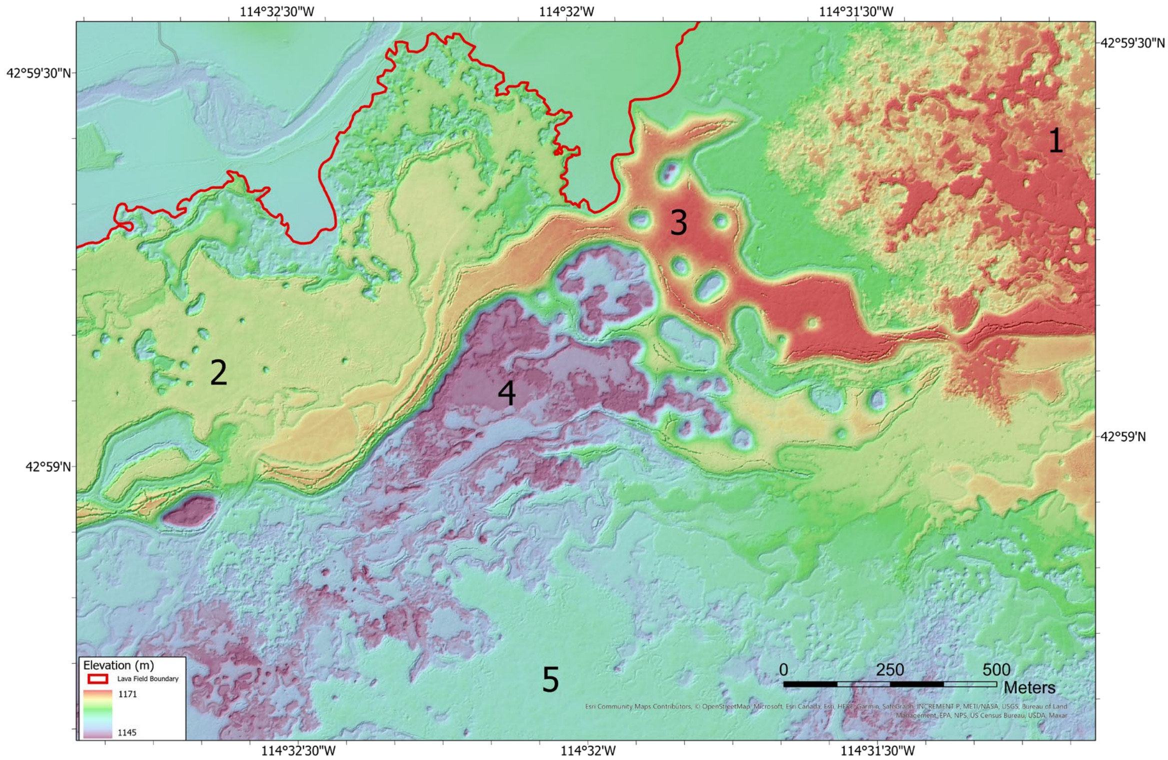

Fig. 2. Black Butte crater lava field with multiple flow lobes about 16 km from the vent, showing two uninflated flows (1 and 4) and three inflation plateaus of differing elevation, with smooth, raised surfaces (2, 3, 5). This suggests multiple steps of eruption progressively inflated the flow and allowed pits to form.

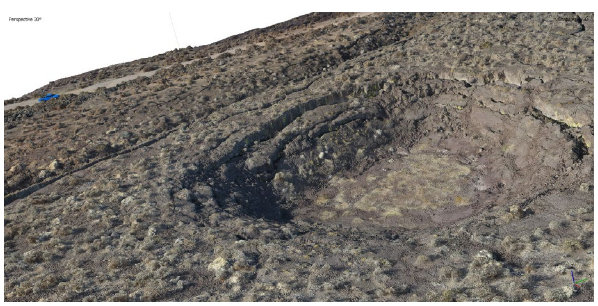

Fig. 3. Three-dimensional model of a 50-58 m diameter and 10 m deep, subcircular pit derived from 435 drone images. The rim has a series of arcuate faults with offsets of 2-6 m bounding inward tilted terraces of lava crust with pahoehoe ropes. The crust is locally brecciated to rubble. The floor is wide, fairly flat, and covered by post-formation lava. We interpret this pit to have formed while the surrounding plateau inflated.

development of breakout flows of pahoehoe which escaped from below the fractured crust. *(3)* A sinuous irregularly shaped, but smooth topped lava plateau formed after (2) as more lava fed into the still open feeder zone along the south side of the plateau between (1) and (2). This plateau is 3-4 m higher than (2) and has pits which are deeper, reach lower absolute elevations, and larger than pits in (2), consistent with their formation during inflation. However, two of the pits near its N margin have steep rubbly walls that expose large caverns. We interpret these pits to have formed by collapse of the surface as sub-crustal lava retreated from this part of the flow. *(4)* An early uninflated flow buried by later inflated flows (2, 3, and 5).

Conclusions: This study reveals complexity in young lava flow features on Earth, and that inflation is an important aspect of flow evolution. Our results have implications for observing and interpreting lava flow fields on other planets, including the Moon, Mars, Venus, and Io.

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