RECONSTRUCTING PHREATIC BLASTS FROM BALLISTIC BLOCK FIELDS AT KINGS BOWL, IDAHO.

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Introduction: Kings Bowl is a 2.2ka volcanic feature in the eastern Snake River Plain of Idaho [1]. It is a mostly effusive feature, characterized by lava flows radiating from a NW-trending fissure associated with the Great Rift [1,2]. Near the end of the eruption, interaction between magma and groundwater resulted in phreatic blasts along the fissure [2]. The region is a popular planetary analog. Past work has assumed that the phreatic blasts were limited to the main pit area, a lozenge-shaped hole 90x30m across and 30m deep, located in the middle of the widest part of Kings Bowl [2,3]. In this work, we report on ballistic blocks associated with the main Kings Bowl pit as well as a series of smaller pits to the north along the fissure that were previously assumed to have been the result of local sagging and collapse. Modeling of the ballistic blocks allows further interpretation of the late stages of the eruptive sequence.

Field Methods: Ejecta block measurements, including position, dimensions, and vesiculation percent, were collected over the 2014 and 2015 FINESSE (Field Investigations to Enable Solar System Science and Exploration) field deployments. Blocks were studied on the western side of the fissure, where they were not buried by the fine tephra and eolian dust present to the east. Three different techniques were used to select blocks for study inclusion (Fig. 1): 1) any block that fell along one of 3 transects radiating from the widest part of the main pit, 2) any block that fell along one of 4 transects sub-parallel to the Kings Bowl fissure, and 3) the largest local block identified during a random walk traverse through the main ballistic field. In all cases, blocks without at least one axis >20cm were excluded from the study to avoid confusion with weathered lava fragments. The 3 techniques were motivated by different subgoals of the study, but combine to give a detailed view of the ejecta.

Deposit interpretation: There were no juvenile clasts or bombs, though limited glass was noted. This is consistent with a phreatic blast interpretation.

Main pit: Blocks associated with the main pit are likely the result of multiple blasts. It was not possible, however, to separate the ballistic ejecta near the main pit into subunits. Stratigraphy of the tephra deposit east of the fissure suggested multiple blasts, but extensive bioturbation and mixing with eolian dust prevented detailed analysis. The maximum block size and concentration decrease with distance from the main pit, consistent with either a single blast or a series of blasts closely spaced relative to their size. Block vesiculation (0-25%) did not vary systematically throughout the deposit.

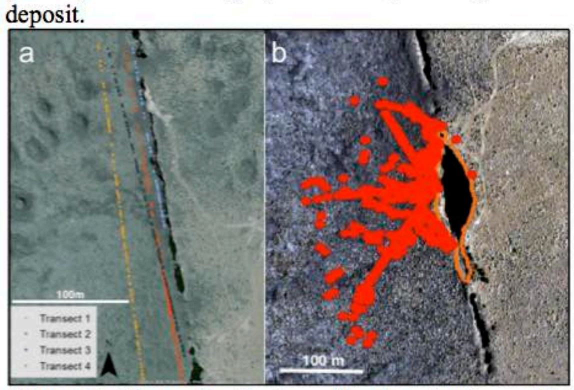

Figure 1. *Kings Bowl ejecta blocks. a) sub-parallel tenasects along small northern pits. b) radial and random-walk blocks around main pit.*

Small northern pits: The sub-parallel transects in this region were intended to cross-cut a series of small ejecta fields if any were associated with the small pits along the fissure. Six zones of increased maximum block size corresponded to increased block frequency, both typical of the center of a blast deposit (Fig. 2). The second of these selected zones is less certain than the others, with the increased size and frequency both near the decision threshold; it is marked in Figure 2 with a question mark. The centroids of the 6 zones correspond to relatively larger pits along this part of the fissure. We interpret these zones and associated pits to indicate separate blasts with overlapping ballistic block fields. The large orange peak in the upper left panel of Figure 2 does not correspond to an increase in block size, suggesting that the high block frequency there is a result of overlapping fields; this area also aligns with an annealed portion of the fissure, further implying that it was not a separate blast.

Deposit modeling: We wrote a code to calculate the initial ejection speed ranges capable of producing the depositional range for each of the main pit blocks; blocks from the northern pits were excluded at this stage due to the challenge of overlapping ejecta fields. The model approximates the block mass using a sphere whose diameter is equal to the geometric average of the 3 measured axes and the vesiculation-adjusted density. Ejection speeds and angles ranged from 10-300 m/s and 45-89°, respectively. Motion was modeled using the equations of motion, with a simple Eulerian solution, time step of 0.001s, and Reynolds number based drag coefficient. To account for the uncertainty in original block position in the main pit, starting position was assumed to be the pit centroid with a buffer distance of +/-25% of the local pit width, or 8m.

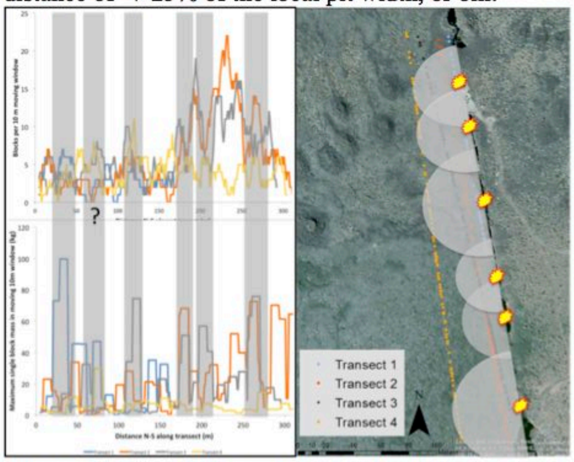

Figure 2. *Upper left panel: Linear block frequency per 10m using a moving window, N to S. Lower left panel: Largest block along transect, using a 10m moving window. Gray boxes denote areas of both increased block size and elevated frequency, suggesting proximity to a bast point. Extra weight was given to transects closer to the fissure. Right panel: Interpreted blast locations (gray semi-circles do not cover entire associated deposit).*

The limits of the maximum and minimum initial speeds for block ejection indicate that the majority of blocks were erupted between 50 and 100m/s. This is consistent with observed and calculated phreatic blast speeds at other volcanoes [4-6]. Separating the blocks by size did not reveal correlation between block size and initial calculated speed (Fig. 3). Overlapping speeds for the <20cm blocks are the result of over-sampling of small blocks near-vent, where their reduced depositional ranges are likely the result of high ejection angles.

The typical maximum and minimum permitted ejection speeds, along with the calculated mass of rock missing from the main pit, were used to calculate upper and lower kinetic energies of 3.0E11 and 6.8E10 J. This energy calculation neglects energy lost to fracturing the rock prior to ejection and does not adjust for possible later collapse of wall rock into the main pit or recycling of blocks. Considering the heat of vaporization of water, this suggests a water volume of 30,000 – 130,000 L was involved in the blast; this is the equivalent of less than 1% of the main pit volume.

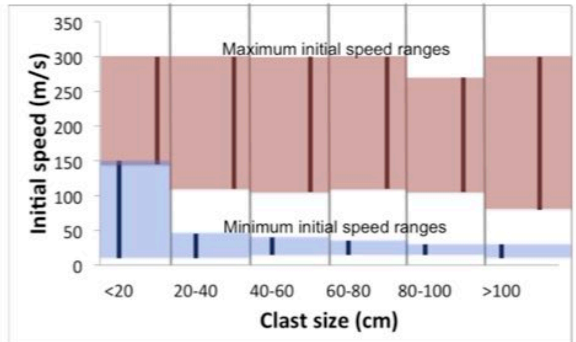

Figure 3. *Initial maximum and minimum speed ranges by average block diameter for main pit blocks.*

Discussion: The existence of several small blast pits along the fissure suggest that the main Kings Bowl pit was likely formed by a series of blasts in relatively quick succession. Relatively little ground water was needed for any individual blast. Groundwater may have entered the system due to changing subsurface pressure during draining of the lava pond. The location of the main pit central to the broadest part of the lava flows, while the smaller northern pits occur in a narrow portion of the flow, suggests that the magmatic heat may have been the limiting factor in the phreatic explosions and explain the concentration of blasts at the main pit. Further steps include modeling the small pits and adaptating the model for planetary use to calculate in-ground volatile budgets associated with blasts like Cyane Fossae, Mars.

Conclusions: Field surveys at the Kings Bowl volcanic feature in Idaho revealed a series of phreatic blast pits in addition to the previously recognized main pit. The blasts occurred as a result of limited water-magma interaction in the late stages of the eruption. Main pit ejection velocities were ~50-100m/s, indicating a water volume of 30k-130k L, very small relative to the pit volume. The relationship between pit volume and placement within the lava flows suggests that thermal energy was the limiting factor in the blasts. This model can be adapted to calculate in-ground volatile volumes for similar planetary blast features.

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References: [1] Kuntz M.A. et al. (1988) *USGS Misc. Invest. Map* I-1632. [2] Hughes S.S. et al. (2015) LPSC, #2846. [3] Sears D.W.G. et al. (2015) LPSC, #1601. [4]Yokoo A. et al. (2002) *GRL* [5] Mastin L. (1991) *Bull. Volc.* [6] Foote L.C. (2012) *MS thesis*