A STUDY OF THE KING'S BOWL PHREATIC EXPLOSION CRATER AS A PLANETARY ANALOG.

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Introduction: With the discovery of pitted terrain on Mars [1,2] and Vesta [3], thought to be produced by the presence of escaping volatiles from impact melt, we sought and found an example of a "pit" produced on Earth when volatiles and lavas interacted. This "pit" is a phreatic crater named King's Bowl near the Wapi lava field within the Craters of the Moon National Monument and Preserve in Idaho. This site of plains volcanism has often been considered a planetary analog [4-6] and is a study area for the SSERVI team named FINESSE (Field Investigations to Enable Solar System Science and Exploration; J. L. Heldmann, PI [7]).

King's Bowl is the largest of a number of craters lying along the Great Rift, which follows an approximtely north-south trend through the region [4-6]. The crater is 85 m long, 30 m wide and 30 m deep and formed 2,220 ± 100 B.P. when a magmatic dike encountered subsurface water. The resulting explosion threw out ejecta blocks over 100 m. To the east of the crater, the blocks have been obscured by wind-blown tephra, and may have been removed by visitors, but to the west the blocks are numerous and clearly exposed [4,6]. In order to investigate the formation mechanisms and energetics of the crater, and its possible analogy to the pitted terrain on Mars and Vesta, we have documented the size and distribution of the western ejecta blocks at King's Bowl Crater. Here we describe fieldwork, observations, and preliminary discussion of the ejecta blocks and the formation of volatile-related pits on solar system bodies.

Methods: We threw three lines (west, 45° north of west, and 45° south of west) from a prominent ejecta block at the center of the western rim of the crater and measured the size (three perpendicular directions), distance and mass (if within the limit of our balance, 18 kg) for all 184 blocks >20 cm along the lines. We also took images of the surface every 10 m along these three lines to determine the number of blocks per unit area, correcting for changes in field of view and area hidden by large blocks, vegetation, or shadow. Realizing how few large ejecta blocks were intercepted by the three lines, we then performed a random walk through the ejecta field and measured location and size of a further 240 ejecta blocks. Finally, we mapped the outline of the crater using differential GPS and obtained profiles of the crater using LASER ranging from a UAV.

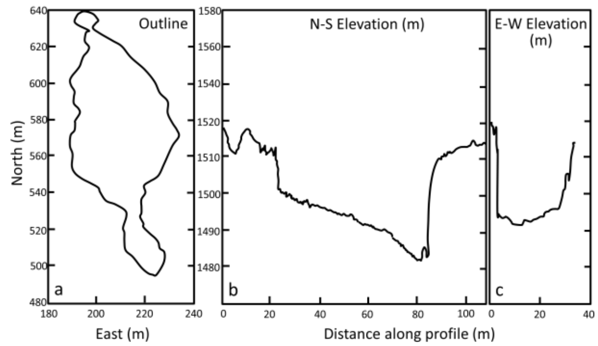

Fig. 1. The shape of the King's Bowl Crater as determined by differential GPS and LASER range finding.

Results: The King's Bowl crater is a lozenge shape, oriented along the rift, with steep walls and a floor that slopes down in the N-S direction. (Fig. 1).

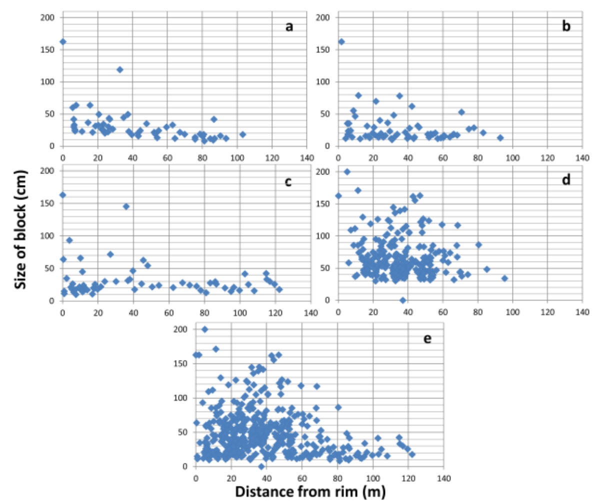

Fig. 2. Block size (geometric mean of length, width, and height) as a function of distance from the rim. (a-c) the three transects, (d) raster pattern, (e) all data

The range of ejecta block sizes decreases with distance from the rim and is similar for all lines (Fig. 2). While small blocks, <50 cm, especially <30 cm, were spread uniformly throughout the ejecta field, the largest block for a given distance decreases with distance from the rim. The greater number of large blocks observed in the raster pattern reflects a deliberate observational bias. Ballistic calculations indicated ejection velocities of 44 – 99 m/s [8].

The number density data for the three lines were also very similar to each other (Fig. 3), decreasing logarithmically from about 10 cm^{-2} at the rim, to 1 cm^{-2} at ~100 m, and zero at ~200 m. Again, the results were very similar in all directions.

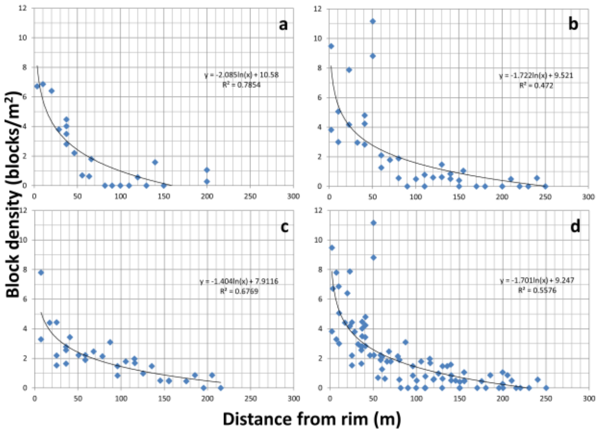

Fig. 3. Number density of ejecta blocks at the King's Bowl crater as a function of distance from the rim for three transects (Fig. 1a). (a) Northwest, (b) west, (c) southwest transects. (d) All three transects.

The aspect ratios for the blocks on the three transects and on the raster pattern showed a very similar spread (a/c 1 – 3 and a/b 0.5 – 2), although the raster samples showed greater clustering due to the greater number of large blocks in the population.

Discussion: Our main interest in King's Bowl Crater is to what degree it is analogous to the Vesta and Mars pits and if it can it shed light on the amount of water needed to make the pits on Vesta, a body long-thought to have been completely dry. In order to understand its formation, we will compare the King's Bowl Crater to other volcanic phreatic craters that have associated ejecta, and to impact craters that have associated ejecta blocks.

The King's Bowl crater resembles phreatic craters reported, for example, in Hawaii [9], in Alaska [10], and in California [11] in that they are all associated with fissures, are lozenge shape along the line of the fissure, and have width:depth ratios of 0.5 to 2. We also note that their ejecta are calculated to have had ballistic velocities of ~100 m/s similar to the present values.

There are many terrestrial impact craters that have ejecta [12], for example Meteor Crater [13,14], Lonar Crater [15], and the Ries Crater [15]. The ejecta fields extend typically 1 to 2 crater radii from the rim, and thin-out with distance from the rim with the ratio of large blocks to fine material decreasing with distance. While terrestrial impact craters only rarely have ejecta blocks, they have been observed in abundance for nuclear explosion craters, asteroids, the Moon, Phobos and Diemos [e.g. 12,17,18].

We discuss each of the properties of King's Bowl Crater with this in mind.

Shape. The shape of King's Bowl is determined by the fissure and thus resembles other phreatic craters rather than impact craters.

Radial extent of the ejecta, decrease in number density with distance and proximity of the largest blocks to the rim, are similar for King's Bowl and ejecta at other phreatic craters and impact craters on Earth. These properties are predicted by the ballistics of explosive ejection.

The aspect ratio of the blocks and the size of the largest blocks produced do not appear to have not been well documented for phreatic craters but are known for impact and nuclear craters and craters on the asteroid Ida where the largest blocks are located near the rims of the Mammoth and Lascaux craters [16]. For impact and nuclear craters $L \sim 0.36\ D^{0.8}$ [16], where L is maximum block size and D is crater size. (See also [19] who find $L \sim 0.29\ D^{2/3}$). So we predict that the largest blocks should be ~5 m which is within a factor of 2 or 3 of the King's Bowl data and consistent given the accuracy of the treatment, especially given the possible movement of blocks by visitors [4,6].

Conclusions: Our data suggest similarities between the King's Bowl ejecta and ejecta of impact craters on Earth, asteroids, Phobos, Deimos, and the Moon and phreatic craters on Earth. This implies a similar physics of formation on differing bodies.

The King's Bowl crater is clearly more analogous to impact craters, than the Vesta and Mars pits, since it involves the instantaneous release of energy below the surface. The pits appear to be analogous to the fluidization channels observed in the Ries ejecta where slow release of volatiles, and collapse at the surface, produces funnel-like structures. Further studies will not only provide new insights into the formation of phreatic explosion pits on other planetary bodies, but most especially to the volume of water (or other volatiles) and relative energetics required.

References:

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