TERRESTRIAL ANALOGS FOR SELF-SECONDARY IMPACT FEATURES – COMPARING LUNAR FEATURES TO FEATURES AT KINGS BOWL, IDAHO. M.A. Matiella Novak[1], C. Neish[2], M. Zanetti[2], S. Kobs Nawotniak[3], S. Hughes[3] [1]Johns Hopkins University Applied Physics Laboratory, 11101 Johns Hopkins Road, Laurel, MD 20723, [2]The University of Western Ontario, [3]Idaho State University.

Introduction: The Kings Bowl (KB) eruptive fissure and lava field, located in the southern end of Craters of the Moon National Monument, Idaho, is an ideal location for planetary analog field studies on volcanic and impact processes. For example, [1] have conducted field studies in this location as a volcanic analog for fissure eruptions, pit craters and dike injections along Rima Hyginus on the Moon, and Cyane Fossae, Mars. Here we look at impact features present in the KB lava field near the main vent. These were caused by the ejection of blocks during the phreatic eruption that formed the Kings Bowl pit, and their subsequent impact into a partially solidified lava pond. We compare and contrast these features with analogous self-secondary impact features, such as irregular, rimless secondary craters ("splash craters"), observed in lunar impact melt flows in an effort to better understand these unusual features [2][3]. We do this using field measurements and National Agriculture Imagery Program (NAIP) satellite imagery for the KB field and visible imagery from the Lunar Reconnaissance Orbiter Narrow Angle Camera (LRO NAC) for lunar splash craters.

Self-secondary Impact Features: Possible self-secondary impact features can be found in association with many lunar impact craters. These are formed when ballistic ejecta from the crater falls onto the ejecta blanket and melt surrounding the newly formed crater. Self-secondary impact features involving impact melt are particularly useful to study because the visibly smooth melt texture serves to highlight the impact points in spacecraft imagery. The unusual morphology of some of these features imply that they formed when the melt had not yet completely solidified, strongly suggesting a source of impactors from the primary crater itself. Self-secondary impact features have also been associated with volcanic activity. For example, in the KB lava field, small puncture holes and squeeze-ups mark where some ballistic blocks broke through the lava pond crust.

Mushroom Features at Kings Bowl Lava Field: Unique positive relief features (aka "mushrooms", Fig. 1) exist at KB, and here we analyze them as an example of self-secondary impact features. [4] described the varying shapes and structures of these mushroom features –referring to them as "squeeze-ups" – noting that many of the impacted mushrooms have irregular open holes in their surface from which fractures radiate. In some, the block that caused the hole and fracture still remains wedged in the hole, while in others these blocks may be found on a floor inside the convex shell of the mushroom. In some mushrooms the central part had drained after they crusted, leaving them as hollow structures. In others, the oozing lava of the mushroom is found wrapped around a block ejected from the KB vent. During our field studies, we were able to positively identify many mushroom features with these same characteristics.

Figure 1. Positive relief self-secondary impact feature, or "mushroom", observed in the KB lava field. This one is roughly 120 cm in diameter.

[5] describes the formation of these features as beginning with the crust of a lava lake that was broken by many of the blocks ejected by a phreatic explosion. The interior of this lake was still molten and oozed up through the holes punched in its crust, resulting in a large number of squeeze-up mounds of gas-charged lava, which we refer to as mushrooms because of their distinct rounded shape.

Figure 2 shows the results of our GPS survey of the mushroom features within the ejecta field at KB. These were documented along two radial transects, away from the central vent, which was the source of the blocks. The mushroom features of the east-west transect are all located 100 m to 250 m from the KB vent and have diameters ranging from ~40-190cm . There is no strong relationship between distance and mushroom size across the field. No mushroom features existed near the vent, where maximum block diameters were >1 m, nor on the fringes of the ejecta field, where blocks were only several cm in size. The fact that these features are not present throughout the entire ejecta field, which extends about 245 m west of the KB vent, is worth noting and may have some bearing on how these features form.

We also noted the surrounding texture of the lava field along the transect. We were able to identify when the ejecta field ended and indeed the mushroom features were only observed well within the ejecta field. Understanding the distribution of these features in relationship to the location of the vent can also provide insight into how these features form.

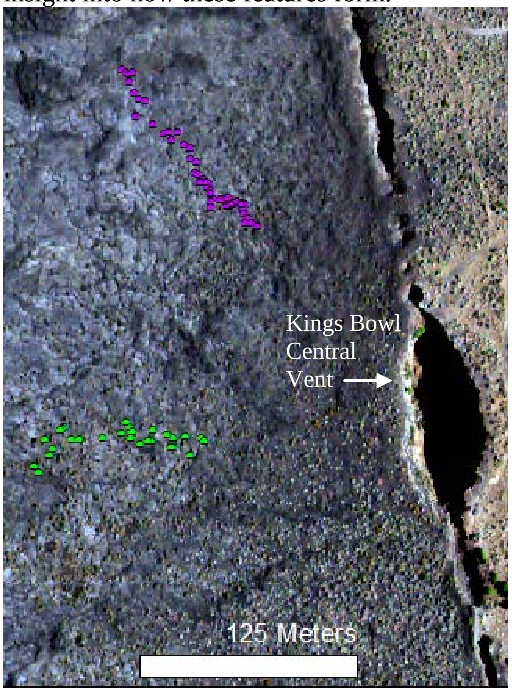

Figure 2. Two transects of mushroom surveys within the KB squeeze-up field. Pink dots are Transect 1 and green dots are Transect 2. The white scale bar is 125 meters.

Analogous Features in Lunar Impact Melts: Observing mushroom features on the Moon is challenging given the spatial limits of spacecraft imagery. Although we continue to look for these features within LROC NAC imagery, the general small size (<2.5 m diameter) of the mushroom features make it unlikely that we will be able to confidently identify them. However, there are other potential self-secondary features that are observed and offer a comparison for morphology, distributions and size-distance relationships. One of these types of features is the splash craters within the Aristarchus melt (Fig. 3).

Discussion: Terrestrial analog comparisons between basaltic lava flows on Earth and impact melt flows on the Moon are important for understanding the emplacement conditions for the melt [6]. For this project, we compare and contrast the morphology of measured mushroom features at KB with splash crater features at Aristarchus Crater (Fig. 3). For example, in Table 1 we list some of the characteristics associated with each type of self-secondary features. The limits of spatial resolution for both sets of satellite imagery have created a challenge for identifying mushroom features. Because of their small size (<2.5 m), being able to distinguish them from surrounding lava surface textures has been challenging even at the 0.5 m/pixel resolution of the NAIP imagery. Likewise, we have yet to confidently identify them in the ~0.5 m – 1 m/pixel resolution of the LRO NAC imagery. However, other self-secondary features, the splash craters, are easily identifiable in impact melts using LRO NAC imagery (Fig. 3). In future work, we will use these splash crater features as a proxy for the mushroom features at KB, focusing on the distribution and physical characteristics of these two features.

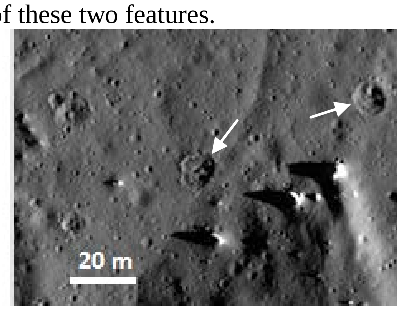

Figure 3. Example of splash craters within the Aristarchus impact melt. White arrows point to these features.

Table 1 – Self-secondary Impact Features

KB Mushrooms	*Aristarchus Splash Craters*
-Located within the KB ejecta field; -Size range between 20-250 cm; -Distributed between 100-250 m from the impactor source. -Positive relief	-Located within impact melt deposits; -Typically <<100m); -Sometimes contain central boulder or mound; -Negative relief

References:[1] Hughes, S.S. et al. (2015) *LPSC 46, 2846*. [2] Plescia, J.B. (2015) *LPSC 46, 2054*. [3] Zanetti, M. et al. (2014) *LPSC 45, 1528*. [4] King, J.S. (1982) *Idaho Bureau of Mines and Geol. Bulletin, 26, 439-451*. [5] Hughes, S.S. et al. (1999) *Guidebook to the Geology of Eastern Idaho, 143-168*. [6]Neish, C. (2015) *AAS DPS, 107.08.*

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