UTILIZING VIRTUAL REALITY FIELD STUDIES TO ENABLE ANALOG RESEARCH OF PLANETARY SURFACES AND SELF-SECONDARY CRATERING PROCESSES A. Matiella Novak[1], J. Strange[1], and J. Heldmann[2], 1. Johns Hopkins University/Applied Physics Laboratory (alexandra.matiella.novak@jhuapl.edu), 2. NASA Ames Research Center, Division of Space Sciences and Astrobiology, Moffett Field, CA 94035.

Introduction: Self-secondary impact craters have been identified in association with impact craters on the Moon [Fig. 1]. For example, unique self-secondary impact features called "splash craters" or "palimpsests" on the Moon have been identified in areas where impact melt ponded and was subsequently impacted with secondary debris [1]. Self-secondary craters have also been identified on Earth in the volcanic terrains of Craters of the Moon National Monument and Preserve (COTM) in Idaho, USA. These features were formed from a phreatic volcanic explosion which released rock into the air on ballistic trajectories which then re-impacted the volcanic melt sheet surrounding the Kings Bowl (KB) fissure system [2]. Although the ejecta that formed these two types of self-secondary impact features originated differently on the Moon and Earth (e.g., via crater and volcanic processes, respectively), features on both planetary bodies fundamentally formed from similar physical processes in that they were the product of ejecta fallout onto a not yet solidified target immediately after the emplacement of that target material.

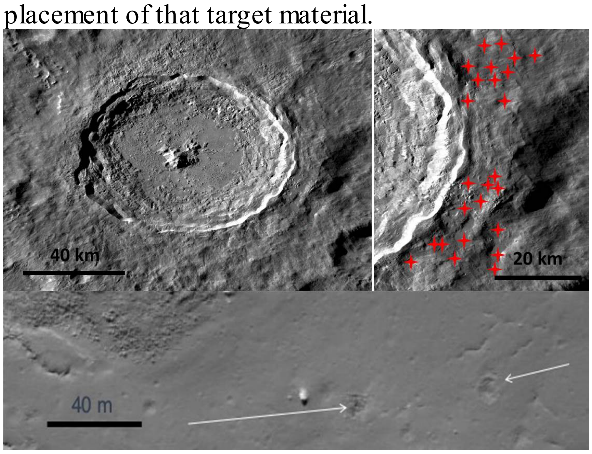

Figure 1: Upper left: LROC image of Tycho Crater. Upper Right: Red stars are location of 25 impact melt ponds on the eastern ejecta blanket of Tycho, chosen for this work. Lower: White arrows point to splash craters in impact melt.

Fieldwork at the Idaho KB site [Fig. 2] in 2015 and 2016 by this team yielded interesting results which confirmed the non-uniform nature of the feature size, distribution, morphology, and morphometry of the SS features [3]. Due to time limitations of personnel in the field, not all SS features were measured in situ. However, high resolution LiDAR data was collected of the SS feature field at KB which covers both SS features measured in situ as well as features not yet measured.

Figure 2: Self-secondary features (aka "squeeze ups") in the foreground and distance, throughout the KB flow field.

For this work, we initialized a proof-of-concept project to finish measuring the SS features with a Virtual Reality (VR) environment rendered from the collected LiDAR data at the KB volcanic field. This approach will allow us to collect the necessary data to complete this science investigation at lower cost (no field travel) and without the associated time constraints of travel to the field. We have developed a proof-of-concept and rendered a subset of the LiDAR data in VR at the Johns Hopkins University / Applied Physics Lab (JHU / APL), and developed the necessary VR tools to measure the SS features in VR. We have compared VR measurements with in situ field measurements of feature size, distribution, morphology, and morphometry by measuring the same features in both environments (field and VR) and found excellent correlation between the VR and field measurements, thereby ensuring the robustness of the proposed VR approach. In addition to completing the science investigation of the KB SS features in Idaho as analogs for lunar SS features, we will also assess the VR technologies required to enable such planetary science fieldwork to be successfully conducted as well as the operational approaches and best practices for conducting fieldwork in VR. A key aspect to ensure the robustness of the VR technology and operations assessments is that the science being conducted in VR is non-simulated (e.g., we are conducting a bona fide scientific investigation), which ensures and requires the integrity of the VR aspect of the work.

Methods: The two main data sets to be used in this project are SS field measurements, collected over two summer field campaigns in 2015 and 2016 at the KB field site, and LiDAR scans collected over one field campaign in 2016 at the KB field site. Strategically, there is geographical overlap among the two data sets (e.g., in situ field measurements and LiDAR data) that allow for ground-truthing the LiDAR data with in-situ field observations. The two field campaigns to KB were in coordination with the NASA FINESSE (Field Investigations to Enable Solar System Science and Exploration) team and [3] summarizes the field work done to survey KB SS features at KB. A total of 386 discrete SS features were measured in the field given the time available in the field.

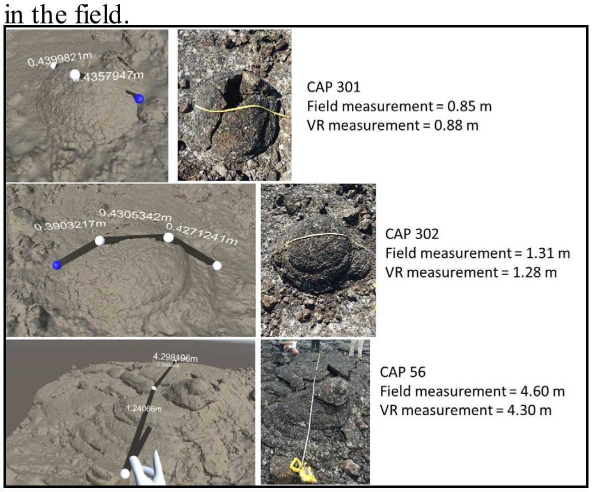

Figure 3: Test measurements taken in VR (left) compared to field measurements (right).

Science: We will render the KB field site in VR using previously collected LiDAR data to enable human exploration of this planetary surface in a lab setting at JHU/APL. As a result of this work, we will 1) conduct a bona fide scientific study of lunar analog self-secondary impact features, 2) identify optimal concepts of operations within the VR environment for enabling field studies, and 3) identify critical capabilities required in VR to enable scientific investigations.

Operations: We will also document and suggest best practices for decision-making protocols, traverse planning, field data acquisition and recording, data flow protocols, and best practices for navigating through the VR field-site. Each one of these operational factors will be tested while we conduct our science investigation by first using traditional field techniques (specifically the ones we used at KB such as using a measurement tool and marking features once we've measured them so that we don't re-measure later) in the VR environment, evaluating the performance in VR, and noting when the traditional field technique either does or doesn't perform reliably in VR, and what modifications need to be made to translate real world field techniques into VR operational techniques [Fig. 3].

Technology: We choose to investigate the efficacy of VR as a key technology to enable and optimize future planetary fieldwork for a variety of reasons. VR platforms can allow fieldwork to be conducted at lower project cost (fewer people having to travel to remote field sites for extended periods of time for fieldwork). VR can also democratize planetary fieldwork [4] and allow individuals to participate in fieldwork science activities who may otherwise be precluded from doing so due to physical limitations (e.g., physical inability to effectively operate in the often difficult conditions of a terrestrial analog field setting), and/or can enable researchers who are unable to travel to field sites (due to time constraints, cost, etc.) to effectively participate and contribute to the field science investigations. This would also provide hazard mitigation by limiting the need to travel to harsh and remote environments for field work.

Conclusions: The primary value of this effort comes from the ability for researchers to make measurements in a virtual environment as if they were physically present on a remote planetary surface. The tools we have built will enable these measurements, as well as expanding on what is typically possible in a real environment.

References:[1] Plescia (2015), Lunar Planet. Sci. Conf., 46, Abstract #2054; [2] Hughes et al., (2018), https://doi.org/10.1016/j.jvolgeores.2018.01.001; [3] Matiella Novak et al. (2016), LPSC 47, Abstract #2716; [4] McGreevy (1993), Virtual Reality, Applications and Explorations, p 163-197.

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