Spectral and Textural Analog Studies of Volcanic Materials Enabled by the Goddard Instrument Field Team. M.J. Henderson1,2, H.N. Vannier3, and C. Achilles2 1Center for Space Sciences and Technology, University of Maryland, Baltimore County, Baltimore, MD 21250, 2Solar System Exploration Division, NASA Goddard Space Flight Center, Greenbelt, MD 20771, marie.j.henderson@nasa.gov 3Purdue University, West Lafayette, IN

Introduction: Analog studies enabled by the Goddard Instrument Field Team (GIFT) sought to understand the spectral and textural properties of volcanic material from a diverse set of eruptions relevant to sites of proposed and selected lunar missions, including Marius Hills and Irregular Mare Patches (IMPs). Utilizing a handheld visible/near-infrared (VNIR) spectrometer complemented by textural observations from camera-based Quantitative Relief Models (QRMs), we analyzed analogs in Hawaii and the Canary Islands. This project provides in-situ comparisons for Moon Mineral Mapper (M3) data in explosive volcanic environments, while testing mineralogical constraints of lunar cones and formation hypotheses of IMPs. The QRM textural observations will provide comparable instrumentation to MAHLI QRMs collected on the Mars Science Laboratory to establish this capability for future lunar and Earth-based observations.

Background: Orbital observations of the lunar surface indicate multiple sites of potentially explosive volcanic origin [1,2]. Diverse and complex explosive deposits have been identified across the Moon using M3, based on strong VNIR glass spectral signatures within a volcanic geologic context [3–5]. However, spectral interpretations are only part of the story, as additional data will be required to understand the origin of the complexity of the composition, morphology, and occurrence of lunar explosive volcanism. In terrestrial investigations, tephra morphology provides important constraints on eruption history and volatile content [8]. However, the spectral properties of volcanic tephra as a function of physical morphology are not well understood, and the spectra of highly porous deposits (e.g., reticulite) have not been characterized. We address this knowledge gap through in-situ spectral and textural analyses of diverse explosive deposits in Hawaii and Lanzarote, Canary Islands.

Lunar cinder cones are identifiable by positive relief morphology [6–8] and confirmed by a glass-rich spectral signature in M3 data [5], indicating an explosive volcanic origin. Cones in Marius Hills have been proposed for Artemis and robotic missions. Lanzarote and Hawaii provided the unique opportunity to examine changes in composition and crystallinity within a singular cone and through multiple cones along a singular fissure. Understanding the textural and compositional changes of these materials could inform traverse planning and investigation protocols for future exploration of a singular lunar cone or field of cones.

IMPs are morphologically distinct volcanic features on the surface of the Moon [9–11]. However, the IMP formation mechanism is still heavily debated, along with whether these are young features or ancient material poorly suited for crater preservation [10,11]. One hypothesis contends that IMPs are composed of a highly porous glassy magmatic foam similar to reticulite [12], an extremely porous basaltic magma foam produced by high-intensity lava fountaining. Previously, no spectroscopic study of reticulite had been conducted. The Keanakākoʻi Tephra [13] and Nāpau Crater have well-documented and accessible reticulite beds. Obtaining reticulite spectra for comparisons to M3 IMP spectra, provides crucial context in evaluating IMP formation hypotheses [14].

Analogue Sites: Fieldwork was funded by the Goddard Instrument Field Team. Support for this research was provided by NASA’s Planetary Science Division Research Program, through the Internal Science Funding Model (ISFM) work package at NASA Goddard Space Flight Center. GIFT explores interdisciplinary science questions and incorporates testing of science instruments comparable to planetary surface instruments through data collection during field expeditions to planetary analog sites. GIFT led expeditions to the island of Hawai‘i in September of 2022 and to Lanzarote, Canary Islands, Spain in May of 2023. The science investigation at each of these locations were selected from submitted proposals.

Hawaii and Lanzarote offered an exceptional opportunity to further understand the properties of explosive volcanic deposits. Two types of explosive deposits were investigated in Hawaii: 1. The Ahu'aila'au volcanic cone [15] in Leilani Estates is similar to small lunar cones [5,8]. 2. Reticulite deposits within the Keanakākoʻi Tephra and Nāpau Crater are a potential analog for lunar IMPs. In Lanzarote, four cones were visited outside of Timanfaya National Park three of the cones were along a fissure while a fourth cone was off the line, but from the same eruptive period.

Methods: The same data collection methodology was used during both field seasons in Hawai‘i and Lanzarote. At each location we identified pyroclast targets (reticulite or cinder cone material) and collected spectra with a handheld ASD QualitySpec Trek Field VNIR spectrometer (350-2500nm). Then, using a QRM imaging setup comprised of a DSLR camera and tripod,
we collected five overlapping images of every target. A camera-based Quantitative Relief Model (QRM) is collected through 5 overlapping images to create micro-relief maps [16]. QRM’s allow interpretation of geologic surfaces at fine scales to characterize minerals, grain angularity, as well as vesicle shapes and sizes. At the cones in Hawai’i and Lanzarote, we completed systematic targeting along linear traverses outward from the cone center, looking for changes in composition and morphology with the handheld VNIR and imaging.

Preliminary Results and Future Work: Full analyses of the data collected in Hawai’i and Lanzarote has begun and the data will soon be archived with the USGS analog data archive.

Reticulite, terrestrial magma foam, collected from Nāpau Crater, Hawai’i, is glass-dominated and has significantly different spectral character than IMPs which does not support a magma foam formation hypothesis [14]. While further study of the cone transects is still underway, in both Hawai’i and Lanzarote glass-rich spectra were collected with the field spectrometer throughout the cone transects which are consistent with M² data or cones in Marius Hills [5]. In Lanzarote, even though all the cones were from the same eruption period and along the same fissure, there were differences in the pyroclasts (amount of reticulate, pyroclast shapes, and weathering), but glass did dominate the VNIR spectrum at all cones. Based on these preliminary results, if the goal in future lunar missions is to retrieve glassy cinder-like material from cones, the astronauts would likely not have to traverse far up the side of the cone to collect a representative sample requiring less time and energy while reducing risk.

In the future, we will continue to prepare and process data from our analog campaigns. We are still working to create our micro-relief maps from the QRM imaging. These micro-relief maps of the volcanic pyroclasts will allow us look for trends in the spectra with changes in texture. We will also further investigate differences in cone materials from different stages of an eruptive period along a single fissure.

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Figure 1: (A) Collecting Spectra of reticulite with field VNIR spectrometer in Nāpau Crater, Hawai’i (B) Collecting images to create micro-relief maps following QRM methodology in Lanzarote, Canary Islands, Spain (C) Handheld sample of reticulite in Nāpau Crater, Hawai’i (D) Line of cinder cones visited for this study in Lanzarote, Canary Islands, Spain.