CHARACTERIZATION OF A POTENTIAL COMPOSITIONAL HALO AROUND INA IRREGULAR MARE PATCH.

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Introduction: Ina (~ 4.9 km^2) was identified as an irregular mare patch (IMP) and interpreted as having formed by basaltic eruptions emplaced within the last 100 Myr [1]. IMPs typically have two morphologies: (1) a topographically high area composed of smooth mounds and (2) a topographically low floor composed of rough areas. IMPs have been hypothesized to be ancient volcanic foam flows [2, 3] or to have formed through release of volatiles/outgassing [4]. Previous studies of IMPs including Ina have revealed sharp morphological boundaries between the smooth and rough units [5] and mound margins with slopes greater than 30˚ [6] Based on previous M^3 results, Ina is of the same overall bulk composition as the surrounding mare flows [7], suggesting that the volcanic source materials have not undergone fractional crystallization (i.e., as they might have in a magma chamber) [7]. Late-stage foam flows of mare basalt composition from a waning dike eruption have been proposed [2, 3]. Some areas of Ina have Diviner [8] Christiansen feature (CF) positions at shorter wavelengths than the surrounding mare materials, which is likely related to fine-scale mineralogical differences, space weathering, and/or surface roughness effects [9].

The focus of this study is on investigating an albedo and compositional halo observed in ultraviolet (UV) to near infrared (VNIR) wavelengths that surrounds Ina (Figs 1, 2). We investigate the mineralogy of the potential halo using 85-band Moon Mineralogy Mapper (M^3) data [11] and conduct ballistic modeling of the halo from the boundary of Ina to help constrain formation mechanisms of both the halo and Ina.

We examine two hypotheses for halo formation: 1) Contemporary outgassing (a mechanical process) [4] which could have modified regolith, weathered by micrometeorites and solar wind over the ~2Ga between the emplacement of the lava flows and Ina and 2) Ina eruption(s) included outgassing with entrained volcanic material, resulting in the emplacement of the halo with particles of pyroclastic material (a chemical change). We test this hypothesis with ballistic modeling of the particles to determine the mechanics required to emplace this halo, based on a range of ejection angles and velocities. We also investigate whether the halo is significantly enriched in glass, which would suggest an explosive volcanic eruption of magma. Outgassing will be tested in the future using phase-ratio analysis of the halo using LROC WAC and NAC images.

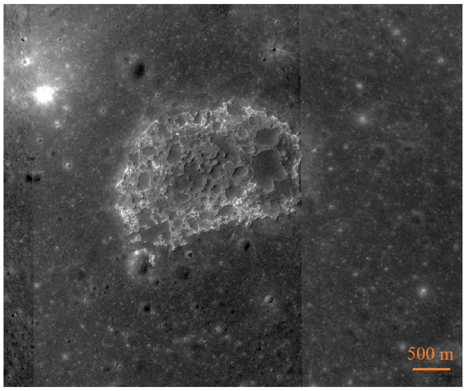

Fig 1: LROC NAC mosaic of Ina (0.5 m/pixel).

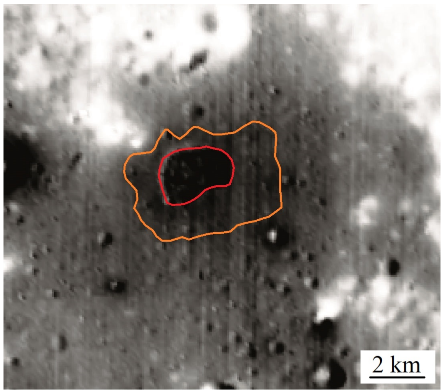

Fig 2: M^3 band 83 reflectance image of Ina (M3G2009025T071411). Orange lines mark a halo that is darker than surrounding material; red lines mark the topographic boundary of Ina.

Methods: We first characterized the halo using M^3 data; we extracted spectra, removed continua, and created 1- and 2-µm band parameter maps (after Horgan et al. [11]). In particular, we created a glass band map (Fig 3) defined by the average of the depth below the continuum at 1.15, 1.18, and 1.20 µm. This parameter detects glass, but also detects olivine and plagioclase feldspar, if present.

A simple ballistic model [13] was used to constrain the emplacement of particles due to pyroclastic eruption. This model allows the user to vary the velocity and ejection angles of massless particles and distributes them in random orientations around a "vent" or a predetermined point or points on a line. We used the boundaries of Ina as lines or points input into the ballistic model and analyzed the areas around Ina where the halo extends to its minimum and maximum distances from the topographic boundary. We tested several variations of ejection angles and velocity parameters, most notably the average ejection velocity of pyroclastic material, 20 – 30 m/s, and the most efficient ejection angle (45°). This allows us to examine emplacement of particles at presumed velocities of lunar basaltic eruption and to assess whether reasonable eruption mechanical behaviors can be observed at Ina.

Results: Fig 2 highlights the dark halo around Ina and the materials of the surrounding region. The glass map (Fig 3) shows that glass is not prominent throughout the region, but is observed around and within Ina. The deepest glass parameter band depth is present within the walls of impact craters, which is likely a saturation effect, impact glass, or an artifact. Glass is also observed on the outer margins of Ina, suggesting that the halo could have a glassy pyroclastic component. The high glass parameter on the slopes of Ina could indicate the presence of pyroclastic or other glass, but it could be a similar saturation or artifact as the impact craters.

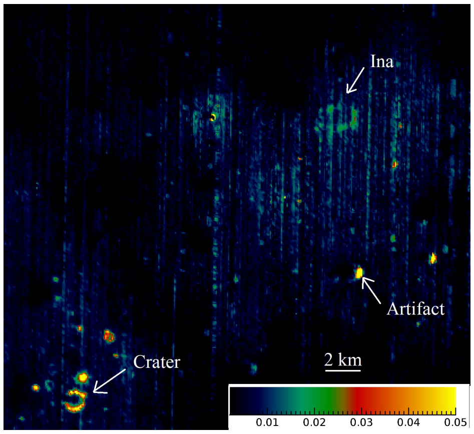

Fig 3: M^3 glass parameter map of Ina and surrounding terrain.

Ballistic Modeling: The nearest margin of the Ina halo is to the north (yellow x Fig 4). At a velocity of 20 m/s, the ejection angle at which a particle must traverse the distance from the boundary of Ina to this boundary is approximately 10° above the surface (lightest pink circular gradation in Fig 4). The exterior extent of the halo that is farthest to the boundary of Ina is to the east-southeast (Fig 2). At a velocity of 30 m/s, the angle at which a particle must travel from the boundary of Ina to this boundary is approximately 15° (middle blue circular gradation in Fig 4). At an angle of 45°, a particle would require a velocity of 9 m/s to travel and 22 m/s to the eastern boundary. These are feasible bounds on a pyroclastic eruption on the Moon, suggesting that the halo may have had a volcanic (and specifically a pyroclastic) origin.

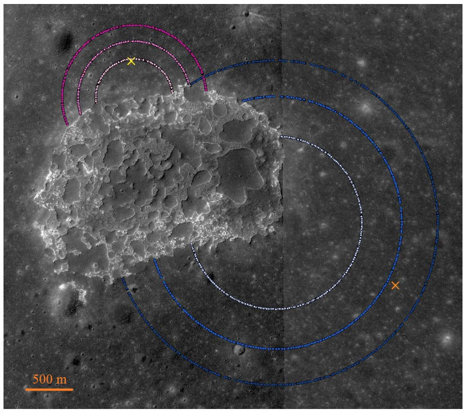

Fig 4: Ballistic model results for Ina (on LROC NAC mosaic); Yellow "x" is closest extent of north halo: 10° (light), 15°, and 20°(dark) at 20 m/s, graded in pink. Orange "x" is farthest extent of southeast halo: 10° (light), 15°, and 20°(dark) at 20 m/s, graded in blue.

Discussion and Future Work: An additional hypothesis to consider is composition of the halo is mixing (or a lesser amount of mixing) with adjacent highlands. The possible presence of glass around Ina is suggestive of an explosive volcanic origin, but further work is needed to characterize the exact relationship between Ina features and the dark halo. Also, other craters within the Lacus Felicitatus area have dark halos, which suggests additional pyroclastic activity in this region or excavation of a darker substrate. We intend to further examine the detailed composition of the halo, Ina features and their surroundings to understand the geologic history of Ina. In addition, the possibility of Ina's emplacement by contemporary outgassing will be investigated using phase-ratio analysis of the LROC images of the halo. Phase-ratio analysis allows the estimation of the roughness of a surface below the resolution originally taken in each pixel [14]. This will be used to determine if there are observable physical differences in the area around Ina that occurred since the emplacement of the mare.

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