RADIATIVE TRANSFER MODELING OF THE ARISTARCHUS PYROCLASTIC DEPOSIT: ASSESSING VOLCANIC GLASS CHARACTERISTICS AND PLATEAU ERUPTIVE HISTORY.

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Introduction: The Aristarchus Plateau in central Oceanus Procellarum is viewed as the most diverse volcanic complex on the Moon [*1*], containing the largest (widest, deepest, longest) sinuous rille [*2*] as well as the largest pyroclastic deposit [*3*]. This plateau is of note because of the variety, density, and scale of volcanic features present.

The pyroclastic deposit (Fig 1) has been well studied and is understood to be fine-grained, largely rock-free, with relatively high Fe or Ti, and glass rich [*1*, *3–6*]. This volcanic glass formed in a long-duration fire-fountain eruption that is expected to have occurred at Cobra Head, the source region for Vallis Schröteri [*7*, *8*]; this eruption dispersed clasts up to 200 km from the source vent, quenching magma rapidly to form volcanic glass in a similar manner to other regional pyroclastic deposits (also referred to as dark mantle deposits, or DMDs) on the Moon [*9*].

While many authors have reported the glass-rich nature of the Aristarchus pyroclastic deposit, the color (and as a result composition) of the glass varies widely between analyses, including orange glass (high-Ti) [*1*, *3*], green glass (low-Ti) [*10*], and yellow glass (intermediate-Ti [*11*]) [*12*].

In addition, previous analyses of the Aristarchus pyroclastic deposit have been performed using ground-based or lower-resolution data than are currently available. With the advent of high-resolution spectral imaging from instruments such as the Moon Mineralogy Mapper (M^3) [*13*], there are ample high-spatial and spectral resolution remotely sensed data. Analyses using the highest-resolution data available would therefore greatly improve our understanding of the deposit.

In this work, M^3 data is applied to investigate the detailed nature of the Aristarchus pyroclastic deposit, with four specific objectives: (1) What is the dominant mineralogy of the Aristarchus pyroclastic deposit? (2) What is the degree of mineralogic variability of the pyroclastic deposit? (3) What kind of volcanic glass is present, and how does it vary in abundance across the deposit? (4) What can we determine about the eruption conditions on the Aristarchus Plateau from this analysis?

Methods: M^3 is a VNIR imaging spectrometer using 83 channels in the spectral range 420-3000 nm with a spatial resolution of 140-280 m/pix; in this work we use data from optical period OP2C1 (Fig 1) [*14*].

Here, we apply Hapke theory of radiative transfer modeling [*15*, *16*] to nonlinearly unmix M^3 data. The approach here (modeled after [*17*, *18*]) models a spectrum in the Aristarchus scene (Fig 1) as a five-component mixture where four components are in-scene endmembers (three approximately pure in-scene mineral spectra and one featureless mare soil spectrum) (Fig 2, top) and the fifth is a laboratory spectrum of a returned Apollo volcanic glass or a synthetic lunar glass (Fig 2, bottom) [*Cannon et al., accepted in JGR Planets*].

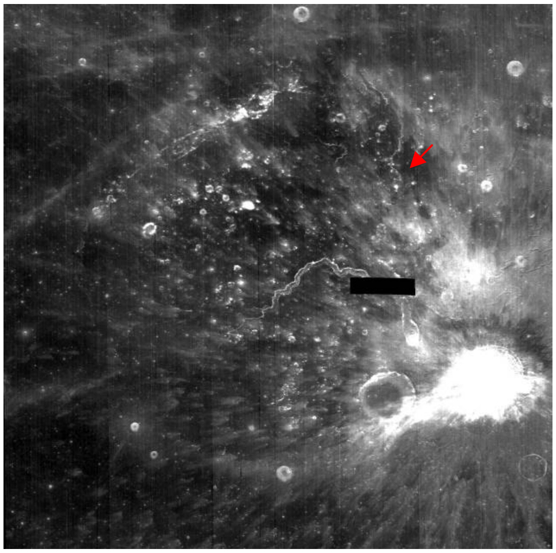

Figure 1. M^3 mosaic of the Aristarchus plateau (OP2C1) 750 nm reflectance. Red arrow indicates location of "DMD" spectrum in Fig 3.

In this model, reflectance in the wavelength range between 540-2400 nm is converted to single-scattering albedo (SSA) and the spectra are mathematically inverted to give relative abundances. This modeling approach does not include endmember optical constants, leaving particle size unaccounted for, so abundances are relative, reported in spectral fractions (rather than absolute abundances typical of full radiative transfer models).

Results: The Aristarchus pyroclastic deposit is very low albedo and the pyroclastic materials contain very shallow absorption bands centered at approximately 1000 nm and 1800 nm (Fig 3). The formation of Aristarchus crater has mantled much of the pyroclastic deposit with higher-albedo ejecta, but various exposures of pyroclastic material appear less contaminated than others, based on their relatively lower albedo (Fig 1). The spectrum used for this analysis (Fig 3) is taken from within this less-contaminated area (see red arrow, Fig 1).

Preliminary results of the M^3 unmixing suggest that spectra of the pyroclastic deposit can be modeled by a mixture of predominantly featureless endmember (EM4, representing the background spectral slope) and a smaller component of glass (~10%, up to 25%), with minimal contributions of the other in-scene endmembers. The modeled glass abundance and the accuracy of the modeled spectrum depend on the type of glass used as an endmember (Fig 2, bottom), but all model outputs have RMSE values <0.006.

In the preliminary results shown here (Fig 3), various glasses were able to fit the pyroclastic spectrum; of the seven glass endmembers (Fig 2, bottom), the best fits were given by synthetic green, synthetic orange, synthetic yellow, and Apollo orange glasses. Of these four spectra, modeled glass spectral fractions ranged from ~4% (green) to 16% (Apollo orange). When comparing real to synthetic glasses, the synthetic glasses were fit more accurately than the Apollo glasses. Of all the glasses analyzed in this study, the modeled spectrum was most accurate with the application of the orange synthetic glass (RMSE of 0.0027).

Discussion: The results shown here confirm that there is a detectable component of glass in the Aristarchus pyroclastic deposit, agreeing with previous analyses [*1*, *3–6*]. Indeed, based on these preliminary analyses, the pyroclastic deposit appears to be relatively glass-rich, on the order of tens of spectral fraction percent, with minimal contributions of other crystalline mineral components, suggesting that soil is dominating the spectral fraction.

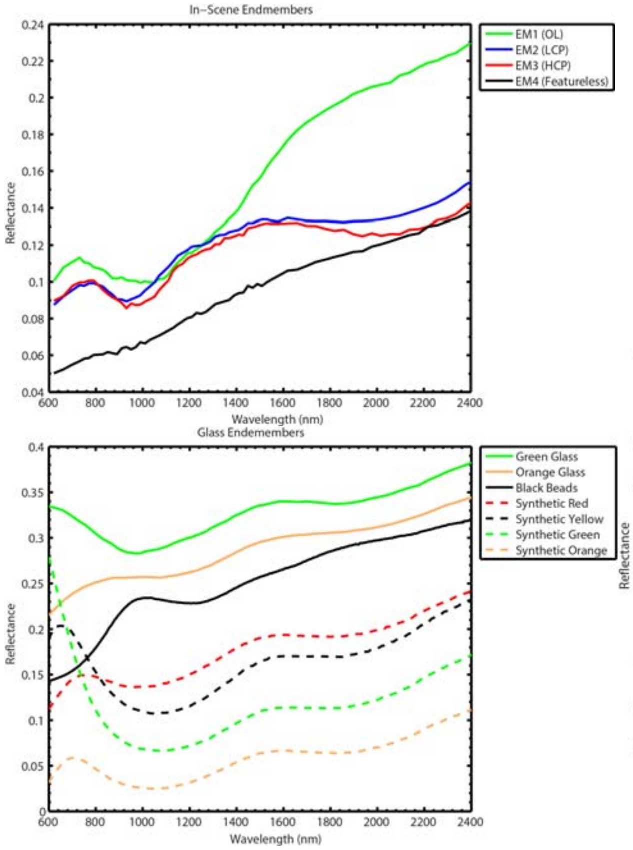

Fig 2. Spectral endmembers. (Top) In-scene endmembers. (Bottom) Laboratory endmembers of real and synthetic lunar glasses.

While several different types of volcanic glass were fit by the model, the orange synthetic glass gave the most accurate results. If the glass in the Aristarchus pyroclastic deposit is similar to lunar orange glass, this agrees with previous analyses that the deposit is high in titanium [e.g., *1*, *3*].

The presence of volcanic glass in the pyroclastic deposit, with the low abundance of crystalline material, supports the model that the Aristarchus pyroclastic deposit formed in a long-duration, hawaiian-style fire fountain eruption [*7*, *8*]. The low abundance of black beads detected by the model also suggests that there are no partly devitrified beads present (as was observed at the Apollo 17 landing site in the Taurus-Littrow pyroclastic deposit [*19*]), suggesting the optical density of the eruptive plume remained low throughout the eruption [*6*] except at locations close to the eruptive vent [*7*].

Future analyses will focus on the variability of the glass detection across the pyroclastic deposit, including further analyses into the type and abundance of volcanic glass, facilitated by applying the spectral unmixing model to the entire M^3 mosaic.

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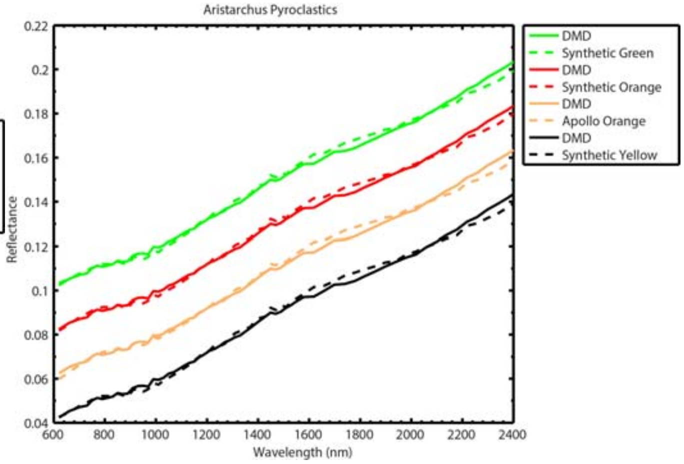

Fig 3. Unmixing results. Solid lines show a spectrum of the pyroclastic deposit. Dotted lines are the unmixing model results with four different glass endmembers: synthetic green, synthetic orange, real orange, and synthetic yellow glass, respectively. Spectra have been offset for clarity.