COMPOSITION OF DARK MANTLE DEPOSIT ON THE ARISTARCHUS PLATEAU.

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Introduction: The Moon's mantle makes up 90% of the Moon's volume. Therefore, it is important to determine the mantle composition in order to understand the lunar bulk composition, which contains information about the Moon's origin and evolution. It is also essential to study the mantle composition in order to understand the process of differentiation by the lunar magmatic ocean. However, the composition of the lunar mantle remains unclear.

Pyroclastic beads are a direct clue to lunar mantle cmposition. These very low-albedo beads on the lunar surface are Fe-bearing volcanic glass or partially crystallized spheres. The color variation of volcanic glass corresponds to its composition. In particular, TiO_2 content strongly affects color, in the order of higher TiO_2 content (e.g., orange glass (>8wt%), yellow glass (3 to 8wt%), green glass (<~0.5wt%)) [1].

Previous studies suggested that if the erupted magma is quenched slowly, the erupted magma of intermediate to high TiO_2 content can be small crystallized ilmenite grains and generate black beads, instead of generating orange and yellow glass as in faster quenching [2]. Therefore, the TiO_2 content of the beads and the quenching speed of the erupted magma correlate with the colors and crystallinities of the pyroclastic beads .

Chemical studies of pyroclastic beads acquired by Apollo missions indicate that pyroclastic beads were formed from erupted magma from deeper (300 to 400km) in the mantle than basaltic magma [3]. It is also assumed that pyroclastic beads retain the original composition of the magma because the magma does not completely crystallize during eruption, due to the extremely high upward speed. Thus, by estimating the composition and crystallinity of pyroclastic beads based on remote sensing data, we can investigate the composition of the magma generated in the deeper lunar mantle and their eruption mechanism (e.g., eruption speed and volume) on global scale.

Dark Mantle Deposits on the Aristarchus Plateau: Dark Mantle Deposits (DMDs) are believed to contain pyroclastic beads, as were found in the Taurus-Littrow region near Apollo 17 site. This region is one of the darkest and smoothest areas on the Moon, and dark smooth terrains similar to those in this region on the lunar surface are categorized as DMDs [4]. However, detailed spectral analysis comparing remote-sensing data of the DMD region with laboratory-measured pyroclastic beads is lacking because of the limited wavelength coverage and spatial resolution of the previous remote-sensing data. However, previous studies have identified several DMDs [5].

This study focused on DMDs on the Aristarchus Plateau and used spectral data obtained by the Multiband Imager (MI) on the SELenological and ENgineering Explorer (SELENE). We chose this region because DMDs on the Aristarchus Plateau are the largest regional DMDs (49013km^2) [6] and because volcanic activity has lasted longer there than in other areas up to the Eratosthenian in this region. Therefore, this region possibly has the most voluminous and stable reservoir for their source [7]. Previous studies reported that the crystallinity of this region is the lowest of all DMDs on the Moon [5] and that its composition is orange glass, indicating high TiO_2 content [6, 8]. This study reevaluates composition and crystallinity of this region in more detail, using data with wider spectral coverage.

Method: We used MI spectral data to estimate the TiO_2 content and crystallinity of the DMDs in this region. The MI is a high-resolution (20m x 20m per pixel) spectral imager with both visible and near-infrared coverages at spectral bands of 415, 750, 900, 950, 1000, 1050, 1250 and 1550nm. At each location, the reflectance is derived by averaging an area corresponding to 30 x 30 pixels in the MI-VIS to remove the effect of relatively higher noise in this very dark region. Using MI spectral data, we can distinguish minerals and glass from the absorption features after removing the continuum. For example, a glass has the absorption features at 1000nm with greater absorption width than pyroxene and olivine [5].

In order to select locations representing DMDs suitable for checking compositional variation within the DMDs, we mapped the Aristarchus Plateau and its vicinity (22^o to 30^{o}N, 303^o to 319^{o}E) using the reflectance data at 750nm and then selected locations where reflectance is lower than 5.5%. We also generated an MI color-composite mosaic based on differences in absorption features, in order to distinguish pyroclastic beads on the plateau from the surrounding mare (Fig.1).

We then estimated the type (TiO_2 content) of pyroclastic beads at each location by comparing the wavelength of the absorption center in the MI data with that of the laboratory-measured data of Apollo pyroclastic beads from the RELAB database (www. planetary. brown. edu / relab) (Fig. 2).

Crystallinity was estimated by comparing modeled spectra of different crystal content. We used the spectra of orange, yellow glass, and black beads from Apollo samples (grain size was set to 40μm) as endmembers. By comparing the spectra (absorption depth ratio at 1000nm and 1050nm) of different mixing ratios of glass and black beads, we estimated the crystallinity (estimated content of black beads) of the DMD.

Results and Discussion: The derived wavelength of the absorption center of the DMD spectra was 1050nm, which is similar to that of yellow glass (Fig. 2). Also, the absorption features are most similar to those of yellow glass. Thus, the pyroclastic beads of the DMD are assumed to be yellow glass, which has intermediate TiO_2 content.

Figure 3 plots the absorption depth at 1000nm and the absorption depth ratio at 1000nm and 1050nm, based on the modeled reflectance of yellow glass and black bead mixtures (A, B, C) with observed DMD spectra. We also plotted modeled results of the pyroclastic beads and Aristarchus crater ejecta (E) mixture. Our results suggests, that the crystallinity of the pyroclastic beads was 20%, and 40 to 50% of this region comprised materials ejected by the Aristarchus crater because the observed DMD spectra was best fitted to the modeled spectra containing 40 to 50% ejecta, on the curve EB (B; yellow glass : black beads = 80 : 20%).

Our result indicating low crystallinity of pyroclastic beads is consistent with that of the previous study [5]. However, the estimated TiO_2 content of the DMDs on the Aristarchus Plateau is lower; therefore, further study is required to estimate the composition of the lunar mantle based on DMD analyses. Because the estimated crystallinity of the pyroclastic beads was low, the erupted magma in this region was quenched very rapidly. It is possible that only small volatile materials were contained in the magma source in this region because magma with higher volatile content cools more slowly and is likely to have higher crystal content.

In addition, our results indicate no regional compositional variation in this DMD. Such compositional homogeneity indicates the possible existence of a large magma reservoir.

References:

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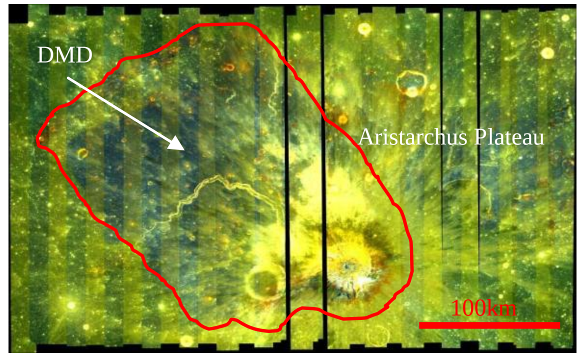

Fig. 1 MI color-composite image of the Aristarchus region. Red, green, and blue are assigned to a continuum-removed absorption depth at 950, 1050, and 1250 nm.

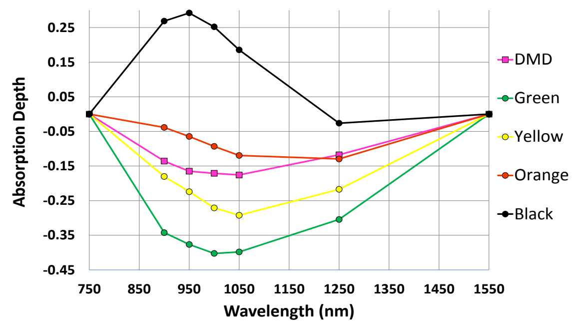

Fig. 2 Absorption after continuum removal of reflectance spectrum. DMDs have a trend similar to yellow glass because the wavelength of absorption center is 1050nm. We use sample data from RELAB (green : 15401, orange : 74220, black : 74001, and yellow : JG-JJG-003~005).

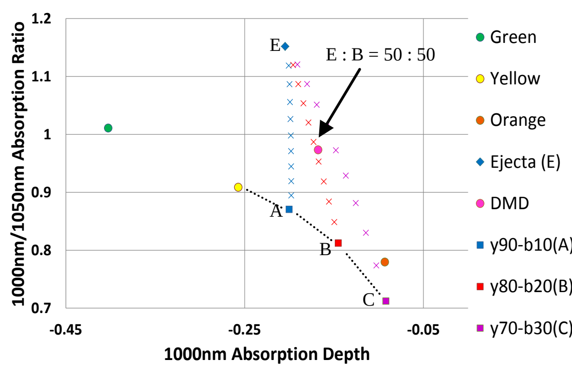

Fig. 3 The mixing ratio between yellow glass and black beads, and the ejecta (E) from the Aristarchus crater and DMD. DMD is on the curve EB (A, B, C ; yellow glass : black beads = 90 : 10, 80 : 20, 70 : 30).