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月全球に分布する火砕性堆積物の分光解析によるマントル組成の不均一性推定
Heterogeneity of lunar mantle composition estimated by spectral analyses of Dark Mantle Deposits

有本 龍三 [1], 大竹 真紀子 [2*], 春山 純一 [2], 岩田 隆浩 [2]
Tatsumi Arimoto[1], Makiko Ohtake[2*], Junichi Haruyama[2], Takahiro Iwata[2]

[1] 東京大学, [2] 宇宙航空研究開発機構・宇宙科学研究所
[1]The University of Tokyo, [2]JAXA / ISAS

The lunar mantle makes up 90% of the lunar volume. Therefore, it is important to determine the mantle composition for understanding the lunar bulk composition and the process of its differentiation from the lunar magmatic ocean. However, the composition of the lunar mantle remains unclear. On the other hand, pyroclastic beads which are volcanic glass or partially crystallized spheres provide a direct clue to lunar mantle composition. Previous studies suggested that pyroclastic beads are the result of an explosive fire-fountain originating deeper (300 to 500 km) in the mantle than basaltic magma and retain the original composition of the magma because the beads have higher Mg# than mare basalts and do not completely crystallize during eruption, due to the high upward speed. It is also reported that the color variation of pyroclastic beads correspond to their composition, in particular TiO_2 content, and the crystallinity of the beads. Also, the crystallinity of the beads correlates with quenching rate of the erupted magma formed them and the volatile content in the magma.

Dark Mantle Deposits (DMDs) are darkest regions on the Moon and are believed to contain pyroclastic beads. Thus, by estimating the composition and crystallinity of DMD based on remote-sensing data, we can investigate the composition and volatile content of the magma generated in the deeper lunar mantle on a global scale.

In this study we estimated the TiO_2 content and crystallinity of the largest 20 DMDs distributed globally over the Moon and investigates the compositional relationships of the magmatic sources, among DMDs and between DMDs and the surrounding mare basalt using spectral data obtained by the Multiband Imager (MI) on SELENE. First, we selected DMD locations which have the lowest reflectance and spectral absorption features of pyroclastic beads. Second, we judged the types of pyroclastic beads by comparing the spectral absorption shapes of DMDs in the MI data with that of the laboratory-measured data for Apollo pyroclastic beads. Finally, by comparing the spectra of different mixing ratios of glass and crystallized beads, we estimated the crystallinity and TiO_2 content of the DMD. We also estimated the TiO_2 content of mare basalts surrounding the DMDs in order to compare the composition of the DMDs with that of the mare basalts by producing Ti-maps based on MI spectral data.

Our results suggest that the TiO_2 estimates of DMDs had 2 groups including intermediate-Ti group ranged from 5.4 to 6.3wt% and high-Ti group with 9.1wt%. Also, the crystallinity of the pyroclastic beads of DMDs had 2 groups, including low crystallinity group ranged from 3 to 35%, and high crystallinity group ranged from 72 to 85%.

In addition, a comparison of Ti estimates for DMDs and the surrounding mare basalts indicated that DMDs tend toward higher TiO_2 content than mare.

This variation of composition and crystallinity of DMDs indicates the presence of an azimuthal heterogeneity of composition and volatile content in the lunar mantle, assuming that the depth of the magma source for each DMD has the same range.

The possibility of azimuthal compositional heterogeneity in the lunar mantle is consistent with and may suggest compositional diversity after a mantle overturn, which is the vertical transport of the mantle caused by gravitational instability of the high-Ti cumulate layer produced during the final solidification step of a magma ocean.

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