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月トリウム高濃度岩石相の成因及び厚さの推定
Estimating the origin and thickness of high-thorium-content rock units on the lunar surface

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The abundance and distribution of thorium, an incompatible element, within a planetary body are very important for understanding the thermal history of a terrestrial planet because it correlates to the heat-source elemental abundance of these planets. Gamma-ray remote-sensing data depicts the global distribution of thorium of the lunar surface, in which thorium concentrates in the western hemisphere of the lunar near side around the mare region. Within this high thorium area are several hot spots, which have significantly higher thorium content. Lunar rocks containing abundant incompatible elements are called KREEP-rich rocks based on the Apollo sample analyses. KREEP should be formed in the boundary area between the lower crust and the upper mantle. However, the KREEP-rich rock is exposed on the lunar surface. Two processes were proposed as the mechanism for transporting KREEP-rich rocks from under the crust to the surface. One is an igneous process, in which KREEP-rich basalts erupt from magma generated in a deep area at the bottom of the crust. The other mechanism is the ejecta origin of Imbrium basin, in which a basin-formation event excavated the lower crust including KREEP-rich rocks and spread it as ejecta on the surface. The thorium hot spots can be considered to have been formed by either mechanism. However, because of a low spatial resolution of gamma-ray observation from orbit, we cannot identify the corresponding rock types of the thorium hot spots. Therefore, the actual distribution of the high thorium unit and its thorium abundance has not been well understood.

In this study, we used high-resolution visible to near-infrared band images obtained by Kaguya (SELENE) and combined them with a simulated thorium abundance based on Lunar Prospector gamma-ray data to estimate the origin of the thorium-rich rocks and their thorium concentrations. We selected two hot spots (Aristillus and Copernicus) to analyze as candidates of the two KREEP origins. Aristillus is a crater within the Imbrium basin, while Copernicus is located outside of the Imbrium basin.

Our results indicate that KREEP-rich rocks around Aristillus contain high calcium pyroxene, and its thorium abundance is estimated to 35 ppm, while there appears to be no thorium inside the crater. In contrast, KREEP-rich rocks around Copernicus contain low-calcium pyroxene with 12 ppm thorium content. By combining the results with their geologic contexts, KREEP rick rocks in Aristillus (Copernicus) are estimated to originate from KREEP basalts (Imbrium ejecta). The KREEP layer around Aristillus is estimated to be 1.6 km thick, and that around Copernicus is estimated to be 9 km thick. These results suggest that the thorium concentration within the crust is not uniform as assumed in a previous model but it forms a layer. It also clearly demonstrates that the previous model assuming constant thorium content within the crust from surface to the bottom (60 km deep) needs modification. Our estimation based on our new thorium abundance model for the Procellarum KREEP terrane derives much lower thorium abundance (50% less) than previously estimated.

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