Detecting mare basalts intruded into the crust on the early Moon

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To understand the lunar thermal evolution, unraveling the eruption rate of mare basalts and its temporal variation is important. Absolute dating of lunar basalt samples returned by the Apollo and Luna missions indicated that lunar magma eruptions were active from 3.9 to 3.0 Ga [e.g., Nyquist and Shih, 1992]. Also, the age of basalt fragments in the lunar meteorite is estimated to be 4.35 Ga by radiometric dating [Terada et al., 2007], implying that mare magmatism already started at that time. However, the magnitude of magma activity before the basin-forming period (>3.9 Ga) remains unknown, because these magmas could hardly extrude to the surface before topographic lows were formed by basin-forming impacts.

In order to verify the existence of pre-basin basalts and estimate its total volume we investigated the inner ring of the Crisium basin, which consists of deposits of crustal materials ejected by the Crisium-forming impact. In this study, we used topographic data and multiband images obtained by Terrain Camera and Multiband Imager onboard Kaguya. The inner-ring area was defined as area with an altitude higher than -1.3 km. Mare basalts in the inner-ring area were identified based on the optical matuality, the FeO content, and the spectral absorption depths at 950nm, 1050 nm and 1250 nm.

The mean FeO content of the fresh regions in the inner-ring area was calculated to be 6.75 wt%, suggesting the limited amount of basalts in the area. However, we found some basaltic outcrops at interior and ejecta of smaller craters excavating part of the ring materials. The surface area of the basaltic outcrops is estimated to be 1.3×10^{-3} % of the inner-ring area. By assuming that the area abundance of the basalts in the inner ring is equal to the volume abundance, we estimated to be the total volume of basaltic intrusions of 1.2×10^{5} km^3. Based on comparison with the total volume of Mare Crisium (2.0×10^{5}–7.2×10^{5} km^3) [Mulis et al., 1992; Solomon and Head, 1980], we conclude that mare volcanism before the Crisium-forming impact was less active than post-Crisium volcanism.

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