Near-Far Asymmetry of Magma Production and Conditions of Magma Eruption of the Moon: Constraints from Mare Volumes within the Impact Basins

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To understand the thermal conditions of the lunar mantle and its lateral heterogeneity, estimates for volumes of mare basalts are essential. However, because of the absence of high-resolution remote sensing data on the lunar farside, accurate volume estimates of farside maria had been limited until recently. In this study, we estimated the volumes of mare basalts within five farside basins, Apollo, Ingenii, Poincare, Freundlich-Sharonov, and Mendel-Rydberg, and one nearside basin, Crüger-Sirsalis, using topographic and multiband image data obtained by SELENE (Kaguya). Furthermore, using the high-resolution crustal thickness model constructed from GRAIL gravity data and LRO topography data, we investigated the crustal thickness of major impact basins and the relationship with the magma eruption. The results of volume estimates indicate that farside mare volumes are ~100 times smaller than those of the nearside. From a relationship between the mare volumes and the crustal thicknesses of each basin, it was also found that the minimum crustal thicknesses within the basins were a dominant factor that determined whether magma erupted at the surface and that the critical crustal thickness for magma eruption were ~12 km for the farside and ~20 km for the nearside. In the areas with thinner crust than the critical thicknesses, the total mare volumes do not depend on the crustal thickness. These results suggest that the lunar diapirs had typical sizes for the nearside and the farside, respectively. The diaper radii were estimated to be 3.5–4.4 km for the nearside and 2.2–3.3 km for the farside based on a simple magma ascent model considering the balance of the positive buoyancy of the diaper at the crust-mantle boundary and the negative buoyancy of a dike in the crust. The ratio in the diaper volumes between the nearside and the farside is only 2.6–4.0, much smaller than the observed ratio of mare volumes (100 times). Therefore, the observed ratio of mare volumes should be explained by difference in frequencies of magma eruption. The eruption frequencies were calculated to be 200–3000 for the nearside and 10–200 times for the farside based on the observed total volumes of mare basalts. Furthermore, from the estimated diaper sizes and eruption frequencies, we estimated that magma production in the farside mantle might be ~15-20 times smaller that of the nearside mantle. This result implies a stronger near-far dichotomy than previously estimated.

Keywords: Moon, Mare volcanism, Lunar dichotomy, Mare basalt, Crustal thickness