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Formation process of linear gravity anomalies and thermal evolution of the Moon

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The investigation of the subsurface structure in the Moon through a gravity distribution is one of means to understand the early evolution history of the Moon. Andrew-Hanna et al. (2013) analyzed gravity data, obtained by GRAIL (The Gravity Recovery and Interior Laboratory) and identified linear gravity anomalies (LGAs). They suggested that the LGAs resulted from ancient intrusions formed by magmatism with globally expansion. We can expect that such intrusions leave other evidences on the surface. In this study, we analyze topography data and FeO concentration distribution to find some characters corresponding to the LGAs and magma intrusion, and, together with the thermal history of the Moon, discuss the formation process of the LGAs on the Moon.

In this study, we focus 20 of LGAs reported by Andrew-Hanna et al. (2013) that show clear gravity anomaly. We use the 1/1024-degree gridded lunar topographic data from LOLA and the 10pixel/degree lunar FeO concentration distribution map from Clementina.

For topography data analysis, we set a study area that ranges 300km in orthogonal direction from a LGA. We apply a filter to remove topographical perturbation due to small craters. On a vertical profile to a LGA, the average, the standard deviation, and the average gradient of relative altitude are calculated with a reference altitude on a LGA. We define a vicinity area as an area within 50km from a LGA and a surrounding area as an area farther than 100km from a LGA on a vertical profile. Based on topographical features of both a vicinity area and a surrounding area, we categorize the topographic feature of LGAs into three types: mountain type, valley type, and unclassified type.

For FeO concentration data analysis, we calculate the average and the standard deviation of FeO concentration in vicinity areas of a LGA from the FeO concentration map.

The topographical data analysis reveals that most of the LGAs regions are categorized as the valley type. This result suggests that the LGAs regions are distributed over trough regions formed by tensile stress in the early history of the Moon. The FeO concentration distribution analysis reveals that the average FeO concentration of the vicinity areas in highland is 6.72 ± 1.62 wt%. This value is higher than that in the highland (<6 wt%) of the Moon, suggesting that an ancient intrusion is possibly exposed by later crater gardening.

We propose a following hypothesis on the formation process of the linear structures as a cause of LGAs from these results and the thermal history of Head and Wilson (1992). The stress state in the early period of the Moon is tensile stress for thermal expansion process. After crack formation due to the tensile stress before 4.0 Ga, the linear structures are formed by magma intrusion. The linear structures are covered by magmatism that forms mare during 4.0-3.0Ga. Ridges are formed in mare during 3.8-3.0Ga because of the compressive stress with the cooling of the Moon or in the impact basin. The formation of the ridges occurs in association with cracks near the linear structures.

Keywords: magmatism intrusions event, expansion, ridge, FeO concentration, Lunar topography data