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Early global expansion of the Moon: constraints from topographic characteristics on linear gravity anomalies

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According to numerical models of the lunar thermal evolution, the lunar radius temporary increased at the lunar early stage because of a thermal expansion resulted from mantle remelting after the magma ocean solidification. However, no clear evidence of lunar early global expansion was observed because many impacts have transformed the lunar surface. Recently, the Gravity Recovery and Interior Laboratory (GRAIL), which was launched in 2011 by NASA, measured the lunar gravity field with high accuracy. Andrew-Hanna et al. [2013] identified large linear gravity anomalies (LGAs) from the analysis of the GRAIL gravity data, and suggested that the LGAs resulted from ancient intrusions or dykes formed by magmatism with the global expansion. To test the hypothesis, we investigated topographical profiles across the LGAs. In addition, we determined formation ages of LGAs to constrain the timing of the global expansion.

We used 1/1024-degree gridded lunar topographic data from LOLA Data Archive [http://imbrium.mit.edu/LOLA.html LOLA_GDR(LRO-L-LOLA-4-GDR-V1.0)]. The topographic profiles across the LGAs were calculated in a range of 300 km from the LGAs. We found graben-like topography along the LGAs, suggesting that the LGAs were formed in the tensile stress field accompanied with the global expansion.

We performed crater counting in areas of 50 km distance from the LGAs to constrain the timing of the global expansion. The estimated formation ages of LGAs are distributed in a range from 4.3 to 3.9 Ga with a peak at 4.1 Ga, corresponding to the oldest ages of the Apollo basaltic samples and lunar basalt meteorites [e.g., Terada et al., 2007]. The results suggest that the lunar global expansion begun at 4.3 Ga.

We estimated the lunar radius change as a function of time based on the estimated ages. We assumed that the topography of the LGAs simply were a dale consisting of two normal faults. The increase of lunar radius is estimated to be ˜2.2 km at most, consistent with the estimation from a lunar thermal model [e.g., Zhang et al., 2014].

Keywords: linear gravity anomaly, early global expansion, tensile stress, topography, crater chronology