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Admittance between gravity and topography show the moon's lithosphere

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The Moon is the only natural satellite of the Earth, and is believed to be formed by an impact of a Mars-sized body with the primitive earth, and the subsequent integration and cooling of fragments formed in the impact. The Moon is an important key to investigate the early history of the solar system because it preserves the ancient surface and is the most accessible planetary body from the Earth. Investigating the formation and evolution of the Moon requires an understanding of the interior structure, heat generation, and differentiation.

The lunar exploration has started with the invention of the optical telescope by Galileo Galilei, which enabled us to see the topographic irregularity of the lunar surface. In the 20th century, scientists sent various probes to the Moon, and have been trying to explore its interiors by various observations with lunar landers and from lunar orbiters.

In this study, we study the relationship between the free-air gravity model from the GRAIL (Gravity Recovery and Interior Laboratory) mission and topographic model from the laser altimetry in the LRO (Lunar Reconnaissance Orbiter) mission. In the GRAIL mission gravity field was derived from the changes in the distance between the two identical satellites on the same orbit. The gravity and topography showed low/high correlation in the low/high degree components. This means that isostatic compensation is highly achieved for long wavelength features due to the ductile flow in the lunar mantle, and that the short wavelength topography is mainly supported by lithospheric strength. For the topography of very short wavelength, with degree/order exceeding 400, the correlation again becomes low due to errors in the gravity model.

It is important to compare the correlation between the gravity and topography of not only the Moon but also other terrestrial planets, such as Mars and Venus, to study degree of isostatic compensation and lithospheric thickness. For example, Mars is larger than the Moon and smaller than the Earth, and its lithospheric thickness and the degree of isostatic compensation will also be between the Moon and the Earth.

In addition to the correlation, we study the admittance, which is defined as the amplitude ratio of topography and gravity anomalies. The admittance is important in the discussion of the thickness of the lithosphere that can support the surface irregularity as an elastic body (referred to as elastic thickness here). Generally, a larger planet has larger surface heat flow and thinner lithosphere. Thin lithosphere would cause high degree of isostasy for the topography of the shorter wavelength. For the Moon, small admittance for long wavelength topographies quickly becomes larger, and the admittance keeps constant at about 110 mgal/km for degrees larger than 50.

Based on the theory in Watts (2001), we estimated the elastic thickness of the Moon as ~14 km. This thickness is comparable to those found in the present Earth in spite of the smaller dimension of the Moon. This may suggest that the majority of the topographic features on the Moon was formed in the early stage of the Moon, when the moon was not so cold as it is today.

In planetary physics, it is important to compare different planets and moons from various aspects. The present study suggests that the Moon still conserves the state of the early-stage isostasy as a fossil to investigate its ancient elastic thickness. After all, it is important to consider not only size but also age of the topography in discussing the elastic thickness of a planet or a moon.

Keywords: the moon, topography, gravity anomaly, lithosphere, correlation, admittance