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月の内部熱進化再考：地殻重力異常形成と火成活動継続期間への示唆

Thermal history of the Moon revisited: Implications for the gravity anomaly and the duration of lunar mare volcanism

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SELENE/KAGUYA spacecraft has precisely measured lunar gravity and revealed the different gravity anomalies on the lunar nearside and farside. On the nearside they contain mascons that are positive gravity anomalies. The farside, on the other hand, has no mascons and there are few lunar maria but a number of negative gravity anomalies. These observations suggest that the interior was hot on the nearside but cold on the farside about 4 billion years ago. In other words, the crust on the near and farside have cooled with different speeds, that is, the crust on the nearside kept warm for a few hundred Myr after the formation of the Moon, while that on the farside cooled down quickly. On the other hand, topographic analyses of SELENE camera data have revealed that duration of the lunar volcanism is longer than previous estimates. For examples, mare volcanism on the lunar farside lasted about 2.5 Ga. This longevity of volcanism seems to be contradicting the thermal state which needs to form the gravity anomalies.

In order to provide the explanation for these discrepancies, we re-investigated the thermal history of the moon by performing the numerical simulations. In order to evaluate the time evolution of an internal thermal state taking into account of the melting curve of rocks, it is necessary to estimate the local heat transport, not bulk energy balance using the Rayleigh number-Nusselt number relation. We estimated the convective heat transport using the mixing length theory, because the viscosity of the solid region shows a strong dependence of temperature. When a solid-state convection occurs inside the moon, this numerical approach can distinguish the mechanical structure into an upper brittle layer termed lithosphere and warm, solid-state convective layer termed asthenosphere. The temperature at the start of the calculations is assumed to be at the solidus in the just solidified magma ocean. Since the numerical model here is 1-D spherical-coordinate system, different thickness of the cold thermal boundary layer on top of the solidified magma ocean is assumed depending on handling of the lunar near and farside. Considering a number of cases for the (radial) distribution of the radioactive heat source (by decaying of U, Th, K) and their abundance ratios, we investigate the temporal change of the temperature profiles after the formation of the Moon especially focusing on an existence and its lifetime of partially-melted region in the lunar mantle.