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Structure of lunar crust from KAGUYA selenodesy data

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Abstract

Using 4-way Doppler tracking with relay satellite OKINA, KAGUYA obtained the first precise gravity field of the lunar farside. Multi-frequency differential VLBI observation of subsatellites OKINA and OUNA improved the accuracy of gravity. KAGUYA also has a laser altimeter (LALT) which obtained the first global topography of the moon including polar regions. Assuming uniform crustal density, we obtain crustal thickness distribution where crustal thickness is nearly zero beneath Mare Moscoviense. The interior structure of the South Pole-Aitken basin (SPA) is investigated using localized representation of gravity potential where Slepian functions were used to estimate the gravity field over certain areas of the Moon. The direction of an ellipse denoting the depression is similar to the previous result. The region with the thinnest crust is nearly circular and offset southward from the center of SPA. We analyzed interior structure of small basins in and around SPA.

1. Introduction

KAGUYA (SELENE) was launched on September 14th, 2007. From the end of October 2007, it started observation of the Moon form polar orbits and continued its operation by June 11th, 2009. KAGUYA had two subsatellites (OKINA and OUNA) for gravity measurements. Using 4-way Doppler tracking with relay satellite OKINA, KAGUYA obtained the first precise gravity field of the lunar farside [11]. Multi-frequency differential VLBI observation of OKINA and OUNA improved the accuracy of gravity. Using one-year tracking data, lunar gravity field model SGM100h was obtained [9] and the model was refined into SGM100i taking into account VLBI data [3]. KAGUYA has a laser altimeter (LALT) which measures the distance between the satellite and the lunar surface with accuracy of 1 m [1].

2. Gravity anomaly and crustal thickness

Bouguer gravity anomaly, Moho depth, and crustal thickness are obtained [7], using crustal density 2800 kg/m^3, mantle density 3360 kg/m^3, and mare basalt density 3200 kg/m^3. Here we assumed a uniform crust. The crustal thickness was constrained assuming that the minimum thickness is not negative. The crustal thickness is nearly zero beneath Mare Moscoviense [7], which would have been formed by twice excavations by impacts and resulting strong mantle uplift [8].

3. The South Pole Aitken basin

The South Pole-Aitken basin (hereafter SPA) is the largest (2500km in diameter), deepest and presumably oldest impact basin in the solar system. It has a degraded morphology and abundant superimposed craters. On the basis of topography, Fe and Th abundance data, Garrick-Bethell and Zuber (2009) (GZ09) [2] showed that the SPA is characterized by an ellipse with axes 2400 by 2050 km with the center at 53S - 191E. More precise topography and interior information from gravity are necessary to decipher the structure of large basin like SPA.

We use localized representation of gravity potential according to the Han (2008) [5] where Slepian functions were used to estimate the gravity field over certain areas of the Moon. Using localized functions, we express the gravitational potential with localized spherical harmonics functions. We include data in a spherical cap area with a radius of 40 degree from the SPA center. This area is fully covered by 4-way Doppler tracking of KAGUYA. We obtained gravity adjustment about -70 to 50mGal in preliminary analysis [4]. The improved gravity field would supply better data of crustal thickness with slightly higher resolutions.

From the topography and the crustal thickness by KAGUYA, the direction of an ellipse denoting the depression is similar to that of GZ09. The region with the thinnest crust is offset southward from the center of SPA. In Fig.1, Moho depth at the central region of SPA is around 30km (25km in crustal thickness) and shallower to the southward. This may be explained by the oblique impact hypothesis advocated by GZ09.

Our crustal thickness is affected by the assumed anorthosite crustal density 2800 kg/m^3. KAGUYA MI showed evidence of anorthosite in SPA [12]. But spectral data of central peaks of craters inside SPA show ultramafic assemblage dominated by Magnesium rich orthopyroxene, suggesting the presence impact melt sheet [10]. This is compatible with previous remote-sensing data [6, 13]. Then, higher crustal density would result in larger crustal thickness. The presence of lower crust in SPA was also discussed by previous gravity analysis [14].

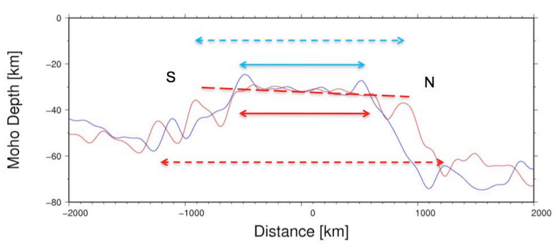

Fig. 1. Cross section of Moho depth of SPA.. Red curve and lines correspond to the long axis of ellipse by GZ09. Blue curve and lines correspond to the short axis by GZ09.

4. Small basins

Since Bouguer anomaly is relatively flat in SPA as well as in the farside highland, surface morphologies could be supported by elastically in SPA. However, there are overprinted small impact basins with gravity anomaly. We analyzed interior structure of small basins in and around SPA using newly estimated localized gravity model [4]. We interpret that a positive gravity anomaly at the basin corresponds to a Moho uplift.

There is a distinct gravity anomaly beneath Apollo. This corresponds to thin crust with a large mantle plug. Just around the rim of SPA, obscure circular structure Amundsen-Ganswindt has a distinct Moho uplift, suggesting a buried impact structure. A distinct Moho uplift beneath Schrödinger corresponds to the presence of olivine at the central peak rings there [15]. In comparison between adjacent Poincaré and Planck, older, less distinct Poincaré shows stronger gravity anomaly/Moho uplift. The observed anomaly corresponds to Type 2 like anomaly [11], where a significant uplift at the center is probably due to overcompensation just after the impact. On the other hand, basin structures in the central SPA show little gravity anomaly. Although it might be due to lower spatial resolution, there are several possibilities such as less density difference between crust and mantle and rapid relaxation of the uplift.

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