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Reconstruction of the selenoid 4 billion years ago using altimetry data in lunar maria

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Observations by the Japanese first lunar explorer ”SELENE (Kaguya)” made a great progress in lunar geodesy e.g. gravity and topography (Namiki et al., 2009; Araki et al., 2009). An unsolved problem on the lunar shape is the odd degree-2 shape of the Moon. If the Earth-Moon system has maintained synchronous rotation throughout its history, the ratio of the centrifugal potential due to the lunar spin to the tidal potential by the earth is 1:3. As for the degree-2 spherical harmonic coefficients, the ratio between C_{20} (=-J_2) and C_{22} should become 10:3. However, the J_2/ C_{22} observed by Kaguya is 9.09 (Namiki et al. 2009), i.e. J_2 is too large relative to C_{22}. Garrick-Bethell et al. (2006) tried to explain this odd ratio by postulating that the Moon used to be in a 3:2 resonance just like Mercury. However, their hypothesis would break down if the present lunar degree-2 gravity coefficient were only 20 percent different. Therefore, their conclusion is far from being robust.

Degree-2 gravity coefficients are often discussed in relationship to ”fossil bulge”. In our study, we evaluate how much of the current lunar degree-2 coefficients are random components irrelevant to the lunar spin or the terrestrial tide. We take two approaches; (1) extrapolating the Kaula’s law fit for degrees $>$ 3 to the degree 2, and (2) calculation of the influence of the formation of major impact basins. Both approaches showed that the random components account for 20-30% of the degree-2 gravity coefficients, i.e. the hypothesis of Garrick-Bethell et al. (2006) lost its ground.

Next we tried to reconstruct the past selenoid (lunar geoid) to discuss the evolution of the Earth-Moon system. The laser altimeter (LALT) and the terrain camera (TC) on board Kaguya greatly improved the lunar global and regional topographic map. First we examine the topography of the mare basalts filling the mascon basins, and estimate tilt angles of their surfaces using the LALT grid data (Araki, et al., 2009). The low viscosity of the basaltic lava might retain information on the past selenoid when they solidified. In our study, we used the least squares method to fit altitude profiles of the surfaces of four mascon basins, Mare Imbrium, Serenitatis, Humorum and Nectaris (they satisfied the requirements that lava covers the whole maria with small undulations), and estimated the combination of C_{20} and C_{22} which best explains the observed tilts. In comparison with the present degree-2 coefficients of the gravity and topography, the inferred combination showed the ratio J_2/ C_{22}, much closer to the theoretical value of 10/3. In the future, we would compare the TC topographic data and flow directions of sinuous rilles, to further discuss differences between the present and the past selenoid.

References

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