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Flexure and isostasy of lunar mascons

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A mascon is a region of a planet's or moon's crust that contains an excess positive gravity anomaly, indicating the presence of additional mass in this area. Mascons on the Moon coincide with the locations of circular basins and hence a related origin for both is likely. The formation of a circular basin includes the excavation of the upper parts of the crust and subsequent upwelling of the lower parts as a result of isostatic compensation [1]. Afterwards, filling of the basins by mare basalts leads to concentrations of dense rocks and is hence suggested as the origin of the mascon. The present day presence of mascons indicates that there was no subsequent isostasy leading to downward migration of the moho and that they are hence supported by an elastic layer on the surface of the Moon. The interaction between mascons and this elastic shell is the main topic of our modeling. Since they were discovered by Muller and Sjogren (1968), the origin of mascons and their interaction with the crust became clearer. As we point out below, several questions have however remained unsolved. Our contribution includes the usage of recent gravity and topography models that have not been applied in mascon studies yet. Mascons act like a dense load on the lunar lithosphere and hence flexure it. Flexure profiles of circular basins have been made by previous authors [2], however, only a single-layered crust was considered until now. Our modeling includes the two-layered crustal model preferred by Wieczorek and Phillips (1997) which explains the gravity to topography ratios of the lunar highlands. On the hand of previously existing data it has been suggested that rings of negative gravity anomalies surround the mascons [3]. Whereas this observation was first questionable, prereleases of the high-resolution KAGUYA gravity measurements recently clearly confirmed the presence of these features. Part of our modeling focuses on the location and extent of the negative anomalies in respect to the flexural depression. Furthermore we model the locations of failure that result from flexural stresses and compare these with the observed faults on the lunar surface, using high-resolution AMIE-images from ESA's SMART-1 mission. We produced flexure profiles for circular basins Humorum, Imbrium, Serenitates and Orientale, that all coincide with mascon locations. We use a modified version of COBRA[4] for PC. The program input and output is managed by macros included in a Microsoft Excel file. Because the mascons have rather an axially symmetric than elongated shape, we calculate the flexure to point loads. The gravity and topography data that we use is provided on the web by Wieczorek (2006) (http://www.ipgp.jussieu.fr/∼wieczor). By combining the most recent topography model [GLTM2C by Smith et al. (1997)], with the most recent gravity model [LP150Q by Konopliv et al. (2001)], he calculated crustal thicknesses for three model types. The first model examines the crust as a single layer in which gravity is assumed to result from Moho relief and Mare basalt fill. The second model has the only difference that Bouguer correction was set to zero before inverting for the relief along the crust-mantle interface. The third model examines a dual-layered crust. Since crustal thickness equals Moho depth on the Moon, we can use these different models as input for our software. We define the characteristics of the initial situation, i.e. height, depth and density contrast of the load before flexure. We vary elastic parameters like elastic thickness and yield strength, and use a Poisson's ration of 0.25 and an average Young's Modulus of 1.1x1011 N/m2. Shearforce and bending moment are assumed to be zero. The coming together of negative gravity anomalies related to distinct mascons (e.g. Mare Imbrium and Mare Serenitatis) suggests interaction of flexure. We aim to use 3D finite element models to visualize this interaction. Furthermore we aim to include the effects of viscous deformation of the lunar interior as a result of mascon loading in our models.

References: [1] Neumann et al., (1996), JGR, 101, 16841-16864 [2] Arkani-Hamed, (1998), 103, 3709–3739 [3] Sjogren et al., (1972), Science, 175, 165-168 [5] program originally based on Bodine (1982), modifications by Zoetemeijer (2001)