EVOLUTION OF IMPACT BASIN GRAVITY SIGNATURES ON THE LUNAR FARSIDE: LONG-TERM ALTERATION PROCESSES. T. Lompa[1,2], N. Holzrichter[3], K. Wünnemann[1,2], J. Ebbing[3], [1]Museum für Naturkunde Berlin - Dynamics of Nature - Solar System, Impacts and Meteorites, Invalidenstr. 43, 10115 Berlin (tomke.lompa@mfn.berlin), [2]Freie Universität Berlin - Institute of Geological Sciences, Malteserstr. 74-100, 12249 Berlin, [3]Christian-Albrechts-Universität zu Kiel - Institute of Geosciences, Otto-Hahn-Platz 1, 24118 Kiel (nils.holzrichter@ifg.uni-kiel.de).

Introduction: The morphology of impact basins formed during the first 700 Ma after the Moon-forming event (e.g., [1-2]) is a function of the impactor's size and velocity, but is also affected by the thermal state of the crust and upper mantle, which is related to the cooling history of the Moon (e.g., [3-5]). Due to alteration and erosion of structural surface features by subsequent impact flux, the size of given basins cannot be determined unequivocally. High resolution Bouguer gravity data from the Gravity Recovery and Interior Laboratory (GRAIL) mission [6-7] show a strong positive anomaly in the center, surrounded by a gravity low for impact basins located at the lunar farside. The relationship between the size of these gravity patterns and basin diameter may allow for estimating the impactor's size and thermal state of the Moon at the time of impact (e.g., [3, 5, 8]). Previous studies (e.g., [7, 9]) showed that basin formation processes are followed by isostatic adjustment and cooling processes. For the latter we account for by assuming that crustal and mantle rocks regain their initial density after cooling from impact-induced heating and melting. In addition, basin structures undergo isostatic relaxation processes, coupled with modifications in gravity signature. Therefore, the direct comparison of GRAIL data with gravity data from numerical models of basin formation may be questionable.

In our previous work [5] we used observed gravity signatures as constraints for numerical basin formation models, which allow for estimating the thermal conditions and the size of the impactor at the time of impact for observable basin structures on the lunar farside. Based on this work we now aim at considering isostatic compensation processes to improve our results. Here, we show preliminary results on how to investigate the problem and first adjustments we applied to our basin formation models.

Methods: In our recent publication [5], we accounted for different impactor sizes, crustal thicknesses, and thermal states of the Moon. Different depth-temperature profiles represent the lunar thermal evolution at 4.5 Ga ("warm"), 4.1 Ga ("intermediate") and 3.8 Ga ("cold"), which correspond to approximate basin ages. We correlated modeled Bouguer gravity from our models of basin formation with observed gravity signatures of 16 lunar farside basins.

To evaluate the state of isostatic equilibrium in our best-fit models, we use as a first attempt the Airy concept. This corresponds to the assumption that different topographic heights are accommodated by changes in crustal thickness. With this approach, we can estimate the location of the crust-mantle boundary for our best-fit models to evaluate the state of isostatic compensation.

Results: Our study [5] revealed that the transient crater (D_t), the basin size (*DLCT*), and the diameter of the Bouguer anomaly from basin formation models (D'_{BA}) increase with increasing impactor size (L_{imp}) (Fig. 1a, b, c, f, g, h). Apparently, all variables depend on the thermal state, especially for impactors larger than 50 km in diameter (highlighted in Fig. 1d, i). Our data suggest a linear relationship (e.g., $DLCT=0.88D'_{BA}$) between the Bouguer anomaly diameter and the basin size (Fig. 1e, j).

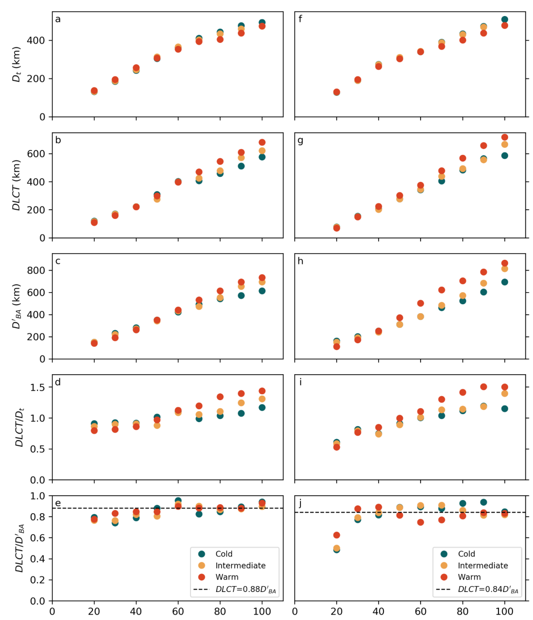

Fig. 1: Results from the basin formation models for two crustal thicknesses (a-e: 40 km, f-j: 60 km) and three thermal states represented by the colors of the points [5].

To demonstrate how we account for isostatic compensation, we present here the best-fit models for Korolev crater (Fig. 3) and Orientale basin (Fig. 2): In

Figure 2, the best-fit model for the Orientale basin suggests that the structure was formed by an impactor of 80 km in a cold lunar environment (3.8 Ga). Figure 3 shows the model for the Korolev crater, assuming an impactor size of 50 km and a temperature profile at ca. 4.1 Ga.

The models are fitted to the observed gravity signal (Fig. 2a1, 3a1, dashed line). The green line (Fig. 2a1, 3a1) corresponds to the gravity anomaly derived from the basin formation model assuming constant densities in crust (ρ_c) and mantle (ρ_m) (Fig. 2b1, 3b1). The latter distinctly deviates from the inhomogeneous density distribution in our basin formation models (Fig. 2b2, 3b2); however, we consider the use of constant densities as a simple estimate of how Bouguer anomalies of our models may look after cooling. The gravity signal (Fig. 2a2, 3a2; black line) based on the inhomogeneous density distribution due to the thermal expansion right after impact shows a much lower amplitude and a "plateau" in the basin center. A closer look to the temperature field (Fig. 2d, 3d) reveals that the "plateau" is directly related to the hot area of the temperature field.

In order to assess the isostatic equilibrium of the basin formation models with the constant density distribution (Fig. 2b1, 3b1), we determine the position of the crust-mantle-boundary according to the Airy concept and modify the basin formation models regarding this new crust-mantle boundary (Fig. 2c, 3c). Our preliminary results show for both models an uplift in the basin center. We also see modifications in the areas next to the basin center: Orientale's crust experiences an overall uplift of ca. 10 km, whereas Korolev' crust subsides into the mantle.

Conclusion: By assuming constant densities in the target, we are able to fit the observed and modeled gravity signatures. But this method of gravity fitting is questionable because the observed gravity data are based on the current subsurface density field, whereas the basin formation models show the density field directly after impact. We expect that cooling of impact structures between the last 4.4 Ga and 3.8 Ga directly affects the density distribution concomitant with isostatic compensation changing the position of the crust-mantle-boundary. Thus, we expect that the gravity signature will also change.

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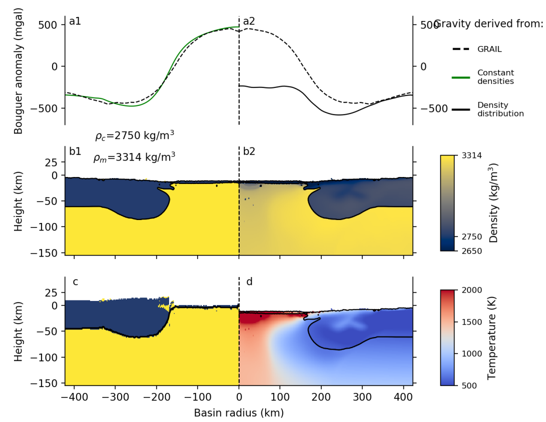

Fig. 2: Best-fit basin formation model for the Orientale basin. a1, a2: Bouguer gravity anomalies derived from the GRAIL mission (black dashed line) shown with the anomalies derived from the models assuming constant (green line) or inhomogeneous (black line) density distributions. b1, b2: Subsurface structures with its density fields for constant (b1) and inhomogeneous density fields (b2). c: Subsurface structure in an isostatic equilibrium after Airy. d: Temperature field for the basin formation model as shown in Figure 1b2.

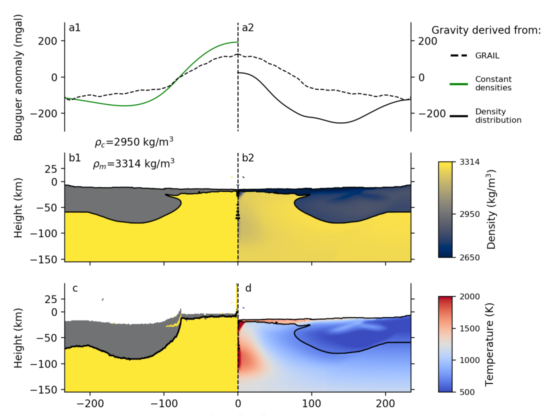

Fig. 3: Best-fit basin formation model for the Korolev crater.