BASIN EVOLUTION AND CRUSTAL STRUCTURE ON MERCURY FROM GRAVITY AND TOPOGRAPHY DATA.

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Introduction: Impact basins are predominant surface features on Mercury, yet our understanding of their formation and evolution is limited [1], owing to lack of data on subsurface structures and processes. Gravity data, recently obtained by MESSENGER, supports the identification of basins not clearly visible on the topographic maps or images and enables insights into subsurface structures [2].

This study focuses on the combined analysis of the topography and gravity data to identify and characterize impact basins. In contrast to previous studies, which focused on image data, topography, or gravity alone, we use the complementary data sets to obtain a more comprehensive picture of basins and possibly their related subsurface structures.

Methods: In this study we use image, gravity and topography data obtained by the MESSENGER spacecraft, which was equipped with the Mercury Dual Imaging System (MDIS), the Mercury Laser Altimeter (MLA) as well as a radio science experiment for gravity field modeling. Digital Terrain Models from stereo images (150m/px) [3] were used in combination with mosaiced image data (166m/px) [4] to support identification of the basins.

Using the most recent gravity model of degree and order 160 [2], combined with a topography model of degree and order 150 [5], we calculated Bouguer anomalies using the Python module SHTOOLS [6]. Also, we determined crustal thickness [7], following the technique of Wieczorek et al. [8]. The mapping was carried out in ESRI ArcGIS, where all mentioned data sets were imported.

Basin Inventory and Classification: We identified, mapped and classified 319 basins larger than 150 km. 302 are classified as *certain*, clearly visible as circular signals in more than one data set. 17 basins are classified as *tentative*, mostly these are buried basins, which only show a circular gravity signature.

A classification scheme was chosen according to rim preservation state, appearance of terraces, filling of the basin floor, depth and diameter. Basins were classified in the following classes: *complex*, *central peak*, *peak ring*, *multi ring* and *modified* basin. According to impact basin formation and physical laws for shock wave propagation, basins are supposed to form ring structures at certain diameter ranges. The great majority of impact basins does show central peaks or peak rings but we could not identify a significant amount ring basin. Instead, a lot of large basins are altered on their basin floor and mostly filled with secondary material and obscured by younger impacts. These basins are classified as *modified* basins. In this class we included also basins that are partially or completely buried.

Depth-to-Diameter: Depth-to-diameter ratios, are a commonly used parameter to quantify basin morphology with increasing diameter ranges (Fig. 1). The decreasing ratio with progressing complexity of morphology in basins on Mercury proves that the modification process is enhanced in larger basins. These modification processes can either be driven by post impact infill of the basins and/or erosion processes of the rim. Also, basins tend to undergo relaxation processes over time. The relaxation of basin floors provides important information on the rheologic state of the impact site over time. Higher temperatures lead to reduced viscosity and rapid relaxation of the crust, hat have direct influence on the basins structure.

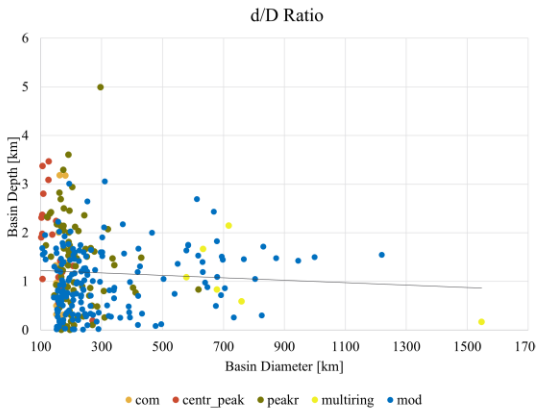

Fig 1: Depth-to-diameter ratio of mapped impact structures on Mercury showing a decrease.

Gravity anomalies: With increasing diameter, basins were found to show more complex gravity signatures. Gravity disturbance are mostly negative for small basins, but become positive for larger basins. Some larger basins show strong positive Bouguer anomalies in their center and negative anomalies in the rim area ("bullseye pattern") (Fig 2). Such structures are also found on the Moon, known as "mascons" [8].

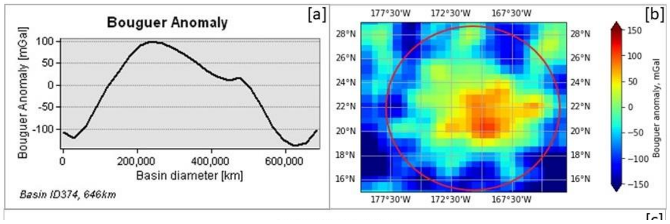

Fig. 2: Bouguer anomaly showing positive center and negative rim area (bullseye pattern).

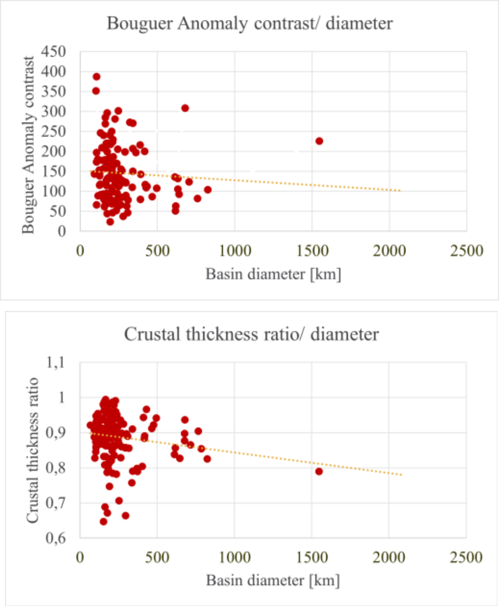

Fig. 3: Bouguer anomaly contrast and crustal thickness ratio from center and rim area. Crustal thinning correlating with maxima of Bouguer anomaly profiles.

A low contrast between the minima and the maxima of the Bouguer anomaly magnitude would represent already relaxed basins, in comparison to a relatively higher contrast. Subsequently, basins with a high relaxation state formed in earlier history of the planet are likely to be older compared to basins that display low relaxation states and therefore low contrast values. According to this, the relaxation state, and therefore the Bouguer anomaly contrast could be a measure for the relative age of basins for unmodified basins.

Crustal structure: To support the understanding of Bouguer anomaly trends, we analyzed recent crustal thickness model [8]. Similar to the gravity anomalies we determined the magnitudes of crustal thickness at the basin’s center and at its rim area. In both gravity anomalies, gravity disturbance as well as Bouguer anomaly, strong centered anomalies reflect high mass and/or density concentrations inside the impact basins, that were caused by an uplift of mantle material after the crater excavation phase. The excavation was followed by an isostatic adjustment caused by cooling and contraction of the melt pool [9]. The negative collar of the Bouguer anomaly profile suspected to be a consequence of depression of crust-mantle boundary, i.e. thickening of the crust. Consequently, profiles of Bouguer anomaly reflect profiles of the crust-mantle boundary. The crust is expected to be thinner in these regions. The contrast of Bouguer anomaly is therefore strongly correlating with crustal thinning.

As the Bouguer anomaly contrast is decreasing with diameter the crustal thickness ratio is decreasing as well. The thinning of the crust is depending on crust-mantle relief and induced by the formation of impact basins, since these structures correlate with morphological properties of the impact basins.

With increasing diameter, the crustal thickness is showing a decrease in rim and center proving a link between crustal thinning and impact basin formation.

This work represents an updated and extended catalogue of impact structures of previous work done on Mercury, including buried basins. It represents new areas of interest and potential target sites for the upcoming arrival of BepiColombo mission.

References:

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