MEGA LAVA DOMING AND COLLAPSE UPON INHERITED TECTONIC STRUCTURES IN CALORIS PLANITIA, MERCURY.

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Introduction: A large 1500 km diameter circular basin called Caloris Planitia has a complex geological history thought to have begun with a large impact event and subsequent infilling [1]. The basin is characterized by a sharp, asymmetrical, rim which has been retained in many places. The infill covers the entire basin and has a highly irregular topography. It is considered to be at least 3.5 km thick [2] and in places exceeds the height of the basin rim (Fig. 1A). In general, the infill exhibits a donut-like form, with a circular bulge and central depression. On the infill's surface, several sets of faulting have been previously observed, including radial graben emanating from the center [3]. Perviously, long-wave folding formed from global contraction has been interpreted from regional scale undulations in the topography, which appear to have influenced the infill topography as well [4] (Fig. 1B).

Although the literature has established a strong overview of the morphological aspects of Caloris, there has yet to be an extensive analysis of the topography and how the actual geometric relationships of the basin fit within the proposed narratives of its geological history. Here we present a new analysis which helps constrain many of these relationships.

We demonstrate that the infill can be described as the vestige of a collapsed lava dome, either from deflation, subsidence, or a combination of the two. Furthermore, we identify new faults that pass through both the infill material and the outer plateau. Thus, the infill topography is also controlled by the underlying tectonic texture. Determining the relationship between these faults and underlying long-wave folds is an important step in understanding the formation of Caloris Basin, and more broadly the tectonic regime of Mercury's past.

Methods: A Messenger Digital Elevation Model (DEM, Fig. 1A) with a resolution of 665 m/px was used as the basis for our analysis. We highlighted topographic trends observed in the DEM by implementing the "Least Squares Regression->Nearest Neighbor Differences->Convolution Filtering" method [5]. Pixels are then given a color based on dip direction (Fig. 1C). The result of this process highlights the slope of all surface features so that the dip direction of linear features in the topography can be easily visualized. This aids the identification of fault scarps.

Infill bulge topography (i.e. donut-shape) was then analyzed with a Monte Carlo statistical approach. By adopting equations for linear and central load flexure within the conditions of several parameters (i.e. Young's Elastic Modulus and Poisson ratio), we can estimate the induced load required to deform a hypothetical lava dome into the present topography.

Results and Discussion: We indentify a plethora of radial structures, and general radial texture, emanating from the center of Caloris that are present in both the infill and outside the basin (Fig. 1D). These are separate structures from the radial graben mapped previously [3]. They were likely produced by the impact event, since radial faulting is a well documented consequence of impacts. Their presence in the infill material implies fault reactivation post infill and collapse.

A circular structure is identified off-center from the basin, to the southeast (Figs. 1C & 1D). This could be a concentric peak ring that complex craters often form, and which the infill has conformed to. Alternatively, it could be a structure formed during the deflation/subsidence period, in which case might also indicate the epicenter of lava expulsion during doming. However, the deepest area of Caloris is actually outside of this circular structure (Fig. 1A), implying it is separate from the infill and collapse events.

Intuitively, as a basin fills, it should fill uniformly. However, the interior of Caloris has a unique, irregular topography. By invoking a collapsed lava dome, the bulge topography, the radial graben, and the central depression can be explained satisfactorily. A force between 3.5E+17 N and 6.7E+17N is required to create the central depression. The infill along Profile 2, which runs parallel to an axial trace of a putative syncline (Fig. 1B), has a lower overall elevation (Fig. 1E). However, a central depression is still observed, implying a central downward force. The infill likely conformed to the underlying topography during deflation/subsidence and thus, many structures (e.g. long wave folds and putative concentric crater rings) are vaguely retained in it.

The basin rim topography is not influenced by the location of any long-wave folds, and in general the rim elevation remains constant where they encounter each other. Thus, if the folds exist, deformation of the basin rim is mostly independent from the folds and implies that the folding ceased by the time the basin rim formed. This fits well with our model in which the infill drapes over the basement topography overtime due to deflation or subsidence, which allows the vague form of a syncline to be seen.

Sequences of Events: 1. Most global contraction activity ceases and the long-wave folds are formed (3.9 Ga). 2. The impact event creates Caloris and becomes partially filled by impact melt to approximately -3000 m (3.7 Ga). 3. Infilling begins and eventually forms a lava dome that reaches a height of approximately 1800 m. Radial graben form on the surface at the center of the dome. During the infill process, an older fault is reactived which lowers the northern basin wall (3.7-3.6 Ga). 4. Over time, weight load induces subsidence and/or void space below Caloris provides volume for the dome to deflate and collapse. As collapse continues over time, the relic topography of the underlying folded lithosphere is followed, creating the appearance of the synclinal structure in the interior of Caloris (3.6-3.4 Ga).

References: [1] Solomon S. C. et al. (2018) *Cambridge Uni. Press*. [2] Potters and Head E. (2017) *Earth & Planet. Sci. Lett.* [3] Cunge A. B. and Ghent R. R. (2016) *Icarus, 268,* 131-144. [4] Byrne P. K. et al., (2014) *Nat. Geosci., 7*. [5] Minin M. (2016) *Brock University M.Sc., Earth Sciences Collections*.

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Figure 1: Topographical analysis of Caloris Basin. Stereographic projection. A) Messenger DEM. B) Location of long-wave folds, northern fault, and Profiles 1 and 2. C) Processed DEM showing pixel dip. Red dips northward, yellow dips westward, green dips southward, and blue dips eastward. D) Mapping of the fault scarps observed in Fig. 1C. E) Best-fit flexure of the infill along profiles P1 and P2 utilizing a Monte Carlo statistical approach.