**LUNAR AND MERCURIAN IMPACT BASIN FORMATION: SIMILAR OR DISSIMILAR? INSIGHTS FROM NUMERICAL MODELING** Ross W. K. Potter[1,2] and James W. Head[1,2], [1]Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI, 02912, USA, [2]NASA Solar System Exploration Research Virtual Institute, ross_potter@brown.edu.

**Introduction:** As with the Moon, a number of impact basins have been recognized on the planet Mercury [1]. These mercurian observations, however, illustrate a paucity of large basins (>500 km in diameter) when compared to the Moon. Mercurian basins appear more degraded than their lunar counterparts, implying greater modification, relaxation, and/or erosion. [1] suggested this may be due to differences in the basin-forming process between Mercury and the Moon.

In this work, therefore, numerical modeling of mercurian basin-forming impacts was undertaken with results compared to previous modeling of lunar basin formation [2]. Mercurian basins over a range of sizes were modeled, with a particular emphasis on Caloris-sized impacts. Caloris is the largest mercurian basin (~1500 km diameter [3,4]) and has undergone significant modification by volcanic and tectonic processes since its formation ~3.9 Ga. One geological unit within Caloris, exposed in crater walls and ejecta – Low-Reflectance Material (LRM) – is of specific interest. LRM may represent the original basin floor material [5] and may have a lower crustal and/or upper mantle composition [5]. The numerical models will be able to predict the composition of Caloris' basin floor material.

**Methods:** The iSALE shock physics code [6-8] was used to model mercurian basin-forming impacts. iSALE has previously been used to study other large-scale impacts within the Solar System including Chicxulub, Earth [9] and South Pole-Aitken, the Moon [10]. Simulations used both a halfspace and fully spherical target (2440 km radius) divided into a 50 km thick crust [5,11], on top of a mantle 350 km thick, with an iron core beneath. Semi-analytical equations of state (ANEOS) for basalt [12], dunite [13] and iron [14] were used to represent the mercurian crust, mantle and core, respectively. Dunite was additionally used to represent the impactor, which varied in size and velocity from 50-250 km and 15-50 km/s, respectively. Grid cell size was 5 km, comparable to other large-scale basin modeling (e.g., [10]). Two target thermal profiles, suitable for the time of mercurian basin-forming impacts [15-17], were investigated. The profiles had gradients of 8 K/km and 15 K/km.

**Results:** Figure 1 illustrates (a) the transient crater and (b) the final basin structure for a Caloris-sized impact (impactor diameter 100 km, impact velocity 42 km/s, 8 K/km thermal gradient). The impact excavates crustal material from the basin center creating a large central zone of (partially and completely) molten mantle material. Mantle material extends to a distance of ~800 km from the basin center. Figure 1a demonstrates that to produce a basin the size of Caloris, its transient crater will not penetrate into Mercury's sizable core; only impacts producing basins larger than Caloris involved core penetration. There is, however, no evidence of basins larger than Caloris on Mercury [1], suggesting that, despite its size, Mercury's core does not affect the basin-forming process. This is reflected in the numerical models, where basin formation follows that predicted by models of lunar basin formation (see discussion).

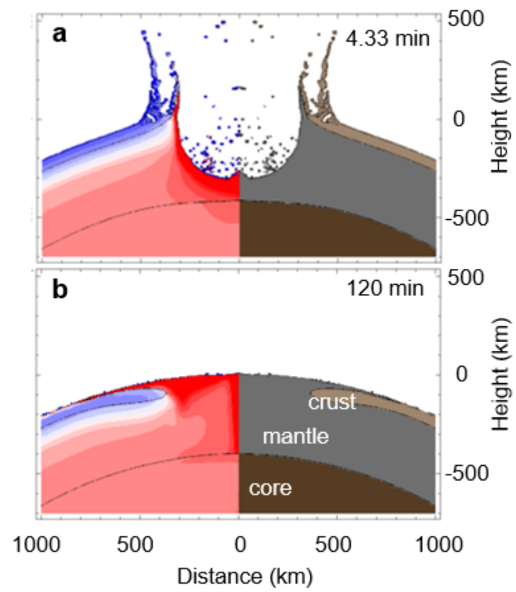


**Figure 1:** A Caloris-sized impact event illustrating (a) the transient crater and (b) the final basin structure. Left panels show temperature (blue is low, red is high); right panels show material (crust, beige; mantle, gray; core, brown). Impactor 100 km diameter, velocity 42 km/s, thermal gradient 8 K/km.

**Discussion:**

*Basin formation.* Pi-scaling relationships (e.g., [18,19]), which can be used to compare impacts of varying size, velocity, and target gravity, demonstrate that the mercurian impacts are comparable to lunar Orientale-sized impacts (Figure 2). Both follow the scaling law for impacts into non-porous rock [19], which is expected given their relatively cool thermal gradients compared to older impacts into warmer targets (e.g., South Pole-Aitken). Excavation depth-to-diameter ratios for the mercurian impacts did, however, show some deviation from lunar impacts (and geological, geophysical and analytical estimates; e.g., [20-22]) when velocities were >25 km/s (a ratio of 0.14 compared to 0.12 for velocities <25 km/s), suggesting a slight dependence on velocity.

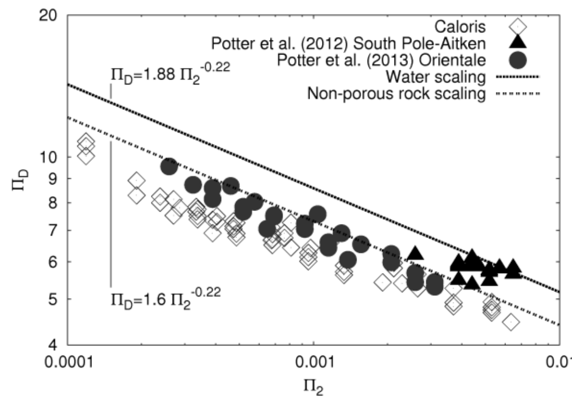


**Figure 2:** $\Pi_D$ as a function of $\Pi_2$. $\Pi_D$ is a crater size measure defined as $D_{tc}/(M_i\ /\rho_t)^{1/3}$. $\Pi_2$ is a gravity-scaled impact size defined as $3.22\ g\ r_i\ /u^2$. $D_{tc}$: transient crater diameter; $M_i$: impactor mass; $\rho_t$: target density; $g$: surface gravity; $r_i$: impactor radius; $u$: impact velocity. Scaling laws from [19].

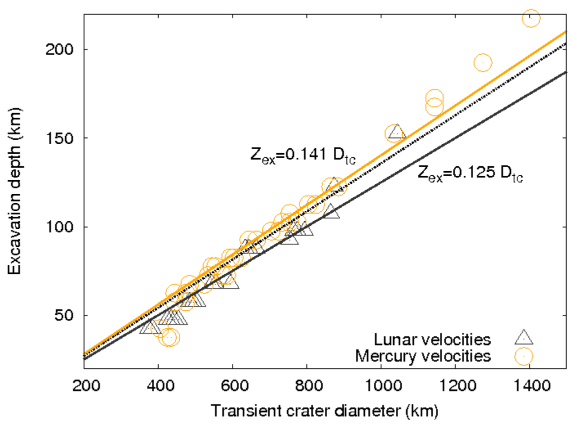


**Figure 3:** Excavation depth ($Z_{ex}$) as a function of transient crater diameter ($D_{tc}$) for mercurian basin-forming impacts. Triangles represent impacts at typical lunar velocities (<25 km/s); circles represent impacts at more typical mercurian velocities (>25 km/s). Best-fits are shown for each set, as well as the best fit for all models (dotted line).

*Caloris.* The numerical models suggest the floor of the Caloris basin will be primarily (partially or completely) molten mantle material. The LRM could, therefore, have originally had a mantle composition. The Caloris impacts produced melt volumes on the order of $10^7$ km$^3$, agreeing with scaling estimates (e.g., [23]). This volume of material is likely to undergo differentiation [24] to form a lower density, crustal-like layer towards the surface. This could explain the discrepancy between the numerical models, which predict no crust at the basin center, and the ~20 km thick crust inferred from gravity data beneath Caloris today [11]. Additionally, [5] estimated the Caloris impact melt layer to be 3-15 km thick, which could also account for the LRM thickness. LRM-like, low albedo deposits have been recognized around other large mercurian impact basins (e.g., Rembrandt) and interpreted as impact melt [25]. A deep origin for the LRM also agrees with the interpretation that its darkening agent is an intrinsic component of Mercury's crust and/or mantle [26]. A source depth of 30 km has been suggested [27], which further implies lower crust and, possibly, upper mantle.

**Conclusions:** This study suggests that the dynamic phase of basin formation on Mercury is comparable to that on the Moon. The higher average impact velocity on Mercury may, however, create greater excavation depth-to-diameter ratios, relative to the Moon. Differences in size and number of basins between Mercury and the Moon is, therefore, most likely due to longer term factors such as basin relaxation, and volcanic and tectonic modification, rather than inherent formation differences.

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