Effects of giant impacts on the mantles and cores of Mars and Mercury

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While impact cratering is a fundamental process that modifies planetary surfaces, sufficiently large impactors may also affect interiors. Here we examine two terrestrial planets whose mantles and cores may have been substantially affected by impacts: Mars and Mercury. Mars has no global dynamo-driven magnetic field today, but strong crustal fields [1] indicate that a global field existed in the past. Surface observations [2] indicate that a sequence of giant impacts occurred over a period of 100 Ma in the mid-Noachian. The youngest of these (e.g. Hellas and Argyre) are demagnetized [3], suggesting that an early dynamo stopped toward the end of the sequence. On Mercury, images reveal evidence for volcanism both within and surrounding the large Caloris basin [4]. Crater counts [5] indicate that the volcanic plains are younger than the basin, and thus cannot be impact melts.

We investigate possible connections between these impacts, core heat flow and dynamo activity, and mantle melting and volcanism on Mars and Mercury. Finite-element models of convection in a spherical shell [6,7] are used to explore the consequences of impacts on mantle dynamics. Impactor sizes are determined from the observed basin using standard methods of crater scaling [8,9]. Impact heating is introduced as an instantaneous temperature increase that decays away from the impact point [10]. Mantle melting is parameterized as a function of pressure, temperature, and composition. Melt residue and unmelted mantle are tracked using a particle tracer method [11].

Impact heating associated with the larger basins on Mars can cause the global heat flow at the CMB to drop by as much as several percent, sufficient to shut down a subcritical dynamo [12,13]. Other modeling results suggest that even without significant reduction in CMB heat flow, the core may become stratified, inhibiting dynamo activity [14]. Conversely, the Caloris impactor is unlikely to have affected the dynamo of Mercury. However, impact heating from Caloris could have promoted melting in upwellings adjacent to the basin, resulting in later volcanism to form the exterior plains.

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