**Introduction:** The crust of Mercury is mostly the cumulative result of partial melting in the mantle associated with solid-state convection [e.g., 1]. The details of how the surface composition represents the result of dynamical processes in the interior are difficult to elucidate. Explanations for the observed geochemically varied surface include a heterogeneous mantle [2], the effects of ancient giant impacts [3], an evolving mantle composition [3, 4], or a combination of these processes. Here we explore the effects of large impacts on mantle dynamics and associated melt production and show that the properties of melt sheets within young large basins on Mercury depend on the mantle thermal state and composition.

**Mantle convection:** With the convection code GAIA [5], we compute thermal evolution histories of Mercury compatible with the expected amount of heat producing elements (HPEs) in the mantle [1, 6] and with the inferred thickness of the crust [6, 7]. We consider the effects of an insulating regolith layer, of different amounts of HPEs, and of variations in the reference viscosity. A large number of models produces a crust which is compatible with the inferred range (Figure 1). Independent of the choice of parameters, crustal production is very rapid in the early phases of evolution and is completed between about 0.5 and 2 Gy. It is important to note that as long as the mantle is producing melt, the depth of the source region is roughly constant during the evolution.

**Impacts:** We estimate the thermal anomalies in the mantle generated by large impacts using scaling laws [e.g., 8]. We simulate impactors with a velocity of 42 km/s and an impact angle of 45°, as appropriate for Mercury [9]. The diameter of the impactors is varied in order to produce basins with diameters in the range from 715 km (Rembrandt) to 1550 km (Caloris).

The thermal anomaly associated with a basin forming event is located in the upper mantle and generates convective currents and associated melting which post-date the impact event (Figure 2).

![Figure 1: Cumulative crustal thickness from convective melting as a function of time. Different curves refer to different combination of parameters, as indicated in the legend. Most models are compatible with the crustal thickness inferred from gravity and topography data (grey band and horizontal black line) [6,7]. Colors indicate the depth of the source region of the partial melts forming the crust. Values for the HPEs are found in [6].](image1.png)

![Figure 2: Temporal evolution of the temperature field (background) and of the magnitude of the velocity field (arrows) in the event of an impact forming a Caloris-sized basin. The thermal anomaly warps the isotherms and convective currents develop in the shallow mantle. The two snapshots are taken 3 (top) and 12 My (bottom) after the impact event.](image2.png)
**Post-impact volcanic eruptions:** A large impact facilitates the subsequent eruption of magma to the surface. Any pre-existing crust is removed, thereby eliminating a possible neutral buoyancy horizon created by a low density crust [10]. In addition, the fractured volume below the impact site [11] allows for an easier upward migration of the melt.

Depending on the timing of the impact, the melt erupting at the surface will be a combination of convective melt generated at depth (Figure 1) and shallow melt resulting from the impact-induced convective currents (Figure 2). The volcanic infillings following an impact happening early in the evolution of the planet, when convection is still vigorous, are dominated by convective melt. Later in the evolution, the erupted melt shows the signature of the impact-induced shallow melt (Figure 3).

![Figure 3: Melt production following an impact forming a Caloris-sized basin. Results for the impact occurring at 170, 500, 750, 1000, 1150 My. For each epoch the cases for the impact occurring over an upwelling and downwelling are plotted (the downwelling curve is plotted over the upwelling curve). Thickness values refer to melt produced below the final basin. Colors indicate the source depth of the melt. The grey background indicates qualitatively the mantle thermal state.](image)

**Young large basins on Mercury:** The youngest large basins on Mercury are Caloris (diameter \( d = 1550 \) km) and Rembrandt (\( d = 715 \) km). They both have volcanic infillings that postdate the basin itself by about 100 to 200 My [12, 13]. The thickness of the surficial volcanic layer is between 500 and 800 m for Caloris [14] and between 360 and 520 m for Rembrandt [13].

We can reproduce both the time delay between the impacts and the emplacement of the volcanic plains in the basins, and the thickness of the surficial volcanic layer (see inset a in Figure 3), if an effusion rate of about 30% is assumed and if the impacts that originated Caloris and Rembrandt happened when the melting associated with mantle convection was feeble (i.e., when most of the crust was already in place). This conclusion is corroborated by the dating of large volcanic units on the surface of Mercury [15].

**Conclusions and outlook:** In this study we show that the properties of the volcanic plains within the young large basins of Mercury (Caloris and Rembrandt) depend on the mantle thermal state and composition. We predict the source depth of the volcanic plains to be different from the source depth of older surface units, a result that can help explaining the singular composition of the volcanic plains inside Caloris [3, 16].

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