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The Thermal Evolution of Mercury and the Implications for Volcanism, Topography and Geoid

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Because of its close proximity to the Sun, the innermost planet of our solar system, Mercury, cannot be studied from the Earth against the dark sky. Among the terrestrial planets Mercury is not only the smallest, but also the densest (after correction for self–compression), has the oldest surface and is the least explored. Understanding this ’end member’ among the earth–like planets seems to be crucial to improve the understanding of the formation of the solar system and the history of the Earth.

For a long time only one spacecraft has visited Mercury up to now: MARINER 10. It imaged only about half of the planet’s surface, while any details of the other hemisphere of Mercury have never been seen so far. Lately MESSENGER was launched and had two flybys on Mercury already, revealing a greater portion of the hermean surface and collecting more data. The BEPICOLOMBO spacecraft will be launched in 2014, arriving in 2020. Although MESSENGER will enter its orbit in 2011 already, the data basis remains relatively poor until then. We can therefore prepare ourselves for the upcoming results and perform test that allow some anticipation of the measured data. Because no material is available, which could have been analysed in a laboratory, numerical models are the most promising tool at the moment.

The model shows the typical behaviour of a one–plate–planet, meaning the surface is not broken into several tectonic plates but the outside is a single rigid shell. The thermal evolution is generally charaterized by the growth of a massive lithosphere on top of the convecting mantle. The lower mantle and core cool comparatively little and stay at temperatures between 1900 K and 2000 K until about 2.0 Ga after the simulation was started. The stagnant lid comprises roughly half the mantle after only 0.5 Ga. Since the rigid lithosphere does not take part in the convection anymore, the heat coming from the interior (due to the cooling of the large core) can only be transported through the lithosphere by thermal conduction. This is a significantly less effective mechanism of heat transport than convenction and hence the lithosphere forms an insulating layer. As a result, the interior is kept relatively warm. Because the mantle is relatively shallow compared to the planet’s radius, and additionally the thick stagnant lid is formes relatively rapid, the convection is confined to a layer of only about 200 km to 300 km. Convection structures are therefore relatively small structured. The flow patterns in the early evolution show that mantle convection is characterized by a numerous upwelling plumes, which are fed by the heat flow from the cooling core. These upwellings are relatively stable regarding there spatial position. As the core cools down the temperature anomalies become colder but not less numerous.

The hot upwellings cause pressure released melting at least in the early stages of the evolution. Due to the more or less uniform distribution of plumes the regions of partial melt are also homogeneously distributed. This would be consistent with observations of evidences for volcanic material at the hermean surface by the MESSENGER spacecraft. The upwelling plumes also deform the surface and the resulting dynamic topography causes gravity anomalies. A global mapping of the entire planet including topography and geoid will therefore help drawing conclusions on the interior dynamics.