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The role of mantle layering and mineralogical-dependent thermal properties on the evolution of Mercury's interior

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Cooling and crystallization of Mercury's magma ocean likely formed a layered mantle composed of various proportions of minerals such as olivine, orthopyroxene, clinopyroxene, sulfides, and plagioclase, each with distinct thermal properties (e.g. thermal diffusivity, thermal conductivity, heat capacity, and melting temperature). Planetary thermal evolution models often consider an homogeneous mantle and treat these properties as constant or only varying with pressure and/or temperature. Their dependence on composition and modal proportions is usually neglected, but can have a large impact on the modeled evolution.

Recent experimental studies gave access to the thermal conductivity and diffusivity of olivine, orthopyroxene and clinopyroxene. We calculated the thermal conductivity and diffusivity profiles of Mercury’s mantle assuming it is made of the Mg-rich endmembers forsterite, enstatite or diopside (i.e. the most likely phases occurring in the reduced interior of Mercury). We used a 1D parameterized model to simulate the thermal evolution of the planet with conductivity values varying from 1 to 4 $Wm^{-1}K^{-1}$, covering the above range of different mineralogies. We investigated several scenarios with (1) homogeneous conductivity over the whole mantle; (2) two layers characterized by different conductivity values. We then analyzed the results in terms of crust production and duration of mantle melting.

At pressures and temperatures relevant for Mercury's mantle, enstatite and diopside have higher conductivities and diffusivities than forsterite. This has a direct impact on the thermal evolution of the planet and on the melting of a fertile layer. Indeed, the more conductive the mantle is, the shorter its melting duration. Therefore, a mantle characterized by the conductivity of enstatite or diopside would promote a shorter melting time than one with conductivity of forsterite. In a two-layer mantle, melting duration is lower when conductivity of the top layer is higher compared to the bottom layer. The melting duration would thus be shorter for a mantle with a refractory olivine-like mantle conductivity at the base and an enstatite- and diopside-bearing fertile mantle-like conductivity in the upper part of the stratigraphic column. Besides the thermal conductivity, other parameters such as solidus temperature and heat production rate will be taken into account to obtain a consistent picture of the influence of mineralogical-dependent parameters on Mercury's evolution.

Accounting for variations in thermal conductivity and diffusivity due to heterogeneity in the mantle is therefore crucial in modeling planetary interiors. These factors significantly affect key parameters like crust thickness and the duration of volcanism.