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Mercury's mantle as constrained by its crust

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Primitive melts provide information on the thermo-chemical state of the mantle of terrestrial planets. On Earth, several billion years of plate tectonics has cycled surface material into the deep mantle, erasing information on the earliest conditions and producing a new fabric of lithological and chemical heterogeneity. On stagnant-lid planets, where cycling of surface material into the mantle is less efficient, we may have a chance to see further back to their formation. In this case, mantle heterogeneity may originate from magma ocean fractional crystallization.

Mercury, as the smallest planet of the solar system, offers the chance to see such a primitive mantle structure. Mercury is characterized by a large core (70 vol.%), a thin (400 km) mantle, and a thick (20-70 km) volcanic crust. It is believed that the volcanic crust was dominantly produced from 4.2 to 3.5 Ga, with minor explosive magmatic activity that may have lasted until as recently as < 1 Ga. Mercury's surface composition was mapped by the MESSENGER spacecraft and reveals various geochemical provinces ranging in compositions from Mg-rich magmas to Al-enriched lavas. In this contribution, we provide constraints on the temperature conditions of mantle melting needed to produce Mercury's volcanic crust, based on low- to high-pressure, high-temperature, experiments. These novel experiments shed light on the likely mineralogy and composition of Mercury's mantle sources. Mercury's mantle is currently dominated by forsterite and enstatite and perhaps some large amounts of sulfide minerals. In contrast, during the main episode of crust formation, Mercury's mantle was likely enriched in olivine-, garnet-, clinopyroxene/orthopyroxene- and perhaps plagioclase-bearing lithologies. Based on partial melting experiments of such sources, we will describe the role of mantle lithology, degree of partial melting, volatiles and Mercury's reducing oxygen fugacity in controlling the major element composition of its erupted lavas as well as their concentrations of volatile (S, Cl, C) and heat-producing (U, Th, K) elements. In particular, we will show how high-degree melting of fertile sources results in highly-refractory mantle residues that cause large-scale magmatic activity to rapidly decline.