EPSC Abstracts
Vol. 17, EPSC2024-1011, 2024, updated on 25 Mar 2025
https://doi.org/10.5194/epsc2024-1011
Europlanet Science Congress 2024

Mineralogy of the mantles in sub- Earths and exo- Mercuries

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The mantle mineralogy of large exoplanets (e.g. super- Earths, planetary bodies having masses between 1-10 M_E) has been widely investigated (Duffy et al., 2015).

However, the minerals constituting the mantle of Mercury-sized objects (here referred to as exo-Mercuries) and sub-Earths (planetary bodies having masses ranging from 1 $M_M < 1M_E$, respectively 1 Mercury-mass and 1 Earth-mass), orbiting closer to their stars, are still underexplored. This modeling work has focused on describing stable mineral associations in those mantles equilibrated under low values of oxygen fugacity (fO_2). Such reducing conditions are not uncommon in stellar systems, as evidenced by various materials in the solar system, ranging from undifferentiated ones (carbonaceous chondrites belonging to the CH and CB groups) to enstatite chondrites, to already differentiated materials like aubrites, and even entire planets like Mercury.

Assuming Mercury as a proxy, we employed the open-source software Perple_X (Connolly, 1990) to characterize the mineral assemblages forming the mantle of these reduced planetary bodies.

The thermodynamic approach here adopted offers the advantage of allowing the investigation of those planetary interiors otherwise not explorable. Moreover, the employed thermodynamic inputs were extrapolated from known precursor materials, which share several properties with exoplanets under examination. This methodology has already been discussed in literature (Néri et al., 2020; Cioria and Mitri, 2022), ensuring the validity of this approach. Bulk silicate compositions of aubrite and CH, CB, EN chondrites, have been used as thermodynamic inputs in our simulations. Calculations were conducted within the pressure and temperature ranges suggested for the mantle of Mercury: 1200 K -1700 K and 3 GPa -5 GPa (Tosi et al., 2013).

We found that orthopyroxene, clinopyroxene, olivine, and accessory minerals constitute the mantles of Mercury and reduced exoplanets. These results indicate that the initial bulk compositions have a first-order constraint on the resulting mantle mineralogy; more specifically, the initial abundance of SiO_2 determines the chemical equilibrium shift between pyroxene and olivine, respectively constituting the dominant phases at high and low silica content. The predicted mantle mineralogy, dominated by pyroxenes, is consistent with that outlined by Putirka and Rarick, (2019) and Putirka and Xu, (2021).

The differences with Earth's mantle mineralogy are significant, necessitating a new and more appropriate classification of these rocks, as already suggested in Putirka and Rarick, (2019).

This outcome holds significant implications for the thermochemical evolution and geodynamics of reduced mantles, also exerting a substantial influence on the properties of the related crusts and cores.

Future investigations on Mercury, conducted by the ESA BepiColombo mission, could shed new light on the possible mineralogy of its mantle, helping to further detail the minerals stable in those exoplanets formed in similar geochemical contexts.

Acknowledgments

G.M. and C.C. acknowledge support from the Italian Space Agency (2017-40-H.1-2020).

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