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The retention of water in the mantle during magma ocean solidification and its impact on planetary habitability

YOSHINORI MIYAZAKI

California Institute of Technology

Presenting Author: ymiya@caltech.edu

Terrestrial planets have experienced multiple giant impacts during the final stage of their formation, and the partitioning of volatiles during the magma ocean stage would characterize the atmospheric mass and composition. Whereas the initial amount of degassed volatile can be estimated by the partitioning between the magma and the atmosphere, the degree of subsequent degassing depends on how efficiently the mushy solidifying layer expels volatiles trapped in their pore spaces (Hier-Majumder & Hischmann 2017). Here, I investigate the problem of magma ocean degassing using a 1-D thermal evolution model based on mixing length theory. When the mantle starts to behave rheologically as solid, heat transport is characterized by gravitational instability rather than convection (e.g., Abe 1997; Maurice et al. 2017), and the magma ocean would solidify mostly through adiabatic compression. Volatiles trapped in the pore space of a partially molten magma are transported downwards and sequestered into the deep solidified mantle, without degassing to the atmosphere. Model results suggest that the majority of water remains in the mantle, with an increasing degree of volatile sequestration for a steeper melting curve and for a lower permeability of the solid-melt mixture. The limited water degassing would also result in a weaker greenhouse effect of the atmosphere, keeping the surface temperature low and allowing for rapid solidification of magma oceans. On the other hand, CO2 is largely degassed to the atmosphere immediately after the giant impact. The amount of CO2 at the surface is expected to remain high throughout the magma ocean stage, so the initial atmosphere of terrestrial exoplanets could be enriched CO2-rich in many cases.