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Magma ocean lifetime and outgassing of the secondary atmosphere in a terrestrial planet.

Athanasia Nikolaou (1,2), Nisha Katyal (1,2), Nicola Tosi (1,2), Mareike Godolt (2), John Lee Grenfell (1,2) and Heike Rauer (1,2,3)
(1) Institute for Planetary Research, German Aerospace Centre DLR, Berlin, Germany, (2) Centre of Astronomy and Astrophysics, Berlin Institute of Technology, Germany, (3) Department of Planetary Sciences, Institute of Geosciences, Free University of Berlin (athanasia.nikolaou@dlr.de)

Abstract

We showcase an example of multidisciplinary work performed in order to study one of the early stages of terrestrial planet formation, the global magma ocean. The terrestrial planet starts without atmosphere and gradually outgasses the bulk of volatiles that envelops it, introducing thermal blanketing. The thermal evolution of the system, therefore, requires coupling between the molten interior and the atmosphere fluid domains, within which the heat propagation occurs via convection and radiation respectively. Moreover, the eventual solidification of the planetary mantle would require treatment of solid state rheology, which poses an additional viscoelastic behavior to be considered at long time scales. It is evident that the study of the magma ocean is a challenging field located at the cross section of multiple disciplines. Here we present a comprehensive study of the influences among the different magma ocean subsystems using a simplified one dimensional model.

1. Introduction

The formation of terrestrial planets has not been fully understood, and that is partially due to lack of long time series of geological record and the few examples of our solar system's rocky planets. Nevertheless, numerical models are used in order to simulate and gain insight on the early planetary evolution. In particular, the magma ocean phase is crucial because it sets the temperature conditions for the onset of solid state convection in the mantle and it is accompanied by the formation of the early atmosphere.

2. Methods

We employ a one-dimensional model for the interior, and a one-dimensional model for the atmosphere. Their thermal evolution is coupled through the surface temperature for which we resolve assuming balance of the heat flux through both layers. We employ experimental H_2O and CO_2 volatile solubility data in terrestrial melts and evaluate the saturation of each volatile at each time step of the evolution. The generated atmosphere thus consists a H_2O, CO_2 mixture. A parameterization of the dynamics helps calculate the efficiency of heat transport through the molten mantle layer to the surface, enabling the planet to cool.

3. Summary

We provide estimations for the solidification time of a global magma ocean on an Earth-sized planet and we find that it varies from thousands to millions of years, according to the processes assumed acting on the system [1]. A parametric study of the role of initial volatile abundance in the solidification time is included.

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References

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