Water Partitioning into the Interior of Mars during Accretion

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Hybrid-Type Proto-Atmosphere on a Growing Mars

According to the recent analyses of Martian meteorites, the early Martian mantle was possibly wet [1, 2, 3]. Because of the lack of plate tectonics on Mars, water is likely to be partitioned to the interior during accretion era. A planetary-scale magma ocean produced by the accretion energy and/or the blanket effect of the proto-atmosphere possibly absorbs a vast amount of water. However, it remains an open question how such a magma ocean could be formed on accreting Mars.

Recent Hf-W and Fe-Ni chronology suggests that the accretion of Mars had been almost completed within a few Myr after the formation of the CAI [4, 5]. During such a rapid accretion, a proto-Mars might gravitationally keep both the solar nebula component and the impact-induced degassed component as a proto-atmosphere. We call this atmosphere hybrid-type proto-atmosphere.

In this study, we analyze the thermal structure of hybrid-type proto-atmosphere by developing a 1D radiative-equilibrium model. For the building blocks of Mars, we employ the two component model [6], which contains 35% of volatile-rich, oxidized CI chondritic material and 65% of volatile-poor, reduced E chondritic material. Degassed volatile consists of H_2, H_2O, CO and CH_4 with mixing ratio determined by the chemical equilibrium with molten silicate and metal produced by impact shock heating. Then, we solve the evolution of hybrid-type atmosphere with the growth of a proto-Mars.

Role for the Wet Martian Mantle

Our numerical model predicts that under the feasible range for the accretion time and nebula dissipation time scale, the proto-atmosphere becomes so massive and hot enough to produce the magma ocean during the last half stage of accretion. The total amount of water partitioned into the magma is estimated to be ~9.6×10^{20} kg or more (~1900 ppm in average for the mantle). This may account for the wet Martian mantle suggested from the petrological evidence.

[1] McCubbin *et al.*, (2012) *Geology* **40**, 683-686. [2] Gross *et al.*, (2013) *EPSL* **369-370**, 120-128. [3] Balta *et al.*, (2013) *Geology* **41**, 1115-1118. [4] Dauphas & Pourmand (2011) *Nature* **473**, 489-492. [5] Tang & Dauphas (2014) *EPSL* **390**, 264-274. [6] Dreibus and Wanke (1987) *Icarus* **71**, 225-240