Stratified hybrid-type proto-atmosphere on accreting Mars

*Hiroaki Saito[1], Kiyoshi Kuramoto[1]

1. Department of Cosmosciences, Graduate School of Sciences, Hokkaido University

The precise Hf-W chronology suggests that Mars reached about half of its present mass within the 1.8 ± 1.0 Myr or less after the formation of CAI with core-mantle differentiation (Dauphas and Pourmand, 2011). Since this timescale is much shorter than the estimated lifetime of the solar nebula, the accretion of Mars mostly proceeded within the solar nebula. On the other hand, the energy released by planetesimals collisions becomes large enough to induce degassing of the volatile compounds such as H_2O when the proto-Mars gets bigger than the lunar size (0.1 M_M). Therefore, growing Mars may have a proto-atmosphere that consists of nebula gas and degassed gas.

We analyze the thermal structure of stratified hybrid-type proto-atmosphere where the solar nebula component dominates the upper layer, and the degassed component dominates the lower layer, by developing a 1D radiative-equilibrium model. Provided that the building blocks of Mars are described by the two-component model, which contains 4 wt% of volatiles, a hot proto-atmosphere is formed with the surface temperature exceeding the melting point of rocks (1500K) when accretion time is within 4 Myr. This suggests that the core-mantle differentiation efficiently proceeds due to the formation of a magma ocean produced by the atmospheric blanketing effect.

However, there is a possibility that the proto-atmosphere may be mixed due to convection or molecular diffusion. The mixing of the proto-atmosphere possibly changes the thermal structure of the proto-atmosphere. There is also uncertainty for the volatile concentration in the building blocks.

In this study, we investigate condition for keeping atmospheric stratification by comparing the level of the compositional boundary (CB) and the tropopause, and the accretion time and mass exchange time scale controlled by molecular diffusion. The accretion times is taken from 1 –6 Myr as the chronology suggests. In the case of the volatile concentration is 4 wt%, we found that the level of the CB is always above the tropopause for any accretion times and proto-Mars mass, which means convective mixing between the solar nebula layer and degassed component layer does not occur. Moreover, the mass exchange time scale is about 10^2 times longer than the accretion time. Thus the mixing by molecular diffusion is unlikely to occur. On the other hand, when the volatile concentration is less than 2 wt%, the level of the tropopause is located above the level of the CB, and therefore the convective mixing occurs across the solar nebula layer and the degassed component layer. The resultant changes in the thermal structure of the proto-atmosphere are now under study.

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