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Thermal evolution simulation of Vesta including convection and melt migration

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Vesta has been regarded as the parent body of the HED meteorites. From the observation of DAWN spacecraft, the uppermost layer of Vesta is composed of howardite and its thickness ranges from 50km to 80km (Jutzi et al. 2013). It is known that the ratio of the number of eucrites to diogenites is around two. Based on these facts, rapidly cooled magma layer on Vesta should be more than 10km in thickness.

In this work, I studied the evolution of internal thermal evolution of Vesta due to heating of decay of 26Al. I calculated the temperature distribution by solving numerically heat conduction equation. According to Formisano et al.(2013), if Vesta completed its formation within 1.4Ma from the injections of 26Al into the solar nebula, the degree of silicate melting inside Vesta exceeds 50 vol%. But in that work, convection and melt migration were not taken into account. These two mechanisms contribute to cool down Vesta. It is expected that the formation of Vesta should be completed earlier if these effects are taken into account. On the other hand, it is known that it takes about a few million years for Vesta-size planet to complete its formation according to the standard model of planetary formation.

As a convection model, I adopted the model of Kaula (1979). It was assumed that generated melt migrates to the surface instantaneously, and the migrating melt to the surface was accounted as the rapidly cooled magma. There are two parameters in this study, including a (the percentage of melt migration) and t0 (formation time of Vesta), and perform simulation taking into account the convection and melt migration.

As a result, convection and melt migration substantially change the evolution of internal thermal structure, and total volume of magma considerably depends on a and t0. The magma volume increases as a increases. On the other hand, the magma volume decreases as t0 increases.

When t0=0, corresponding to no decay of 26Al at the beginning, and if a>0.3, the erupting magma layer of 10km in thickness is formed. When a=1, corresponding to total melt migration, the magma layer of 10km is formed if t0<0.9Ma. According to these results, Vesta should be completed its formation within 0.9Ma after CAI formation, and more than 30% of generated melt should migrate the surface. But total generated melt migration is not reasonable . If a<1, Vesta has to be formed earlier than a=1.

Therefore, it is suggested that the formation time of Vesta should be earlier than the estimate by Formisano et al.(2013), and rapid formation mechanism of 100km sized objects is needed.