Fluid flow in hydrous asteroids induced by H_2 gas pressure

*Wataru Fujiya[1]

1.Ibaraki University, College of Science

Physicochemical models on thermal history associated with material evolution of hydrous asteroids have been explored by many authors (e.g., Grimm and McSween 1989; Cohen and Coker 2000). A few models included fluid flow in these bodies to reproduce the characteristic oxygen isotopic compositions of aqueously altered meteorites like CM and CI chondrites (e.g., Young 2001; Palguta et al. 2010). These fluid flow models predicted convective or exhalation flow induced by temperature gradient or vapor pressure. Although these models involved hydration reactions, gas phases such as H_2 produced by the reactions were not taken into account.
Here I present a model on fluid flow in hydrous asteroids considering H_2 gas generated by oxidation of metallic iron. Since H_2 gas pressure in hydrous asteroids is inferred to be hundreds of bars from the amount of metallic iron in primitive chondrites, steep pressure gradient occurs between the surface and interior of the asteroids. The model is 1D spherically symmetric and includes thermal conduction of heat generated by ^{26}Al decay, phase transition of water/ice, a simplified aqueous alteration reaction, and fluid flow. I assume that the asteroids accreted 2.7 Myr after CAI formation, resulting in the initial $^{26}Al/^{27}Al$ ratio of 3.7×10^{-6}. The velocity of fluid flow is derived from the Darcy’s low. The radii of the asteroids range from 30-100 km. The initial temperature is 173 K, and the surface temperature is fixed to this value. The asteroids initially consist of 70 vol% rock, 5 % water/ice, and 25 % void space. When liquid water is present, the rock reacts with water and 90 % of the consumed water is assumed to convert to H_2 gas until metallic iron is completely oxidized.
The results of the simulation suggest that fluid (H_2 gas and liquid water) flows outward soon after ice melts and water reacts with rock. However, water stops flowing ~8 km below the surface because temperatures there are lower than the freezing point of water. Then an icy shell forms near the surface, and liquid water accumulates just below the icy shell. As a result, water heterogeneously distributes throughout the asteroids in spite of its initially homogeneous distribution. Water consumed by the alteration reaction amounts to ~1.7-3.1 vol% around the center of the asteroids and to 5.5-16 % below the icy shell, depending on the asteroid sizes. The peak temperatures range from ~800 K around the center to ~370 K in heavily altered regions. These combinations between peak temperatures and alteration degrees are consistent with those inferred for CO and CM chondrites. This may imply that CO and CM chondrites originated from the same parent body, suggested from their oxygen isotopic compositions forming a single regression line in an oxygen three-isotope plot.

Keywords: fluid flow, hydrous asteroids, hydrogen gas

