Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SIT39-P01 Room:Poster Time:May 2 14:00-15:15

Effects of hydrous rocks on behaviors of subducting slabs

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Introduction: It is widely accepted that Earth's deep mantle contains water in several tens to several hundreds ppm, and that the water causes plate tectonics, volcanoes in subduction zones, deep earthquakes, and large-scale transportation of hydrophilic elements. A number of previous numerical studies on water transportation in the deep mantle are performed. In theses simulations, constant plate velocities and/or fixed plate shapes are synthetically imposed. In this study, we systematically investigated water transportation into the deep mantle and how the water changes the spontaneous behavior of the slab using a numerical model of whole mantle convection without external forces.

Numerical Model: Based on 2-D fluid mechanics simulation (Tagawa *et al*., 2007, *EPS*), the motion of mantle rocks is calculated. Advection of hydrous rocks is calculated using a Marker-And-Cell method, and dehydration/hydration reactions are evaluated by experimentally determined phase diagrams of the hydrous basalt and peridotite (Iwamori, 2007, *Chem. Geol.*). Effects of the hydrous rocks are formularized in constitutive laws (*e.g*. Karato and Wu, 1993, *Science*) and a state equation; therefore, the water transportation and the motion of solid phase are interactive. Only two parameters r (= 0, 0.7, 1.0, 1.93) in constitutive laws (viscosity reduction by hydration) and β (= 0, 1.0, 2.0) in a state equation (density reduction by hydration) are treated as variable, and other settings are equalized.

Results and Discussion: The reaction path (p-T path) of subducting hydrous rocks in each result is the same as that of southwest Japan (Iwamori, 2007), and a hydrous ultramafic layer along the slab surface ($\sim$2000 ppmH_2O in NAMs) is formed beneath $\sim$200-km depth. Large hydration weakening seems essential for back arc spreading because the subducting slab causes tensile stress within the overlying continental plate, and then the expansive deformation is concentrated on the hydrous weak area. Comparing the results with each other, at large r, the subduction rate increases. This is because a hydrous layer reduces viscous resistance above the slab. In contrast, at large β, the subduction rate decreases. This is because the positive buoyancy of the hydrous layer partially canceled to the gravitational instability of the slab. The subduction rate significantly controls the velocity field of the corner flow in the mantle wedge. A rapid corner flow causes strong suction force along the slab surface, which determines the angle of subduction. This also causes effective heat advection from the deep mantle to the back arc, and that contributes rapid, sustainable back arc spreading. The analytical discussion enables us to understand why scenarios differ when r and β are changed. In east Asia, stagnant slabs and back arcs are widely distributed. To realize both, large r and small β are needed. This is because they require strong corner flow, but β declines it. Thus the slab shapes and the period of back arc spreading may constrain scales of hydrous buoyancy and hydrous weakening in the mantle wedge comparing with those in nature.

Keywords: water transportation, free convection, subduction dynamics, plate velocity, big mantle wedge