Forward analyses of dehydration reactions in mafic rocks

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Fluids in the subduction zone play an important role in magmatism, metamorphism, and mechanical processes involving seismic activity. Additionally, recent geophysical researches find low-frequency tremors which may be related to the movement of fluid (Obara, 2002) and a zone of high Poisson's ratio which reflects high pore fluid pressure (Kodaira et al.,2004) in the Southwest Japan fore-arc. It is widely accepted that these fluids are supplied by dehydration of hydrated metamorphic minerals in the subducting oceanic plate. Although many previous studies attempted to estimate the water content of the subducting oceanic crust experimentally and theoretically (e.g., Schmidt and Poli, 1998; Hacker et al., 2003), there have been no studies which quantify the continuous dehydration reactions.

The aim of this study is to quantify continuous dehydration reactions of mafic rocks in the condition of greenschist facies, corresponding to low-intermediate depth (10-50km) of warm subduction zone. We use the differential thermodynamics which include mass balance to predict the continuous metamorphic reaction history of mafic rocks along the P-T trajectory of the subducting slab.

With fixed bulk chemical composition the thermodynamic system is divariant, as specified in Duhem's theorem. This means that the molar amounts of all minerals (Ms) and their chemical compositions (Xs) are uniquely determined at any pressure (P) and temperature (T) of interest (P-T-X-M phase relations: Spear 1993). In differential thermodynamics, applying a series of changes in pressure and temperature (dP and dT, respectively) from initial conditions (P0, T0, X0s, M0s), we trace dXs and dMs, in other words, the progress (history) of the metamorphic reactions along the arbitrary P-T trajectory (Thermodynamic forward modeling).

According to Okamoto and Toriumi, 2001, we modeled the greenschist/blueschist assemblage of mafic rocks, which consist of the following phases: Amphibole + Epidote + Chlorite + Plagioclase + Quartz + Fluid (H_2O), in the system of Na_2O - CaO - MgO - FeO - Fe_2O_3 - Al_2O_3 - SiO_2 - H_2O. Amphibole solid solution is treated as Ca - Na amphiboles, expressed by 6 end-members. Epidote, chlorite and plagioclase are assumed to be binary solid solutions, and quartz and fluid are treated as pure phases. The reference compositions and modes of minerals were assumed according to the natural sample of greenschist which have MORB-like bulk composition (Hacker et al. 2003). The reference temperature and pressure were set to be 300C, 3kbar.

Calculations were performed along the P-T paths of Southwest Japan and Cape Mendocino (North California) predicted by Yamasaki and Seno, 2003. As a result, the water production rates have peak depths at the boundary between the greenschist facies and the epidote-amphibolite facies in the Southwest Japan, and at the boundary between the greenschist facies and the amphibolite facies in the Cape Mendocino, respectively. Chlorite decomposition is the main dehydration reaction. These peak depths correspond to the zone of low frequency tremors, high Poisson's ratio and active seismicity (30-50km) in the Southwest Japan, and active seismicity (10-20km) in the Cape Mendocino, respectively.