Fluid flow meter using chemical and isotope mobility in a reaction zone

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Fluid-rock interaction is important physical processes for the mechanism of formation of rocks in various environments. The rock-forming mechanism can be understood by the study on the behavior of fluid flow during metamorphism. This study shows a method to derive amount of fluid and fluid flux. The geologic record of chemically reactive fluid flow is an evidence for the transport of chemical and isotopic species by the moving fluid.

A reaction zone between a metamorphosed basic dyke (MB) and marble at Hirao-dai, north Kyushu, Japan, consists of well-organized sequential zones of diopside, garnet and wollastonite; textures are characteristic of diffusion-controlled structures. The reaction zone formed during contact metamorphism associated with intrusion of a Cretaceous granodiorite at about 300 MPa and 700^{o}C (Fukuyama, *et al*., 2004). The MB consists of diopside, biotite and plagioclase (X_{Ab}=0.4 - 0.8), whereas the marble is almost pure calcite.

Geochemical and petrographical studies provided outline of amout of fluid flux. Minimum estimate of time-integrated fluid flux which formed the reaction zone is 3.46 mol fluid/mol reaction zone. It is made up as follow, 1.29 mol fluid/mole as reactive fluid and 2.17 mol fluid/mol as non-reactive fluid. This estimate is inferred from the mineralogical evidence and steady-diffusion modelling (Fukuyama *et al*., 2006).

We measured delta^{18}O and delta^{13}C of calcite from reaction zone-marble boundary. delta^{18}O changes in proportion to distance from the reaction zone-marble contact. This shows that ^{18}O is strongly fractionated between CO_2 and H_2O and because mineral reactions may buffer the CO_2-H_2O content of fluid.

The duration of oxygen isotope exchange (t) can be calculated from effective diffusive width (W) and diffusive coefficient of oxygen in calcite (D) using the following equation: $W^2=2Dt$

The duration during oxygen isotope exchange is 357 year at D=3.8$*10^{-14}$m^2/s or 4528 year at D= 3.0$*10^{-15}$m^2/s. We assume this duration is same as the duration of formation of the reaction zone, fluid velocity lead to 5.3$*10^{-11}$ m/s or 4.2$*10^{-12}$ m/s. This result consists with the duration of the heating caused by granite in this area.