

Microscale Stable Isotopic Zonation in the Crust and Formation of Isotopic and Chemical Fronts During Contact Metamorphism

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The role of fluids is recognized to be important in evolution of the Earth's crust, including transport of heat and materials, dissolution, precipitation of minerals and deformation. Stable isotopes are widely used tools for clarifying the origin of fluids and identifying metamorphic fluid-rock interaction and fluid flow pathways. During contact metamorphism, devolatilization and dehydration processes around the intrusive body, intensifies the fluid activity which consists of mainly C-H-O chemical components. Models on the fluid flow through the surrounding country rocks suggest to pervasive and/or channelized flows. Such manner of fluid migration during metamorphism mostly depend on the physical properties of the country rocks such as porosity and permeability under ambient P-T condition. There is a dilemma that the permeability, a primary parameter influencing fluid flow, cannot be directly measured (Baumgartner et al. 1997). In contrast to the pelitic and psammitic rocks that show high permeability and allow pervasive fluid flow in large scales, marbles are less permeable for fluid flow. The pervasive grain-boundary fluid flow in marbles is controlled by the chemical component in the fluid (Holness and Graham, 1995). Wada et al. (1998) showed that marbles are impermeable for carbon and permeable for oxygen, while no evidence for infiltration and advection surrounding wollastonite vein was observed. The channelized fluid flow in marble forms metasomatic skarn veins with distinctive chemical front during fluid-rock reaction processes. Obviously microscale studies on two or more tracers with differing fluid-rock ratios will provide us independent constrains on fluid flow processes including the role of grain boundary and empirical estimation of diffusion coefficients of lattice and grain boundary diffusions. We have investigated the precise behavior of stable isotopes in marbles. I would like to present our field-based studies including microscale zonation processes that are effective to test the usefulness of fluid flow models. The fluid flow model, the continuum theory for constant permeability in rocks, assumed that the instantaneous isotopic equilibrium is attained during diffusion and infiltration processes. As shown in previous works (Wada, 1988, Arita and Wada, 1990, Wada et al. 1998), local equilibrium in mm to m-scale fluid flow pattern in crystalline marble was not attained in most cases. The first application of microscale isotopic zoning is in a poly-metamorphosed marble of Wada river area of Hida terrain where contact metamorphism was followed after the previous regional metamorphism up to gran-

ulite facies. Along calcite-calcite-graphite grain boundaries, we can distinctly observe the metamorphic fluid flow along the grain boundaries as evidenced by the isotopic trough in the grain boundaries. Carbon and oxygen isotopic profiles around a low pressure metasomatic wollastonite reaction front in marbles in Utsubo district, central Japan, showed typical metamorphic fluid-enhanced isotopic zonations. Isotopic profiles obtained from detailed microscale analyses perpendicular to the reaction front in calcite marble show that diffusion controlled. Oxygen isotope trough around the calcite-grain boundaries is widely observed, demonstrating that grain boundary diffusion in calcite dominated over the lattice diffusion in calcite. On the other hand, there is no specific role of grain boundary of calcite for diffusion of carbon. Carbonate ions in fluid could not penetrate the grain boundary. These evidences on different behavior of carbon and oxygen isotopes indicate that the grain boundary in marbles can accommodate only a thin film of one water molecular layer. Empirically, lattice diffusion of oxygen isotopes is almost six times faster than that of carbon isotopes, and oxygen grain-boundary diffusion is ten times faster than oxygen lattice diffusion constants. These differences of values are relatively smaller than those experimentally determined by many authors. As noted by Farver (1994), the presence of water vapor promote two order magnitude faster than in dry conditions. Application on the natural system will give us a considerable mature results on the equilibrium condition. We are further studying on the new isotopic profiles formed by a basaltic dike intrusion and multistage garnet forming skarn deposits at Kushiro quarry, Hiroshima prefecture. At the contact of the intrusives, typical diffusion profiles were formed in oxygen and no significant gradients on carbon. This indicates that the carbon dioxide formed during skarn formation immediately escape out from the vein system.

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