From the initial transient to the steady state in metamorphic reactions: An experimental study in dolomite - quartz - water system

Tadao Nishiyama[1]; Aiko Tominaga[2]; Hiroshi Isobe[3]

[1] Earth Sci.,Kumamoto Univ.; [2] Earth Sci.,Kumamoto Univ; [3] Dept. Earth. Sci., Fac. Sci., Kumamoto Univ

Metamorphic reactions in non-equilibrium states usually overstep plural tie – line exchange reactions, as observed in a reaction zone. In such a case plural reactions compete with each other, resulting in different products ratios depending on the relative magnitude of the reaction rates. Varieties in mineral assemblages and zonal sequences in reaction zones between the same reactants from the same outcrop may be the results of such effects. We carried out hydrothermal experiments in a system of dolomite – quartz – water to track the temporal change of the reaction rates of plural reactions and observed the transition from the initial transient state to the steady state in the formation of a reaction zone.

Experiments

Starting materials: Configuration A: dolomite crystal + quartz powder + water in a gold capsule
Configuration B: Quartz crystal + dolomite powder + water in a gold capsule
(Weight ratios of minerals are both 1: 1)

Apparatus: a cold seal pressure vessel

Physical conditions: 600 C and 0.1 GPa

Run durations: 45hrs, 71 hrs, 168 hrs, and 336 hrs

Results

1. A reaction rim develops only around the dolomite crystals. No reaction rim is observed around the quartz crystals.

2. Varieties in mineral assemblages and zonal sequences in reaction rims are observed in the same experimental condition and even in the same run.

45hrs experiments:

(1) Quartz (Qtz) / Diopside (Di) / Fosterite (Fo) + Calcite (Cc) / Cc + Dolomite (Do) / Do

(2) Qtz / Wollastonite (Wo) / Cc / Di / Cc + Do / Do

71 hrs

(3) Qtz / Wo / Cc / Talc (Tlc) / Di / Fo + Cc / Cc + Do / Do

(4) Qtz / Di / Fo + Cc / Cc + Do / Do

168 hrs

(5) Qtz / Di / Fo + Cc / Cc + Do / Do

336 hrs

(6) Qtz / Di / Fo + Cc / Cc + Do / Do

3. Results of short duration runs involve varieties of mineral assemblages and of zonal sequences, and those in longer duration runs show only one kind of mineral assemblage and zonal sequence as revealed in (5) and (6) above.

Discussions

1. The steady diffusion model of a reaction rim can explain why a reaction rim form only around a dolomite crystal. The amount of mineral form around the reactant phase depends on the relative magnitude of diffusive flows, which in turn depends on the ratio of phenomenological coefficients of diffusing components.

2. Observed varieties in mineral assemblage and in zonal sequence may imply that in the initial transient state far from equilibrium the relative magnitude of reaction rates is quite sensitive to the initial conditions which involve some fluctuations. The initial transient state involves the following eight reactions competing with each other.

$Do + Qtz = Di + CO_2$

$Do + Qtz = Fo + Cc + CO_2$

$Do + Qtz + H_2O = Tlc + Cc + CO_2$

$Do + Di = Fo + Cc + CO_2$

$Tlc + Cc = Di + Do + H_2O + CO_2$

$Cc + Qtz = Wo + CO_2$

$Wo + Do = Di + Cc$

$Wo + Do + H_2O + CO_2 = Tlc + Cc$

3. A unique mineral assemblage with a unique zonal sequence in longer duration runs may indicates that the system has reached a steady state. Thus this experiments show a transition form an initial transient state to a steady state in the process of a reaction rim formation.

4. We estimated the temporal variations in the extent of reactions of the following two reactions which took place in all runs:

$Do + Qtz = Di + CO_2$ (R1)

$Do + Qtz = Fo + Cc + CO_2$ (R2)

The ratio of the reaction extents of R1 and R2 increases from 45 hrs to 168 hrs, and then decreases towards 336 hrs, resulting in a half of the peak value. This temporal change may reflect the change in the fluid composition due to the progress of reactions.