Evolution of the metasomatic zoning: temporal change in the growth mode in the system dolomite - quartz - H2O

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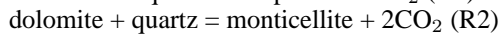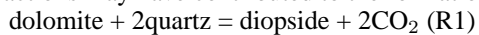
We examined a temporal development of a reaction zone between dolomite and quartz in the presence of H_2O to clarify the effect of reaction kinetics on the growth mode of the reaction zone. This is a companion paper of Tanoue et al.(2007) which discussed the temporal development of a void within the reaction zone.

Experiments

Hydrothermal experiments were done at 800 ^oC and 0.1 GPa with an internally heated pressure vessel (Dr. HIP made by Kobelco) . Dr. HIP is equipped with a quench system which is crucial in our experiments, because slow cooling results in precipitation of minerals in the void within the reaction zone. The reaction zone formed only on the dolomite single crystal in all runs. The reaction zone has the same layer sequence irrespective of run duration: Dol / Cal + Dol / Fo + Cal / Fo / Mon / Di / Wo / Qtz. A void always formed between Fo + Cal and Cal + Dol layers.

Phase relations

Mineral compositions are plotted on the ternary SiO_2 - MgO - CaO diagram to clarify the phase relation. Following three reactions may have contributed to the formation of the reaction zone:

dolomite + 2quartz = diopside + $2CO_2$ (R1)

dolomite + quartz = monticellite + $2CO_2$ (R2)

2dolomite + quartz = forsterite + 2calcite + $2CO_2$ (R3)

Temporal variation of mineral mode

We measured area ratios of diopside, monticellite, forsterite and forsterite + calcite layers in the reaction zone with Sion Image (a free software for image analysis) and converted them into molar ratios by assuming equality of area and volume ratios. Diopside shows a monotonous decrease from 48 hrs to 357 hrs, whereas monticellite increases from 48 hrs to 222 hrs and then decreases again at 357 hrs. Both forsterite monomineralic layer and forsterite + calcite layer show a slight increase from 48 hrs to 357 hrs. This temporal change in mineral mode may reflect the temporal variation in the progress of above three competing reactions. We calculated the ratio of reaction extents of R1 and R3. It decreases monotonously from 48 hrs to 357 hrs, whereas the ratio R2/R3 increases from 48 hrs to 222 hrs then decreases at 357 hrs.

Steady diffusion modeling

The steady diffusion modeling is useful to clarify the mass transfer within the reaction zone and also helpful to understand the stability of the specific zonal sequence. Here we have modeled the zonal sequence of Dol / Fo + Cal / Mon / Di / Wo / Qtz , because calcite + dolomite zone is formed not by a diffusion-controlled process but by an internal precipitation (Nishiyama et al., 2007) and hence neglected. The system is assumed to be closed between dolomite and quartz. The closed system formulation together with phase-ratio equations gives successfully exchange cycles which show the growth mode of the reaction zone in each run product. The phase-ratio equations are based on the measured molar ratios of minerals in each run. The result shows the temporal change of the growth mode from diopside-dominant (the diopside layer grows both sides) mode at short duration (48 to 109 hrs) runs through monticellite - dominant mode at 222 hrs run to forsterite + calcite - dominant mode at 357 hrs run. Plots of $L_{SiO2SiO2}/L_{CaOCaO}$ versus $L_{SiO2SiO2}/L_{MgOMgO}$ reveal the stability field of each growth mode. The stability fields have a feature common to each run such that the stability filed of the diopside-dominant mode occurs at higher L values, that of the monticellite at intermediate values, and that of the forsterite + calcite - dominant mode at lower values. The extent of each stability field is, however, different depending on the run duration. This difference reflects the relative magnitude of the reaction extent of competing reactions. The temporal change of the growth mode is simply due to the reaction kinetics rather than the change in L-ratios.