Preliminary calculation of the formation of chemical zoning in Mg-Fe-Mn-Ca garnet

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Chemical zoning in garnet is thought to retain temperature and pressure history during garnet growth, assuming chemical equilibrium between garnet surface and other matrix minerals. Although differential thermodynamic method (Gibbs' method) is enough to derive the P-T changes, the absolute P-T values or the history of volume changes of garnet are not determined. Forward calculation was performed to model the formation of Mg-Fe-Mn-Ca garnet consuming chlorite, epidote, and quartz, in a Mg-Fe-Mn-Ca-Al-Fe(3+)-Si-H system. Garnet was treated as four end-member mineral (pyrope, almandine, spessartine, grossular), chlorite as four (clinochlore, amesite, daphnite, Mn-chlorite), epidote as two (clinozoisite, pistacite). Published thermodynamic data of garnet, chlorite, epidote, and water fugacity were used. Fluid phase was assumed to be pure water. Closed system was assumed except for quartz and water. Fe(3+) is only incorporated in pistacite, which do not contribute in any chemical reaction in this model. 15 variables are present in the system, whereto 13 thermodynamic constraints were available assuming chemical equilibrium and closed system, leaving the system divariant. Therefore, the values of all variables could be uniquely determined if pressure and temperature were given. The calculation predicts the chemical composition of garnet which is in equilibrium with chlorite and epidote of given chemical compositions at a given P-T condition. It is possible to obtain the compositional change of garnet along certain P-T path. In addition, considering mass balance in the rock system, change of amount of minerals along the P-T path is also derived. Chemical composition of chlorite from the chlorite zone of the Sambagawa metamorphic belt was used as the initial chemical condition. Heating and compression path were given to reconstruct 'normal zoning' observed in garnet from the Sambagawa metamorphic belt. As the result, the bell-shaped profile of spessartine was reconstructed as well as the Mg/Fe increase from the core to the rim of garnet. Predicted grossular content in garnet was 5 to 10 % which increased slowly from the core, but eventually decreased in response to the depletion of Ca in the bulk rock chemistry. Predicted temperature range of garnet formation was slightly lower and more realistic compared to the previous calculation made by the author excluding Ca end-member in garnet. However, the behavior of Ca strongly depends on the bulk rock chemistry and would have to wait for more detailed examinations.