Attempt to estimate initial composition of the nucleus of homogenized garnet in pelitic gneisses from the Lützow-Holm Complex

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The Lützow-Holm Complex (LHC), East Antarctica, underwent a high- to ultrahigh-temperature metamorphism. Most garnet grains in pelitic gneisses represent a chemical zoning that has homogeneous interior and locally-zoned rim. The features of the rim and interior have been interpreted as a result of retrograde resorption of the garnet grain and homogenization of growth zoning at high temperatures, respectively. Disappearance of growth zoning of garnet has prevended from deciphering any constraints during prograde metamorphism except from inclusion minerals.

We found a feature common to these garnet grains such that the outermost part of the grains is inclusion-free and has homogeneous content of phosphorus that does not diffuse even at high temperatures. The growth of this periphery without any inclusions suggests low growth rate at final stage under high temperature conditions. Intracrystalline diffusion may be a slower process than garnet-forming reaction and intercrystalline diffusion. Then we consider that such a part was formed due to homogenization of the zoned garnet that was formed during prograde metamorphism. That is, the former zoned grains need change in it grain size to conserve the total mass provided that the surface equilibrium has been maintained during the homogenization. This study attempts to formulate this process and propose a method to estimate the initial composition of garnet when it nucleated, using the thickness of the inclusion-free periphery.

Consider a system that is composed of a chemically zoned grain of spherical garent and homogeneous grains of biotite. We chose an element that is contained in both phases, the concentration of which is a function of radius of the zoned garnet *C(r)* and is constant C_{Bt} in biotite. The mass concervation law contrains the following relation,

$$\int_0^R 4\pi r^2 C_{(r)} dr + V_{\mathrm{Bt}} C_{\mathrm{Bt}} = \frac{4}{3}\pi R'^3 + V'_{\mathrm{Bt}} C_{\mathrm{Bt}}$$

where R denotes the radius of zoned garnet, which is changed to R' after homogenization. V and V' represent the total volume of biotite that reacted with garnet before and after homogenization, respectively. The left-hand side of the equation represents the total amount of the chosen element before homogenization, and the right-hand side does so after homogenization. The second term of the both sides of the equation would be cancelled when the amount of biotite is large enough as compared with garnet volume. It can also be eliminated if the content of the chosen element in biotite is negligible such as manganese at high temperatures.

Assuming a linear zoning with C_0 at the center and C_R at the rim provides the initial composition at the center as,

$$C_0 = \left[4\left(\frac{R'}{R}\right)^3 - 3\right] C_R$$

We applied this method to a pelitic gneiss from Akarui Point as an example. The thickness of the rim with inclusion-free and homogeneous in phosphorus occupies about 17 % of the present radius of the garnet. The homogeneous garnet represents the manganese content as low as 0.01. This suggests that the initial nucleus of garnet was estimated to show the manganese content still low as about 0.03 to 0.06.

Low-grade pelitic rocks commonly contain garnet that represents larger compositional difference between the core and rim than the present estimation by the first order of magnitude. Such garnet grains have been considered to grow by any continuous reactions with Fe-Mg minerals such as chlorite and biotite. In contrast, the present result suggests that the studied garnet has represented a zoning of significantly small in magnitude. Growth of garnet without chemical zoning is expected when it nucleates and grows by any discontinuous reactions. Combined with very low manganese content even at the former core, we consider that the garnet grains were formed at high temperatures near the homogenization temperature by any discontinuous reactions. Formation of garnet by the discontinuous reaction predicts an abrupt increase in the amount of garnet, implying large growth rate of garnet. The large growth rate would enhance roughness of the growing surface of garnet, which would make garnet easy to incorporate matrix minerals within it. Formation of garnet at high temperatures with large growth rate is also consistent with the fact that such garnet includes only coarse-grained minerals.