Diffusion-controlled change in the shape of a mineral inclusion within a crystalline host

Atsushi Okamoto[1]; Katsuyoshi Michibayashi[2]

[1] Geosci, Shizuoka Univ.; [2] Inst. Geosciences, Shizuoka Univ

Interfacial tension (T) and differential stress (S) can act to change the shape of a mineral grain included within a crystalline host. In this study we present a simple model that describes the rate process of change in shape of the inclusion. For the model, we adopt the following assumptions: 1) uniaxial tensile stress, 2) constant volume of the inclusion, 3) isotropic interfacial tension between inclusion and host minerals, and 4) grain boundary diffusion. When a rock exists under differential stress at high temperatures, differential stress makes the shape of mineral inclusion to be like an elongated lense, the interfacial tension makes it to be spherical. We focus on the development of aspect ratio ((L = b/a) of the inclusion, where a and b are long and short axial lengths of the inclusion. The model indicates that the change in shape of the inclusion depends strongly on grain size, and that the aspect ratio changes toward a steady state (dL=0). Furthermore, the aspect ratio (L) - grain size (R) distribution pattern predicted in this model shows the minimal aspect ratio the intermediate grain size until inclusions does not reach at the steady state.

The aspect ratio (L) - grain size (R) distribution pattern of garnet inclusions in a granulite-facies quartzite from the Skallen district in the Luzow-Holm Complex, East Antarctica, were measured to compare with the model results. Microstructures of garnet inclusions systematically vary with the grain size. Smaller grains (R is less than 0.1 mm) are generally sub-spherical (L is larger than 0.7). Larger grains record smaller aspect ratios (L), with a minimum for grains of size 0.2~0.3 mm. Large grains (R is larger than 0.3 mm) commonly show subgrain boundaries. On the other hand, the sub-spherical small grains do not have any substrucutre.

The L-R distribution pattern of inclusions, which R is less than 0.2 mm, is similar to the model curve of A (= - S/T) = 1.0*104 ~ 2.0*104 m-1 at steady state conditions. Similarity in the L-R distribution pattern between the analyzed data and the model, and the observation of microstructures imply that the shape of garnet inclusion was mainly dominated by diffusion processes rather than dislocation creep. Furthermore, small grains achieved the steady state conditions of their shape. The interfacial free energy of the quartz/garnet boundary is about 340 mJ/m2, and from this we estimate the magnitude of differential stress affecting garnet inclusions to be 3.0*10-3 ~ 9.0*10-3 MPa.