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Morphological inversion of garnet

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The mineral of garnet groups is one of the most important ones, which occurs under a wide range of metamorphic conditions. Because garnet in high-P/T type metamorphism shows compositional zoning controlled by the metamorphic history, much work has been carried out to deduce metamorphic conditions and P-T path from the analysis of such zoned garnet (e.g. Tracy et al., 1976; Tompson et al., 1977; Banno et al., 1986; Spear and Selverstone, 1983; Spear, 1993; Inui and Toriumi, 2004).

This study concerns other information from garnet that is critical to evaluate the formation conditions of metamorphic rocks. Nicolas Steno has indicated that the diversity of crystal shapes was governed by relative growth velocity of each face about 340 years ago. His work concluded that the face with fast growth rate becomes smaller or extinct. Such growth rates are affected by intensive parameters such as temperature, pressure, chemical potential gradient, degree of supersaturation, and chemical environment. The relative growth rate of crystallographic faces depends on not only the atomic structure but also the interfacial energy with surrounding environment (chemical potential gradient and dihedral angle). Thus, morphological research can become a powerful tool not only to analyze mineral growth processes, but also to determine growth conditions, as the growth habit reflects the growth environment. If grain shape can be expressed quantitatively, it may provide useful insight into the petrogenesis of rocks.

In the case of cubic system, Miller's index *hkl* can be treated as normal vector of plane, and the equation of plane in the Cartesian coordinate space can be expressed by Miller's index and distance r_i from center to i-th plane:

$h*x + k*y + l*z = r_i$

Moreover, growth forms are drawn as a function of time by specifying the growth rate of each face. Garnet has a body centered cubic lattice (space group Ia3d) with the shape of rhombic dodecahedron which is bounded by d{110} principal faces. These faces are physically equivalent. If garnet growth is isotropic, the maximum aspect ratio of any cross-section is 2^(0.5). However the aspect ratio of some garnet grains in the Sambagawa metamorphic rocks is over 2^(0.5), which implies that equivalent crystallographic faces had different growth rate (=anisotropic growth model).

Now we focused on growth increment in each garnet face. Garnet in the Sambagawa metamorphic rocks contains chemical zonings, from which isocomposition lines, recording a given time can be drawn. From the results of chemical analyses and X-ray mapping images by microprobe, the incremental growth rate, the interfacial angle, and the edge length can be measured. The cutting angle and distance from center may be deduced from linear algebraic procedure using these observed values if final form is known (=rhombic dodecahedron). However, the relative growth rate of crystallographic faces is an unknown variable in natural samples such as Sambagawa metamorphic rocks. From these measurement data, our model aims at determining the relative growth rate of crystallographic equivalent faces. We propose that the growth rate is controlled by the supply of elements from the surrounding medium. An anisotropic supply, possibly related to the shear stress, resulted in anisotropic growth of garnet faces.