Fractal properties of dynamic recrystallized quartz grain boundary

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Experimentally, Masuda and Fujimura (1981) had provided dynamic recrystallized quartz aggregates under condition sets of high temperature (800 deg. C, 900 deg. C and 1000 deg. C), strain rate (1 microstrain/sec, 10 microstrain/sec and 100 microstrain/sec) and high confining pressure (400 MPa). They found quartz grain boundary shapes become serrate with increasing strain rate and decreasing temperature. So present authors have tried various fractal analyses on the experimental products of Masuda and Fujimura (1981), in order to study the relationship between the microstructures of quartz grain and the deformation conditions such as temperature and strain rate. Here we review the results of the fractal analyses of quartz grain boundaries and will note unresolved problems related to fundamental problems of rheology of rocks.

We investigated both the individual fractal dimension Di for each grain, using the box-counting method, and the collective fractal dimension Dc for the whole grain fabric using the area-perimeter method. The individual fractal dimension Di showed an inverse variation with grain size and converged to the value of Dc as the grain size increases. During dynamic recrystallization, the grain boundary serration would be interfered by neighboring grain interactions including bulging, nucleation and boundary migration. The variation of Di means that a restricted range of shapes results from grain boundary serration or smoothing processes as the grain is growing or being consumed.

We also note a simple relationship between the collective fractal dimension Dc and the deformation condition had been found; Dc - 1 is proportional to logarithm of Zener-Hollomon parameter Z. This Z-value including Arrhenius term compiles deformation conditions of strain rate and temperature. To measure the collective fractal dimension, therefore, is a methodology to obtain the paleo-strain rate of dynamic recrystallized quartz rocks providing the metamorphic temperature data. This relationship between Z and Dc - 1 was successfully explained theoretically by modified grain boundary migration model (GBM or cell dynamics model). Additionally, the fractal dimension minus 1, Dc - 1, indicates a section`s fractal dimension when the fractal object (quartz grain) is in 2D. The section`s fractal dimension is concluded as the fractal dimension of the crossing point distribution on the grain boundary transected by the circumscribing circle or ellipse with the equivalent-area of the grain, and a power law relationship between the Zener-Hollomon parameter. Moreover, the number of crossing points is found. Therefore, summarizing power laws among the Zener-Hollomon parameter, the differential stress and the number of the crossing points on the grain boundary, the number of crossing points could respond to the differential stress.

We have left a big question - why does the recrystallized grain boundary become fractal? Further studies on dynamic recrystallizations with fractal quartz grain boundaries would be required.