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Static Grain Growth in Contact Metamorphic Calcite: A Cathodoluminescence Study.

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In the Adamello contact aureole, monomineralic mesozoic limestones were investigated in terms of grain size evolution and compared to results on numerical modeling performed by Elle.

The sampled area shows no deformation and therefore represents an appropriate natural laboratory for the study of static grain growth (Herwegh & Berger, 2003). For this purpose, samples were collected at different distances to the contact to the pluton, covering a temperature range between 270 to 630°C. In these marbles, the grain sizes increase with temperature from 5 μm to about 1 cm as one approaches the contact (Herwegh & Berger, 2003). In some samples, photomicrographs show domains of variable cathodoluminescence (CL) intensities, which are interpreted to represent growth zonations. Microstructures show grains that contain cores and in some samples even several growth stages. The cores are usually not centered and the zones not concentric. They may be in touch with grain boundaries. These zonation patterns are consistent within a given aggregate but differ among the samples even if they come from the same location. Relative CL intensities depend on the Mn/Fe ratio. We assume that changes in trace amounts of Mn/Fe must have occurred during the grain size evolution, preserving local geochemical trends and their variations with time. Changes in Mn/Fe ratios can either be explained by (a) locally derived fluids (e.g. hydration reactions of sheet silicate rich marbles in the vicinity) or (b) by the infiltration of the calcite aggregates by externally derived (magmatic?) fluids. At the present stage, we prefer a regional change in fluid composition (b) because the growth zonations only occur at distances of 750-1250 m from the pluton contact (350-450°C). Closer to the contact, neither zonations nor cores were found. At larger distances, CL intensities differ from grain to grain, revealing diagenetic CL patterns that were incompletely recrystallized by grain growth. The role of infiltration of magmatic fluids is also manifest in the vicinity of dikes, where intense zonation patterns are prominent in the marbles.

The software Elle was developed to simulate microstructural evolution in rocks. The numerical model with the title "Grain boundary sweeping" was performed by M. Jessell and was found on http://www.materialsknowledge.org/elle. It displays the grain size evolution and the development of growth zonations during grain boundary migration of a 2D foam structure. This simulation was chosen because the driving force is the minimization of isotropic surface energies. It will be compared to the natural microstructures. At the last stage of the simulation the average grain and core sizes have increased. All, even the smallest grains, show growth zonations. Grains can be divided into two groups: (a) initially larger grains, increasing their grain size and maintaining their core size and (b) initially smaller grains with decreasing grain and decreasing core size. Group (a) grains show large areas swept by grain boundaries into the direction of small grains. Grain boundaries between large grains move more slowly. Their cores do not touch any grain boundaries. Cores of group (b) grains are in contact with the grain boundary network and are on the way to be consumed.

In the numerical model and in the natural example similar features can be observed: The cores are not necessarily centered, the zonations are not necessarily concentric and some of the cores touch the grain boundary network. In the simulation, grain boundary migration velocity between large grains is smaller than between a large and a small grain. From this we would predict that - given enough time - a well sorted grain size distribution of increased grain size could be generated. But since many small grains occur we infer that this equilibrium has not been obtained. Analytical results of some natural samples that could be analyzed up to now indicate a

relatively well sorted grain size distribution suggesting a more mature state of static grain growth. In comparison to the simulation, grain and core boundaries in the marbles are not always straight. For lobate grain boundaries the surface area has not been minimized in respect to the grain size. An explanation for this might be grain boundary pinning or a local dynamic overprint. Some cores and growth zones in the investigated calcites show a continuous change in luminescence. This is interpreted to be an effect of late diffusion within the grain and/or a continuous change of fluid composition and supply. The absence of zonation in samples close to the contact might be explained by fast grain growth due to high temperatures and/or fast fluid transport. Possibly, this is combined with an enhanced component of volume diffusion. Thus concentration variations of Mn/Fe are diminished and not visible in form of a growth zonation.

Herwegh M, Berger A (2003) Differences in grain growth of calcite: a field-based modeling approach. Contr. Min. Pet. 145: 600-611