Modeling the effect of growth, diffusion and exsolution during contact metamorphism on measured calcite-dolomite temperatures.

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The crystallization history of a mineral can be recorded in its chemical composition. Mg-exchange between calcite and dolomite is a well calibrated thermometer, so that Mg-zoning in calcite could be used to decipher mineral reaction history in siliceous dolomites. The application of this thermometer to a single sample of contact metamorphic carbonates results in large Mg-composition variations even though no simple (concentric) zoning patterns for individual grains are apparent. To understand these variations we developed quantitative forward models to evaluate the effects of growth zoning, volume diffusion and the formation of submicroscopic exsolution lamellae (<1µm) of Mg-distribution in calcite grains.

Calcite-temperatures obtained for the Ubehebe Peak contact aureole (USA) are presented. Results on aureole scale show an increase in Mg-content of calcite with decreasing distance from the contact of the intrusion as expected. Analyses of several hundred points in a single section yield typically gauss-shaped distributions of X_{Mg} with 1σ values of about 0.02, corresponding in over 100°C uncertainty. This measured variation is ten times larger than the analytical uncertainty. On thin section scale, X_{Mg}-values correlate with adjacent silicate phases, yielding domains of lower X_{Mg} in calcite crystals surrounding tremolite when compared to values measured in the vicinity of forsterite in the same section. Hence, apparent higher temperatures are measured around olivines than around tremolite. This systematic trend is in agreement with the phase petrology, since formation of tremolite will typically take place at lower temperatures than that of forsterite. Hence, the original crystallization Mg-content of calcite seems to be at least partially preserved.

Using our best temperature-time path estimate for the Ubehebe Peak aureole and experimentally derived Mg-diffusion data in calcite (Kent et al., 2001) no prograde Mg-zoning is preserved if calcite is modeled to grow slowly during the prograde history. Lower Mg-values associated with tremolite growth can only be preserved if the entire calcite crystal grew over a small temperature interval as expected for infiltrative driven tremolite growths.

Modeled Mg-distributions were transformed to histograms by taking into account intersection probabilities of grains in thin sections. These histograms are similar to the measured ones, assuming random microprobe analyses. But this model by itself does not explain the lack of systematic zoning. In a second set of models, retrograde equilibration is modeled by the presence of fine, submicroscopic exsolution lamellae. This results for selected values of spot and lamellae sizes in randomly distributed higher and lower X_{Mg} -values, which will hide any zoning that survived the T-t-path.

These data together with the models demonstrate that calcite does preserve partially a memory of the temperature-reaction path. It is obscured by both diffusion and exsolution.

REFERENCES

Kent, A.J.R., Hutcheon, I.D., Ryerson, F.J.,& Phinney, D.L. 2001: The temperature of formation of carbonate in Martian meteorite ALH84001: Constraints from cation diffusion.