American Mineralogist, Volume 93, pages 1245–1259, 2008

Forward modeling of the effects of mixed volatile reaction, volume diffusion, and formation of submicroscopic exsolution lamellae on calcite-dolomite thermometry

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Abstract

This paper reports the results of several thousand analyses of the Mg content of calcite from 31 samples from the Ubehebe Peak contact aureole, Death Valley, California. All data reported are from metamorphic calcite formed during mixed volatile-mineral reactions in which dolomite remained in the rock. The Mg content generally increases toward the intrusive contact and bend with increasing temperature, but it varies strongly. Indeed, probability distributions for each sample are near Gaussian, possess a relatively small skewness (–1.72 to 3.32), and a variance that is a multiple of the estimated measuring uncertainty. These findings complicate direct application of the Mg content in calcite for use as an accurate thermometer.

The purpose of the study presented in the second part of the paper is to explore the significance of these systematic variations of Mg composition of calcite to aid the interpretation of contact metamorphic temperatures recorded in carbonates. We developed forward models to evaluate the effect of growth zoning, volume diffusion, and the formation of submicroscopic exsolution lamellae (<1 μm) on the measured Mg distribution in individual calcite crystals and compared the modeling results to the field data. Modeled Mg distributions were transformed into histograms by taking into account intersection probabilities and random microprobe analyses. Modeling results reveal that the original prograde Mg zoning in calcite crystal will be reset if the calcite crystal is assumed to grow slowly along a prograde path. Original low-Mg compositions can only be preserved if the entire grain forms over a small temperature interval, as can be expected for infiltration-driven mineral reactions. It is shown that all three mechanisms combined give an adequate model for the Mg-content data. We demonstrate that Mg distributions in calcite grains of the Ubehebe Peak contact aureole are the consequence of rapid crystal growth in combination with diffusion and exsolution.

Keywords: Calcite-dolomite thermometry, contact metamorphism, Ubehebe Peak, mineral growth, fluid infiltration