American Mineralogist, Volume 92, pages 898–908, 2007

INTRODUCTION

Synthetic tremolite is known to form with about 3–7 mol% Mg, or 0.06–0.14 atoms per formula unit (apfu), appearing to replace Ca in the M4 site and shifting it slightly from its ideal composition Ca2Mg5Si8O22(OH)2 (e.g., Jenkins 1987; Graham et al. 1989; Maresch et al. 1994; Zimmerman et al. 1996; Gottschalk et al. 1999; Bozhilov et al. 2004). The great level of interest that this relatively minor deviation from ideal composition has generated stems from the far-reaching implications that it has on such things as: (1) the role that chain multiplicity faults (CMFs) vs. solid solution plays in controlling the bulk mineral composition (Ahn et al. 1991; Maresch et al. 1994); (2) the effect that configurational entropy, arising from cation disorder, can have on stabilizing non-ideal mineral compositions (Hawthorne 1995); (3) the influence that the mineral-forming process (the reaction path) can have on the final mineral composition (Maresch et al. 1994; Bozhilov et al. 2004); and even (4) the relevance of experimental studies on the phase equilibria and thermodynamic properties of tremolite and perhaps other Mg-rich amphiboles. Essentially all of the tremolite synthesis studies have used starting mixtures consisting of gels or mixtures of oxides, carbonates, and hydroxides. These are, however, highly unusual starting materials compared to nature, where the precursor phases to tremolite formation, though rarely preserved, are mixtures of common minerals such as dolomite, calcite, talc, clay minerals, quartz, etc. As a companion to the earlier studies that considered tremolite formation from starting mixtures of amorphous gels or oxide mixtures (e.g., Maresch et al. 1994; Bozhilov et al. 2004), the present study deals with the formation of tremolite from dolomite and quartz.

EXPERIMENTAL METHODS

Starting materials and sample treatment

Natural white dolomite (northwest Adirondacks, New York) and quartz (locality unknown) were used in this study. Microprobe analysis (procedure described below) of the dolomite indicated that it was unzoned and had a uniform composition of Ca1.024(7)Mg0.975(7)Fe0.001(1)(CO3)2, where the number in parenthesis is the uncertainty in the last digit. Dolomite and quartz were ground (but unsized) and mixed in the weight proportions of dolomite to quartz of 65.7 to 34.3 wt%, respectively, with a mole fraction of CO2 of 0.2 for durations up to 582 h. The initial reaction of dolomite and quartz led to rapid formation of talc and calcite instead of tremolite and calcite by the intended reaction: 5 dolomite + 8 quartz + H2O = tremolite + 3 calcite + 7 CO2. With continued treatment, the talc + calcite + quartz assemblage gradually reacts to form increasing amounts of tremolite and diopside with the eventual loss of quartz and nearly complete loss of talc.

The detailed structure of the amphibole and the nature of the Mg enrichment were revealed using AEM analysis of individual amphibole crystals. The most abundant defects are triple-chain chain multiplicity faults (CMFs), which appear as isolated lamellae with single periodicity in short-duration experiments and increasingly as groups of lamellae with variable multiplicity and periodicity in longer duration experiments and especially in a long-duration experiment without retreatment. In the latter experiment, a calcian clinopyrothomsonite domain extending 15 unit cells along the b axis was observed. The sample after 582 h and five retreatments shows, on average, 3.5% true solid solution with Mg expressed as the Mg-cummingtonite (MC) component after correction for the presence of CMFs. This sample is thought to most closely approach the equilibrium composition for the amphibole. The sample after 250 h with three retreatments has about 10%, whereas that after 582 h without retreatment has 0.6% MC component, the latter having a relatively high density of CMFs. This study affirms the importance that precursor non-amphibole biopyriboles play in the formation of tremolitic amphibole.

Keywords: Tremolite, HRTEM, analytical electron microscopy, mineral growth, calcian clinopyrothomsonite

ABSTRACT

A series of experiments with and without sample retreatment was performed on a starting mixture of dolomite plus quartz at 0.5 GPa and 600 °C in a CO2-H2O fluid with a mole fraction of CO2 of 0.2 for durations up to 582 h. The initial reaction of dolomite and quartz led to rapid formation of talc and calcite instead of tremolite and calcite by the intended reaction: 5 dolomite + 8 quartz + H2O = tremolite + 3 calcite + 7 CO2. With continued treatment, the talc + calcite + quartz assemblage gradually reacts to form increasing amounts of tremolite and diopside with the eventual loss of quartz and nearly complete loss of talc.

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EXPERIMENTAL METHODS

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