Single-crystal X-ray studies of trioctahedral micas coexisting with dioctahedral micas in metamorphic sequences from western Maine

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ABSTRACT

A crystal-chemical study of thirteen biotite (twelve of 1\textit{M} polytype and one of 2\textit{M}1 polytype) and four muscovite samples was made. The biotite coexists with the muscovite. Samples are from metamorphic terranes and from granitic and granodioritic bodies occurring in three areas of western Maine. The metamorphic mineral zones identified by mineral compatibilities are, in order of increasing metamorphic grade: the Lower Sillimanite Zone (LSZ), the Upper Sillimanite Zone (USZ), and the K-feldspar + Sillimanite Zone (K + SZ).

The muscovite compositions cluster near ideal muscovite and display a small celadonite substitution and a small, but variable, paragonite substitution. The biotite composition has values of $\text{VIMg}^{2+}/\text{VI(Mg}^{2+} + \text{Fe}^{2+})$ ranging from 0.26 to 0.54 and significant octahedral Al content ($0.48 \leq 1\text{Al} \leq 0.72 $ apfu in metamorphic biotite samples, $0.51 \leq 1\text{Al} \leq 0.67$ in those from granites).

In trioctahedral micas from western Maine and especially in those with graphite, there are a greater number of interlayer vacancies than in common micas. Interlayer vacancies have an increase in interlayer cation-basal oxygen atom distances and a decrease in tetrahedral flattening angle $\tau$, thus suggesting a reduced interlayer charge. With a few exceptions, tetrahedral rotation angle $\alpha$ is related to crystallization temperature. In particular, $\alpha$ decreases with a temperature increase, and $\alpha$ is also related to octahedral chemical substitutions. Results tentatively suggest, for micas from metamorphic environments, a direct influence of genetic parameters ($T$ and $f_0_2$) on mica crystal structure, and not just chemical composition.

Keywords: Biotite, muscovite, western Maine, crystal chemistry, crystal structure

INTRODUCTION

Structure and crystal chemistry of micas are recognized as powerful petrogenetic indicators. Several studies hence related the features of trioctahedral and dioctahedral micas to crystallization conditions, as shown in the early reviews by Guidotti and Sassi (1976) for muscovite and by Guidotti (1984) for both micas. More recent data for the chemistry of plutonic trioctahedral micas may be found in Brigatti et al. (1996, 2000a, 2000b) and Benincasa et al. (2003), and of metamorphic muscovite and biotite in Guidotti and Sassi (2002) and Henry et al. (2005) and references given therein. Determining the changes of layer topology of micas under changing metamorphic environments is difficult because most mica crystals from metamorphic rocks are not of sufficient quality for a single-crystal investigation.

Single-crystal high-pressure and high-temperature structural investigations on dioctahedral and trioctahedral micas have described geometric variations of each site and order-disorder processes involving both the tetrahedral and octahedral sheets (Guggenheim et al. 1987; Comodi and Zanazzi 1995; Russell and Guggenheim 1999; Comodi et al. 2002, 2004; Zanazzi and Pavese 2002). These studies, which provide great insight and are an advancement in the knowledge of micas, cannot mirror completely the thermodynamic and kinetic trends of these minerals in the rocks, because of differences between the experimental setup and natural environment.

Crystal-chemical studies on dioctahedral and trioctahedral micas of metamorphic origin have involved several different experimental methodologies, e.g., Mössbauer, cell parameters refinement from powder X-ray diffraction (XRD) and XANES spectroscopy. Such studies show the effect of chemical composition on cell parameters and have clarified several petrogenetic problems, including the role of the oxidation state of Fe on mica crystal chemistry (Blencoe et al. 1994; Dyar 1990; Dyar et al. 2002; Guidotti 1973, 1984; Guidotti and Dyar 1991; Guidotti and Sassi 1976, 1998a, 1998b, 2002; Guidotti et al. 1988, 1989, 1992, 1994a, 1994b, 1994c, 2000, 2005; Rieder et al. 1992).

The mica samples investigated in the present work, all from western Maine, are both trioctahedral micas in the phlogopite-annite join and coexisting dioctahedral micas in the muscovite-paragonite join. Detailed petrologic and chemical descriptions, and in particular the compositional changes of metamorphic micas as a function of metamorphic grade, are found in Guidotti...