Nano- to micro-scale decompression products in ultrahigh-pressure phengite: HRTEM and AEM study, and some petrological implications

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ABSTRACT

Samples of phengite-3T, \((K_{0.93}Na_{0.01})(Al_{1.44}Mg_{0.56}Ti_{0.02})(Si_{3.54}Al_{0.46})O_{10}(OH_{1.93}F_{0.07})\), which formed at about 3 GPa and 1000 K in ultrahigh-pressure metamorphic rocks of the Dora-Maira Massif (Western Alps, Italy), were investigated by HRTEM, AEM, EMPA, and SEM. The matrix of phengite-3T, which is almost free of stacking faults, contains single-crystal \(\alpha\)-quartz platelets 100–700 Å thick that are confined by (001) planes of phengite. In the vicinity of quartz, the 30 Å period of the phengite-3T matrix is faulted by short sequences with about 19 Å periodicity, interpreted as talc-2\(M\). The occurrence of these phases is not connected with any defects in the host phengite nor is their spatial distribution homogeneous on the TEM scale. The shape control exerted by phengite on the quartz crystals, the absence of deformation around them, and the nearby presence of an interlayered 19 Å phase, suggest that quartz and talc may have been produced within mica by a reaction of the type:

\[
3 \text{alumino-celadonite} + 2 \text{H}^+ = \text{1 muscovite} + \text{1 talc} + \text{5 quartz} + 2 \text{H}_2\text{O} + 2 \text{K}^+
\]

which leads to a less celadonite-rich phengite during decompression, after the rock had left the coesite stability field. In addition, examination by optical microscopy along [001] of “thick” sections of the Dora-Maira phengite and of phengite samples from other high-pressure terranes (Monte Mucrone and Sesia Zone in the Italian Western Alps, Dabie Mountains in central China), revealed the presence of micrometer-wide, amoeboid platelets of quartz interlayered at various depths parallel to (001) of micas. In spite of the different observation scale, these are interpreted as the same reaction product as identified by HRTEM. These new observations show that high-pressure white micas may not be homogeneous and should be examined more carefully. Some consequences for thermobarometry of such heterogeneity and intracrystalline re-organization during decompression are considered; they depend on the resolution of the analytical method employed. Implications for thermochronometry still have to be evaluated.

INTRODUCTION

White micas are among the most important sheet silicates in metamorphic rocks. Four homogeneous polytypes (Nespolo et al. 1997) (2\(M_1\), 1\(M\), 3\(T\), and 2\(M_2\)) are known for natural muscovite and phengite (Bailey 1984), but only the 2\(M_1\) and 3\(T\) polytypes are common. Some workers have suggested that the polytypes form under different pressure-temperature (P-T) regimes (Amisano-Canesi et al. 1994; Sassi et al. 1994; Pavese et al. 1997, 1999a, 1999b). The reasons for a difference in the stability of 2\(M_1\) and 3\(T\) polytypes may be related to cation ordering (Sassi et al. 1994). The increase in cation ordering from 2\(M_1\) to 3\(T\) polytypes at high P/T ratios is allowed by the presence of two symmetrically independent octahedral sites (M2 and M3) in 3\(T\) structures, instead of one in the 2\(M_1\) structure (Amisano-Canesi et al. 1994; Ferraris et al. 1995; Pavese et al. 1997).

The \[^{41}\text{Al}^{46}\text{Al} = ^{41}\text{Si}^{46}\text{Mg}\] substitution results in large compositional variations between the muscovite and alumino-celadonite end-members, reflected in the ideal phengite formula \(K(Al_{2–x}Mg_x)(Si_{3+x}Al_{1–x})O_{10}(OH)_2\), \((0 \leq x \leq 1)\), ignoring a minor trioctahedral component. These variations are P-T-X dependent in low-variance systems (Massonne and Schreyer 1986, 1989; Essene 1989), and are important in natural white micas in terms of their extent and petrological significance. Indeed, chemically zoned crystals or chemically and/or polytropically distinct mica generations, which may coexist in a given rock, record changes of P and T through time and indicate the absence of mica re-equilibration (Guidotti and Sassi 1998).

Phengite from the ultrahigh-pressure (UHP) metamorphic rocks of the Dora-Maira massif, Western Alps, has attracted petrological and crystallographic interest because of its uncommon formation conditions, crystal perfection, high Si content, and 3\(T\) polytypism. However, neutron diffraction, X-ray diffraction, and electron microprobe data on these phengite-3\(T\) (Pavese et al. 1997, 1999b; Amisano-Canesi et al. 1994; Lanfranco et al. 1997) suggested the presence of quartz and...