

The octahedral sheet of metamorphic $2M_1$ -phengites: A combined EMPA and AXANES study

**GIANNANTONIO CIBIN,^{1,2,*} GIANFELICE CINQUE,^{2,3} AUGUSTO MARCELLI,² ANNIBALE MOTTANA,^{1,2,†}
AND RAFFAELE SASSI⁴**

¹Dipartimento di Scienze Geologiche, Università degli Studi Roma Tre, Largo San Leonardo Murialdo 1, 00146 Roma, Italy

²Laboratori Nazionali di Frascati, Istituto Nazionale di Fisica Nucleare, Via Enrico Fermi 40, 00030 Frascati RM, Italy

³Diamond Light Source, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire OX11 0QX, U.K.

⁴Dipartimento di Mineralogia e Petrologia, Università degli Studi di Padova, Corso Giuseppe Garibaldi 37, 35122 Padova, Italy

ABSTRACT

Two types of metamorphic phengites are known: one is linked to high pressure and is $3T$; the other is $2M_1$, and its composition is linked to rock-compositional constraints. This work investigates the octahedral sheet crystal-chemical differences between the two phengite types. Seven dioctahedral micas were studied: (1) one $3T$ phengite from an ultrahigh-pressure metagranitoid in the Dora Maira massif, Italy ($P \sim 4.3$ GPa, $T \sim 730$ °C); (2) five $2M_1$ phengites from medium- P orthogneisses in the Eastern Alps metamorphic basement, Italy ($P \leq 0.7$ GPa, $T \sim 500$ – 600 °C); and (3) one $2M_1$ ferroan muscovite from pegmatite in Antarctica ($P \leq 0.2$ GPa, $T \sim 500$ °C). All micas display significant extents of celadonite substitution. In particular, the $2M_1$ -phengite formulae (calculated on the basis of 11 O) have $0.68 < {}^{\text{IV}}\text{Al} < 0.82$ atoms per formula unit (apfu); octahedral atoms are dominated by Al (1.6–1.8 apfu), with minor and variable Fe (0.20–0.35 apfu) and Mg (0.05–0.17 apfu), and very minor Ti, Mn, and Cr. Total octahedral occupancies are slightly above 2.00 apfu, i.e., there seems to be partial occupancy of the third M site. For all micas, we recorded XAFS spectra on mosaics of carefully separated flakes oriented flat on a plastic support that could be rotated so as to account for the polarization of the synchrotron radiation beam, and we processed them on the basis of the AXANES theory. Spectra show angle-dependent absorption variations for Al and Fe, which can be deconvoluted and fitted by dichroic effects. Pre-edges consistently show most Fe to be Fe^{3+} and little angle-dependent intensity variations. The $2M_1$ -ferroan muscovite from Antarctica displays the same AXANES behavior as $2M_1$ -phengites. By contrast, the ultrahigh-pressure $3T$ -phengite from Dora Maira (having ${}^{\text{IV}}\text{Al} = 0.42$ apfu, and Al and Mg as the dominant octahedral constituents) has XAFS spectra that differ significantly. Not only is the ${}^{\text{IV}}\text{Al}$ feature strongly reduced, in agreement with the increased Si content, but also Fe XAFS spectra show one broad feature only, indicating that all Fe is Fe^{2+} in a fully disordered distribution with no angle-dependent variations. We conclude that this $3T$ -phengite is actually contaminated by exsolved Fe-bearing pyrope platelets, which cannot be resolved under SEM examination; by contrast, the $2M_1$ -phengites, unrelated to high-pressure, suggest Al/Fe³⁺ order over the M1 and (M2, M3) sites, as also does the $2M_1$ pegmatitic muscovite.

Keywords: Muscovite, aluminoceladonite, celadonite, white micas, dioctahedral micas, XAFS, XANES, geothermobarometry