



Quantifying the stabilities of biopyrboles in Nature

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Quantification of the stability relations of rock-forming minerals is fundamental to understanding their role in geological processes, yet very few experimental studies of amphibole stability have been made. This lack of information is mainly due to the difficulty of finding suitable natural samples (compositional complexity, zoning) and significant problems in producing suitable synthetic analogues. Furthermore, it is well-known that some amphiboles contain abundant chain-width ("polysomatic") defects, most commonly triple-chains. In some cases these defect-rich amphiboles occur in retrogressed ultramafic rocks, but there is also strong petrographic evidence that triple-chain silicate can also grow from amphibole as a prograde phase [1]. Furthermore, a recent study of the synthetic triple-chain silicate $\text{Na}_2\text{Mg}_4\text{Si}_6\text{O}_{16}(\text{OH})_2$ [2] has demonstrated that triple-chain silicate can be a stable phase, rather than always being a metastable intermediate, as is often assumed. Here, we focus on quantifying the high-P and high-T behaviour of a major amphibole end-member, anthophyllite, ideally $\text{Mg}_7\text{Si}_8\text{O}_{22}(\text{OH})_2$, which is a significant component of amphiboles from low-Ca amphibolites and ultramafic rocks. The synthesis of anthophyllite, is plagued with unsurmountable problems associated with the metastable growth and long-term persistence of talc and fine-scale lamellar intergrowths of intermediate polysomes. As a result, it is necessary to calculate stability relations using measured enthalpy, heat-capacity, compressibility and expansivity data. We discuss the phase relations of anthophyllite and triple-chain silicate (jimthompsonite/clinojimthompsonite) in ultramafic rocks at deep-crustal and upper-mantle conditions, and indicate the key issues involved in determining stability vs metastability, focusing on key H_2O -conserving reactions that relate different biopyrboles. For example, the high-P stability of anthophyllite is defined by anthophyllite = enstatite + talc [3,4]. Attempts to locate this reaction by direct experiment suffer from the occurrence of mixed-polysome intermediate states, so that the attainment of equilibrium cannot be demonstrated conclusively. Consequently, the P-T locus of this reaction must be calculated. As part of a wider study of the stability and thermochemistry of geologically-important amphiboles and triple-chain silicates, we report the determination of the compressibility, expansivity and high-P,T behaviour ($\text{P}_{\text{max}} = 7 \text{ GPa}$, $\text{T}_{\text{max}} = 973 \text{ K}$) of a natural anthophyllite (orthorhombic, Pnma) of nearly end-member composition $\text{ANa}_0.03 \text{ B}(\text{Na}_0.04\text{Mg}_1.30\text{Mn}_0.57\text{Ca}_0.09) \text{ C}(\text{Mg}_4.96\text{Fe}_0.02\text{Al}_0.02) \text{ T}(\text{Si}_7.99\text{Al}_0.01) \text{ O}_{22} \text{ W}(\text{OH})_2$ from Talcville, New York, USA. The studies indicate the quality of data that can be obtained and how they help to constrain the stability of anthophyllite in ultramafic rocks and low-Ca amphibolites to P-T conditions of the lower crust and upper mantle.

References cited: [1] Droop (1994), Mineral Mag 58, 1-20; [2] Ams et al. (2009), Am Mineral 94, 1242-1254; [3] Chernosky et al. (1985a) Am Mineral 70, 223-236; [4] Chernosky et al. (1985b) Am Mineral 70, 237-248.