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# Coexisting pseudobrookite, ilmenite, and titanomagnetite in hornblende andesite of the Coleman Pinnacle flow, Mount Baker, Washington: Evidence for a highly oxidized arc magma

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## Abstract

Pseudobrookite microphenocrysts occur in cognate inclusions in the ~305 ka Coleman Pinnacle hornblende andesite flow from the Mount Baker volcanic field, Washington. Pseudobrookites are associated with hornblende phenocrysts and glomerophyric clusters of orthopyroxene, clinopyroxene, plagioclase, ilmenite, titanomagnetite, apatite, and zircon in a matrix of fresh rhyolitic glass. Grains of pseudobrookite are rimmed by or intergrown with ilmenite. These textures are analogous to those observed between armalcolite and ilmenite in high-Ti lunar basalts. In a unique occurrence, pseudobrookite, and titanomagnetite form a symplectitic intergrowth surrounding a core of ilmenite. Mass balance calculations show that the pseudobrookite + titanomagnetite assemblage is not an isochemical decomposition of ilmenite. In the $TiO_2$-FeO-$Fe_2O_3$ system (Mg-free), pseudobrookite and titanomagnetite solid solutions do not coexist. However, all three Fe-Ti oxides in the symplectitic assemblage contain significant amounts of Mg. In the $TiO_2$-MgO-FeO-$FeO_{1.5}$ system at high oxygen fugacities, the Mg-rich pseudobrookite + titanomagnetite assemblage is stable relative to the conjugate pair of Mg-bearing ilmenite solid solutions. At lower $f_{O_2}$, $Fe^{2+}$ increases, Mg/(Mg+$Fe^{2+}$) (Mg no.) decreases and the conjugate ilmenite pair becomes the stable assemblage at Mg no. < ~0.6. The compositions of coexisting ilmenite + titanomagnetite pairs in the Coleman Pinnacle andesite yield $T$ = 900–1000 °C and $f_{O_2}$ = NNO + 1.5 to + 1.75, one of the highest redox states on record for arc magmas. The calculated $f_{O_2}$ range is consistent with the composition of the ilmenite in equilibrium with pseudobrookite ± rutile and with $Fe^{3+}$-rich cores in hornblende phenocrysts.

**Keywords:** Pseudobrookite, ilmenite, titanomagnetite, oxygen fugacity, andesite, Mount Baker