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 symplectic intergrowth surrounding a core of ilmenite. Mass balance calculations show that the pseudobrookite + titanomagnetite assemblage is not an isochemical decomposition of ilmenite. In the TiO2-FeO-Fe2O3 system (Mg-free), pseudobrookite and titanomagnetite solid solutions do not coexist. However, all three Fe-Ti oxides in the symplectic assemblage contain significant amounts of Mg. In the TiO2-MgO-FeO-Fe2O3 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 fO2, Fe2+ increases, Mg/(Mg+Fe2+) (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 fO2 = NNO + 1.5 to + 1.75, one of the highest redox states on record for arc magmas. The calculated fO2 range is consistent with the composition of the ilmenite in equilibrium with pseudobrookite ± rutile and with Fe3+-rich cores in hornblende phenocrysts.

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

INTRODUCTION

The compositions of coexisting ilmenite–hematite and ulvöspinel–magnetite solid solutions, hereafter referred to as ilmenite and titanomagnetite, respectively, have been widely used as a geothermometer/oxybarometer in magmatic systems following the initial calibration of Buddington and Lindsley (1964). The third solid solution in the TiO2-MgO-FeO-Fe2O3 system is pseudobrookite, which has an ideal end-member formula of Fe3+TiO2 and encompasses the compositional range extending to Fe2+Ti2O3 and Fe3MgTi2O10 (Bowles 1988). For brevity in some figures and tables, we refer to Fe2+Ti2O3 as “ferropseudobrookite” and Mg3Ti2O7 as “karrooite” (following Lindsley 1991) although we recognize that these names have been discredited (Bowles 1988). Compositions extending further toward Mg3Ti2O7 are known as armalcolite, which has the ideal formula Fe2+Mg3Ti2O7. Pseudobrookites commonly also contain minor amounts of aluminum and manganese.

Pseudobrookite is much less common in terrestrial volcanic rocks than ilmenite and titanomagnetite. Microphenocrysts relatively rich in the Fe3Ti2O7 end-member occur in the early phases of the 1955 basalt eruption along the lower east rift zone of Kilauea volcano (Anderson and Wright 1972). The pseudobrookite grains are rimmed by ilmenite and embedded in a glassy matrix, indicating a reaction relationship between pseudobrookite and melt. Titanomagnetite phenocrysts also occur in the 1955 basalt. Pseudobrookite coexisting with titanomagnetite has also been reported in alkaline basalts from Gough Island (Le Roex 1985), in tinguaites and syenite dikes at Katzenbuckel volcano, Germany (Stähle and Koch 2003), in ultrapotassic basalts and basalts from the central Sierra Nevada (van Kooten 1980) and in an alkaline gabbro from Kauai, Hawaii (Johnston and Stout 1984). Insofar as textural details are not provided for the Gough and Sierra Nevada occurrences, it cannot be unequivocally established that they represent equilibrium assemblages. The Hawaiian occurrence shows highly acicular pseudobrookite (referred to as “kennedyite” by Johnston and Stout 1984) associated with euhedral magnesioferrite, euhedral salite, and acicular “swallow-tail” olivine in an oligoclase-rich matrix. Very high Fe3+ contents in all ferromagnesian phases attest to the extremely oxidized nature of the parent magma. At the Katzenbuckel locality, primary pseudobrookite in the tinguaita dike is partly replaced by ilmenite or by fine myrmekitic intergrowths of hematite, ilmenite, and magnetite (Stähle and Koch 2003). Pseudobrookite and titanomagnetite coexisting in a syenite vein is interpreted by Stähle and Koch (2003) as a secondary assemblage replacing primary ilmenite.