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Niobian rutile from the McGuire granitic pegmatite, Park County, Colorado: Solid solution, exsolution, and oxidation

PETR ČERNÝ ,[1,*] RON CHAPMAN,[1] WILLIAM B. SIMMONS,[2] AND LEONARD E. CHACKOWSKY[1]

[1] Department of Geological Sciences, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada
[2] Department of Geology and Geophysics, University of New Orleans, New Orleans, Louisiana 70148-2850, U.S.A.

ABSTRACT

Coarse crystals of niobian rutile occur in the hydrothermally altered core-margin zone of the McGuire granitic pegmatite, Park County, Colorado, associated with potassium feldspar, quartz, biotite, ilmenite, and monazite-(Ce). Primary homogeneous niobian rutile, with $Fe^{3+} \cong Fe^{2+}$ and a small excess of (Fe,Mn) over the amount required to compensate the incorporation of (Nb,Ta,W), underwent three stages of exsolution. Primary homogeneous niobian rutile exsolved a fine trellis-like pattern of minor lamellar Nb-bearing pseudorutile I. Most of this phase was broken down to pseudomorphs consisting of microgranular Nb-rich pseudorutile II imbedded in niobian-ferrian "ferropseudobrookite." Continued exsolution in niobian rutile and reconstitution of the early exsolution products generated (Fe,Nb)-depleted, microgranular niobian rutile, titanian ferrocolumbite, and minor ilmenite. These three phases did not attain chemical equilibrium but may represent a stable phase assemblage. All these processes seem to have maintained charge balance, suggesting a closed system. Subsequent to the three stages of exsolution, extensive oxidation converted the mineral assemblages to anatase + hematite + titanian-tungstenian ixiolite; primary ilmenite was oxidized into an anatase + hematite intergrowth. In both cases, the hematite component was almost completely leached out, leaving highly porous aggregates of the other phases. The exsolution products in niobian rutile are controlled by the (Fe+Mn+Sc)/(Nb+Ta+W) ratio of the primary phase and by its $(Fe^{3+}+Sc)/(Fe^{2+}+Mn)$ ratio. Dominance of divalent A-cations facilitates exsolution of titanian ferro- to manganocolumbite or titanian ixiolite, whereas dominant trivalent cations lead to exsolution of titanian $(Fe,Sc)^{3+}NbO_4$ phases. Excess (Fe,Mn) over the columbite-type $Fe^{2+}Nb_2$ stoichiometry causes exsolution of (Fe,Mn)-rich Nb,Ta-oxide minerals or complementary (Fe,Mn,Ti) phases.