American Mineralogist, Volume 108, pages 277–296, 2023

Paragenesis and precipitation stages of Nb-Ta-oxide minerals in phosphorus-rich rare-element pegmatites (Buranga dike, Rwanda)

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Abstract

Nb-Ta-oxide minerals (NTO) are commonly associated with rare-element pegmatites where they are interpreted to precipitate at magmatic to magmatic-hydrothermal conditions. Although high-temperature experiments show that phosphorus and other fluxing elements (e.g., Li, B, F) can affect the saturation of NTO in pegmatitic systems, it is still uncertain how NTO saturation occurs in natural, flux-rich pegmatitic melts and whether crystallization occurs at multiple stages during magmatic or subsolidus conditions. The lithium-cesium-tantalum (LCT) family P-rich Buranga granitic pegmatite (western Rwanda) is used as a type locality to address this question. NTO mineralization in the Buranga dike occurs in two mineralogical units: in mineralogically complex phosphatic nodules, and in albitized parts. In the phosphatic nodules, Fe-Nb-Ta-rich rutile and columbite-group minerals (CGM) are observed, while in the albitized parts, only CGM is found. Fe-Nb-Ta-rich rutile precipitates at the magmatic stage along with early primary phosphates (i.e., F-rich montebrasite, wyllieite, and fluor-apatite). Conversely, CGM mineralization occurs at the magmatic-hydrothermal stage in association with replacement phosphates like bertossaite, after primary minerals (i.e., rutile, wyllieite, rosemaryite, and trolleite) are destabilized due to crystal-melt-fluid interactions. NTO textures and chemical zoning show uneven evolution from core to rim and are related to localized alteration phenomena of the surrounding minerals. This indicates that local processes and element transfers are more important than dike-scale fractionation processes for NTO mineralization in P-rich granitic pegmatites. The restricted availability of Fe and Mn in the system, which is related to the competition between phosphate and oxide minerals, is identified as the main control on the CGM mineralization in the Buranga dike. CGM precipitation is only possible during the magmatic-hydrothermal stage when Fe and Mn are leached from the primary phosphates and remobilized to the Nb-Ta-bearing residual melt by the exsolved fluid.

Keywords: Nb-Ta mineralization, granitic pegmatite, pegmatitic phosphates, mineral paragenesis, Raman mapping, Buranga pegmatite