Magmatic vs. hydrothermal origins for zircon associated with tantalum mineralization in the Tanco pegmatite, Manitoba, Canada

MARIEKE VAN LICHTERVELDE,1,2,* FRANK MELCHER,1 AND RICHARD WIRTH3

1Bundesanstalt für Geowissenschaften und Rohstoffe, Stilleweg 2, D-30655 Hannover, Germany
2Institut für Mineralogie, Universität Hannover, Callinstrasse 3, D-30167 Hannover, Germany
3GeoForschungsZentrum Potsdam, Department 4, Telegrafenberg, D-14482 Potsdam, Germany

ABSTRACT

Complex textures in zircon associated with Ta oxides have been used to assess the processes at the origin of zircon crystallization and associated Ta mineralization in pegmatites, in particular the role of magmatic vs. hydrothermal processes. The Tanco pegmatite is used as an example because its zircon is devoid of post-magmatic alteration and its petrogenesis is well constrained. Zircon in primary units is metamict with high U-Pb-Th contents. By contrast, in secondary assemblages affected by late-magmatic micaceous alteration, zircon is devoid of radiogenic elements, but it may contain abundant Ta2O5 (up to 4.7 wt%). The incorporation of Ta into zircon may occur through coupled substitution mechanisms involving other minor elements such as P, Al, Mn, or Li. The presence of Ta accounts for the distorted structures in the Ta-rich zircon, as revealed in high-resolution TEM images. Four zircon types occur sequentially in single zircon crystals, which permits a new model for zircon growth and evolution in rare element pegmatites to be advanced: (1) zircon (Z1) is Ta-rich and crystallized possibly before discrete Ta phases; (2) Z1 was overgrown by regularly zoned zircon Z2 and Z3, which show lower Ta and extreme Zr/Hf fractionation (HfO2 up to 38.9 wt%), suggesting crystallization from a highly fractionated melt, possibly at the onset of Ta mineralization; and (3) close to the solidus, the aqueous fluid at the origin of micaceous alteration corroded the distorted structure of Z1, and a low-Ta zircon (Z4) replaced Z1 by dissolution-reprecipitation, whereas Z2 and Z3 resisted this alteration. Tantalum was no longer stable in the zircon structure and crystallized as Ta-oxide inclusions in the reequilibrated zircon (Z4).

Keywords: Zircon, tantalum mineralization, hydrothermal alteration, pegmatite, Tanco

INTRODUCTION

The contribution of magmatic vs. hydrothermal (or some continuum between these two) processes in the formation of rare-element granitic pegmatites is still unclear, and the debate has been revived by the need to understand the processes that control associated rare-metal mineralization. The nature of fluids that operate in the late stages of pegmatite formation is important to constrain the formation of Ta ores, because high-grade Ta mineralization is commonly associated with late-stage pegmatic units. Early pegmatite models (e.g., Jahns and Burnham 1969; Jahns 1982) proposed that aqueous fluids coexisted with pegmatic melt during most of the pegmatite formation; however, subsequent experimental work (e.g., London et al. 1989) showed that the presence of an aqueous fluid was not necessary for the formation of typical pegmatitic features such as large crystal size, textural and chemical heterogeneities, metasomatic units, and metal concentration. In particular, elevated Ta concentrations in pegmatites may be obtained by high degrees of fractionation of late-stage pegmatic melts (Linnen and Cuney 2005; Černý et al. 2005), rather than concentration in a fluid, as Ta has been shown to be relatively immobile in aqueous systems (Cuney et al. 1992; Chevychelov et al. 2005).

Zircon is a common accessory phase in granitic rocks, and its association with Nb-Ta minerals has been reported in several rare-element granites and pegmatites (e.g., Fontan et al. 1980; Wang et al. 1996). In such occurrences, the Hf content of zircon can attain very high values (for example, up to 35.2 wt% HfO2 in the Koktokay no. 3 granitic pegmatite in China [Zhang et al. 2004]), and a close positive correlation between the Hf/(Hf + Zr) ratio of zircon and the Ta/(Ta + Nb) ratio of associated Ta oxides has been observed in many cases (e.g., Wang et al. 1996). Such evolutionary trends are commonly used to predict the degree of fractionation within pegmatite bodies (Černý et al. 1985). However, the textural features of zircon or Ta oxides have rarely been used to decipher the internal evolution of rare-element pegmatites (e.g., Van Lichtervelde et al. 2007). The goal of the present study was not only to gain information on the formation and evolution of zircon in rare-element pegmatites, but also to relate textural features in zircon to pegmatite evolution. The Tanco pegmatite was chosen as an example for this study because it is almost devoid of post-emplacement deformation, low-temperature alteration, and weathering effects (Černý 2005), and its petrogenesis is well constrained (see Černý 2005 and the references therein).

The Tanco pegmatite is one of the major Ta deposits in the