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Solubility of monazite and cheralite in highly fluxed peralkaline to peraluminous pegmatitic melts

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Granitic pegmatites are known to host rare-elements described as strategic metals as a result of their critical role to a country's economy or defence. Along with REEs, Ta, Nb, Be, Sb, Li, Sc and Zr, uranium is another strategic metal which is mostly hosted by abyssal-class pegmatites (following the classification of Cerny and Ercit, [1]). The parent granites represent some of the most extremely fractionated melts on the earth [2], with compositions ranging from peralkaline to peraluminous. Several uranium-rich occurrences belonging to the granite-related ore deposits have been reported in literature. For example, the well-known Rössing deposit in Namibia is characterized by leucocratic dykes of "alaskite" granite and pegmatite mineralized in uraninite, UO_2 [3]. The high uranium content of these magma is related to several parameters including, among others, temperature, melt composition, water content,as well as volatile components like F and P, that act as fluxing agents.

Few experimental studies have described the behavior of the U-Th elements in aluminosilicate melts [4, 5, 6]. The role of this study is to provide solubility data for monazite-cheralite solid solution ($REE[PO_4]$-$Ca(Th,U)[PO_4]_2$) in the presence of Li-, P- and F-components in granitic to pegmatitic melts. The composition of these melts varies in term of aluminium saturation index (ASI_{Li}=Al/[Na+K+Li]) from 0.83 (peralkaline) to 1.17 (peraluminous), corresponding to the common compositions reported in natural granitic pegmatites. We present results of dissolution experiments conducted at 800 °C and 200 MPa under water-saturated conditions. The melts and starting minerals (monazite/cheralite with variable Th/U ratio) are synthetic.

The highest amounts of U (up to 1300 ppm) and Th (up to 700 ppm) dissolved in the glass occurs for peralkaline composition (low ASI). However, melt composition is probably not the only parameter that controls U and Th solubility. In the set of experiments, the increase in alkalinity is coupled with the increase of flux content, so it is difficult to clearly conclude on the dominant parameter. In these peralkaline glasses, dissolution of cheralite is followed by the crystallization of new apatite grains. In contrast, in peraluminous glasses, Th-bearing uraninite grains have crystalized. The crystallization of uraninite seems to be controlled by Th/U ratio of the parent dissolved mineral: Th/U ratios greater than 1 are required to crystallize uraninite in peraluminous melt (ASI≥1.15). It is interesting to emphasize that these Th-bearing uraninite with a ThO_2 content ranging from 3.5 to 9.0 wt.% share the same composition as natural magmatic uraninites hosted by metaluminous (e.g. Rössing deposit, Namibia) to peraluminous (e.g. Tanco deposit, Canada) pegmatites.

Providing solubility data for U-Th-bearing minerals is a key parameter to understand the behavior of these elements in granitic-pegmatitic systems. Moreover, magmatic U-Th-bearing minerals may represent uranium primary deposits (e.g. Rössing deposit, Namibia) as well as a source for late hydrothermal deposits (e.g. Beauvoir deposit, France).

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