Alkali pyroxene as monitor of concentration and fractionation processes of Rare Earth Elements in peralkaline granites

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Peralkaline granites and associated pegmatites are notoriously enriched in rare metals, i.e. the REE and high-field-strength elements (HFSE), and as such represent potential economic resources. It is now equally accepted that the differentiation processes leading to peralkaline melt production are mainly responsible for concentrating the rare metals. Nevertheless, there exists compelling evidence for a significant role of hydrothermal fluids. To this day, however, it is still unclear how and when light REE - heavy REE fractionation occurs in these rocks. We investigated the involvement of hydrothermal fluids in these processes and their potential role in REE remobilization and fractionation, by studying peralkaline granites and pegmatites from six alkaline complexes worldwide, namely, Manongarivo and Ambohimirahavavy in Madagascar, Evisa in Corsica, Khan Bogd in Mongolia, Strange Lake in Canada, and Amis in Namibia. Alkali pyroxene is a perfect candidate to monitor REE concentration and fractionation processes as it is common to all complexes and contains significant amounts of REE and HFSE. Our results show that alkali pyroxene is invariably zoned in peralkaline pegmatites, with a core enriched in REE, Zr, Hf and Sn. This decreasing concentration from core to rim is more important for light-REE than for heavy-REE (e.g. respectively 44 and 23 % loss for Evisa, 85 and 19 % loss for Amis). The close association of zoned pyroxene with secondary rare-metal bearing minerals that typically form pseudomorphs after primary phases, points to a hydrothermal origin for the rims. We thus propose that late-stage exsolution of a hydrothermal fluid is a common process in peralkaline pegmatites and that this process has a strong potential for transporting and fractionating at least some of the rare metals.