Tracing the REE composition of an evolving peralkaline granitic magma via the composition of arfvedsonite

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There are a number of peralkaline granitic plutons, which show significant enrichment in the REE and, in some cases, host REE deposits; the grades of the deposits represent the final enrichment in the REE. Thus, it is important to understand how this enrichment occurs and by which processes, in order to develop tools for discovering other similar deposits. The best way to reconstruct the REE composition of an evolving magma is by analysing melt inclusions, i.e., the tiny samples of magma trapped at different stages of its evolution. Such inclusions, however, are rarely preserved and difficult to analyse. Another way to reconstruct the REE composition of an evolving magma is to analyse the REE composition of the minerals crystallising from this magma at different stages in its evolution. This, however, requires that the REE mineral-melt partition coefficients be known. Here we present a model for the calculation of arfvedsonite-melt REE partition coefficients, based on data from the Strange Lake pluton (Canada). The model employs the lattice strain theory, which derives mineral-melt partition coefficients from the values of the ideal partition coefficient (D_0), the ideal radius (r_0) and the elastic response (E_M) of the mineral. There are two sites in arfvedsonite into which the REE partition, namely the M4 site, which is preferred by the light REE and the M2 site, which is preferred by the heavy REE. Partition coefficients for both sites were modelled. Significantly, values of D_0, r_0 and E_M for the M4 site vary linearly with the Ca content of the arfvedsonite, whereas for the M2 site these parameters vary linearly with the temperature of arfvedsonite crystallisation. Using these two relationships, a set of equations was derived, which enables the calculation of arfvedsonite-melt REE partition coefficients for any arfvedsonite for which the Ca content and crystallisation temperature are known. This model was tested on a peralkaline granitic pegmatite from the Amis complex (Namibia), for which data on the composition of the amphibole and corresponding magma (melt inclusions) have been reported. The model successfully predicts the concentrations of the various REE in the Amis magma, thereby providing confidence that it can be used to trace the REE content of evolving granitic magmas in other plutons.