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Peralkaline Igneous Complexes: The Frontier of REE Deposits

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Peralkaline igneous complexes have been attracting interest over the last few years as they can host large deposits of rare-earth elements (REE), Ta, Nb and Zr. All of these elements are in high demand in technological industries, however the scarcity of economically viable deposits means they are generally considered to be 'critical metals'. The Ilímaussaq Complex, south Greenland is one of the best examples to study these deposits as it contains some of the most evolved igneous rocks in the world with excellent exposure. One of the places these critical metals are concentrated is in the Kakortokite Layered Series, on which our work focuses, where they are hosted within eudialyte.

This series comprises 29 repetitive tripartite units, numbered -11 to +17 [1] relative to the Unit 0 marker horizon, which has one of the richest concentrations of eudialyte. Each unit is subdivided into layers through modal mineralogy: the lower layer is arfvedsonite-rich black kakortokite, the middle layer is eudialyte-rich red kakortokite and the upper layer is nepheline- and alkali feldspar-rich white kakortokite. Despite much work on the development of the Kakortokite Layered Series, no consensus on the physico-chemical processes that led to the formation of the rhythmic layering has been forthcoming, although most hypotheses suggest gravitational sorting and settling contributed to layer formation. We present a detailed petrographic, quantitative textural and mineral chemical study of samples across Unit 0, which provide an insight into the magmatic processes involved in the development of the unit.

The sharp boundary from Unit -1 to Unit 0 can be traced for kilometres across the entire complex, indicating that large-scale magma chamber processes are responsible for development of the layering and concentration of the critical metals. The data from this study indicate that multiple processes of crystallisation were in operation during the development of the layering, including *in situ* crystallisation, which we suggest was most effective during formation of the black and red kakortokites. Gravitational settling cannot be discounted, but is suggested to have been most effective during the development of the white kakortokite layer. The order of crystallisation is inferred to have been controlled by variations in the concentration of volatile elements. During development of the black kakortokite this would have allowed for initial formation of arfvedsonite at high concentrations of volatiles [2]. Above this layer eudialyte crystallised concentrating the ore elements in the red kakortokite. Decreasing volatile concentrations would allow for crystallisation of alkali feldspar and nepheline to form the top layer of white kakortokite. Chemical variations in Fe_{TOT}/Mn of eudialyte were additionally noted between the 3 layers of Unit 0, indicating they developed from an evolving magma. We use this in combination with the petrography to infer that Unit 0 formed in response to a replenishment event in an open-system magma chamber

References:

[1] Bohse *et al.* (1971). Rapport Grønlands Geologiske Undergesølgelse, Vol. 36, 43 p.
[2] Sørensen (1969). Lithos, Vol. 2, pp. 261-283