Margins of the North Atlantic Craton: the world's most prospective zone for the critical rare earth elements?

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Seven years after the "rare earth element crisis" of 2009, the rare earth elements (REE) remain among the most critical of metals, with supply concentrated in China. Despite intense global exploration efforts, it has proved difficult for mining projects outside China to successfully commence production of the REE, due to a complex set of financial, environmental and technical concerns. REE prices have fallen, but demand remains strong – particularly for the most critical REE used in high-strength magnets that are essential to modern technology and green energy applications, notably Nd, Dy and Pr. Phosphors also represent an important market, using Eu, Y and Tb.

Worldwide, over 50% of all identified REE resources are associated with carbonatite complexes (Weng et al, 2015). In these complexes, the ore minerals are typically bastnäsite or monazite, which are highly enriched in the light REE such as La and Ce, but contain lower contents of the heavy REE such as Dy and Tb. Much current research focusses on development of processing methods for REE ore minerals such as eudialyte and apatite from which the REE have never been commercially extracted. Importantly, these minerals typically contain higher contents of the heavy REE relative to the light REE.

Eudialyte is found in very highly peralkaline (agpaitic) igneous intrusions. The largest examples occur close to the margins of the North Atlantic Craton: in the Mesoproterozoic Gardar Province of southern Greenland, and in the Devonian Kola Province in Russia. In the Kola Province, small quantities of REE are already produced from loparite in the Lovozero Complex, which is also eudialyte-rich. Apatite is mined in the Khibiny Complex, but REE are currently not extracted as part of this process. In the Gardar Province, the Ílimaussaq Complex hosts two major REE exploration projects, Kringlerne and Kvanefjeld. In Europe, the only other significant known agpaitic intrusion is at Norra Kärr, in central Sweden, which is also the subject of REE exploration (Goodenough et al., 2016). On the other side of the Atlantic, the Red Wine Complex in Labrador is agpaitic in composition, and the nearby Strange Lake Complex is a highly peralkaline granite which is currently being explored for the REE. In Québec, close to the margins of the Superior Craton, other agpaitic intrusions include the Mont St Hilaire and Kipawa complexes, the latter representing another REE prospect.

It is remarkable that the areas around the margins of the North Atlantic Craton host by far the largest volumes of agpaitic and highly peralkaline igneous rocks known on Earth, and as a result are also highly prospective for the most critical REE. The explanation for this is likely to lie in the protracted Precambrian history of the craton margins, with repeated episodes of subduction and plume magmatism, which have allowed a wide range of elements to be concentrated in the underlying lithospheric mantle. To understand this potential wealth of REE and other critical metal resources, we need to develop 'big picture' understanding of the geological history of the North Atlantic Craton.

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