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Assessing advanced rare earth element-bearing deposits for industrial demand in the EU

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ABSTRACT

This article examines proposed REE-product volume supply from six advanced rare earth-bearing mineral exploration projects, two of which in Greenland, for REE demand by industrial users in the EU. A methodology is developed which draws on supply chains and published feasibility studies, emphasizing timely data certainty as significant factor of exploration project feasibility. For 2014, our findings for the Greenlandic project exploration proposals reveal that Kvanefjeld would significantly exceed EU demand except for Eu, on which it would undersupply. In contrast, Kringlerne would undersupply on La, Ce and Pr, oversupply on Nd and Y, and on all heavy REE with the exception of Eu. Various disparities between the proposed REE supply from Australian, Canadian and South African projects and EU demand in 2014 are also noted.

1. Introduction

The rare earth elements (REEs) are a group of elements summarized as lanthanides plus scandium (Sc) and yttrium (Y) (IUPAC, 2005). The lanthanides are commonly subdivided into two groups, yet a universally accepted division and definition is absent[1]: Light Rare Earth Elements (LREE) comprising lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), and gadolinium (Gd) metals, and Heavy Rare Earth Elements (HREE) including terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), lutetium (Lu), and yttrium (Y) metals. This division can be used for the benefit of reporting exploration projects by reducing the elements in the LREE category, and raising the comparatively higher valued HREE.

In this article, we exclude Pm, Tm, and Lu, and Sc due to no or insufficiently documented indication of their use in the REE end-use sectors. With the exception of ^{147}Pm, Pm cannot be identified for its very small concentration levels in the entire crust since it generally does not form stable isotopes (Wall, 2014; Chakhmouradian and Wall, 2012, p. 334).

REEs are used mostly in minor portions for key functions in components of downstream end-products that enable, among other: reading, sending and storing energy codified in data (which allows for communicating across distances, lighting spaces, travelling, producing and storing energy, producing images with magnet resonance). Some of these products are made by firms in Europe[2] which are hereafter jointly referred to as European high-tech industry.[3] Since the 2011 REE price peak, this industry is alerted to securing and diversifying REE supplies, including through firms which explore for new REE-bearing deposits. This applies specifically if the respective firm is without reliable access to REE-bearing minerals in China, where most REE-bearing mining and processing occurs today.

Low REE recycling rates (Binnemans and Jones, 2014) and growing

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[1] Other sources (such as Wall, 2014; Chakhmouradian and Wall, 2012) allocate the REE slightly differently, whereby in the different allocations it is mostly the dividing line between the SEG group (Sm–Eu–Gd) that is being contested. Flow sheet designers and process engineers refer to the SEG group as a third, medium REE group, 'on the basis of initial segmentation during the separation process' (Hatch, 2012, p. 341).

[2] A list of firms which are known to use or can be assumed to use REE in their manufacturing, either directly in the processes or as a portion in intermediate product, are listed in Appendix C.

[3] We define 'European high-tech industry' by building on the Eurostat (2015) definition for high-technology products: Industries which partake – directly or indirectly e.g. as component suppliers to – in the manufacturing of products for aerospace, computers office machines, electronics telecommunications, pharmacy, scientific instruments, electrical machinery, chemistry, non-electrical machinery and armament. The intermediate REE-using industrial sectors can also be defined as high-tech industry.

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demand for REE-using high-tech appliances necessitate mining of primary materials which involves changes in the affected environment with effects on, among other, human health (Izatt et al., 2014). At present, public acceptance for mining is comparatively low in densely populated European countries illustrated by a recent considerations of gold mining at Rosia Montana, Romania (Euromines, 2012; Reuters, 2012), and strict environmental regulations raising mining costs. This applies particularly to REE, which commonly occur in minerals associated with radioactive elements such as thorium and uranium.

Greenland appeared on the radar for REE-bearing mineral resources and reserves which are high in HREE as compared to the carbonatite[4] deposits such as Bayan Obo and Mountain Pass, which are or have been mined for LREE (Chakhmouradian and Zaitsev, 2012; Verplanck and Van Gosen, 2011). A total of 13 REE-deposits[5] are currently being explored in Greenland, of which two have reached, by means of a feasibility study, an advanced stage of exploration. These two projects are explored by two Australian registered firms and belong to the Ilímaussaq intrusive complex in South Greenland: Kuannersuit, or Kvanefjeld, and Killavaat Alannguat, or Kringlerne (by Greenlandic and Danish names, respectively). Public discourses on REE supply security and mining in the Arctic, have focused on these projects.

Also scholarly discourse has turned to supply strategies in the REE industry (Massari and Ruberti, 2013; Golev et al., 2014; Machacek and Fold, 2014), most recently with a focus on resilience in material supply chains (Sprecher et al., 2014; Mancheri, 2015) and security implications of rare earths (Kiggins, 2015). References to the rising number of exploration firms (Hatch, 2012; Van Gosen et al., 2014) and to the nature of these firms (Majuri, 2014), which propose to secure REE raw materials supplies (Sprecher et al., 2014) were made.

Guyonnet et al. (2015) provided a detailed material flow analysis with precise accounts of the methodology applied for deriving estimates and assumptions for REE flows. Their comparison of Kvanefjeld and Kringlerne with the Norra Kärr project in Sweden has them suggest Norra Kärr as the most likely European project to enter into REE production. The respective project advancement, measured by the state of data certainty reached by elaboration of a feasibility study, reaches beyond the immediate objective of their article.

However, the state of project advancement presents significant evidence for the progress of a project as it indirectly points to a timeframe for when a project could come into production and for an understanding of which projects are – due to having reached the same reporting status on their project – under competition of providing REE supplies in the timeframe. Further, chemical separation capacity defines whether REE products for industrial use from mined REE minerals can be produced, as highlighted in Guyonnet et al. (2015), jointly with suggestions that REE mining in Europe would stimulate capacity enlargement at the European chemical separation plants of Solvay and Silmet.

We would like to carry the discussion on estimating project feasibility and chemical separation capacity further by emphasizing that none of these occur within a vacuum of a European market, but more so within supply chains that operate across national and regional boundaries. With this background, we discuss how the proposed, advanced production plans for REE deposits in South Greenland and in the rest of the world would meet REE volume demand of EU industries, in the context of global supply-demand dynamics and the Chinese REE market supremacy, given the absence of mining to complete a REE-supply chain within Europe. This is an issue that requires rigorous reflection and discussion since the securing of jobs and production in Europe is tied to access to primary raw materials and the down-stream products, including of REE (Dansk Industry, 2013; European Commission [EC], 2014).

We recognize that regulatory aspects, including obtaining a social licence to mine and process REE-bearing minerals, through stakeholder dialogue, carefully conducted environmental and social impact assessments need to be met alongside access to a technologically advanced and economically operable processing and chemical separation facility. All of these factors will influence decision-making as to whether an exploitation licence is to be granted to mine REE-containing minerals. These factors set aside; this paper contributes to the existing literature on the REE industry by unveiling questions as to the conceptualization of supply issues from a quantitative mineral volume perspective, at the early stage of applications for exploitation licences when mining plans are issued.

2. Methodology

We estimate REE production volumes in t REO from production plans of advanced REE exploration projects to compare these with estimates of REE demand in t REO of different REE-using industrial sectors in the EU. Comparisons with other, similarly advanced projects in other parts of the world are drawn. We apply the term'supply chain' as opposed to'value chain', since we limit our analysis to the account of material flows and exclude distributional effects such as from governance, which explores, in a snapshot, the influence of power exerted in transactions of materials, information and services, and affects material flows.

Our use of 'advanced REE exploration project' refers to the project status of a published feasibility study (FS).[6] Two projects in Greenland and four projects in Australia, Canada and South Africa fulfil these requirements in September 2015, as depicted in Table 3. Kvanefjeld and Kringlerne in South Greenland are illustrated in Fig. 1. These deposits could be argued to have historical-jurisdictional ties to the EU through the Kingdom of Denmark of which Greenland is part, and its Overseas Countries and Territories status (OC) with the EU[7].

2.1. Volume focus of potential REE supply from mining

The supply–demand comparison is conducted from a material (volume of individual REE) perspective, defined by the geology and the ore body, as established in the FS. We also acknowledge that production plans might involve REE-mining as co- and by-product and that mineral supply and demand is dynamic with numerous parameters influencing both supply and demand. However, this study disregards aspects associated with profitability. Our emphasis is on potential new mining projects and their proposed mineral volume capacity.

Exploration projects usually work with REE price forecasts

[4] Carbonatites are defined as igneous rocks that contain more than 50% primary carbonate minerals (Chakhmouradian and Zaitsev, 2012).

[5] Besides Kvanefjeld and Kringlerne, the further currently explored REE-deposits in Greenland are Motzfeldt Sø (associated with the Igaliko Complex), in Westgreenland there are Safartoq, Qaqarssuk, Tikiusaaq, Niaqornakavsak, as well as Bjørnedal and Milne Land in East Greenland (Thrane, Kalvig and Keulen, 2013). Further REE occurrences are located at Ivituut and Grønnedal-Ika, Niaq/Karrat and Kap Simpson (GEUS, 2013). Charles et al. (2013) have provided an overview of the geological potential of REE in Europe and Greenland, however, with limits to their geological data.

[6] This is in contrast to the use of 'advanced rare-earth projects' by Technology Metals Research (TMR), wherein projects are formally defined as a mineral resource or reserve, under the guidelines of a relevant scheme such as NI 43-101, the JORC Code or the SAMREC Code. This includes projects such as those owned by private companies that are not required to produce estimates under these guidelines, but which have reported adherence to the technical report format prescribed by one of these schemes (TMR, 2015).

[7] 'Greenland enjoys a special relationship with the EU through its Overseas Countries and Territories status (OCT). The purpose of the Association of the OCTs with the EC is to promote social and economic development of the OCTs and establish close and economic relations with the EC.' (EC, 2012)