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Editorial

Editorial for Special Issue "Rare Earth Deposits and Challenges of World REE Demand for High-Tech and Green-Tech at the Beginning of the 3rd Millennium"

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Citation: Kynický, J.; Smith, M.; Salvi, S. Editorial for Special Issue "Rare Earth Deposits and Challenges of World REE Demand for High-Tech and Green-Tech at the Beginning of the 3rd Millennium". *Minerals* **2021**, *11*, 378. https://doi.org/10.3390/min11040378

Received: 23 March 2021
Accepted: 29 March 2021
Published: 2 April 2021

We are living in a time of unprecedented technological innovation. This is tied to the relentless development of micro computing and related applications on the one hand, and to the global efforts to develop alternatives to fossil fuels on the other. From smartphones and laptops to electric cars and renewable energy infrastructure, modern technologies use a wider variety of chemical elements than ever before. The consequence is that the demand for primary resources has never been this high. This is particularly true for those known as high-technology metals, which are fundamental in the manufacturing of both high- and green-technologies. Among these, most high field-strength elements, especially the rare earth elements (REE), are essential in many of these new applications and play a particularly strategic role [1,2].

However, despite their necessity, these elements are needed in much smaller quantities than many other metals. As a result, only a few mines are required to meet the demand, leading to a lack of diversity in the production chain, thus increasing the risk of supply of these elements, which is the case for the REE [3,4]. China's increasing demand and dominance as a producer, refiner, and user of REE has raised international concern about the security of the supply of these elements [5,6], leading them to be identified as critical raw materials and strategic resources by many organisations around the world [7–9]. This has led many countries to diversify their sources of supply and initiate work to discover new deposits [10].

The huge growth in research and exploration into REE deposits outside of China ultimately needs to support new REE supply chains if the growing demand for the REE is to be met in the coming decades. Jaroni and co-workers [11] provide this context to a volume otherwise focused on the mineralogy and petrology of REE deposits. They evaluate advanced exploration projects outside of China in terms of required investment, operating cost, and potential revenues, alongside the consideration of risk in each host nation. Global growth in REE supply also needs understanding of the potential distribution of resources on a nation-by-nation basis. A case study of this approach is provided by Al-Ani et al. [12] for the example of Finland. This contribution focuses on the occurrence and mineralogy of carbonatite and granite pegmatite-related REE mineral occurrences, and evaluates them in terms of REE pattern both as a discriminant of deposit type, and as an indicator of how igneous fractionation processes may produce deposits of variable economic REE distribution.

Carbonatites, being amongst the most REE enriched rocks types, coupled with well-established mineral processing streams, remain a core focus of research and exploration efforts for REE resources. Three papers included in this volume all focus on the origin and evolution of REE mineralisation in carbonatites, stressing the importance of both magmatic and hydrothermal effects. Kzolov et al. [13] tracks carbonatite evolution from the magmatic to metasomatic stage in the Petyayan-Vara carbonatites, with a particular focus on the role of sulphate. Chikanda et al. [14] investigate the Kangankunde Complex, in Malawi, making use of novel ($\delta^{56}Fe$) as well as traditional stable isotope systems to track the influence of post-magmatic fluids on REE mineralisation. Jia and Liu [15] present research on the origins of grade variation in the Weishan REE deposits, China, noting the importance of both magmatic evolution and post-magmatic, fracture controlled, fluid flow, in producing high REE grades and in controlling the REE pattern.

Alkaline igneous-related REE mineralisation potentially hosts reserves of the REE as large as or larger than carbonatite-hosted deposits. However, the association of the REE with zirconosilicate minerals in these systems means that there are significant processing issues before they can contribute global supply. The processing issues mean that detailed understanding of mineralogy in these deposits is critical for their future development. No and Park [16] investigate the origin of zircon–allanite–magnetite bands in alkaline rocks intruding the Chungju Unit, South Korea, and develop hypotheses for the role of crystal settling during magmatic crystallisation. Van de Ven and co-workers [17] examine the processes of hydrothermal alteration of eudialyte from the Illimaussaq complex, Greenland, resulting in the formation of HREE and LREE-enriched phases, and discuss the potential for the targeted processing of alteration minerals. Guastoni et al. [18] present the results of studies of Nb–Y–F bearing pegmatites in the Italian Alps, including both their genesis and the detailed crystallography of Nb and REE-bearing phases.

Sedimentary-hosted REE accumulations offer potential for greater ease of extraction, but may be lower in concentration than bedrock hosted deposits, or face issues of radioactivity when derived from the weathering of granitic protoliths. Deady et al. [19] investigated these issues in relation to volcanic derived placers at Aksu Diamas, Turkey, finding that a range of REE and REE-bearing minerals are concentrated with Quaternary sediments derived from weathering of alkaline igneous rocks. Rudmin et al. [20] extend the study of sedimentary deposits to those produced by authigenesis, identifying processes for the formation of REE phosphates in ooidal ironstones and discussing the implications for potential future processing.

This volume closes with a study related to the resource lifecycle of the REE by Romero-Freire et al. [21]. The biogeochemical cycling of the REE is critical in understanding the potential impacts of increased REE production and the resulting waste streams. Their paper presents data on the distribution of the REE in soil, freshwater and plants around the Montviel ferrocarbonatite, Canada, drawing conclusions about the REE bio-geochemical cycle. Such studies, alongside investigations of actinide behaviour, are needed if the understudied environmental impact of REE extraction is to be constrained and controlled.

Overall, the papers in this volume provide a snapshot of REE resources currently under investigation and demonstrate some of the integrating studies that are necessary to understand the influence of geology and mineralogy on the future supply of the REE. Such studies, when coupled to work in resource recovery by recycling, will contribute to the future use of these metals in high technology and low-CO_2 energy production. Further work is required to establish the environmental impact of REE extraction and use which will underpin the legacy of the growth in usage going forward from the early 21st century.

Author Contributions: All authors contributed equally to the preparation of this editorial. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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