Primary rare earth element resources: a decade of research and development

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Since the price spike of 2010 there has been extensive research on geological resources of the rare earth elements (REE). This has occurred in tandem with widespread exploration, largely by junior companies, and has increased our knowledge of the variety of REE deposits worldwide. Despite this, only one new large-scale mine outside China (Mt Weld, Australia) has begun operation with REE as the primary product. This talk will summarise research from our EURARE, SoS RARE and HiTech AlkCarb projects that were designed to inform the next decade of REE resource developments.

Primary rare earth element resources can be broadly divided into those formed by high-temperature (> 150˚C) magmatic-hydrothermal processes, and those formed by low-temperature processes such as weathering at the Earth's surface. Among the high-temperature group, the most important types of REE deposits are associated with alkaline igneous rocks and carbonatites[1]. These have been widely explored since 2010, with new resources being identified on every continent, including Europe[2], but opening of new mines has been limited. The geology of alkaline-carbonatite systems has been investigated during the HiTech AlkCarb project, with the development of new scale-dependent geomodels to guide exploration efforts in these systems. Although we now understand the geology and distribution of REE in these deposits better than ever before, recent research has also illustrated the complexity of their mineralogy, and the metallurgical challenges this creates for mineral processing[3,4]. Processing issues, environmental concerns, and economic factors have contributed to restrict development of new 'hard-rock' REE mines.

Rare earth element resources formed by low-temperature processes include mineral sands, and ion adsorption clays and other weathered deposits. Ion adsorption clays occur where REE-bearing igneous rocks have been weathered in temperate to tropical climates, releasing the REE that are then adsorbed onto the surfaces of clay minerals in the weathered material. Such deposits have been mined in South China for many years, providing the main source of the world's heavy REE; more recently similar resources have been mined in Myanmar. Our SoS RARE project has studied ion adsorption clays in Madagascar and showed that the magmatic-hydrothermal history of the protolith rocks represents the main control on the nature, and REE enrichment levels, of the weathered ore[5]. Mineral sands are increasingly exploited for the REE, which may be mined as co-products of other metals such as titanium. However, in many mineral sands, the REE are hosted in thorium-bearing minerals such as monazite and xenotime, the radioactivity of which may cause problems for transport and processing. As part of the EURARE project, we have studied alternative types of mineral sands, in which the REE may be hosted by less radioactive minerals[6].

Finally, REE can be obtained as by-products of other commodities, particularly aluminium and phosphate. The REE hosted in the red mud waste from alumina production, currently stored in many European countries, could provide much of Europe's REE demand[7]. This is just one example where the REE resources are easily available, but the techno-economic challenges of extraction and processing prevent these resources being developed.

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