

Rare earth elements in Australian uranium deposits

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Abstract. Rare earth elements (REE: La to Lu) are critical for high-technology applications. In Australia, undeveloped REE resources are associated with several deposit types including uranium ores. These include the Olympic Dam Cu-U-Au-Ag deposit and uranium mineralisations in the Yilgarn, Mount Painter, Olary and Mount Isa regions. At the Mary Kathleen uranium mine site, tailings are stored in a purpose-built tailings dam structure, with an estimated 7 Mt of mill tailings carrying approximately 3 wt% total REE oxides. This makes it one of the largest undeveloped REE resources in Australia.

Introduction

Rare earth elements (REE) are becoming increasingly important in high-technology devices such as rechargeable batteries, magnets and catalysts, with demand expected to increase significantly in these areas. Currently, much of the REE supply is effectively restricted to several mining districts in China, which has brought these elements to the headlines and created a critical-metals agenda (Chakhmouradian and Wall 2012; Hatch 2012).

The distribution and concentration of REE into mineral deposits is influenced by various rock-forming processes including enrichment in magmatic or hydrothermal fluids, separation into mineral species and precipitation, and subsequent redistribution and concentration through weathering and other surface processes (Hoatson et al. 2011). Using this evolutionary framework, Walters et al. (2011) proposed that REE deposits can broadly be divided into: (1) primary deposits associated with igneous and hydrothermal processes (e.g. carbonatite, alkaline igneous rocks); and (2) secondary deposits concentrated by sedimentary processes and weathering (e.g. marine and alluvial placers, ion-adsorption clays, laterites). By contrast, the classification of REE deposits by Cassidy et al. (1997; cited by Hoatson et al. 2011) is based on the relative ‘abundance status’ of the REE component in the deposit, i.e., where the REE are either a co-product or primary product, or a by-product of the deposit. In Australia, elevated concentrations of REE are known

to occur in six major deposit groups: (i) beach sands and placer deposits, (ii) carbonatites, (iii) alkaline igneous rocks, (iv) pegmatites, (v) phosphorites, and (vi) uranium mineralisations (Lottermoser 1991). This contribution documents the latter REE resources, which could potentially fulfill future economic needs.

Uranium mineralisations

There are numerous uranium \pm thorium occurrences in Australia, which contain elevated REE as well as yttrium and scandium contents. These include the Olympic Dam deposit, and uranium mineralisations in the Yilgarn, Mount Painter, Olary and Mount Isa regions (Hoatson et al. 2011).

Olympic Dam

The Olympic Dam deposit in northern South Australia represents a world-class Cu-U-Au-Ag resource (Reeve et al. 1990; Oreskes and Einaudi 1992; McPhie et al. 2011). The deposit is principally hosted by a thick sequence of Proterozoic sedimentary and granitic breccias. Ore minerals are characteristically very fine-grained and intimately intergrown with gangue phases. REE and yttrium predominantly occur in REE minerals and to a lesser extent as cation substitutions within uranium minerals. The light REE (LREE: La to Eu) and heavy REE (HREE: Gd to Lu) tend to occur in different host minerals (Lottermoser 1995). Most of the LREE are present as the essential structural constituents of LREE fluorocarbonates (bastnaesite, synchysite), phosphates (monazite, britholite), and aluminophosphates (florencite). Yttrium and the HREE occur mostly as minor concentrations in the form of cation substitutions within uranium minerals (uraninite, brannerite, coffinite). Xenotime, yttrium-bearing bastnaesite and unidentified phases are rare and account only for minor yttrium and HREE concentrations (Lottermoser 1995). The deposit is LREE enriched. Submarginal and inferred resources of REE oxides amount to 53 Mt @ 0.2 % La and 0.3 % Ce (Hoatson et al. 2011).

During hydrometallurgical treatment and sulfuric acid leaching of the processed uranium ore, significant fractions of REE and yttrium (several %) are leached and liberated from uranium ore minerals and become enriched in the uranium liquors. No provision has been made for the extraction and recovery of REE as recovery is currently considered not to be economic. Hence, it is likely that Olympic Dam tailings contain significant REE concentrations.

Olary district

In the Olary district of South Australia, uranium mineralisation is related to the metamorphism and anatexis of Proterozoic volcano-sedimentary sequences (Ashley 1984; Lottermoser and Ashley 2006). REE minerals occur in pegmatites and as disseminated fracture fillings within granites and migmatites (Lottermoser and Lu 1997). REE-bearing minerals in these occurrences are allanite, betafite, brannerite, davidite, euxenite, fergusonite, florencite, monazite, polycrase, samarskite, synchysite, thorite, xenotime and yttracrasite.

The Radium Hill uranium deposit is located within shear zones of Precambrian feldspathised gneisses, aplitic gneisses and schists, intruded by basic and acid bodies (Lottermoser and Ashley 2006). Mineralised rock at Radium Hill comprises quartzofeldspathic gneiss, schist, amphibolite and pegmatite, with the ore minerals (davidite-brannerite-uraninite) being part of a refractory Fe-Ti-U-REE oxide assemblage (Fig. 1). The Radium Hill mine operated from 1954 to 1961. Underground mining occurred with processing of ore on site, resulting in the generation of mill tailings dams and numerous dumps of waste rock material. The principal REE ore mineral is davidite. The deposit was mined mainly for uranium but a total of 136 kg of high-purity scandium oxide was produced as a by-product. Abandoned waste rock and tailings dumps are LREE enriched, with maximum concentration of 0.13 wt% La (Lottermoser and Ashley 2006).

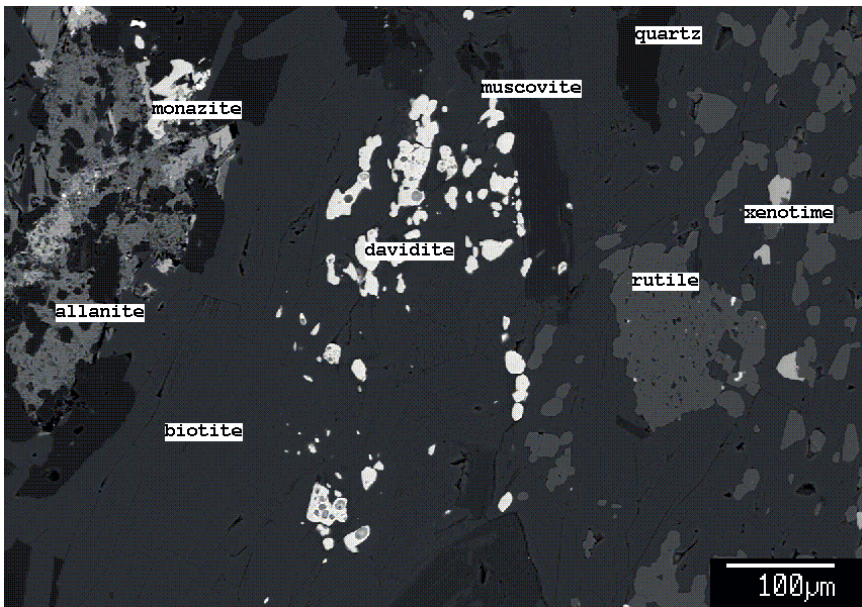


Fig.1. Scanning electron microphotograph of Radium Hill ore, South Australia, demonstrating the fine-grained nature of the ore mineral davidite $(\text{La,Ce,Ca})(\text{Y,U})(\text{Ti,Fe}^{3+})_{20}\text{O}_{38}$.

Mount Isa district

Several uranium-bearing skarn orebodies in the Mount Isa region contain elevated REE contents. The deposits were exploited for uranium until 1982 but REE were not recovered. The commonly occurring REE minerals are stillwellite and allanite; other REE-bearing minerals are apatite, uraninite, sphene and garnet (Oliver et al. 1999).

The Mary Kathleen uranium mine, in northwest Queensland, operated from 1956 to 1963 and again from 1976 to 1982. Mineralised rock at Mary Kathleen (ore and waste rock) is dominated by a metasomatic calc-silicate assemblage, with minor amounts of sulfide minerals, rare earth minerals and uraninite (Lottermoser et al. 2005; Lottermoser and Ashley 2005). Rehabilitation of the Mary Kathleen open pit mine, mill and tailings repository sites occurred between 1982-1985 (Fig. 2). The Mary Kathleen deposit is strongly enriched in the LREE. Tailings are stored on site in a purpose-built tailings dam structure, with an estimated 7 Mt of mill tailings carrying approximately 3 wt% total REE oxides (DNRM 2013). This makes it one of the largest REE deposits in Australia.



Fig.2. Open pit of the Mary Kathleen mine, Queensland. Disposed tailings contain approximately 0.2 Mt of REE oxides. Based on current world prices, the value of this resource would be approximately US\$4000 million.

Conclusions

REE are used in a wide range of consumer products and have become indispensable in electronic, optical, magnetic and catalytic applications. As research and technology continues to advance many more applications for REE are being developed, especially in the areas of energy conservation and efficiency and environmental protection (Walter et al. 2011). Consequently, future demand for REE can be expected to increase.

In Australia, elevated concentrations of REE are known to occur in various deposit types including uranium mineralisations (Lottermoser 1991). The presence of high REE and yttrium concentrations in uranium ores is not unique to Australian uranium occurrences. There exists several other uranium deposits around the world with elevated REE and yttrium contents, and REE have been recovered from uranium operations in Canada (Elliot Lake). The elements are either present as separate REE minerals or they are incorporated as cation substitutions in other mineral phases. The presence of REE within uranium ores and minerals is due to chemical crystallographic constraints as the ionic radii of uranium are very similar to those of REE. In addition, the close mineralogical association of uranium, yttrium and REE is likely due to the transport of these elements by the very same complexing agents during the ore formation processes.

In some of these undeveloped REE resources, the unusual crystallographic siting of the REE, the exceptionally fine grain size of the REE minerals and their intense intergrowth with other phases may require new processing and extraction methods. This in turn may lead to new patents for the processing of REE minerals and for the extraction of REE.

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