Elements that Rule the World: Impending REE Metal Crisis – P. V. Sukumaran, *Deputy Director General (Retd.) Geological Survey of India, "Sukrutham", Ambika Road, Mangalore - 575 022. (Email: pvs341950@gmail.com)*

The rare earth elements (REEs) or lanthanides include 15 elements of the periodic table from lanthanum to lutetium. They are all metallic elements closely related to each other in their chemical properties, geochemical behaviour and distribution in the earth's crust. REEs are high-tech metals with endless uses in Smartphones, LCD screens, computer hard disks, CFL, LED, MRI, positron emission tomography (PET), portable X-ray units, fibre optics, lasers, petroleum refining, glass colouring, permanent magnets, hybrid cars, wind turbines, atomic reactors and defence hardware. Potential uses include magnetic refrigeration, medical diagnostics and treatment and hetero-metallic hydrides for hydrogen fuel storage. Many applications of REE metals in defence weapons system such as smart bombs, guidance missiles and lasers are kept under strict governmental control.

REEs are large-ion-lithophile elements incompatible in the structure of upper mantle minerals and are thus fractionated into the earth's crust. Because of the property of lanthanide contraction, the LREEs easily get into the melt phase and eventually are concentrated in crustal rocks, while the HREEs are left in mantle minerals during partial melting of the upper mantle. The REEs are not that rare and are more abundant compared to metals like Cr, Ni, Cu, Zn, Mo, Sn, W or Pb in the earth's crust but have no tendency to concentrate and form economic mineral deposits like the base metals or iron ores.

The process of mining and beneficiation of REEs is environmentally hazardous as it produces enormous mine waste, toxic and reactive effluents and radioactive tailings. The associated radioactive U and Th pose problems of beneficiation and safe handling. Isolation of the individual REEs from the beneficiated ore is again a cumbersome process owing to their similar chemical properties.

There are more than 200 minerals containing essential or significant REEs. But bastnaesite, xenotime and monazite are the three most economically significant REE minerals while eudialyte, loparite and allanite are less important REE minerals. REE carbonates and phosphates are better amenable to beneficiation than REE silicates. Besides, small amounts of Th and U are always associated with the REE minerals.

REE minerals are distributed in diverse types of igneous, sedimentary and metamorphic rocks. Often many REE minerals occur in complex associations in these rocks. The chief geological environments where they are known are: (i) Carbonatites and related rocks such as syenites, nepheline syenites and nephelinites (ii) Beach placers containing detrital REE minerals associated with other heavy minerals (iii) Peralkaline granitic and syenitic igneous rocks, (iv) Iron-REE deposits of hematite-granite-breccia-style, (v) Pegmatites, hydrothermal quartz and fluorite veins (vi) Skarn deposits and (viii) 'Ion-adsorption clays', where the REEs occur as ions adsorbed onto residual clay minerals. In addition phosphorites contain the LREEs, La, Ce and Nd in the mineral francolite.

Almost 97% of the world production of REEs today comes from China which produced 1,30,000 tonnes of REEs in 2010, while the share of the rest of the world was a mere 3600 tonnes of which India accounted for 2700 tonnes. In 2010 China also produced 97% of the world's rare earth oxide, 89% of the world's rare earth alloys, 75% of the world's NdFeB magnets and 60% of SmCo magnets. China thus holds the monopoly in the production and export of these critical metals today. Many REE mines in the West had to be closed when cheap REEs from China flooded the market in the 1990s. The known world reserves of REEs are 110 million tonnes, nearly half of which is in China. Following a maritime dispute with Japan, which buys roughly 50% of Chinese REE exports, China has considerably reduced export of REE since 2010 seriously affecting electronic industries in Japan and the industrialized western countries. If China stops export of REEs completely as is feared, Japan and the western world will face shortage, crippling their electronic industry.

As a consequence of these developments, many countries are vigorously exploring for REEs and many mines long closed are being reopened. There are several new discoveries, the most promising one being in Afghanistan, where a million tonnes of REE ore has been identified within the Khanneshin carbonatite complex, Helmand Province. But any new mine would require 5-10 years to reach the production stage, which means China's preeminence in REE production and supply would continue for decades.

Over the past few decades, China has mastered the entire gamut of REE technology: mining, processing and isolation of REEs, and their application in electronic industries. China is also the major producer of REE magnets, the demand for which is likely to leapfrog with the world poised for greener technologies. If China continues to increase the export embargo, electronic industries in the rest of the world will be forced to move to China, a development that it would readily welcome. But what worries multinational REE mining companies is the likely fall in prices of REEs in international markets, if China floods the market, leading to closure of mines and throwing the mining companies out of business.

Numerous complaints have been lodged in the WTO against China of which it is also a member, primarily by other member nations, like the USA, Japan and the European Union. One complaint was submitted as recently as 13th March 2012 against China's restricted supply of REEs. In January 2012, the WTO ruled in favour of the USA, Mexico and the EU in a case concerning China's restrictive supply policies, and China is yet to react positively to this situation.

Summary of the lecture to be delivered at the monthly meeting of the Geological Society of India on 29 August 2012