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Editorial

Combating Global Warming and Modern Wars is much about Sedimentology

The Paris Agreement on climate change came into force on 4 November 2016 which was adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris on 12 December 2015. Under this agreement, 175 countries are legally bound to commit themselves to limit the increase of global warming temperatures to under 2 °C above pre-industrial levels. To achieve this goal, mitigation and adaptation policies have been adopted at the national and international levels. Mitigation measures include decarbonisation policy, for example the large-scale development of low-carbon energies to replace fossil fuel energy in a sustainable way. At present, efforts are focussed on the energy transition from fossil fuel driven energy to low-carbon energy which is mineral intensive. Rare earth elements (REEs) are core components of clean energy technologies such as solar, wind turbines and electric vehicles in the process of energy transition. In the quest for slow down the global temperature rise, development of low-carbon energy to achieve carbon emission reduction goals, rare earth elements are the key components to the energy transition. The criticality of supply and demand of raw materials is the key issue in planning the sustainable transition from fossil fuel driven energy to green energy. Over the past few years many countries established critical raw materials lists, in which rare earth elements have been given most attention.

Many critical minerals extracted from sedimentary ore deposits contain critical chemical elements, rare earth elements (REEs), which are vital in transition from fossil fuel driven energy resources to green energy to combat the global warming at the one end. At the other end some of these critical elements are used in development of high-tech equipment and weapons including, guided missiles, drones and new generation satellites, lasers, magnets for motors, optical devices, etc. being used in modern warfare, e. g., Ukraine-Russia war. Some of the REEs are used in the production of the batteries with greater energy density, better discharge characteristics and fewer environmental problems upon disposal. Others, are used in the manufacture of miniaturized higher-strength magnets, and fibre-optic cables capable of transmitting signals over long distances, on account of their capacity to amplify signals to a comparatively greater magnitude.

This family of chemical elements are not relatively scarce in the Earth's crust but typically dispersed and sporadic in economically exploitable ore deposits. Rare earth elements constitute a family of 17 chemical elements, including 15 lanthanides (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium) and scandium and yttrium which have chemical properties similar to lanthanides and tend to occur in the same ore deposits as lanthanides. The rare earth elements have similar chemical properties and are divided into light rare earths (cerium, lanthanum, praseodymium, neodymium, promethium, europium, gadolinium and samarium), and heavy rare earths (dysprosium, yttrium, terbium, olmium, erbium, thulium, ytterbium, yttrium and lutetium). Rare earth elements occur in various types of salt deposits, in placer deposits of marine sands, in volcano-sedimentary deposits and in seafloor sediments. Details on occurrence, distribution and geology of REEs is discussed in vast literature base (e. g., Gupta and Krishnamurthy, 1992; Ganguli and Cook, 2018; Balaram, 2019; Dushyantha et al., 2020 and reference therein). Despite their denomination REEs are not particularly rare in their crustal abundance concentration compared to regular metals such as zinc and copper (Gupta and Krishnamurthy, 1992). REEs show a great variation in their distribution and abundance in sediments and sedimentary rocks; the most abundant one is cerium and the least is thulium. The sparse distribution of REEs in Earth makes their processing and recovery a technological challenge which results in their dispropotionate availability among the countries. Studies on REEs have revealed that these deposits are located in the interior and marginal regions of continents, for example, in the Inner Mongolia, East African rift zones, Northern Scandinavia-Kola peninsula, Eastern Canada, Southern Brazil and Southern China. Gupta and Krishnamurthy (1992) and Balram (2019) state that overall there are 250 minerals which contain REEs out of these only a dozen are commercially viable for extraction. The most common rare earth minerals and the principal economic source of REEs are Monazite, Bastnaesite, Xenotime and Ion-adsorption clay. Others include Euxenite, Apatite, Gadolinite, Laporite, Uraninite, Brannerite, Doverite, Pyrochlore, Allanite, Perovskite and Zircon.

Figure 1 represents the World wise REEs distribution and, deposits in production and exploration

Fig. 1: Global REEs distribution including deposits in production and exploration targets.(after Depraiter and Stephane, 2023), Sources: GEUS, USGS, Canadian Government, TMR

targets. Among these the three major deposits are 1) Bayan Obo (China), Mountain Pass (USA) and Mount Weld (Australia). Bayan Obo deposit is located northwest of Baotou, a northern China industrial region, 2) The Mountain Pass deposit is located in the Mojave Desert of California (the second largest deposit in the world and the only REEs-mine in the United States, 3) Mount Weld comprises four deposits with monazite as the main REEs mineral. This deposit is enriched in heavy rare earths, and it is the only heavy rare earths mine outside China.

Another important resource of REEs is the ion adsorption clay deposit which occur along seven provinces in outhern China. This deposit of rare earths comprises of heavy rare earths which is more economically viable compared to others. Rare earth elements have been extracted from the surface clay in China which accounted for 26% of the China's REEs production from 1988 – 2008.

Initially, the United States was the world's first supplier of REEs starting in 1950s with production of REEs from the Mountain Pass deposit. The USA was also the leader in rare earths applications and innovation. China's interest in rare earths emerged in the 1960s when it developed the mining of non-ferrous metals in the Baotou region. They set up the Baotou as the industrial region for large factories to process coal, steel, and rare earth metals (Klinger, 2017). According to the Center, N.M.I.U.S. Geological Survey Mineral Commodity Summaries (2022), the global reserves of rare earth elements are estimated at 120 million metric tons. China possess the largest reserve with 44 million metric tons, followed by Vietnam (22 million metric tons), then Russia and Brazil with 21 million metric tons. India, Australia, the United States and Greenland's individual reserves exceed 1 million metric tons. The current legal annual global production of rare earths is estimated at 280 thousand tons, of which China produces 60%, USA 16%, Myanmar 9%, Australia 8% and 3% Thailand. India is a country rich in mineral resources, especially rare earth minerals, and owns the fifth-largest reserves of rare earth minerals in the world, and produces about 2.5% of the global output. The important rare earth element bearing minerals found in India include Monazite. Zircon. Ilmenite. Columbite-tantalite. Beryl. Apatite and Sillimanite. Recently, in February 2023 with the speculated discovery of massive lithium reserves at Reasi in Jammu and Kashmir, the estimated reserve of 5.9 billion tonnes (if proved) would make India one of the world's largest lithium producers.

As we know, the world nations are showing an increasing interest in rare earth elements due to their use in many advanced technologies, including low-carbon technology, mainly in wind turbine generators, solar energy and electric vehicle motors. India is among the nations who is at the forefront of implementing the Paris Agreement to reduce global temperature by shifting to low carbon energy resources which require rare earth element resources. REEs are principally produced in China, and its political management of the resource, China has maintained monopoly in REEs production, supply, innovation and application. In addition, studies have drawn attention to the availability risks of main REEs used for wind turbines and electric vehicles, and more generally, the challenges surrounding rare earth elements supply (Wang et al., 2020). Few articles focus on the challenges of rare earths in the energy transition concerning disparity in supply and demand. Evidently the energy transition is putting pressure on the extraction of critical minerals required in low-carbon technologies. Rare earths used in wind turbines and electric vehicles are in more and more demand, whereas the supply is controlled by production concentration in China and it's protective resource policy. This current situation raises several issues regarding the availability of the resource for the development of renewable energy resources and electric mobility. As we know, neodymium, praseodymium, dysprosium, terbium and lithium are the main rare earth elements critical to the energy transition through their application in wind turbine generators and electric vehicle motors. The demand for these minerals is likely to grow substantially over the next decade, and so is the critical mineral supply.

The natural resources and materials needed to meet the needs of the transition from fossil fuel energy to green energy are required to be explored, mined in sustainable manner and develop technology to increase production to meet the demand. Strong actions are needed to be taken to innovation and recycling, make production rapidly enough to meet the demand growth to make the large investments and strong policy support are needed to ensure that the demand - supply gap is reduced of key REEs minerals arising from energy transition or other sectors. However, even with these actions, it is being projected that there could be significant supply gaps for six key energy transition materials: lithium, nickel, graphite, cobalt, neodymium and copper by 2030. The most vital solution is to explore for more and more REEs and technology development for their production in the country. Contribute your bit in this quest as Sedimentologists.

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