Geology of the Kamthai Rare Earth Deposit

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Abstract: A wide spectrum of calciocarbonatites and associated alkaline rocks are exposed around Kamthai, Rajasthan. The mineralogical studies exhibit a bimodal distribution of REE minerals. The southeastern block has carbocernaite and the eastern block has bastnaesite ± ancyrite / synchysite as the dominant REE minerals followed by parisite and other accessory minerals. Calcite is the most abundant of the gangue phase, followed by biotite, albite, k-feldspar and iron oxide / hydroxide. Minor and trace gangue phases include pyrite, ilmenite, apatite, siderite, ankerite, amphibole, pyroxene, strotianite, barite, ilmenite / pyrophanite, celestone, clay minerals, spalherite, pyrochlore, fluoride and Mn-rich phases including hollandite and Mn-Fe oxides. Calciocarbonatite occurring as intrusive veins, sills/dykes and plug, is perhaps a product of crystallization of a primary carbonatite melt generated at upper mantle. The first phase magmatic calciocarbonatite is alvikite type, rich in carbocernaite whereas second hydrothermal phase, sovite type, is enriched in bastnaesite. The absence of supergene activity and minerals (crandalite, florencite, gorceixite) indicate minor role of secondary enrichment. A rift-related mechanism, thermal equivalent to Deccan flood basalt (65±2 Ma), invoking “Reunion plume - continental hot spot” might have triggered Tertiary alkaline magmatism.

Keywords: Carbonatites, Mineralogy, REE, Kamthai, Rajasthan.

INTRODUCTION

The rare earth group of lanthanides has fifteen elements in the periodic table with atomic numbers from 57 to 71 namely from La to Lu. The light rare earth elements (LREE) have atomic number from 57 to 63 (La, Ce, Pr, Nd, Pm, Sm & Eu), whereas heavy rare earth elements (HREE) are those with atomic numbers from 64 to 71 (Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu). Senso stricto there are only fourteen REE, Pm being scarce due to highly unstable and radioactive nature. There is another term in the financial market called ‘critical rare earths’, which includes Nd, Tb, Dy, Er and Sm. REE are high field strength elements (HFSE) and display lithophile character since they occur in silicate mineral.

The REE are characterised by high melting point, conductivity and thermal conductance. Due to their unique magnetic, fluorescent and chemical properties, REE are key components in hybrid rechargeable batteries, catalyst converter, glass, polishing, magnets, laser, components of colour TV, superconductors, ceramics and high end defence systems.

The REE minerals are hosted by magmatic carbonatites or as hydrothermal deposits formed by replacement and even supergene enrichment of in-situ weathering of carbonatite bodies (Le Bas, 1999). The other rocks hosting either LREE or HREE minerals are pegmatites, alkali syenite, phonolite, bauxite, laterites, metamorphic rocks, phosphorite, clay, placers and heavy mineral beach sands. The major REE bearing minerals are bastnaesite, ion-adsorption clays, monazite, xenotime and laporite, the last mineral occurs either in nepheline syenite or replacement of perovskite in carbonatite.

Monazite (Ce,La,Th,Y) PO₄ , rare earth phosphate and bastnaesite (Ce,La) FCO₃ : a rare earth flurocarbonate are two principal commercial rare earth ore minerals. Monazite is present in beach sands around the coastal belts of India, Brazil, Australia, South Africa and USA. Boatou Mianning and Weishan deposits in China and Mountain Pass, California, USA are the most significant bastnaesite deposits. Bastnaesite contains 75% combined rare earth oxides and minor amount of Yttrium. (Kim et al., 2010). 60-70% of rare earth oxides (Re₂O₃) in world are extracted from bastnaesite (Ren et al., 1997).

Carbonatite occur as magmatic, intrusive or extrusive, hydrothermal or replacement bodies which contain more than 50% by volume, primary igneous carbonate minerals derived from, carbonatite magma (Streckeisen, 1980, Woolley 1982). Calciocarbonatites are either coarse grained Sovite (C1) or medium to fine grained alvikite (C2) type (LeBas, 1999). According to Tuttle and Gittins (1966),
carbonatite complexes are always associated with ijolites, nephelinites and other alkaline rocks indicating origin of carbonatites from an alkaline magma.

Globally there are 527 carbonatite occurrences, (Woolley and Church 2005; Woolley and Kjarsgaard, 2008), with 49 of these being extrusive, ranging in age from Archean to present. The oldest dated carbonatite 3007 ma old, is located in Tupertalik, Greenland (Downes et al., 2012.). Most of the extrusive carbonatites are pyroclastic in nature. (Bailey and Kearns, 2012). According to Jaireth et al., (2014) there are 140 REE deposits being explored out of which only 12 deposits have > 1% rare earth oxide (REO).

In India, REE are of endogenic as well as exogenic origin. The endogenic type includes carbonatite pegmatite and metamorphic - metasomatic veins. The exogenic variant includes coastal or beach placers and offshore placers. Monazite is the principal ore mineral occurring in beach placers along west as well as east coast of India. India has estimated reserve of 5 MT of monazite and xenotime, 70-75% occur in beach placers and the rest in the inland and offshore. Monazite concentration of beach sands may be upto 11% where REO content may exceed 60%.


Regarding REE content from Indian carbonatites, Schleicher (1998) reported 3.22% and 8.2% REE from carbonatites of Pakkanadu and Samalpatti respectively from Tamil Nadu. The average lower rare earth oxides (LREE) of carbonatites from Ambadongar does not exceed 0.25% (Viladkar and Dulski, 1986). However Bhushan and Kumar (2013) recorded 19.39% LREE from Kamthai carbonatites.

The Tertiary Alkaline Complex (TAC) of Sarnu-Dandali; Rajasthan was first reported by Narayan Das (1973) followed by Udas et al., (1974), Chaube et al., (1974), Wall et al., (1993). Chandrasekharan, 1987 and Chandrasekharan et al., (1990), described ultramafic alkaline rocks including ijolites, melaneephenelite, phonolite, alkali basalt and carbonatites of the area. Srivastava et al., (1993), Simonetti et al., (1998), Bell (2001), Ernst and Bell (2010). Bhushan and Chandrasekharan (2002) gave detailed account of geology and geochemistry of the TAC rocks. Bhushan and Kumar (2013) reported the first carbonatite hosted LREE deposit from India, the geological, major, trace and REE geochemistry along with resource estimation has been carried out. A revised resource of 7.36 mt with average grade 1.62% REO, is expected from Kamthai carbonatite.

GEOLOGICAL SETUP

The TAC of Sarnu-Dandali comprises of ultrabasic alkaline rocks, ijolite, nepheline syenite, phonolite and carbonatite. The TAC is intrusive into the Neooproterozoic Malani rhyolites and lower Cretaceous sandstone, (Chandrashekaran et al., 1990). Around Kamthai (Fig.1A.) the Malani rhyolite occurring as basement rock is seen towards, south, west and eastern side, whereas in north, nepheline syenite pluton of TAC intrude through the rhyolites. This is intruded by ijolite plug having intrusive relationship with the adjacent Malani rhyolite and foidal syenite. The first influx of calcio carbonatite, alivikite type, occurred as thin to thick E-W trending intrusives through the ijolite. The second and strong Ba & Sr bearing calcio carbonatite phase, sovite type, (Fig.1C) pierced through the ijolite plug resulting in concentration of high grade bastnaesite (> 8% REE) with small amount of either synchysite or anecylite. In the LV section of the SE block, the 12 boreholes exhibits 2D configuration of carbocernate rich fine grained alvikite type calciocarbonatite (Fig.1B). This calcio carbonatite ore is dominated by carbocernate (low grade REE upto 5%). The carbonatite samples studied are of two types: TYPE (1) Banded and brecciated rocks consisting of a melanocratic and leucocratic component, the latter hosts the bulk of the REE mineralization. Both components are calcite carbonatites. The calcite in these differ in texture and composition. The calcite in the melanocratic component is Mn-bearing (up to 4 wt.% MnO) and characterized by alteration to small patches of Ca-Fe-Mn-carbonates and characterized set in Mn-poor calcite. The overall appearance of this component results from oxidation and alteration of Fe- and Mn-bearing carbonates to diverse amorphous Fe- and Mn-oxides. In some instances, phlogopite (femite) mica and magnetite are present, together with minor amounts of pyrochlore and niobian rutile. REE-minerals when present are commonly enriched in La relative to Ce.

The leucocratic component consists principally of colourless Mn-poor (< 0.5 wt.% MnO) anhedral calcite crystals with interstitial REE-carbonates associated with barite and cerianite. Barite abundance varies greatly within and between samples, with leucocratic zones in sample containing the most barite (c. 20 vol %). Cerianite-(Ce) is developed as a secondary mineral on pre-existing REE-