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**GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA**



**GENERAL INFORMATION DOSSIER
FOR RARE EARTH ELEMENTS (REE)**

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GENERAL INFORMATION DOSSIER FOR RARE EARTH ELEMENTS (REE)

1.0.0: Introduction

1.1.0 The term "rare earth" arises from the minerals from which they were first isolated, which were uncommon oxide-type minerals (earths) found in Gadolinite extracted from one mine in the village of Ytterby, Sweden. However, with the exception of the highly-unstable promethium, rare earth elements are found in relatively high concentrations in the earth's crust with cerium being the 25th most abundant element in the earth's crust at 68 parts per million

The Rare earth elements (REE) are a collection of 17 elements namely scandium, yttrium and lanthanides (15 elements in the periodic table with atomic numbers 57 to 71 namely: lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb) and lutetium (Lu)).

Although these elements tend to occur together, the lanthanide elements are divided into two groups. The light elements are those with atomic numbers 57 through 63 (La, Ce, Pr, Nd, Pm, Sm and Eu) and the heavy elements are those with atomic numbers from 64 to 71 (Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu).

Rare earths are characterized by high density, high melting point, high conductivity and high thermal conductance. These unique properties make them indispensable for a variety of emerging and critical technology applications relevant to India's energy security i.e. clean energy technology, defence and civilian application etc. rare metals play a significant role in modern day high-technology industries. Generally the light rare earth elements are more common and more easily extracted than heavies. In spite of its low atomic weight Yttrium has properties more similar to the heavy lanthanides and is included with this group. Scandium is found in a number of minerals although it may also occur with other rare earth elements (REE).

The ever increasing demand for these RM and REE necessitates a concerted effort to augment the resource position of our country. The Atomic Minerals Division (AMD) of the Department of Atomic Energy has been actively

engaged in the exploration of such mineral deposits in different parts of our country. The Geological Survey of India, as a part of routine mineral survey, has been carrying out preliminary investigation for identifying such RM and REE rich zones in selected sectors.

1.2.0 Industrial use:

Rare earth elements are used in many modern technological devices, including superconductors, samarium-cobalt and neodymium-iron-boron high-flux rare-earth magnets, electronic polishers, refining catalysts and hybrid car components. Rare earth ions are used as the active ions in luminescent materials used in optoelectronics applications, most notably the Nd-YAG laser. Erbium-doped fibre amplifiers are significant devices in optical-fibre communication systems. Phosphorus with rare earth dopants are also widely used in cathode ray tube technology such as television sets. The earliest color television CRTs had a poor-quality red; europium as a phosphor dopant made good red phosphors possible. Yttrium iron garnet (YIG) spheres have been useful as tunable microwave resonators. Rare earth oxides are mixed with Tungsten to improve its high temperature properties for welding, replacing thorium which was mildly hazardous to work with. Many of these are essential ingredients in mobile phones, video game machines, computers and even green technologies. Tiny amounts of rare earths dysprosium or terbium might soon be used in electric cars as these let batteries work at high temperatures.

Rare earth materials are utilized in India in a wide range of critical products enabling many emerging green energy technologies, high tech applications and defence systems such as hybrid cars, plug-in-hybrid electric vehicles (PHEVs), the latest generation of efficient wind power turbines, computer disc drives, missile guidance systems, etc. The requirement of REE for various uses including strategic and civil purposes may be projected from end use wise potential markets, consumption and import scenario of the country which is outlined below:

A list of Rare Earth Elements and their uses are tabulated as follows:

Symbol	Name	Selected applications
Sc	<u>Scandium</u>	Aerospace components, Hg vapour lamps

Symbol	Name	Selected applications
Y	<u>Yttrium</u>	YAG lasers, superconductors, MW filters
La	<u>Lanthanum</u>	Battery electrodes, camera lens, catalytic cracking catalyst
Ce	<u>Cerium</u>	Catalytic converters, petroleum refining
Pr	<u>Praseodymium</u>	Magnets, lasers, carbon arc lighting
Nd	<u>Neodymium</u>	Magnets, lasers, ceramics capacitors
Pm	<u>Promethium</u>	<u>Nuclear batteries</u>
Sm	<u>Samarium</u>	Cancer drug, Precision guided munitions, magnets
Eu	<u>Europium</u>	Screen brighter: Red/blue phosphorus, Hg vapour lamps
Gd	<u>Gadolinium</u>	Magnets, X-ray tubes
Tb	<u>Terbium</u>	Green <u>phosphors</u> , <u>lasers</u> , <u>fluorescent lamps</u>
Dy	<u>Dysprosium</u>	High temperature batteries, magnets, lasers
Ho	<u>Holmium</u>	<u>Lasers</u>
Er	<u>Erbium</u>	Amplifiers in fiber optics data transmission
Tm	<u>Thulium</u>	Portable <u>X-ray machines</u>
Yb	<u>Ytterbium</u>	IR lasers

Symbol	Name	Selected applications
Lu	<u>Lutetium</u>	PET Scan detectors, high refractive index glass

(Source: **An Overview of Rare Earth Elements: C-TEMPO, 2011**)

1.2.1 Extraction method of rare earths

Due to the phenomenon known as lanthanide contraction, yttrium, which is trivalent, is of similar ionic size to dysprosium and its lanthanide neighbors. Due to the relatively gradual decrease in ionic size with increasing atomic number, the rare earth elements have always been difficult to separate. Even with eons of geological time, geochemical separation of the lanthanides has only rarely progressed much farther than a broad separation between light versus heavy lanthanides, otherwise known as the cerium and yttrium earths. Rare earth minerals, as found, usually are dominated by one group or the other, depending upon which size-range best fits the structural lattice. Thus, among the anhydrous rare earth phosphates, it is the tetragonal mineral xenotime that incorporates yttrium and the yttrium earths, whereas the monoclinic monazite phase incorporates cerium and the cerium earths preferentially. The smaller size of the yttrium group allows it a greater solid solubility in the rock-forming minerals that comprise the earth's mantle, and thus yttrium and the yttrium earths show less enrichment in the earth's crust, relative to chondritic abundance, than does cerium and the cerium earths. This has economic consequences: large ore bodies of the cerium earths are known around the world, and are being actively exploited. Corresponding ore bodies for yttrium tend to be rarer, smaller, and less concentrated. Most of the current supply of yttrium originates in the "ion adsorption clay" ores of Southern China. Some versions of these provide concentrates containing about 65% yttrium oxide, with the heavy lanthanides being present in ratios reflecting the Oddo-Harkins rule: even-numbered heavy lanthanides at abundances of about 5% each, and odd-numbered lanthanides at abundances of about 1% each. Similar compositions are found in xenotime or gadolinite.

1.3.0. World scenario: .

Most of the current supply of yttrium originates in the "ion adsorption clay" ores of Southern China. Some versions provide concentrates containing about 65% yttrium oxide. China holds the leading position both in the resource potential and production of REE in the world. It holds 48% of the world's reserves. United States, Russia and other CIS countries, Australia (Nolan Project in Central Australia and Mt. Weld project), South Africa, East African countries and Brazil have substantial deposits. Given the concerns over the China's restrictions on exports of REE, a wave of exploration projects have been taken up and old projects were revived world wide to tap the REE occurrences. World demand for REE are estimated at 134,000 tons per year and is projected to rise to 180,000 tons by 2015

Until 1948, most of the world's rare earths were sourced from placer sand deposits. Through the 1950s, South Africa took the status as the world's rare earth source, after large veins of rare earth bearing monazite were discovered there. Through the 1960s until the 1980s, the Mountain Pass rare earth mine in California was the leading producer. The Hoida lake project of northern Canada supply about 10% of consumption of North America every year. Today, the Indian and South African deposits still produce some rare earth concentrates, but they are dwarfed by the scale of Chinese production. China now produces over 97% of the world's rare earth supply, mostly in Inner Mongolia, even though it has only 37% of proven reserves. All of the world's heavy rare earths (such as dysprosium) come from Chinese rare earth sources such as the polymetallic Bayan Obo deposit.

In 2011, Yasuhiro Kato, a geologist at the University of Tokyo who led a study of Pacific Ocean seabed mud, published results indicating the mud could hold rich concentrations of rare earth minerals. The deposits, studied at 78 sites, came from "hot plumes from hydrothermal vents pulling these materials out of seawater and depositing them on the seafloor, bit by bit, over tens of millions of years. One square patch of metal-rich mud 2.3 kilometers wide might contain enough rare earths to meet most of the global demand for a year, Japanese geologists report July 3 in *Nature Geoscience*." "I believe that rare earth resources undersea are much more promising than on-land resources," said Kato. Concentrations of rare earths were comparable to those found in clays mined in China.

A comparative evaluation of world resources of REE including India gives a status of the resource position is furnished below:

Country	Resource base (in ' 000 tonnes of REO content)
Australia	1600
Brazil	48
China	55000
Common wealth of Independent states	19000
India	3100
Malayasia	30
USA	13000
Other countries	22000
World: Total	110000

Source: Mineral commodity Summaries, 2012

1.4.0: Indian Scenario:

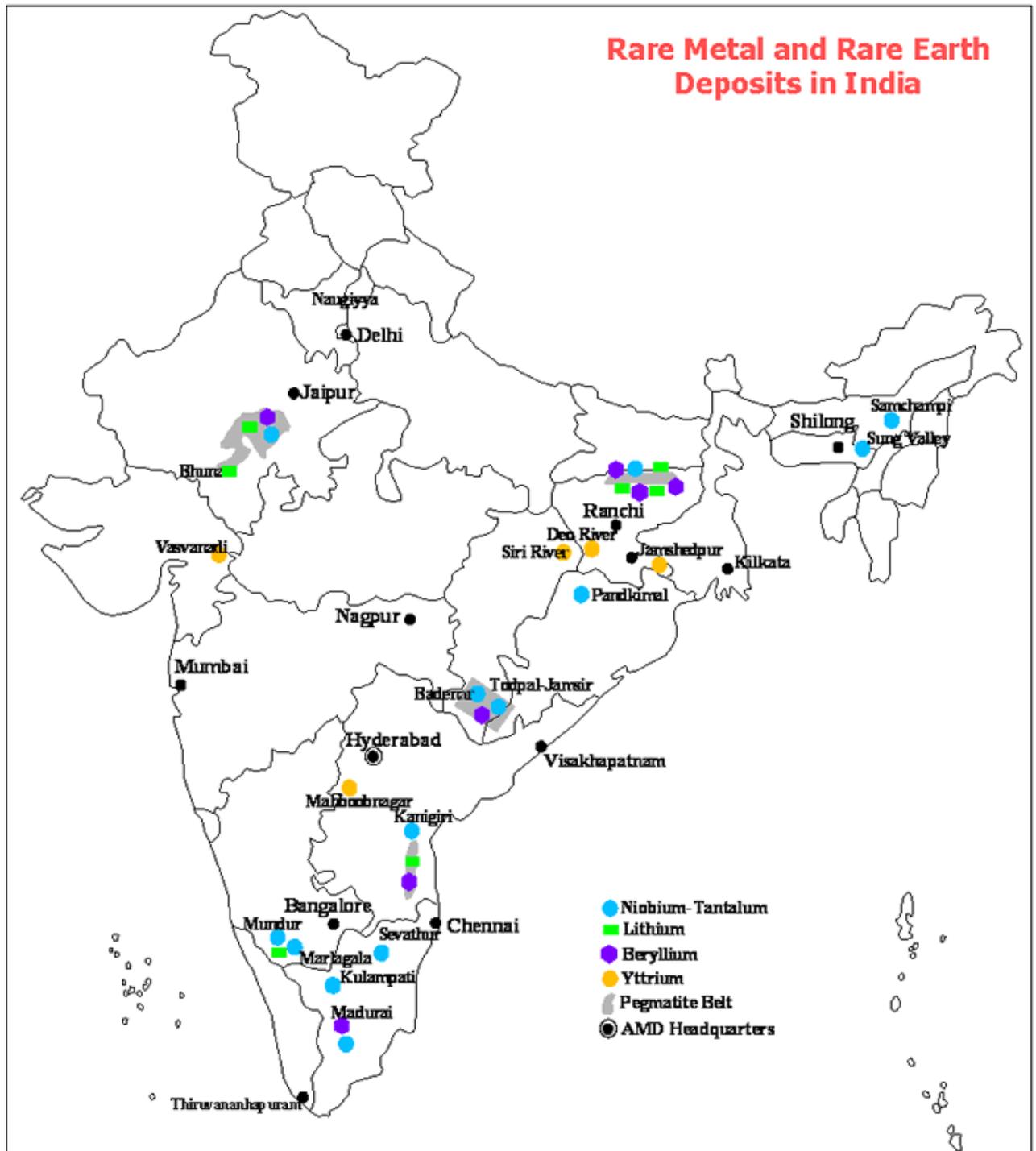
1.4.1 Mineralogy and occurrence of Rare earth elements

There are about 70 REE minerals identified so far. Commonly and widely found among the REE minerals are, xenotime, samarskite, euxenite, fergusonite, yttrantalite, yttritungstite, yttrifluorite, thalenite, yttrilite and gadolinite. Small amounts of REE occur in zircon, which derives its typical yellow fluorescence from some of the accompanying heavy REE. The zirconium mineral eudialyte contains small but potentially useful amounts of yttrium.

Rare earth deposits in India are of two major types: endogenic and exogenic. The Endogenic types include some carbonatites, pegmatitic rocks (Chhotonagpur), metamorphic-metasomatic veins, the Exogenic types comprise coastal or beach placer, inland placer and offshore placer. The endogenic deposits do not appear to be very much attractive from exploitative point of view. Mainly beach placers are mined in India at present. Monazite is the principal ore mineral for REE in India, although xenotime holds out some prospect for the future. Of India's estimated reserve of 5 million tonnes of monazite, 70-75 % occurs in beach placer and the rest in the inland and offshore varieties. Monazite-content of beach sands may be up to 11 wt%. ThO₂ ranges between 8-10.5%. Average S REO 60%. Inland placers contain either monazite or xenotime as the principal REE-bearing mineral. Of late, work on inland placer has started for xenotime. Factors controlling placer formation are: (1)

provenance, (2) physico-chemical properties of the minerals in the placer, (3) physico-chemical ambience, the source rocks/earlier deposits are exposed to, and (4) physical process of concentration. In the development of India's beach placer deposits, granites, granitic pegmatites, migmatites, gneisses, charnockites, leptynites and khondalites provided the necessary source and the tropical climate with heavy rainfall and strong wave action was especially conducive to the concentration of the placer-minerals in suitable locales.

1.4.2. Distribution



Map courtesy AMD, Hyderabad

Geological provinces in India favourable for RM/REE mineralization, is given as follows:

I. RM/REE mineralisation in pegmatites and quartz veins.

- Nellore Mica Belt, Andhra Pradesh.
- Bihar Mica Belt, Jharkhand .
- Bhilwara mica belt, Rajasthan
- Sausar belt (in skarns) in central India.
- Tin belt of Orissa and Chhattisgarh.

II. RM/REE in carbonatite complex

- Newania carbonatite-fenite complex, Udaipur district of Rajasthan.
- Ambadongar carbonatite complex, Gujarat.
- Purulia carbonatite, West Bengal.
- Sung valley Ultramafic Alkaline carbonatite complex, East Khasi Hills District, Meghalaya.
- Carbonatite and molybdenum bearing areas in Tamil Nadu.
- Mundwara alkalic carbonatite complex in Sirohi district, Rajasthan.

III. RM/REE in igneous complexes

- Alkaline rocks in Rajasthan.
- Nepheline syenite of Kishangarh, Ajmer district, Rajasthan.
- Around Sirohi, Sirohi district, Rajasthan.
- Granite plutons within Erinpura Granite Terrain.
- Jalore and Sewaria granitoid terrain in Rajasthan.
- Chhotnagpur Gneissic Complex in Jharkhand.
- Bundelkhand Granitoid Complex.
- Gneisses and granites in the western part of the North Purulia Shear Zone, Jharkhand

IV. REE enrichment in laterites

- Jharkhand – Eastern India
- Orissa – Eastern India
- Laterites developed over Deccan Traps in Gujarat – Western India.

1.4.3 Resource position in India

In India, Monazite is the principle source of rare earths, which is a prescribed substance as per the notification under the Atomic Energy Act, 1962. Indian Rare Earths Limited (IREL) has been the sole producer of Rare Earth

compounds in the country. The recovery of Rare Earth Elements (REE) from Monazite has been restricted due to its associated thorium and uranium content. AMD has been carrying out its resource evaluation for over five decades. Monazite occurs in association with other heavy minerals, such as ilmenite, rutile, zircon, etc. in concentrations of 0.4 - 4.3% of total heavies in the beach and inland placer deposits of the country. The resource estimates of monazite in the beach and inland placer deposits have been enhanced from 7.90 million tonnes in 2002 to 10.21 million tonnes in 2005.

The resource estimates of monazite in the beach and inland placer deposits stands at 10.21 million tones. The state wise resource is tabulated below.

State	Resources(million tonnes)
All India	10.21
Andhra Pradesh	3.73
Bihar	0.22
Kerala	1.37
Orissa	1.82
Tamil Nadu	1.85
West Bengal	1.22

(Source: An Overview of Rare Earth Elements: C-TEMPO, 2011)

1.4.4 End use wise potential REE markets of India:

End use	REE required	Present status	Expected(2030)
Magnets for wind turbines	Nd,Pr, Dy, Tb	12,000 MW of wind power capacity	Around 50,000 MW
EV, Hybrid vehicles (batteries, motor. Catalytic converter)	La Nd	Negligible EV	Perhaps upto 1 million vehicles
LED	Y,Eu, Tb	Negligible LED	Being promoted by government, could

			reach -1 million bulbs
Al, Steel, Mg industry, grain refinement	Ce, La, mischmetal	Huge growth rate	
Screens brighteners (Cell phone. Computers, TV screen)	Eu	Mostly imported	Huge growing market.
Other magnets	Pr,Sm,Gd	Mostly imported	Computer hard disks, microphones

(Source: An Overview of Rare Earth Elements: C-TEMPO, 2011)

1.4.5 Consumption of Rare Earths 2008-09 to 2010-11 (By Industries)

The total consumption of rare earths in 2009-10 and 2010-11 was estimated at 118 tonnes and 128 tonnes, respectively. The Paints Driers/Pigments Industry was the main consumer accounting for about 59% of the total consumption followed by Cinema Arc Carbon Industry (36%) in 2010-11.

In tonnes

Industry	2008-09	2009-10	2010-11
All Industries	158	118	128
Paints Driers/Pigments	95	92	76
Cinema Arc Carbon	66	25	46
TV Colour picture tube	---	1	---
Glass/Optical polishing	2	--	1
Glassware decolouring	---	---	1
R&D and others	5	---	4

Source: Department of Atomic Energy, Mumbai. Consumption relates to sales figures of IREL

1.4.6 Import of Rare earths during 2006 to 2010 (Data in Kg)

Element		2010	2009	2008	2007	2006
Lanthanum	Lanthanum oxide	0	9100	250	0	0
	Lanthanum Acetate	2400	1250	1750	2000	1000
	Lanthanum Nitrate	2400	750	1325	200	0
	Total	4800	11100	3325	2200	1000
Cerium	Cerium oxide	240000	202000	564000	99700	407500
	Cerium Acetate	10700	8200	2900	3200	0
	Cerium Nitrate	3600	385	2960	930	265
	Cerium Zirconium Oxide	95200	99250	84500	27400	33200
	Cerium Chloride	11275	12400	555	31100	0
	Cerium Carbonate	0	10000	0	40000	0
	Total	360775	332235	654915	202330	440965
Ytterbium	Ytterbium Oxide	500	800	500	0	2
Neodymium	Neodymium Nitrate	5500	2750	4150	1450	150
Yttrium	Yttrium Oxide	50	460	1960	0	1000

Prasodmium	Prasodmium Oxide	0	1750	5300	7140	3500
Erbium	Erbium Oxide	300	700	200	85	0
	Total	371925	376775	670350	213205	446617

Source: Rare earth and energy critical elements: A road map and strategy for India: Ministry of Mines, Government of India, July, 2012

2.0.0 . Prospecting/ Exploration of REE in India:

RM, REE and ECE occur usually in very low content (<1%) in rocks. Hence, these are difficult to locate and identify by normal megascopic and microscopic techniques, which are used in identification of rock-forming minerals that occur in major to minor quantities (>1%). Therefore, there is a need for pursuing exploration efforts with modern concepts and tools for possible breakthrough requiring high investments in sophisticated survey and spatial data management technologies including remote sensing and complex computerization capabilities to produce more detailed and accurate data and information of areas and depths so far unexplored. Specific and high precision laboratory studies aimed at guiding and substantiating field studies pertaining to ore localization are the need for success of the exploration. This requires procurement of high precision equipments for both laboratory and field and upgrading of existing equipments.

Investigation/Exploation of RM/REE elements was normally considered within the purview of AMD. GSI has already accorded high priority for exploring for these minerals in XII Five Year Plan document.

The present investigation strategy of GSI for search of RM/REE mineralisation includes identification of zones of anomalous concentration of RM/REE elements on the basis of Base Line Data Generation (STM & NGCM) and delineation of target zones for enhanced potential through reconnaissance stage investigations. If enhanced potentiality is established in the area, follow up investigation under prospecting stage is carried out.

GSI is carrying out National Geochemical Mapping Programme (NGCM), in which stream sediments are being collected systematically and are being analysed for 68 elements including the REEs and the RMs to understand the elemental distribution patterns of the country. During the XII plan, search for RM and REE is proposed to be

taken up in the above belts. The proposed work component includes 3000 sq km of Large scale mapping (1:10,000 – 1:12500) and 10.00 sq km Detailed Mapping (1:1000 to 1:2000) supplemented by a quantum of 4000 m of drilling in the states of Tamil Nadu, Uttar Pradesh, Andhra Pradesh, Jharkhand, West Bengal, Orissa, Rajasthan, Gujarat and Meghalaya. The detail of the items to be taken up in different states is being worked out. Besides, GSI is trying to collect and examine the chemical and other data generated from the past mapping and investigation reports for locating suitable target areas for further search of REE.

AMD carried out exploration for REE and rare metals. The niobium and tantalum is required as structural materials in nuclear reactors. The columbite-tantalite bearing pegmatites are located in Bastar district, Chhattishgarh, Mandya district, Karnataka and in parts of Bihar, Jharkhand besides the Known mica belts of Andhra Pradesh, Bihar & Rajasthan. AMD operates pilot plants for recovery of columbite tantalite from pegmatitic gravel. Sizeable reserve of xenotime has been established in the riverine placers of Siri river in Raigarh district, Chhattishgarh, Deo river in Gumla district, Jharkhand and in apatite magnetites veins of Kanyalunke, Singhbhum district, Jharkhand. REE and rare metals investigation was also carried out by AMD at Siwana ring complex and Newania Carbonatite in Rajasthan, and Amba Dongar in Gujarat. Scandium has been reported from Bichun near Jaipur (which is an encouraging indication).

3.0.0 State /Belt wise Description of REE prospects in India.

3.0.1. ANDHRA PRADESH:

a) Kanigiri granite,Prakasm district, Andhra Pradesh.

Among the granite hosted RM mineralisation, the most significant one is the recent discovery of RM bearing granite in Kanigiri – Podili tract of Nellore and Prakasam districts, Andhra Pradesh (Ramachar et al., 1989). The airborne radiometric survey with the help of a gamma-ray spectrometer by AMD in 1977 had indicated high radioactivity confined to the peripheries of this granite body which occurs as main hill mass just NE of Kanigiri town. The leucogranite occurs as an intrusive body within the metabasic rocks represented by sericite-chlorite schist and hornblende-schist/gneisses.

The granite is made up of potash feldspars (perthitic), plagioclase and biotite with accessory zircon, fluorite, topaz, apatite and arsenopyrite. The potash feldspars

are at places replaced by albite. The heavy minerals separated from a sample of this granite have indicated the presence of columbite – tantalite, samarshkite, fergusonite, monazite and zircon in the order of decreasing abundance. The heavy mineral concentrate has analysed 14.9% Nb₂O₅ and 2.2% Ta₂O₅. Subsequent detailed work by AMD has proved that both this granite and the soil developed over it provide a major source of niobium and tantalum. The resource is estimated at 3.73 million tonnes.

3.02. ASSAM:

a. Samchampi alkaline complex of Assam

Samchampi alkali complex in Mikhir hills of Assam is another potential area for Nb-Ta minerals. The Samchampi Alkaline complex (SAC) was discovered by G.S.I in the year 1984. The major part of the SAC is made up of leucocratic rocks represented by pulaskite, lusitanite, shonkinite, ijolite and malignite while the mafic rocks comprise mainly alkali pyroxenite and biotite pyroxenite (Sunil Kumar et al., 1996). The carbonatites (sovite and kasenite variety) occur in the peripheral zone of the alkaline complex and form ring dyke. Other rock types of this complex include magnetite-hematite and magnetite-apatite rocks.

Considering the possibility that the weathered residual soil developed over the carbonatite concentrate high content of certain rare metals, AMD had evaluated the residual soil and proved a reserve of 14,966 tonnes of Nb, 4,983 tonnes of Ta and 2,520 tonnes of Y over an area of 10.94 sq.km. Their detailed work has also indicated that the SAC has good potential for pyrochlore with a total reserve of 11,720 tonnes at an average grade of 400g/tonne (Hoda et al., 1996).

3.03. BIHAR & JHARKHANDA

a) Pegmatites of Bihar mica belt:-

The Bihar mica belt stretches along WSW – ESE direction for nearly 160Km between Gurpa in Gaya district in the west upto the southern part of Bhagalpur district in the east. Within this belt, more concentration of pegmatites are noticed in a small area of about 12 sq.km in the Kodarma R.F. Area. These pegmatites occur within the Archaean pelitic metasediments and hornblende schist/amphibolite. Saha (1986) had classified these pegmatites into three types, viz. a) deformed pegmatites, b) muscovite – bearing pegmatites and c) Rare – metal and other pegmatites and he considered them to represent successive stages of evolution. Among these, the RM

bearing pegmatites are reported to contain cleavelandite (An 4-8) in addition to microcline, plagioclase, quartz and muscovite. The RM bearing minerals present in this type include columbite – tantalite, samarskite, etc. **The potash feldspars present in these RM bearing pegmatites contain high Rb, Cs and Li and low Ba compared to the K – feldspars present in the other pegmatites.**

Studies carried out by Banerjee and Bhattacharyya (1986) on the pegmatites of Tisri, Lachhimpur and Kodarma areas of this mica belt have shown that rich pockets of muscovite are invariably associated with folourapatite and tourmaline. Preponderance of plagioclase over K – feldspar has also been noticed in the zones rich in muscovite books. The RM pegmatites commonly contain lepidolite and cleavelandite with enrichment of Li, Ta, La, etc.

3.0.4 GUJARAT:

a) RM bearing pegmatites of Gujarat

Occurrence of REE and RM bearing pegmatites with gadolinite, cassiterite, and tourmaline in Palanpur – Hosainpur area of Gujarat is known for quite sometime. Recently, the AMD has reported a new occurrence of RM bearing granitic pegmatite with discrete minerals of columbite – tantalite in **Limboi area, Sabarkantha district of Gujarat (Muralikrishna et al., 1995).**

The Limboi pegmatite, forming part of the Late – proterozoic Idar granite, occurs within the Mid – proterozoic metasediments of Delhi Supergroup. The pegmatite is an interior type of zoned one, measuring 350m x 200m in size. It shows highly fractured quartz core surrounded by an intergrowth zone consisting of quartz, K-feldspar, muscovite and tourmaline with columbite – tantalite, fersmite [(Ca, Ce, Na) (Nb, Ta, Ti)₂ (O, OH, F)₆], fluorite and beryl.

Columbite – tantalite occurring in this pegmatite has analysed upto 60.07% Nb₂O₅, 15.35% Ta₂O₅, 2.71% Y₂O₃, 1553 ppm Sn, 0.30% Ce₂O₃, 1.3% WO₃ besides 1.2% eU₃O₈, 0.2% U₃O₈ and 2.4% Th O₂. The higher content of Y₂O₃ (upto 2.71%) in the columbite - tantalite samples of Limboi pegmatite has been attributed to possible xenotime mineralisation associated with this zone.

b.) RM and REE bearing carbonatites of Gujarat:

The pyrochlore ($\text{Na}_2\text{Ca Nb}_2\text{O}_6$) mineralisation in the carbonatite of Ambadongar area has been well documented by Udas (1983). In addition to this, a number of carbonatite and carbonatite-breccia bodies, and dykes of alkaline rocks such as phonolite, nepheline syenite, alkali pyroxenite and alkali-gabbro have been reported from **Saidiwasan-Nakkal-Panwad-Kawant** are of Baroda district. They occur as dykes and sills in the infratrappean sandstone and Deccan Trap basalt (Pant et al., 1996).

All these rock types show enrichment of LREE over HREE with the ΣREE content ranges from 0.0016 to 0.59%. The Nb values of carbonatites of Saidiwasan – Nakkal area ranges from 155 to >1000ppm. Interestingly, the infratrappean sandstone also analyses higher REE, Nb and Y contents. Pyrochlore, microlite, sphene, apatite and zircon are the REE bearing minerals found in these rock types.

3.0.5 Karnataka:

a) RM bearing pegmatites of Karnataka

In Southern Karnataka, a zone of RM bearing pegmatites extending over an area of 4Km x 1Km has been delineated in Maralagalla – Allapatna area in the eastern margin of the Karighatta schist belt exposed east of Srirangapatnam (Banerjee et al., 1994). These pegmatites occur as N – S to NNE – SSW trending bodies traversing the hornblende schist/amphibolite of Dharwar Supergroup (Sundaramoorthy and Pazhamalai Nathan, 1984).

These pegmatites are complex type showing well developed zoning with an outer zone (a) of blocky feldspars, a middle zone (b) with graphic intergrowth between quartz and K – feldspar and an inner zone (c) of quartz core. The rare metals are mostly confined to the contact between the zone 'b' and zone 'c' and sometimes along the fractures in the zone 'b'. They contain rich quantities of spodumene (Li_2O – 6.55 to 7.35%), tantalites (Ta_2O_5 -50 to 70%), beryl (BeO – 11%) and rare pollucite. Spodumene constitutes about 10 – 15% of the bulk of the pegmatites (Banerjee et al., 1994).

Besides these, several RM bearing pegmatites have been reported in the western margin of Yedyur – Karighatta belt north of Byderahalli, around Hadanur and Doddakoppal, Amareshwar in Raichur district and near Kabbur and Doddakadanur in Holenarasipur schist belt. Among these, the Kabbur and

Doddakadanur pegmatites contain hiddenite ($\text{Li}_2\text{O} - 6.11\%$) in addition to significant quantities of beryl and columbite – tantalite. Although spodumene is reported from several places, viz. Ooregum mine of Kolar Gold Field and in parts of Hutti and Sandur schist belts, the spodumene occurrence in the pegmatites of Amareshwar in Raichur district is reported to be of economic significance (Devaraju et al., 1990).

3.0.6 MEGHALAYA:

a) Sung Valley carbonatite complex, Jaintia Hills District, Meghalaya.

The carbonatite complex of Sung Valley is emplaced within the quartzites, phyllites and quartz – sericite schists of Shillong Group of Precambrian age. The other members of the alkaline complex include pyroxenite, peridotite, ijolite, syenite and felspathic veins (Krishnamurthy, 1985). Besides, minor dykes and veins of magnetite – serpentine rock, ijolite and melilite – bearing types with a rough radial disposition are also present.

Fenitisation, due to both ijolites and carbonatites, is manifested in the form of development of wollastonite – rich aegerine – augite bearing rocks and K-feldspar – aegerine – augite veins.

Carbonatites of Sung Valley complex are mainly sovite with minor beforosite types rich in magnetite and apatite.

The sovite variety analyses 154-606 ppm of Nb, 50-100 ppm of Y, 244-471 ppm of Ce, 50-100 ppm of La, 3355-3509 ppm of Sr, 513525 ppm of Ba, <0.3 to 29 ppm of U and <0.6 to 7.8 ppm of Th. On the otherhand, the beforosite variety analyses high Nb (512 ppm) and Ba (622 ppm) and low Y (10-50 ppm), Ce (149 ppm), La (30-50 ppm) and Sr (1399 ppm).

3.0.7 ODISHA:

a) RM bearing pegmatites of Bastar – Koraput – Pegmatite Belt (BKPB).

The pegmatites of BKPB occurring in the southeastern part of the Bastar craton of Central India are associated with tin, niobium, tantalum, beryllium and lithium mineralisation in the form of cassiterite, columbite – tantalite, beryle, lepidolite and amblygonite (Ramesh Babu, 1993). They occur as intrusive bodies of varying dimensions within the andalusite schist, quartz – muscovite schist, sericite schist and quartzite of the Archaean Bengal Group.

Based on the detailed study of size, shape, internal zoning and associated mineralisation, of over 200 pegmatites of BKPB, Ramesh Babu (1993) has classified them into the following five types:

Type – I	Simple, unzoned biotite or muscovite – microcline pegmatites without tin and rare metal mineralisation.
Type – II	Partly differentiated muscovite – microcline pegmatites with beryl.
Type – III	Fully differentiated muscovite – microcline pegmatites with beryl, columbite –tantalite \pm cassiterite.
Type – IV	Replaced lepidolite – albite – muscovite pegmatites with amblygonite, cassiterite, beryl \pm columbite – tantalite.
Type – V	Replaced muscovite – albite pegmatites with cassiterite and beryl.

Trace Elements	Minerals	Type – I	Type – II	Type – III	Type – IV
1) Rb	perthites	533 - 652 ppm	1235 -1320 ppm	2587 - 6903 ppm	
2) Rb	muscovites	1201 - 1424 ppm	—	—	2765 - 5585 ppm
3) Cs	muscovites	28 - 72 ppm	—	—	566 - 695 ppm
4) Rb/Sr ratio		7 - 8	23 - 35	65 - 121	—

The type I to type V indicate internal evolution of the pegmatites forming a paragenetic sequence. This is very well reflected in their trace element geochemistry. The Rb content in perthites and muscovites show gradual increase from type I to type – IV. Similarly the Rb/Sr ratio also shows considerable increase from type – I to type -IV pegmatites indicating the trend of evolution. Based on detailed assessment, Ramesh Babu (1993) has concluded that among the pegmatites of BKPB, those of

type – III, IV, V are more important from the point of tin and rare metal mineralisation. These mineralised pegmatites are mostly well zoned with distinct indications of hydrothermal alteration in the form of albitisation and greissenisation (Ramesh Babu et al., 1993).

3.0.8 RAJASTHAN:

a) Malani granites of Rajasthan:-

The granites of Malani igneous suite of Rajasthan show anomalous RM and REE values. The geochemical studies carried out by Kochchar (1996) reveal that the Malani granites contain distinctly higher amount of U, Th, Ta, Zr and relatively lesser amount of Ba, Rb and Sr than the average for the fertile granites of Cerny and Meintzer (1988). The Thunjuhunu and Tosham granites have the highest abundances of U, Th and Sn amongst the Malani suite of rocks. It is to be mentioned that rich mineralisation of tin-tungsten has been located in Tosham area where G.S.I, is carrying out detailed exploration.

The location of the Thunjuhunu granite along the same lineament which passes through the mineralised granite of Tosham area, and its high U and Th content together with its low K/Rb, Ba/Rb and depleted Zr trend makes it a potential source for RM mineralisation.

The tectonic setting and geochemical characters of these granites indicate that they belong to 'A' – type granite of Whalen et al., (1989).

b.) Pegmatites of Bhilwara mica belt, Rajasthan

The pegmatites of Bhilwara area are classified into the following three types (Bhattacharjee, 1986).

Type – I : Barren

Type – II : Muscovite pegmatites

Type – III : Muscovite – Rare metal pegmatites with Be, Nb, Li, Sn, W mineralisation.

The geochemical studies carried out by Bhattacharjee (1986) have brought out that Li values and K/Rb ratios in muscovites can be used as effective criteria to

discriminate the RM pegmatites from the barren ones. His studies have shown that there is a gradual increase of Li, Rb and Cs and decrease of Ba values and Ba/Rb and K/Rb ratios from type – I to type – III pegmatites.

Detailed petrological studies of part of this pegmatite belt in Ajmer, Bhilwara and Udaipur districts have resulted in classifying them into nine varieties based on their mineral assemblages (Datta, 1986). Among them, the variety showing smoky quartz - cleavelandite – green muscovite association is reported to contain subordinate amounts of tourmaline, beryl and columbite – tantalite.

3.0.9. TAMILNADU

1) Pegmatites:-

In Tamil Nadu, RM bearing pegmatites have been reported in parts of Salem, Dindigul and Madurai districts.

a) Salem district:-

In Kullampatti area lying south of Alasiramani, a zone of six parallel to sub-parallel discontinuous bodies of ENE-WSW trending leucocratic pegmatites has been delineated within an area of 1.6 x 0.3km (Nathan and Kanishkan, 1994). The width of the individual body varies from 2m to 14m. The pegmatites are essentially made up of quartz and sodic plagioclase (albite) with profuse development of muscovite and garnet. No distinct zoning is seen in the individual bodies. Groove samples (47nos) collected from these pegmatites have analysed the following values of rare metals (Nathan and Kanishkan, 1996).

Elements	Range (in ppm)	Mean (n=47) (in ppm)	Crustal abundance in acid igneous rocks (in ppm)
Nb	40 - 171	101	20
Ta	5 - 70	29	3 - 4
Y	10 - 245	76	—
Li	10 - 31	18	30 - 70
Be	2 - 14	8	3 - 5
Zr	145 - 784	386	170 - 200
Sn	10 - 40	22	3
Pb	138 - 417	265	10 - 30
Rb	130 - 860	383	—
Sr	30 - 310	87	—

Ba	5 - 159	44	600 - 830
Ga	70 - 150	107	—
K/Rb	—	94	—
Ba/Rb	—	0.156	—
Ga/Al	—	2.63	—
Rb/Sr	—	6.37	—

From the above data, it is clear that these pegmatites analyse anomalous values of Nb, Ta, Y, Zr, Sr, and Rb which are comparable with the tin mineralised Ijero and Egbe pegmatites of southwestern Nigeria. They show striking depletion of Ba and Sr compared to the temporally and genetically related Sankari-Tiruchengode granite. These pegmatites are characterized by low K/Rb and Ba/Rb and high Ga/Al and Rb/Sr ratios similar to several specialised RM bearing granite-pegmatite systems.

Although beryl was reported to have been mined from the Alasiramani pegmatites, no discrete crystals of beryl or topaz could be seen in the pegmatites of Kullampatti area. The Be values shown by these pegmatites are also too low.

Lack of data on the fluorine content of these pegmatites notwithstanding, the higher Nb and Y values (>Li and Cs) characterise them to be of 'NYF'/Mixed' type of Cerny and Meintzer (1988).

In Jalakandapuram area lying about 15km north of Idappadi, several NNE – SSW to NE-SW trending zoned pegmatites are exposed. These pegmatites are well zoned with quartz core and a border zone of pink perthitic potash feldspars and quartz showing graphic intergrowth at places. One such pegmatite vein exposed immediately south of Kunda Malai contains rich pockets of columbite-tantalite recording moderate to high radioactivity. A sample collected from this mineralised portion analyses Fe₂O₃ – 1.45%, FeO-8.60%, MnO – 8.60%, TiO₂ – 0.89%, P₂O₅ – 0.30%, Nb – 700 ppm, Zr – 500 ppm and Sn – 30 to 70ppm (Krishna Rao and Nathan, 1992).

b) Dindignl – Anna district:-

During 2001 detailed studies of the pegmatites carried out in Kadavur area to assess their potentiality for RM and REE mineralisation. The pegmatites of Kadavur area, granites of Pudukkottai and Pulangkurichi areas and carbonatites of

Kambammettu area were studied in detail for Rare Metals and REE mineralisation. The pegmatites of Kadavur area show radial distribution in NE-SW, NW-SE and E-W directions within the gabbro-anorthosite suite of rocks. The pegmatites are tabular to pod shaped and most of them exhibit zoning with quartz core and quartz-feldspar-mica intergrowth in the borders. Based on the mineral assemblages and the intensity of radioactivity, these pegmatites are classified into a) Rare – Earth (RE) type, b) Beryl type, c) Albite type, d) Tourmaline type and e) other pegmatites.

Among the twenty three major pegmatites and granites of Kadavur area studied under this project, the pegmatites of Karumanpatti and Gujiliyamparai areas and the granite of Servaikkaranpatti area show higher concentration of Y, Nb and LREE while the pegmatites of Ramareddiyapatti and Kalpatti areas are significant from the point of Y, Nb and HREE mineralisation. The RM and REE bearing mineral phases identified in these pegmatites indicate columbite – tantalite, allanite and samarskite.

c) Madurai district:-

An occurrence of beryl and gadolinite bearing pegmatite has been reported 1km southwest of Karattupatti village (Toposheet No 58F/16) in Tirumangalam taluk, Madurai district (Perumal, 1974).

The area around Karattupatti exposes migmatitic hornblende – biotite gneiss \pm garnet interbanded with garnetiferous quartzo felspathic gneiss, quartzite, calc – granulite and pyroxene granulite. The pegmatite are mostly confined to the gneissic rocks and are absent in the quartzites.

The pegmatite is a zoned type with a central zone of perthite surrounded by a perthite – quartz – plagioclase zone and an outer zone of quartz – felspar – muscovite pegmatites. It contains RM and REE bearing minerals such as allanite, polycrase (a niobate and titanate of yttrium, erbium, cerium and uranium), gadolinite, golden yellow and green beryl and tourmaline. These minerals occur as disseminations, small seggregations and pods in the pegmatites, as well as float in the debris surrounding it.

The gadolinite of Karattupatti is reported to be greenish black in colour showing conchoidal fracture and vitreous lustre. It has analysed 51.84% of combined Ce_2O_3 , $\sum La_2O_3$, $\sum Y_2O_3$, 22.04% SiO_2 , 15.7% of $Fe_2O_3 + FeO$ and 9% of

BeO (Perumal, 1974). The sample has also analysed 0.54% U_3O_8 and minor amounts of REE such as Er, Gd, Yb, Dy, Ho, Lu and Tm.

In view of the presence of such radioactive minerals in the pegmatites of Karattupatti area, a systematic study of all the pegmatites occurring in this area has to be taken up.

2) Alkali granites (a – type):-

In Tamil Nadu, granites showing Pan-African ages (612-390 Ma) are predominantly found within the E-W trending Cauvery shear zone of central Tamil Nadu. Among them, the prominent ones are Maruda Malai granite in the west, Punjai Puliampatti and Karamadai in the centre and Sankari – Tiruchengode granite in the east (Nathan et al., 1994).

a) Sankari – Tiruchengode granite:-

Detailed studies carried out on the Sankari – Tiruchengode granite show that it is made up of two distinct varieties, viz. Leuco granites and pink granites showing distinct mineralogical and geochemical signatures (Nathan et al., 1994). While the albite rich leuco granites are restricted to the periphery of the pluton, the potash feldspar rich pink granites are emplaced in the central portion along the axial zone of F_3 fold.

The geochemical studies indicate that the leuco granites are predominantly of tonalite – granodiorite composition while the pink granites show alkali – granite/quartz – monzonite composition.

Among the leuco granites, the pegmatoidal variety occurring in the northern part of the pluton (Kullampatti area) hosts Nb, Ta, Y, and U mineralisation. It also shows anomalous Pb and Sn values. A sample (KR/1) collected from the highly radioactive zone has analysed 6917 ppm of Nb, 1248 ppm of Ta, 169 ppm of Sn, 3188 ppm of Y, 2610 ppm of U_3O_8 , 325ppm of Th and 258 ppm of Pb. The higher values of Nb, Ta and Y with minor Sn can be attributed to the presence of columbite – tantalite and fergusonite in the granite. It is also seen that the higher radioactivity shown by these leuco granites is mainly due to presence of significant uranium in it.

The pink garnites, on the otherhand, do not show any anomolous enrichment of RM such as Nb, Ta and Y. But they show higher thorium values (38-1320 ppm)

in the areas like Tiruchengode, Velammavalasu and Morur. In all these place, rich concentration of allanite in the form of thin streaks could be seen within the pink granites. They record moderate to high radioactivity of 2 to 18 times above back ground values.

The pink granites, on the otherhand, show higher Σ REE content varying from 73.94 to 375.05 ppm. In the highly radioactive zones, the Σ REE goes upto 7049 ppm with large LREE/HREE ratios. Among the LREEs, La and Ce account for a major part and these REE are mostly concentrated in the allanite associated with these radioactive zones.

The above studies have revealed that in the Sankari-Tiruchengode area, the Na₂O rich leuco granitoids show enrichment of RM (Nb, Ta, and Y), U, Th and HREE while the K₂O rich pink granites show enrichment of Th and LREE in zones rich in allanite. These striking differences observed in the RM and REE distribution pattern of these granites possibly indicate that they were derived from a heterogenous source.

b) A-type granites of Madurai:-

AMD has located certain RM and REE bearing pegmatites spatially related to a granite body near Nagamalai – Minakshipuram areas in Madurai district (Pandey et al., 1994). The pegmatites contain gadolinite, fergusonite and allanite and it may form part of the Karattupatti pegmatites described elsewhere in this paper. The associated granite, which has yielded an Rb-Sr isochron age of 837 Ma, shows geochemical similarity with the 'A' – type granites which are generally considered to be parental to RM and REE rich pegmatites. The authors consider that these fergusonite, gadolinite and allanite bearing pegmatites might be genetically related to the Nagamalai – Minakshipuram granite. They have also reported that the graphites found in calc-granulites, calc-schists and calc-gneisses of this area are uraniferous.

3) Alkaline – carbonatite complexes:-

In Tamil Nadu, major bodies of alkaline – carbonatite complex occur within a 200km long NNE – SSW trending belt extending from Gudiyattam in the north to Bhavani in the south. This lithotectonic belt characterized by intense shearing and emplacement of alkaline plutons is bound on either side by major NNE-SSW to NE-SW trending lineaments. Three major carbonatite bodies are reported within this zone, viz. Sevattur carbonatite, Samalpatti carbonatite and Pakkanadu-Mulakkadu

carbonatite. These bodies are associated with dunite/pyroxenite and syenite in all these places. A major syenite pluton with sub-ordinate pyroxenite and rare carbonatite has been delineated in the northernmost part in and around Elagiri hill.

Detailed description of these alkaline-carbonatite complexes and their REE potentiality are described below:

a) Sevattur carbonatite:-

The Sevattur carbonatite is both of sovite and beforosite variety. Based on the detailed studies, Udas and Krishnamurthy (1970) have worked out that the beforosites which occupy the central portion of the complex are the youngest while the sovites are relatively older. Development of large books of biotite, phlogopite/vermiculite is characteristically seen in the pyroxenites associated with the carbonatite.

The Sevattur carbonatite analyses 1663 ppm of Ba, 6427 ppm of Sr, 763 ppm of Zr, 78 ppm of P₂O₅ and 16 ppm of Sc. The enrichment factor for certain diagnostic elements such as Ba, Sr, Zr, La + Ce, Nb, Sc and P in the Sevattur carbonatite ranges from 16 to 332 times over sedimentary limestone or marble.

The pyroxenites and the carbonatites of Sevattur have yielded Rb-Sr whole rock and mineral isochron age of 770 Ma. (Anil Kumar and Gopalan, 1991).

b) Samalpatti carbonatite:-

In Samalpatti area, the carbonatites occur as lenses mainly within the pyroxenite-the major one extending from Gargipalli to Onnakkarai for a distance of about 2km with width varying from 20 to 150 metres (Viladkar and Subramanian, 1995). The carbonatite is mostly sovite variety showing grain size variation from fine to coarse grained. Minor dolomitic and ankeritic variants are also seen. A rare Benstonite variety has been identified near Jogipatti village (Semenov, 1971). This variety is reported to contain 1.8% Rare Earths both in soluble and insoluble portions. The soluble rare-earths contain La-27.5 ppm, Ce-48.3 ppm, Pr-4.7 ppm, Nd-18.8 ppm, Sm-2.7 ppm, Eu-0.3 ppm and Gd 0.5 ppm (Semenov, 1971).

The Samalpatti carbonatites contain the following REE minerals (Semenov et al., 1978).

Cubic fergusonite [Y(Nb,Ta)O ₄]	Nb ₂ O ₅ -44%
	TR ₂ O ₃ -37.58% (Total Rare Earth oxides)
Ilmenorutile [Fe-Nb-TiO ₂]	Nb ₂ O ₅ -12.50%
	FeO-4.38%

	TiO ₂ -82.71%
Monazite [(Ce,La,Y) PO₄]	P ₂ O ₅ -28.60%
	U ₃ O ₈ -0.35%
	ThO ₂ -1.09%
	TR ₂ O ₃ -69.08%

In the syenites and syenitic pegmatites, presence of allanite, chevkinite, sphene, thorite and zircon are reported in varying proportions.

c) Pakkanadu-Mulakkadu carbonatites:

In Pakkanadu and Mulakkadu areas, carbonatite occurs as thin veins and lenses in the highly altered biotite rich-pyroxenites surrounded by syenites. These carbonatites are pure calcite rich sovite type with minor variation to biotitic and ankeritic variants. Apatite, magnetite, allanite, barite, monazite, zircon and cerianite are the accessory minerals present in them (Suryanarayanan Rao et al., 1978). The carbonatites and the associated pyroxenites show high radioactivity of 5 to 20 times above BG with enrichment of LREE, especially La & Ce. Monazite is mostly concentrated in the carbonatites and in the calcite-mica rocks to the west of Pakkanadu, while allanite is predominant in the pyroxenites of Mulakkadu. Eschynite is reported in association with baryte and allanite in the carbonatites of Pakkanadu. It contains 48% of Nb₂O₅, 13.78% of TiO₂ and 24.02% of TR₂O₃ (Semenov et al., 1978).

The eU₃O₈ values of the Pakkanadu carbonatite ranges from 0.01 to 0.058% while that of pyroxenite from 0.02 to 0.054%. The calcite-mica rock of Pakkanadu area has analysed higher eU₃O₈ values from 0.030 to 0.069%. The assay data of allanite sample indicate predominance of thorium over uranium (Suryanarayana Rao et al., 1978).

d) Hogenakkal carbonatite complex:-

Apart from the well documented Koratti, Samalpatti and Pakkanadu carbonatites of Neo-proterozoic age (700–770 Ma), a Palaeo-proterozoic (Ca-2000 Ma) pyroxenite – carbonatite complex has been identified in Hogenakkal area lying about 40km to the west of Dharmapuri, close to the Karnataka border (Srinivasan, 1977; Natarajan et al., 1994).

The Hogenakkal alkaline complex comprises pyroxenite, syenite and carbonatites, occurring as linear bands and dykes. The carbonatites occur as a series

of discontinuous bodies within two parallel NNE-SSW trending pyroxenite dykes intruding the charnockite. These carbonatite lenses which are of sovite variety, show variation in strike length from 25 to 800m and width from 3 to 50m. Eighteen such lenses of carbonatites have been delineated within these two pyroxenite bodies.

Based on the mineral assemblages, the carbonatites of Hogenakkal have been classified into three types (Natarajan et al; 1994). They are,

- i. Mica – Apatite – Calcite carbonatite (MAC carbonatite)
- ii. Mica – Pyroxene – Apatite - Calcite carbonatite(MPAC carbonatite)
- iii. Carbonate – Mica pyroxenite (CM pyroxenite).

The three types of Hogenakkal carbonatites show the following geochemical signatures.

Elements	MAC carbonatite	MPAC carbonatite	CM pyroxenite
Sr	9523 - 11458 ppm	6426 - 11348 ppm	3552 - 6203 ppm
Ba	317 - 635 ppm	212 - 448 ppm	978 - 1023 ppm
Sr/Ba	14.90 - 36 ppm	16.23 - 30	3.63 - 6.07 ppm
∑REE	46.53.5 - 4741.2 ppm	2763 ppm	1427 - 1535 ppm
La/Yb	110.6 - 170.3	287.05	51.8 - 86

The above table shows that the MAC and MPAC carbonatites are enriched in Sr with Sr/Ba ratio ranging from 14.90-36. The total REE content is very high in MAC carbonatite compared to the MPAC carbonatite and CM pyroxenite. All these varieties show LREE-enriched patterns with steep slopes (Natarajan et al., 1994).

The total REE content (4653-4741 ppm) of the MAC carbonatite of Hogenakkal area is strikingly higher than the sovitic carbonatites reported elsewhere in the world (753-2569 ppm).

e) Carbonatite of Kambammettu area:-

In Southern Tamil Nadu, a small body of carbonatite of magnetite-sovite variety has been located in the foothills, east of Kambammettu in Madurai district (Balakrishnan et al., 1985). This carbonatite body appears to have been emplaced along a NNE-SSW trending lineament within the charnockite - gneiss terrain.

The carbonatite is essentially made up of calcite and magnetite with accessory amount of apatite and phlogopite. Few grains of monazite, barite and bastnaesite are also reported.

Balakrishnan et al (1985) reported that a grab sample of this carbonatite has analysed 15 ppm of Y, 100 ppm each of La and Ce, 10 ppm of Gd, 15 ppm of Dy, 2 ppm of Ho and 8 ppm of Er. The Ba and Sr values are > 1000 ppm. The analysis has not indicated any significant values of Nb, Ta and Th.

3.1.0 WEST BENGAL

a) Pegmatites of Chotanagpur Gneissic complex of Purulia district, West Bengal.

Recent studies by Sarkar et al., (1996) in Beku, Jabor, Belamu and Parga villages in Purulia district of West Bengal have resulted in locating several pegmatite bodies within the high-grade supracrustals comprising garnet – sillimanite – mica schist, calc – gneisses and amphibolites. These pegmatite bodies, occurring in different host lithologies in each of the above mentioned places, show variation in their strike length and width. These fertile pegmatites delineated so far, have followed both the E–W and ENE–WSW trending megalineaments. While those associated with the E–W trending lineament show enrichment of Y, REE, Sc, Ti, Zr, Be, Th, U, F and Nb>Ta, the pegmatites associated with the ENE–WSW trending lineament are enriched in Li, Rb, Cs, Be, Ga, Sn, B, P, F and Nb<Ta. As per the characterization of pegmatites by Cerny (1991), the pegmatites of former can be grouped under 'NYF' type while those of latter under 'LCT' type.

During the period from 1998-99 to 2005-07, Exploration carried out by GSI for Cesium at Southern slope Of Belamu Hill and Khatanga areas of Chhotanagpur Gneissic Complex, Purulia District. Possible category reserve of Cesium had been estimated at 0.3%, 0.1% and 200 ppm cesium cut-offs which are as follows-

1. At 200 ppm Cs-cut off

A. Belamu area

1. Aplite: 46801.73 tonnes of aplite having average 3040.13 ppm Cs, 373.52 ppm Rb and 236.76 ppm Li.

Pegmatite: 57852.81 tonnes of Pegmatite having average of 2668.62 ppm Cs, 1059.66 ppm Rb and 286.22 ppm Li.

B. Khatanga Area:

1. Pegmatite: 2364 tonnes of pegmatite having average 4654.17 ppm Cs, 988.95 ppm Rb and 299.08 ppm Li.

2. At 0.1% Cs-cut off

A. Belamu area

Aplite: 30994.18 tonnes. Pegmatite: 30427.88 tonnes.

B. Khatanga Area:

Pegmatite: 1140.73 tonnes.

3. At 0.3% Cs-cut off

A. Belamu area

Aplite: 23370.98 tonnes. Pegmatite: 14825.37 tonnes.

B. Khatanga Area:

Pegmatite: 1130.83

Investigation for rare metal mineralization in selected pegmatite bodies of Chhotonagpur gneissic Complex.

Resource estimation :**Beku area**

Probable category reserve of Cs, Li and Rb had been estimated for Beku pegmatite with assay limit of $\geq 0.3\%$ and $\geq 0.1\%$ for Cs and $\geq 0.5\%$ for Li and Rb. Reserve estimation had given rare metal bearing pegmatite of 65906 tonnes with 0.6% Cs, 8383 tonnes with 1.05% Li and 1233 tonnes with 0.52% Rb.

Jabar - Belamu-Khatanga-Damrughutu area

Only preliminary investigation involving DM, Pitting/trenching and sampling had been carried out which shows presence of pegmatite and aplite containing maximum 2.58% Cs in Belamu. Reserve was not estimated

b. Alkaline – carbonatite complex of West Bengal.

The alkaline carbonatite complex emplaced along the South Purulia shear zone (SPSZ) comprises alkali-syenite, carbonatite, apatite-magnetite rock and alkaline ultramafites occurring within the Precambrian Singhbhum Group of rocks. The carbonatite and the apatite-magnetite rocks are significantly enriched in REE (Basu et al., 1996). The mineral assemblages present in the carbonatites of SPSZ are apatite, riebeckite, acmite, biotite, phlogopite, tetra-ferriphlogopite, sphene, perovskite and magnetite in a matrix of calcite.

The \sum REE content of these carbonatites ranges from 231 to 1046 ppm with an average of 662 ppm. The REE pattern indicates fractionation between LREE and HREE. In addition to the high REE content, the alkaline-carbonatite complex of SPSZ is significantly enriched in Nb, Zr, Sr and Ba (>1000ppm

4.0.0 Promising Area for future exploration ;

Based on preliminary information available for REE investigation carried out during F.S.10-12 and 12-13 ,GSI reported the presence of REE in anomalous concentration from different localities which can be considered for future exploration after getting final results. They are

1. The alkaline ultramafic complex of Samchampi area, Assam is a potential source for phosphorus (P), Niobium(Nb), Tantalum(Ta), Gallium(Ga), Zirconium (Zr), and REE & radioactive elements.

2. The alkaline complex of Sung valley is rich in P & REE elements, reported by GSI in 1989-90.
3. The apatite deposits of Beldih, Purulia district, West Bengal is found to be associated with alkaline Carbonatite Complex which is enriched in REE & Nb. (2007-08)
4. In Tamil Nadu & Pondichery in Toposheet no. 58 J/5 presence of high values of Cesium was reported from "C" horizon & regolith samples during NGCM (2008-09).
5. REE mineralisation in Dhani Granite area, Pali district, Rajasthan as well as Sendra-Chitar area are being explored. Channel samples from hydrothermally altered Dhani granite indicate Σ REE of more than 0.1%. Five zones of REE mineralization have been identified which are as follows:

Mineralized zones	Width x assay
Zone-I	1m X 0.24 % Σ REE
Zone-II	1.5m X 0.10 % Σ REE
Zone-III	2m X 0.32 % Σ REE
Zone-IV	1.5m X 0.64 % Σ REE
Zone-V	2m X 0.14 % Σ REE

5. In Sausar and Koradi-Kolar areas of Maharashtra, evidences of xenotime concentration have been reported through SEM-EDX study. SEM-EDX studies indicated the presence of REE minerals like monazite and xenotime. The analytical results indicate highest concentration of Σ REE of 2470.48 ppm in the foliated granite from Ghuksi area. Pegmatite vein assay highest concentration of Σ REE of 1173.50 ppm. One stream sediment sample from north of Satrapur area shows Σ REE of 1468.53ppm. Analytical results also indicate Be and Rb concentration up to 601.7ppm and 565ppm.
6. Some of anomalous values of REE reported earlier in the Nongpoh pluton are being verified

In course of NGCM work, the following areas were identified as likely target areas for future search of REE:

1. A NW-SE trending 80 km long and 15 m wide anomalous zone in toposheet Nos: 57E/1, E/5, E/6, E/10 which is litho controlled and falls over grey hornblende biotite granite, biotite gneiss, grey hornblende biotite gneiss, grey biotite granite.

2. Anomalous zones of REE, U, Th, Nb, Zr and Hf on the eastern and northern side of Hutti-Maski schist belt falling over granitoids.
3. Anomalous concentration of REE is recorded over the Gothara Granite. Out of 26 samples analysed by ICP-MS, 4 samples recorded anomalous concentration of REE, especially LREE (La, Ce and Nd) with Total REE ranging from 1077.35 to 1685.56 ppm.
4. A NE-SW trending linear corridor represented by intrusives within the Mangalwar complex from the NE corner of toposheet 45K4 to SE corner of toposheet 45K/13 has been identified as target area for REE investigation
5. Anomalous zones of Scandium were delineated in Toposheets 58I/3 of Tamilnadu, 47J/2 in Maharashtra, 53E/2 in HP and 52L/13 in J&K.
6. Anomalous values of Yttrium were recorded in 58I/3 and 58I/4 of Tamilnadu, 55F/12 and 55F/16 in Maharashtra, 53D/15 in Haryana, 52L/13 in J&K, 41E/3 and 41E/4 in Gujarat, 72L/1 and 72L/5 in Bihar, 72I/11 and 73I/12 in West Bengal.
7. Anomalous concentration of REE was recorded in parts of Toposheets 57M/7,8,10,11,13 of Andhra Pradesh, 58I/4,8,11 and 58J/5 of Tamilnadu, 57E/1,2,5,9 and 56D/11, 15 of Karnataka, 58A/4, 58B/1,5,6 of Kerala, 53P/10,11 of Maharashtra, 53D/2,6 of Haryana, 53A/3, 53B/9 of HP, 52L/13 of J&K, 44M/9 of Punjab, 72L/11,15 of Bihar, 73I/3,7,10 of Jharkhand and 73I/11 of West Bengal.

GSI expects future plan of exploration should involve all the exploration organizations to avoid any overlap of programmes and sharing of data and experience. For that, partnership among various organisations, particularly between **GSI, AMD, IRE Ltd** and State Governments needs to be strengthened which in turn will certainly yield more fruitful results.