Investigation of Rare Earth Elements Potential in Iron Ore Deposits in Sri Lanka

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Abstract

Sri Lankan geological terrain is mainly comprised of three different types of Iron ore deposits, which are not in the scale for economic extraction. When we consider the iron deposits on a global scale, most of them are associated with high concentrations of rare earth elements (REE). This research is focused on investigating the potential for REEs of the Sri Lankan iron ore deposits. Three major iron ore deposits of different genesis were selected for sampling, and collected samples were subjected to inductively coupled plasma mass spectrometry (ICP-MS) analysis. Analysis revealed a high potential for REE in Panirendawa and Buttala deposits, while Dela deposits showed the least potential. Although high concentrations were shown in a few samples collected from magnetite deposits, it also contains high variation within a few (10–100) meter distances. This variation was due to different degrees of weathering and transportation of iron ore materials. The highest REE potential was associated with the heavily weathered and transported material rather than the fresh iron ore. If the explored potential for REEs is consistent with the associated geological profile of these iron ore bodies, they could present a mineable REE source for Sri Lanka.

Keywords: Chondrite normalisation, Hydrated iron ore, ICP-MS analysis, Magnetite

1. Introduction

Rare Earth Elements (REEs) are a group of 17 chemically similar metallic elements, which includes Scandium, Yttrium and 15 Lanthanides. They are subdivided into two main categories as light REEs (LREEs; La to Eu) and heavy REEs (HREEs; Gd to Lu and Y). HREEs are scarce in nature and expensive, while LREEs are abundantly found in natural occurrences [1], [2]. Until 1950 the annual REE consumption around the world was less than 5000 metric tons per year, and they were not consumed in day-to-day life. Since the new technologies came to light and they are being used in a wide range of applications such as petroleum refining, high tech designs, medical systems, and emerging clean, renewable energies [3], [4]. As the available resources are only enough to sustain the global production in the current phase for about 100 years more, rapid increment of demand will influence the researchers for finding new sources for REEs [5], [6].

In the global market, 80% and 10% of REE supply are controlled by China and Australia, respectively. China's largest REE deposit is the Bayan Obo Fe-REE-Nb which is comprised of 1 metric ton of iron ore and an average REE concentration of 6.19 wt%. This is said to be the largest REE deposit in the world.

The second-largest supplier of REE in the world is Australia, and they have the richest REE deposit in the globe. This REE deposit is situated in Mount Weld in Western Australia, which is associated with a lateritic Iron ore deposit. Some of the other major iron ore deposits containing high concentrations of REE are Kiruna type iron ore in northern Sweden, Olympic dam (Australia) and Mountain pass iron ore deposit in California in the USA [1], [3]. With the trend of exploring the highest tonnage and highest concentrations for REE associated with iron ore deposits in the world, it is highly probabilistic to explore iron ore with high potential for REE in any country.

There are mainly three types of iron ore deposits in Sri Lanka: Hydrated Iron oxide, Magnetite Deposits and Seruwila copper magnetite type of ore. In this research, we have selected major three deposits, including two types of iron ore categories. Samples were collected from different parts of ore bodies representing fresh iron ore rocks, weathered iron ore, topsoil containing weathered and transported material, and samples from the host rock.

The purpose of this study is to reveal if there is any potential for REEs associated with Sri Lankan iron ore bodies.

2. Methodology

2.1 Study Area

Three main sampling locations were selected for this study, Panirendawa, Dela and Buttala. These locations were distributed in two geological terrains of Sri Lanka, namely, the Vijayan complex and the Highland Complex (Shown in Fig. 1).

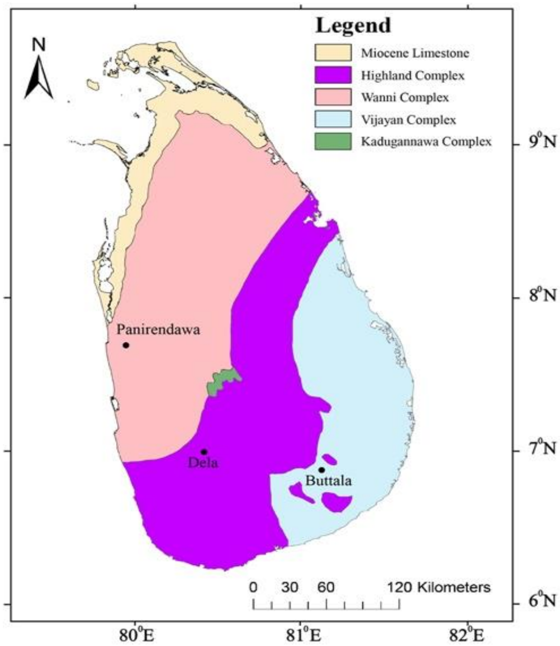

Figure 1: Study areas with respect to the simplified geological map of Sri Lanka.

2.2 Sample Collection

The sample collection was firstly carried out in the Panirendawa Iron ore deposit. This deposit is a Magnetite iron ore deposit situated in the northwestern part of the country. The iron ore deposit is exposed to the surface, and heavily weathered and transported parts also were well seen at the location. Sampling details of the location are as follows (Table 1).

Table 1: Panirendawa sample location details.

Sample Name	Location data (UTM)	
	Latitude (m N)	Longitude (m E)
I-01	380953	834558
I-02	377272	834558
I-03	377274	834559
I-04	377275	834553
I-05	377278	834548
I-06	377297	834529
I-07	377297	834529
I-08	377257	834559
I-09	377259	834555
I-10	377260	834553
I-11	377260	834550

The second sample location was Dela hydrated iron ore deposit, which was presented as surface capping. Samples were collected directly from the iron ore. Iron ore was presented as boulders with different levels of weathering. Sample location details are in Table 2.

Table 2: Dela sample location details.

Sample Name	Location data (UTM)	
	Latitude (m N)	Longitude (m E)
D-01	439634	730479
D-02	439637	730473
D-03	439636	730470
D-04	439631	730469
D-05	439619	730471
D-06	439619	730465
D-07	439611	730466

The third sampling location was the Buttala Magnetite deposit. This deposit was presented as a small hillock. The main ore body was a magnetite vein, and weathered and dispersed ore particles were seen in the vicinity of the deposit.

Sampling was carried out in the crest of the iron ore vein from the topsoil and dispersed weathered iron ore particles. Sample location details are in Table 3.

Table 3: Buttala sample location details.

Sample Name	Location data (UTM)	
	Latitude (m N)	Longitude (m E)
Uva-01	520175	738954
Uva-02	520191	738982
Uva-03	520200	738994
Uva-04	520200	739008
Uva-05	520211	739021
Uva-06	520208	739035
Uva-07	520215	739046
Uva-08	520079	739050
Uva-Soil-01	520009	739029
Uva-Soil-02	519965	739157

A total of 28 samples were collected from all three sampling locations.

2.3 Sample Analysis

The samples were firstly crushed using a laboratory jaw crusher and then powdered using a tema mill. Using a 63 µm sieve, samples were graded prior to digestion.

Conc. HCl and Conc. HNO_3 (1:3 volume ration) with 1 ml of H_2O_2 were used to digest 0.5 g of each sample for 2 hours. 1 ml of the digested sample was filtered, and then it was diluted 100 times using ultra-pure water. This diluted sample was subjected to the ICP-MS analysis.

3. Results

Results of ICMPS analysis of all 28 samples are shown in Table 4, Table 5 and Table 6.

Table 4: ICPMS Results: average concentrations in (ppm) and sample standard deviations - Panirendawa iron ore samples.

REE	Average concentration (ppm)	Sample S.T.D.
TREE	328.88	312.2434
LREE	272.51	240.5015
HREE	56.37	75.62954
La	24.9	14.66576
Ce	140.97	100.9784
Pr	22.64	54.23525
Nd	65.97	150.3092
Sm	12.54	5.269918
Eu	5.5	4.164149
Gd	34.3	45.01139
Tb	3.12	6.516497
Dy	7.87	11.30398
Ho	1.1	0.989987
Er	5.68	9.392846
Tm	0.43	0.347795
Yb	3.52	4.18151
Lu	0.37	0.336545

The obtained concentrations of REEs are complex to interpret and compare with other concentration values of REE sources. To overcome this, the chondrite normalisation was carried out, and the Enrichment Factors were also calculated. They are shown in Fig2, Fig3, Fig4, Fig5, Fig6 and Fig7.

Table 5: ICPMS Results: Average Concentrations in (ppm) and sample standard deviations - Dela iron ore samples.

REE	Average concentration (ppm)	Sample S.T.D.
TREE	49.66	16.9319
LREE	33.95	11.70185
HREE	15.72	6.601267
La	5.1	1.9465
Ce	18.14	9.080359
Pr	1.47	0.447742
Nd	5.94	1.625636
Sm	2.41	0.564872
Eu	0.89	0.259687
Gd	4.2	1.420605
Tb	0.6	0.239859
Dy	3.69	1.615973
Ho	0.9	0.391661
Er	2.81	1.134796
Tm	0.44	0.20891
Yb	2.66	1.460871
Lu	0.41	0.222357

Table 6: ICPMS Results: Average Concentrations in (ppm) & sample Standard Deviations- Buttala iron ore Samples

REE	Average concentration (ppm)	Sample S.T.D.
TREE	164.1816	341.1319
LREE	138.956	291.174
HREE	25.2256	49.9936
La	26.3895	60.06821
Ce	63.4466	127.4948
Pr	6.0987	12.32252
Nd	33.6906	80.64285
Sm	7.7199	13.56455
Eu	1.6107	0.853417
Gd	15.6917	33.55995
Tb	1.2419	2.659319
Dy	3.729	6.768316
Ho	0.5478	0.82932
Er	2.2814	4.062966
Tm	0.2051	0.245065
Yb	1.3267	1.827867
Lu	0.202	0.286004

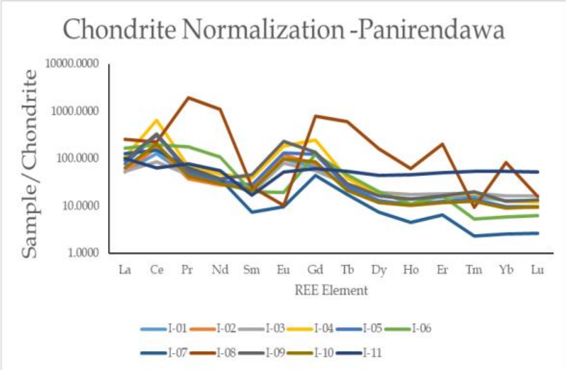

Figure 2: Chondrite normalisation of Panirendawa samples.

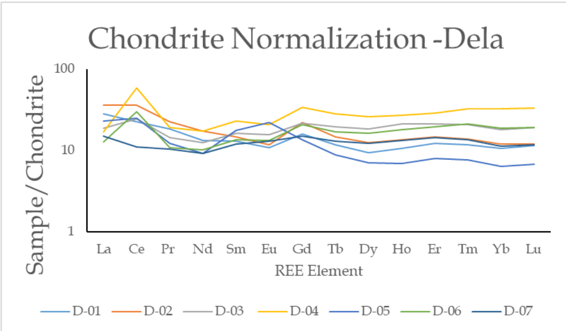

Figure 3: Chondrite normalisation of Dela samples.

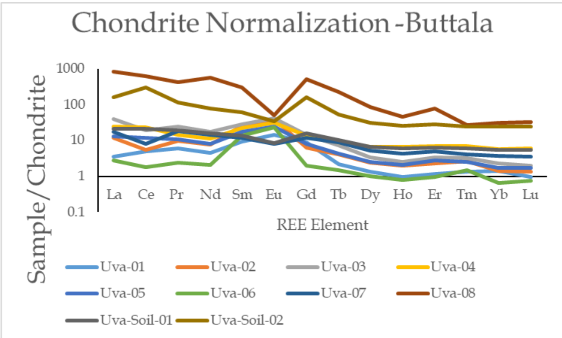

Figure 4: Chondrite normalisation of Buttala samples.

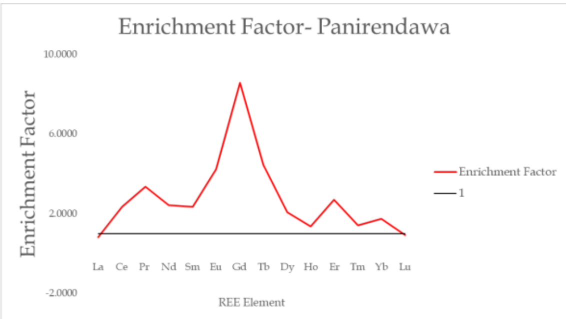

Figure 5: Enrichment factors of Panirendawa samples.

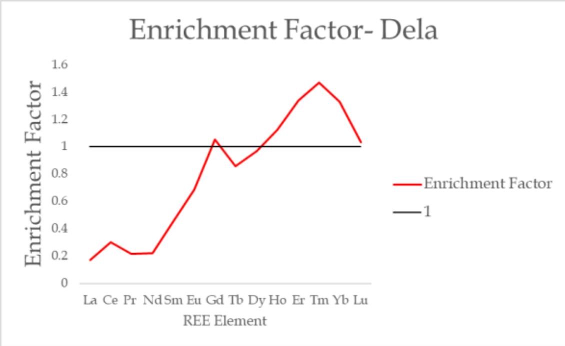

Figure 6: Enrichment factors of Dela samples.

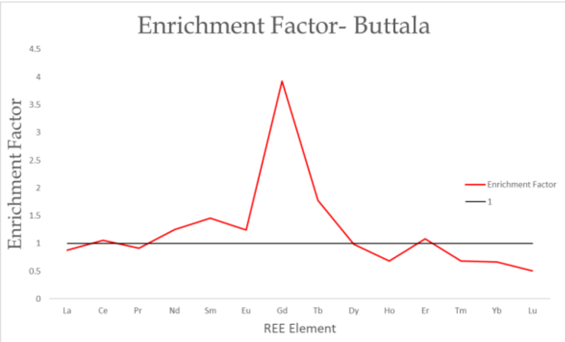

Figure 7: Enrichment factors of Buttala samples.

4. Discussion

First, the comparison was carried out with the results obtained from the three deposits. The highest average values for Total Rare Earth (TREE) were obtained from the samples collected from the Panirendawa deposit. Within this deposit, the highest values were shown in the samples collected from the highly weathered and transported loose material. Somewhat noteworthy here is that the highest TREE sample contained a high concentration of "Nd- Neodymium". Since Nd is highly used in the production of permanent magnets, they are in high demand and hence have good market value. Therefore, more explorations need to be carried out searching for Nd within this geological profile to assess the economic viability of this deposit to REE extraction.

The second highest TREE concentrations were shown in the Buttala iron ore samples. Compared to the global trends and the trend shown in the Panirendawa deposit, the highest concentrations for REEs were also shown in the highly weathered and transported iron ore samples collected from the topsoil profile in the vicinity of the main iron ore (vein) body. Samples collected directly from the top of the iron ore vein did not show any promising concentrations. Further studies need to be carried out to assess the REE concentration association within the Buttala magnetite deposit, and sampling should be targeting the highly weathered iron ore profile, which has been dispersed in the vicinity and covering the area for a few square kilometres. Although we could acquire samples from different depths in the Panirendawa deposit, due to its formation, in the Buttala deposit, we could not obtain any samples from depth to assess the variations vertically. If such variations are to be explored, drilling operations must be carried out.

The least average for TREE concentrations was shown in the hydrated iron caps in the Dela deposit. Most of the iron ore samples collected were directly acquired from the iron ore body itself, which were exposed to the surface. These exposed hydrated iron caps showed different levels of weathering. TREE values for this deposit are within close range (30-80 ppm). If REEs are associated with the highly weathered and finer particles, they may get transported away from this deposit with natural drainage patterns along the steep slope of this formation.

Secondly, the values obtained from this study were compared with some of the main iron ore deposits in the world (Fig. 8).

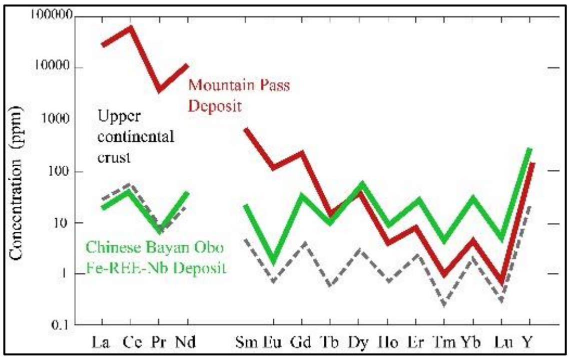

Figure 8: Major iron ore deposits REE chondrite normalisations: Reproduced from: (Lehmann, 2010)

In Fig. 8, the chondrite normalised values are illustrated for some of the biggest REE deposits in the world associated with iron ore deposits, including “Chinese Bayan Obo FE-REE deposit” and another major iron ore deposit in California, USA “Mountain pass deposit”. In comparison, no significant difference is evident between REE concentrations in Panirendawa and Buttala iron ore deposits with global deposits. But the economic viability cannot be clearly revealed by just comparing the average REE concentrations since Sri Lankan deposits had high variations within small distances. And, when compared to global iron ore deposits, the amount of iron ore availability is drastically low in the Sri Lankan iron ores. Finally, comparing REE concentrations of Sri Lankan iron ores with the highest concentrated REE deposit in the world, which is “Mount Weld Fe-REE deposit - Australia”, it was found that the Australian deposit contains an averagely of 10,000 times of the highest concentration found from this study.

With the objective of exploring REE potential within iron ore bodies of Sri Lanka, this study has found that there are some geological profiles within Sri Lankan iron ore bodies that contain high REE concentrations. To assess the economic value, more detailed explorations must be carried out.

5. Conclusions

The highest concentrations for the REE were shown in the Panirendawa deposit, and then the Buttala deposit and the least was shown in the Delta deposit. Within small distances (10-100 m), high variations were shown in Buttala and Panirendawa deposits. Dela deposit had almost the same variation of REE concentrations within the ore body. The highest concentrations shown in the Magnetite deposits were related to highly weathered and transported material away from the main ore body. If such high concentrations are consistent within those geological profiles, these deposits could be another source for REE in Sri Lanka.

6. Acknowledgement

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7. References

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