Investigation of Rare Earth Element Potential in Granitic Rocks of Sri Lanka Special Reference to Thonigala Granite

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Abstract

Rare earth elements include lanthanide series elements plus Sc and Y. These 17 elements are characterised by the European Union (EU) as critical raw materials with significant supply risk due to their broad of emerging technological applications. Due to this ever-increasing demand for rare earth element (REE) related products, new REE-bearing mineral deposits need to be identified and evaluated for the purpose of filling the supply scarcity in the world. Therefore, this research is focused on investigating REE potential in granitic rocks of Sri Lanka, with special reference to Thonigala granitic intrusions. Thonigala granite is enriched with REEs, relatively with high light REE (LREE) concentration. In the rock samples, the average total rare earth element (TREE), LREE, and heavy REE (HREE) concentrations were 328, 285, and 43.1 mg/kg, respectively. The corresponding sediment values were 619, 472, 147 mg/kg, respectively. The presence of REEs in both insitu rock and sediment samples indicated that significant weathering and erosion occurred in the area. Therefore, this research provides insights into REE potential in granitic rocks of Sri Lanka, focusing on Thonigala granite. More geochemical analysis followed by mineralogical and compositional analysis needs to be carried out for future benefit.

Keywords: Granite, ICP-MS analysis, Rare earth elements, Sri Lanka, Thonigala

1. Introduction

Rare earth elements are a set of 17 chemical elements in the periodic table which consist of 15 lanthanides plus scandium and yttrium. This set of elements is further divided into two categories as light REEs (LREEEs; from La to Eu) and heavy REEs (HREEs; from Gd to Lu and Y) [1], [2].

Currently, the supply of REEs has become a crucial factor due to the expansion of their application in high-tech and green products such as superconductors, mobile phones, LED lightings, metal alloys, catalysts, super magnets, solar panels, etc. [3], [4]. This demand was arisen mainly due to their unique properties such as chemical, physical, luminescent & magnetic properties [1]. As a result, there is a significant gap between the supply and demand of REEs, especially for HREE. This issue was arisen not only due to the demand but also the limited supply of

HREE by the currently identified deposits. In the present world, most of the HREE are produced to the market from ion-adsorption type REE deposits in china [1]. With all the REE productions in China, they control the global REE market with more than 79% of world production and 37% of the world's REE reserves. The ion-adsorption type deposits are commonly formed by the chemical weathering of granitic rocks. The average REE concentration of these types of deposits varies from 300 ppm to 2000 ppm approximately [3].

In Sri Lankan terrain REE containing minerals are mostly found in carbonatites, pegmatites, and beach placer deposits. Among these deposits, Pulmoddai beach sand deposits and Eppawala carbonatite deposits are highly enriched with REEs [3]. Granites are found throughout the Sri Lankan basement, especially in the Thonigala and Ambagaspitiya of the Wanni complex [5]. However, not many prospecting studies were carried out to investigate the REE potential in these granitic rocks of Sri Lanka. Therefore, this study aims to assess the REE potential of Thonigala granitic rocks of Sri Lanka.

2. Methodology

In this study, a total of 20 samples, including 17 rock samples and three sediment samples, were collected considering the geological origin and rock formation of the Thonigala area (Table 1).

All the samples were air-dried, and then sediment samples were further oven-dried at 110° C for 8 hours. All the samples were crushed and powdered using a laboratory jaw crusher and tema mill to reduce average grain size. Powdered samples were sieved using a 63-micron sieve. Sieved samples were then digested using aqua- regia in the presence of conc. Nitric acid, conc. Hydrochloric acid (3:1 volume ratio) and Hydrogen peroxide. After the digestion, samples were analysed using an inductively coupled mass spectrophotometer (ICP-MS) to obtain REE concentrations.

Table 1: Sampling Locations in Thonigala.

Symbol	Northing Coordinate	Easting Coordinate
T- 1	7.90260	79.992444
T- 2	7.902577	79.992435
T- 3	7.902451	79.992507
T- 4	7.90246	79.99248
T- 5	7.902596	79.992815
T- 6	7.902406	79.992634
T- 7	7.902451	79.992789
T- 8	7.90247	79.992915
T- 9	7.902398	79.993015
T- 10	7.90223	79.993043
T- 11	7.901936	79.992962
T- 12	7.901828	79.992989
T- 13	7.901774	79.993053
T- 14	7.902714	79.992815
T- 15	7.902858	79.992579
T- 16	7.901137	79.990977
T- 17	7.901127	79.990751
T-18-S1	7.901246	79.991113
T-19-S2	7.901263	79.99085
T-20-S3	7.901037	79.990869

3. Results

Table 2 represent ICP-MS results for rock samples from T-1 to T-17 and sediment samples from T-18 to T-20.

Accordingly, the ranking of the average REE concentrations in the rock samples followed as Ce > Nd > La > Gd > Pr > Sm > Dy > Er > Tb > Eu > Yb > Ho > Lu > Tm. The average TREE concentration of the rock samples was 328 mg/kg, whereas LREE and HREE concentrations were 285 and 43.1 mg/kg, respectively. The concentrations of LREEs were higher than the HREEs (Table 2), and LREE fraction was about 87%. The average LREE/HREE ratio in the rock samples was 6.6 ranging from 6.0 to 7.7. Ce was the most abundant REE, which accounted for 35.2% of the TREE content. Similarly, Nd, La, and Gd contributed 20.8%, 19.8% and 9.0%, respectively.

The ranking of the average REE concentrations in the sediment samples followed as Ce > Nd > Gd >La > Pr > Sm > Dy > Er > Tb > Yb > Eu > Ho > Lu > Tm.

Table 2: REE concentrations of Thonigala granite rock and sediment samples (in ppm).

Label	TREE	LREE	HREE	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
T -1	367	318	49.5	52.6	144	25.8	78.7	15.6	1.1	34.3	2.6	6.5	0.75	3.9	0.15	1.2	0.18
T -2	285	250	35.7	51.77	104	20.9	60.5	11.6	0.85	25.0	1.9	4.4	0.48	2.9	0.09	0.78	0.11
T -3	352	307	45.4	65.4	117	28.9	81.3	14.1	0.92	32.0	2.4	5.7	0.57	3.7	0.10	0.85	0.12
T -4	553	479	74.8	98.4	209	37.2	112	20.4	1.7	52.9	3.8	9.2	1.1	6.0	0.22	1.8	0.26
T -5	203	176	26.8	51.5	68.0	11.4	35.6	8.3	1.4	17.2	1.4	4.1	0.58	2.3	0.16	0.94	0.14
T -6	247	219	27.6	73.3	76.9	14.5	45.7	8.3	0.97	18.9	1.5	3.6	0.41	2.2	0.11	0.75	0.11
T -7	580	501	79.6	104	195	42.2	134.5	23.8	1.3	53.7	4.3	11.0	1.3	6.63	0.28	2.1	0.31
T -8	281	244	37.2	76.8	90.6	16.1	48.8	10.9	1.5	25.2	1.9	5.1	0.70	2.9	0.17	1.2	0.18
T -9	267	236	30.8	71.1	89.0	17.4	49.4	9.0	0.84	21.7	1.6	3.9	0.44	2.3	0.09	0.71	0.10
T -10	142	124	17.6	33.1	58.2	6.8	21.3	4.7	0.58	12.6	0.78	2.1	0.30	1.2	0.08	0.50	0.08
T -11	301	261	39.8	49.37	108	22.2	68.2	12.5	0.78	27.0	2.2	5.5	0.61	3.2	0.12	1.1	0.16
T -12	358	309	49.1	60.9	133	25.3	74.3	14.2	0.95	33.6	2.5	6.5	0.81	4.1	0.17	1.3	0.20
T -13	307	263	43.9	48.8	105	23.1	71.4	14.0	1.2	29.2	2.4	6.4	0.77	3.6	0.17	1.3	0.19
T -14	173	151	21.8	40.9	65.2	8.8	27.2	7.5	2.0	14.7	1.14	2.7	0.50	1.6	0.26	0.67	0.23
T -15	614	535	79.1	100	226	45.1	138	23.2	1.2	58.5	4.0	8.5	0.8	5.7	0.18	1.3	0.23
T -16	337	292	45.0	67.6	108	26.2	76.0	13.2	0.9	30.5	2.5	5.9	0.71	3.8	0.16	1.2	0.18
T -17	214	186	28.6	61.9	63.7	12.6	38.9	8.2	0.9	17.4	1.5	4.6	0.67	2.7	0.19	1.3	0.2
Label	TREE	LREE	HREE	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu

T -18	1122	797	324	106	227	113	318	28.1	3.6	228	16.8	35.0	3.7	25.9	0.78	12.6	0.97
T -19	404	350	53.8	30.8	268	8.0	26.1	12.4	5.0	39.0	1.5	5.5	1.0	3.3	0.47	2.6	0.40
T -20	331	267	64.1	71.7	97.6	17.3	60.3	16.0	4.7	30.8	3.1	12.6	2.3	7.8	0.94	5.6	0.93

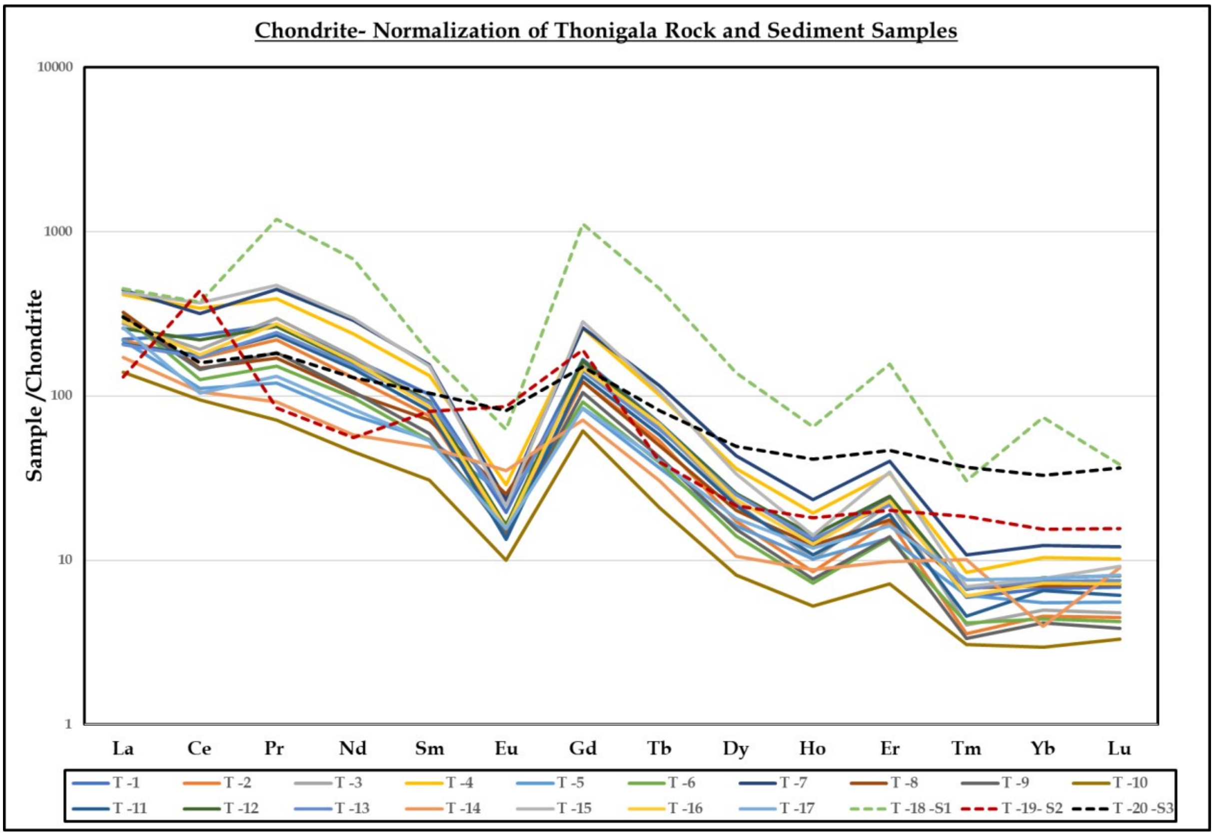

Figure 1: Graph of chondrite – normalisation of Thonigala rock and sediment samples

The TREE, LREE, and HREE concentrations in the sediment samples were 619, 472, 147 mg/kg, respectively. The LREE/HREE ratio ranged from 2.5 to 6.6, with an average value of 3.2. Even in the sediment samples in Thonigala, Ce (31.9%) was the most abundant REE along with high percentages of Nd (21.8%), Gd (16.1%), and La (11.3%). Accordingly, the LREE percentage (76.2%) was higher than the HREE percentage (23.8%) in the sediments. In comparison, all the REEs show high concentrations in the sediments compared to the corresponding rock sample values.

According to Figure 1, most of the samples show a similar chondrite-normalised REE pattern, and they are basically enriched in LREEs than HREEs. All the samples show pronounced Eu anomaly except T-19. Sample T-19 showed a distinct positive Ce anomaly. Most of the samples show Pr, Er and Yb enrichments with a sharp and higher Gd enrichment than most of LREEs. Sediment samples (T-18, T-19, and T-20) show higher REE enrichment compared to rock samples, particularly sample T-18. REE distribution pattern of T-19 is slightly different from other patterns and shows higher Ce, Sm and Eu enrichments. Ce anomaly of the sample T-19-S2 shows a positive anomaly, and also, it does not show Eu anomaly as other samples. Most of the samples show Pr, Er and Yb enrichment with a sharp and higher Gd enrichment than most of LREE.

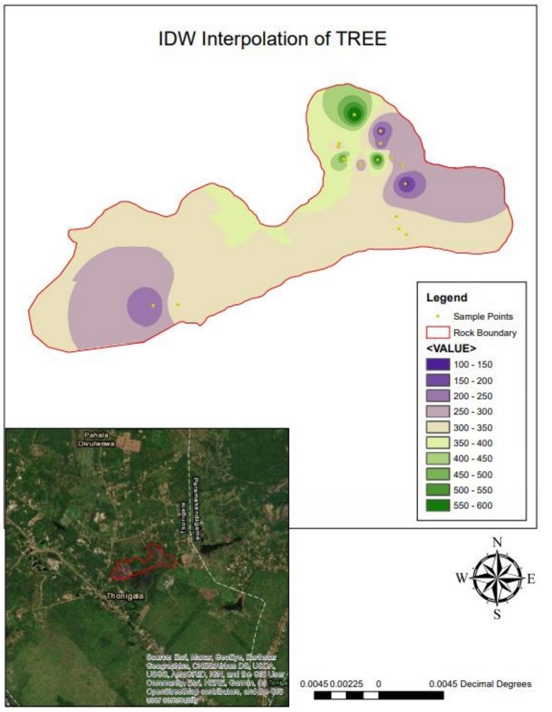

Figure 2: IDW interpolation for TREE distribution for a selected area (values in ppm).

REE distribution for the study area in Thonigala granitic intrusions was estimated using Inverse Distance Weighted Interpolation (IDW) with reference to rock samples (Figure 2). It can be concluded that TREE enrichment can be observed in the Northern part of the map (Figure 2). Moreover, Eastern and S-W regions show significant depletion for the values in the range of 100-300 ppm.

4. Discussion

Results show that Thonigala granite contains an enrichment of LREE over HREE.

All the samples show pronounced Eu anomaly, which is a characteristic feature of granitoid rocks except sample T-19. Sediment sample T-19 showed a distinct positive Ce anomaly, which may be due to the presence of oxidised Ce^{4+} in Cerianite mineral formed by alteration of other REE minerals. Therefore, it can be concluded that there was an oxidising condition during the formation of Thonigala granite.

Most of the samples show Pr, Er and Yb enrichment with a sharp and higher Gd enrichment than most of LREE.

Based on IDW, eastern and S-W regions show significant depletion for the values in the range of 100-300 ppm. This may be due to the considerable weathering and erosion of the parent rock.

As a further approach to the study, the results of Thonigala granite is compared with local and global granitic occurrences. Massenna zircon granite was used for the comparison as a local deposit, while a deposit in Laos was used for the global comparison.

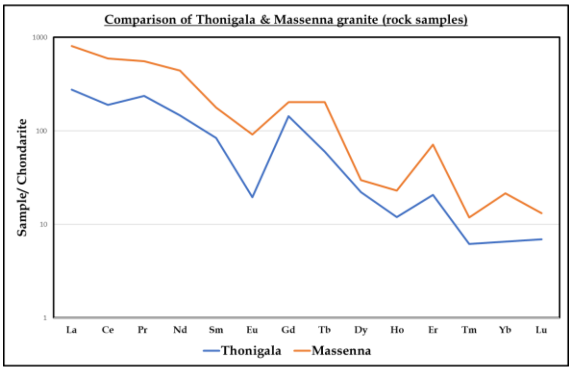

Figure 3: Graph of comparison of Thonigala granite and Massenna granite rock samples

According to Figure 3, it is evident that REEs are enriched in the Massenna granite rock samples compared to Thonigala granite.

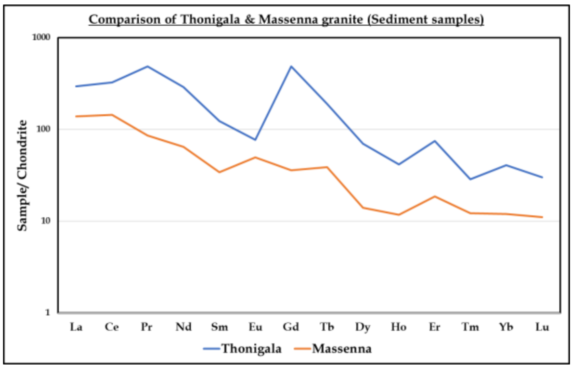

Figure 4: Graph of comparison of Thonigala granite and Massenna granite sediment samples.

Based on Figure 4, REEs are enriched in the Thonigala granite sediment samples than in Massenna sediment samples.

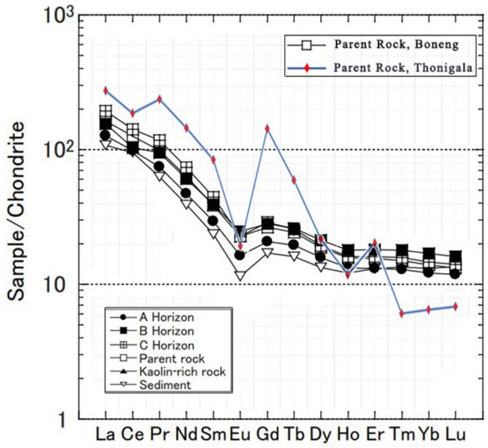

Figure 5: Comparison of Thonigala rock samples with global granite deposit in Boneng, Laos.

When comparing REE potential in Thonigala granite with a global granite deposit, based on Figure 5, Thonigala rock samples were enriched with LREEs than deposit in Laos, while sharp Gd enrichment was indicated by Thonigala granite.

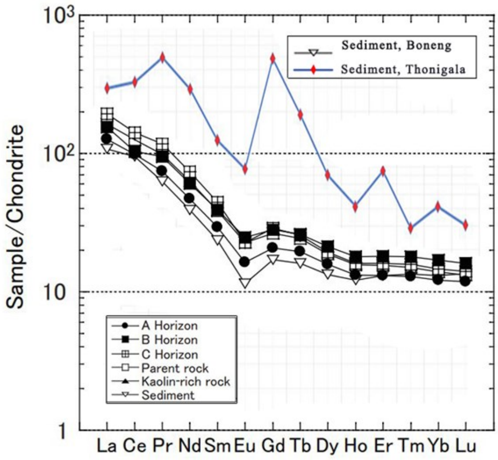

Figure. 6: Comparison of Thonigala sediment samples with global granite deposit in Boneng, Laos.

Based on Figure 6, Thonigala sediments were enriched with all the REEs than deposited in Laos, while sharp anomalies were indicated for Pr, Gd, Er and Yb in Thonigala sediments.

5. Conclusions

REE concentrations in Thonigala granite intrusions were investigated in this work. The average TREE and LREE concentrations in the sediment samples were high compared to the corresponding values in the rock samples.

Thonigala granites are enriched in REEs, particularly LREE, than HREE. Ce was the most abundant REE, which accounted for 35.2% of the TREE content in the rock and 31.9% in sediments. Rock has an average LREE fraction of 87%; thus, it can be concluded that Thonigala granite is a good source rock for LREE.

Since the higher REE enrichment in sediments, it can be concluded that they have been transported and deposited by physical or chemical weathering and erosion processes from the ore body.

Based on IDW, the broad study area is enriched with TREE in the range of 250 - 400 ppm. Also, it indicates significant weathering and erosion in the Eastern and S-W regions of the map.

Thonigala granite rock samples showed relatively low REE enrichment compared to Massenna granite.

Global comparison with the deposit in Boneng, Laos showed relatively higher LREE enrichment and sharp Gd enrichment in Thonigala rock samples, while significant REE enrichment was shown by Thonigala sediments compared to sediments in Laos deposit.

Acknowledgement

The authors are acknowledging to all academic and non-academic staff in the Department of Earth Resources Engineering, University of Moratuwa.

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