The Abundance of Rare Earth Elements in Tropical Montane Forest Soils in Sri Lanka

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Abstract - Lanthanide series that consists of 14 elements (from La to Lu) is the major portion of the rare earth elements (REE). There is an increasing interest to study lanthanides in pedology as their role in nature is still poorly understood. The objective was to present the role of REEs in nature by determining REE content within the soil in montane forests (MFs) of Sri Lanka. The study presents the content of lanthanides in the soils of MFs in Sri Lanka. Seventeen near-surface representative soil samples were collected (up to 25 cm) in 1 ha sized plots at Horton-Plains (HP) and Piduruthalagala (PDG) forests. The REE contents were quantified by using ICP-MS. Total average content of lanthanides in HP and PDG soils were 62.1 and 127 mg kg^{-1}, respectively, whereas the mean content varied in order of Ce>La>Nd>Pr>Gd>Sm>Dy>Er>Tb>Ho>Eu>Lu>Tm. Higher content of Light REE (La-Nd) with depleted Eu content is a significant feature in both forest soils. The upper continental crust-normalized patterns were comparable in both sites with positive Tb and Er anomaly, indicating a similar nature in soil genesis. The higher content of lanthanides in PDG site is probably due to enriched clay content. It is well-known that clay minerals can incorporate lanthanides in their structure. The average organic matter content was determined using the loss on ignition method which showed 14.94 and 22.58 % for HP and PDG, respectively. A higher amount of lanthanides in the PDG soils is thus supported by greater organic matter content. In conclusion, both forests showed similar nature in soil genesis and lanthanide distribution may be a result of clay mineral and organic matter that adsorb REEs in soils.

Keywords: Rare earth elements; Tropical montane forests; ICP-MS; upper continental crust-normalized REE patterns

I. INTRODUCTION

Rare earth elements (REE) include all elements of the lanthanide series from lanthanum (La) to lutetium (Lu) of which fourteen elements (except Pm) are relatively abundant in the earth's crust. These elements are typically subdivided into two groups known as light-REEs (LREEs; La-Eu) and heavy-REEs (HREEs; Gd-Lu) [1]. The abundances of REEs in soils are influenced by their parent materials, weathering history, texture, pedogenic processes, anthropogenic disturbances, organic matter contents and reactivity. The Sri Lankan upper montane forests are characterized by natural vegetation ranging in altitude from 1,500 to 2,500 m. Among these, the Horton-Plains (HP) and Piduruthalagala (PDG) forests are two of the most crucial natural ecosystems in the country. Major and trace elements in plants and soils in MFs in Sri Lanka have been studied by several researchers [2] but there are no previous studies related to REEs in soil. Therefore, the objective of this study was to present the role of REEs in nature by determining REEs content within the soil in MFs of Sri Lanka.

II. MATERIALS AND METHOD

Soil samples were collected in selected forest plots of one hectare in size at Piduruthalagala and Horton Plains Systematic sampling was carried out in each plot and 17 near-surface representative soil samples were collected up to 25 cm in depth. Samples were microwave digested using 3:2 HNO_3: HCl and element contents were quantified by using inductively coupled plasma mass spectrometry (ICP-MS). In addition, the organic matter contents were determined using the loss on ignition method.

III. RESULTS AND DISCUSSION

The REE concentrations in the soils from HP and PDG are summarized in Table 1 which allows easy comparison of the REE contents of the different MFs. The total content of REEs (ΣREE) in these HP and PDG soils were 62.1 and 127 $mgkg^{-1}$ respectively. The mean content of REE varies in the order Ce>La>Nd>Pr>Gd>Sm>Dy>Er>Tb>Ho>Eu>Lu>Tm in both HP and PDG sites (Table 1). Higher content of light-REE (LREE; La to Eu) with depleted Eu content was a significant feature of the element distribution pattern in both HP and PDG soils. In addition, both LREEs and heavy REEs (HREEs; Gd to Lu) concentrations were higher in PDG soils than in HP soils. The upper continental crust normalization is a widely used and accepted method for the comparison of REE abundances in the soil environment. In this study, the REEs concentrations in the upper continental crust proposed by Rudnick and Gao [3] were used for normalization. The upper continental crust normalized REE distribution patterns (Fig. 1) were similar in both HP and PDG sites, with positive Tb and Er anomalies, indicating a similar nature in soil genesis in both plots. The normalized plots also confirmed that REE concentrations are higher in PDG soils than in HP soils.

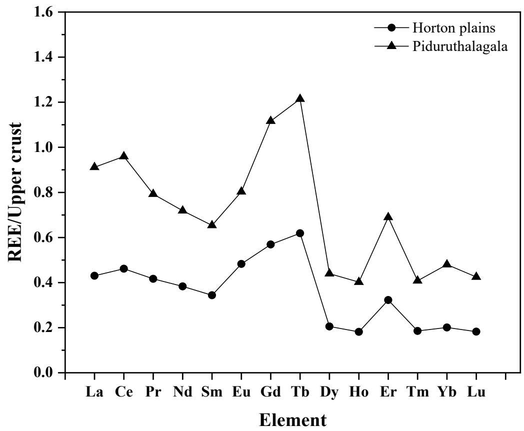

Fig. 1 Upper continental crust-normalized REE distribution patterns in soils from HP and PDG sites (Upper continental crust normalized values from Rudnick and Gao, 2003)

The breakdown of primary minerals that are inherited from bedrock during weathering releases a variety of chemical substances, including REEs, which is beneficial for the accumulation of soil REEs. The soil samples were collected from similar geological terrain, the upper continental crust–normalized REE distribution patterns suggest similarities between the two MFs. However, the influence of parent material on REE content in soil cannot be determined without geochemical data on the REE content of the underlying rock types. In addition to that, secondary processes such as clay mineralogy, organic matter content, soil type and agricultural practices can also influence REE content of the soils [4]. Generally, REEs are the least soluble trace elements and remain mostly immobile even in the most deeply leached environments. Some researchers were noted that REEs are adsorbed more readily onto kaolinite than other clay minerals [5]. Formation of complexes between Al and humic compounds that speed up the dissolution of kaolinite under acid condition [6]. Some previous studies reported that the behavior of REEs in environments where there are enough humic compounds to form a coating on the surface of inorganic particles is most strongly affected humate formation [7]. The amount of dissolved REEs (especially LREE) would decrease as a result of adsorption on the solid surface as humate complexes in an acidic environment [7]. These factors may have an impact on the soils' REE geochemistry. However, the higher content of REE in the PDG site is probably due to enriched clay content. It is well-known that clay minerals can incorporate REE in their structure. The average organic matter content was 14.94 and 22.58% for HP and PDG sites, respectively. This is relatively a higher amount compared to other soils of the country and a higher amount of REE in PDG soils is thus supported by greater organic matter content as well.

IV. CONCLUSION

The REE content of PDG soils may be explained by the greater dominance of clay content and organic matter. Both MFs showed similar nature in soil genesis and REE distribution may be a result of clay mineral and organic matter that adsorb REEs in soils. Further studies are required to elucidate the clay mineral adsorption of REE in MFs soils in Sri Lanka.

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Table 1. The REE content in soils from Horton Plains, and Piduruthalagala montane forests.

REE (mg/kg)	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Horton Plains														
Mean	13.33	29.07	2.96	10.35	1.62	0.48	2.28	0.43	0.80	0.15	0.74	0.06	0.39	0.06
median	11.95	23.92	2.59	9.11	1.46	0.45	1.95	0.38	0.74	0.14	0.69	0.05	0.36	0.05
SD	6.28	12.99	1.50	5.29	0.69	0.21	1.21	0.21	0.31	0.06	0.33	0.02	0.14	0.02
Minimum	5.95	12.91	1.30	4.66	0.82	0.24	0.97	0.20	0.45	0.08	0.37	0.03	0.21	0.03
Maximum	26.43	61.55	6.27	23.32	3.42	1.04	5.09	0.99	1.73	0.32	1.60	0.10	0.76	0.10
Piduruthalagala														
Mean	28.26	60.45	5.63	19.41	3.07	0.80	4.47	0.85	1.71	0.33	1.59	0.12	0.94	0.13
median	27.21	58.23	5.48	18.59	2.93	0.79	4.20	0.78	1.63	0.30	1.48	0.11	0.87	0.12
SD	6.24	10.73	1.29	4.79	0.89	0.23	1.06	0.25	0.74	0.16	0.55	0.06	0.40	0.06
Minimum	19.56	44.62	3.79	12.76	1.89	0.42	3.04	0.55	0.89	0.14	0.99	0.06	0.50	0.06
Maximum	38.32	78.01	7.81	29.06	4.93	1.36	6.87	1.43	3.51	0.70	2.79	0.28	1.94	0.29
REEs content in the upper continental crust proposed by Rudnick and Gao (2003)														
Mean	31	63	7.1	27	4.7	1	4	0.7	3.9	0.83	2.3	0.3	1.96	0.31

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