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ORIGINAL PAPER

DISTRIBUTION OF RARE EARTH ELEMENTS IN CORE SEDIMENTS OF KOLAKKUDI LAKE, SOUTHERN INDIA

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ABSTRACT

The lake Kolakkudi represents a small, isolated and fresh water lake situated in southern part of TamilNadu, India and it surrounded by fluvial placer deposits of garnet rich sands. In the study area to obtain information about rare earth elements (REEs) of core sediments and conceded sediment composition and distribution of rare earth elements as well as surrounding soil was investigated. The concentration of REEs in core sediments varies from 0.42 to 49.1 ppm. The higher REE content in the core sediments samples from various locations whichsignificance the plethora of clay and/or quartz with less significant effect caused by sedimentary sorting. According to the difference in the levelsof the rare earth elements, the rare earth elements normalized patterns and associated fractionation parameters (SLREE/SHREE, (La/Yb)N, and (NdYb) N) showed similarities between the lake sediments and the surrounding clays, confirming a widespread influence of nearby local lithology on the lake sediment composition. On the other hand, the results of the statistical analysis suggest the contribution of both clay rich soils and garnet rich sands in the lake sediments to the total content of rare earth elements.

1. INTRODUCTION

Rare earth elements (REEs) comprise a group of 15 chemical elements with similar physical-chemical characteristics (Henderson, 1984). Rare earth elements have been widely used as geochemical indicators in sediments (Haskin et al., 1966). This is an excellent quantitative analytical technique capable of determining 8 REE's (La, Ce, Nd, Sm, Eu, Tb, Yb and Lu) and wide range of concentrations. The lanthanide series are commonly divided into two groups by their atomic number and masses: light REE (LREEs: La–Eu) and heavy REE (HREEs: Gd–Lu) (Sadeghi et al., 2013; Chen et al., 2014; Wang and Liang, 2016; Silva et al., 2017a) In Addition to our investigations provide information on the distribution of rare earth elements for the lake sediments of Kolakkudi. Some trace elements such as Sc, Ga, Th, Pb, Cr, Zr, Rb, Sr, and rare earth elements (REEs) are useful indicators of geological processes, provenance, and tectonic settings of sedimentary basins (e.g., Taylor and McLennan, 1985; Jin et al., 2001; Das, 2002; Jin et al., 2003; Das and Haake, 2003; Rose et al., 2004; Armstrong-Altrin et al., 2017, 2018). However, there is still lack of knowledge of REE accumulation in sediments of Kolakkudi lake area where concentration of REEs is likely to be inflated. Rare earth element concentrations in soils are influenced by the mineralogical composition of the parent material, weathering intensity, pedogenic processes, organic carbon and clay contents and anthropogenic activities (Tyler, 2004; Morgan et al., 2012; Anaya-Gregorio et al., 2018; Ramos-Vázquez et al., 2018). The distribution and fractionation patterns of rare earth elements (REE) in sediments relative to those in local source rocks may be related to these factors(Santos et al., 2007). The objectives of this study were as follows: (1) to assess the level of rare earth elements in core sediments of Lake Kolakkudi (2) to get an overview of spatial variations in rare earth elements abundances and fractionation patterns (3) to determine the influence of surrounding geological setting on the distribution of rare earth elements in lake sediments; and (4) to determine the major factors which are controlling the level of these elements in the lake sediments. In this paper we discuss about the geochemical response of rare earth elements to clay rich deposits and garnet rich sands during Kolakkudi lake sediments and their description of the geochemical processes that affecting the distribution of rare earth elements.

2. TECTONIC SETTING AND REGIONAL GEOLOGY OF STUDIED AREA

Kolakkudi Lake, located in the Tiruchirappalli district of southern India, is surrounded al soby fluvial placer deposits extending up to 0.60 sq km. The origin of the whole lake especially ephemeral river type of lake. Sediment layers 30 to 45 cm thickness of clay

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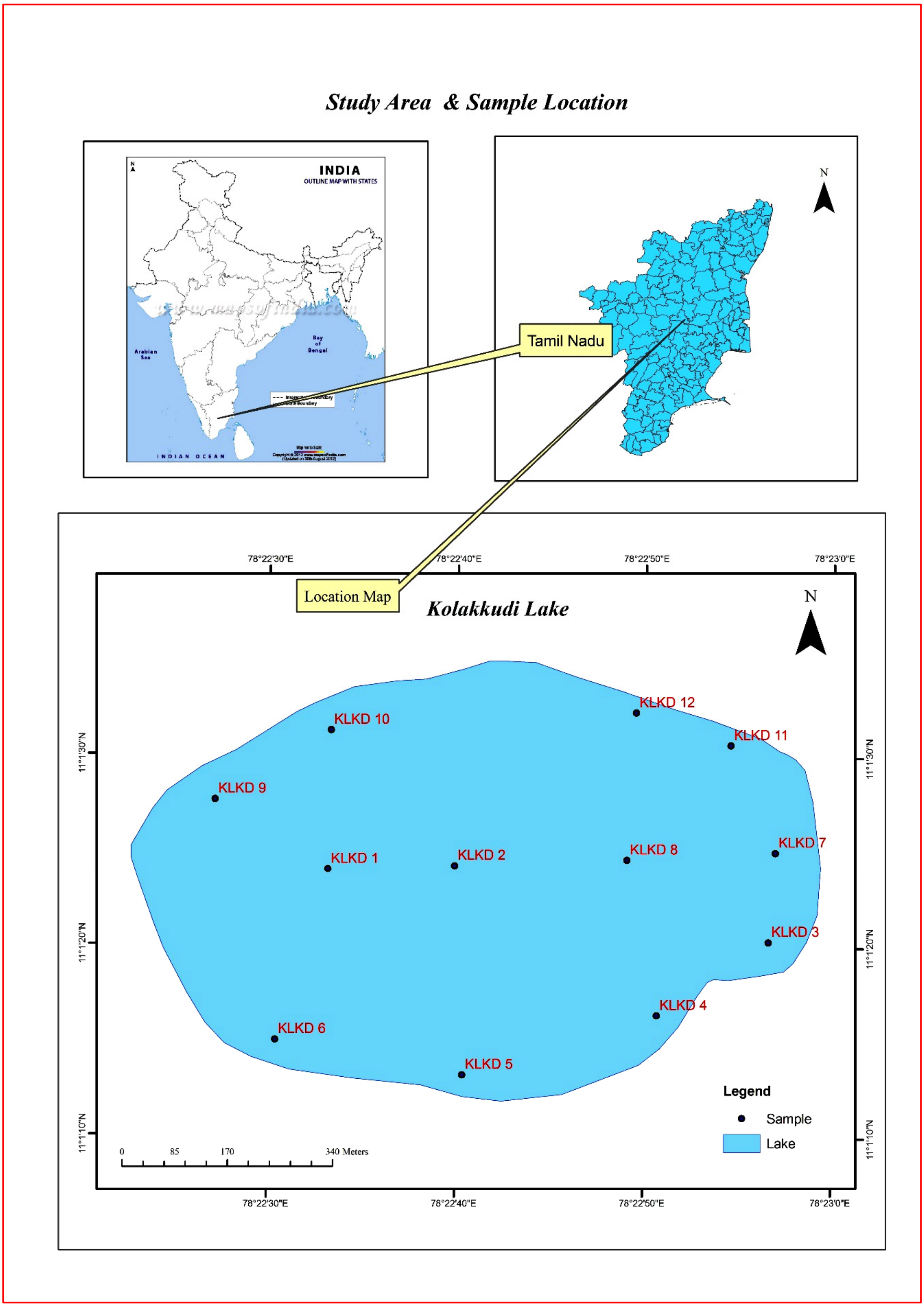

Fig. 1 Location of the study area.

deposits that recordsof fluvio-lacustrine environment are underlined in this area occupied freshwater lake. The area investigated by Kolakkudilake is part of the peninsular shield granulite terrain in Tamilnadu district of Tiruchirappalli (Fig. 1). The study area is located between North latitudes 11^{0}01'19" and East longitudes 78^{0}22'37" and covered 0.60 sq. km it forming a part of Musiri taluk the Tiruchirappalli district of Tamilnadu. Geomorphologically, the area northeast of Tiruchchirappalli is in an active erosionstage and illustrates typical topography of the land. Geomorphological units were classified in Tiruchirappalli district based on interpretation of satellite imaging such as Alluvial Plains, Fluvial channels, Valleys, Buried Pediments, shallow Pediments and Structural Hills. The river channels run in to the Tiruchirappalli district's northern bank of Cauvery River. Geologically active, the Kolakkudi Lake, where in the older rocks exposed mostly from sedimentary origin and pegmatite in the deltaic area, and Augen gneiss in the surrounding lake.

3. MATERIALS AND METHODS

In October 2013, twelve sediment cores were collected with rotary drill at regular intervals in the Kolakkudi Lake (Fig. 1). Inductively coupled plasma mass spectrometry (ICPMS) itself has analyzed sediment samples of with in the 2m core sediments. The core that are used for geochemical analysis was subdivided into one centimeter intervals (upper 10 cm) and into Loss on ignition (hereafter assumed to represent the organic matter content-OM) was calculated by burning previously dried sediment at 450 °C for 24 h, whereas the percentage of fine-grained sediment (0.062 mm) was calculated after mechanical separation through wet sieving (Suguio, 1973).

Sediment samples for REEs, major oxides and trace elements were thoroughly investigated. The samples were air-dried at 501 °C, homogenized and grounded at 200 mesh sizes prior to the geochemical analysis. REEs were measured in twenty sediment samples from the Kolakkudi Lake inlet, central and outlet. After digesting the samples completely with HF, HNO_3 and $HClO_4$ in Teflon crucibles. Before the treatments, these crucibles were properly cleaned with a mixture of HCl and HNO_3 (3:1). For the digestion, 50 mg of each sample was heated and concurrently treated with 1 ml of 65 % HNO_3 for organic carbon removal, with 2 ml of 40 % HF and 2 ml of 70 % $HClO_4$ to dissolve the silicates. This procedure was followed at least three times till the silica gel showed no more trace of colour. Then the residues also were dissolved with 1 NHCl and the volume was made to 50 ml and measured by HR ICP-MS. For a few samples, total and complete digestions on the carbonate-leached fractions were performed for few samples to determine the effect of carbonates on the mobilityof REE. For the analysis of carbonate leached fractions, bulk samples were treated with 1 M cold dilute HCl before their digestion as prescribed by Tripathiet al. (1999). REE concentrations in sediment samples were determined by ICP-MS according to the procedures of (Yamamoto et al., 2005).All sediment samples were analyzed for a total concentration of 15 elements Ce, Dy, Er, Eu, Gd, Ho, La, Lu, Nd, Pr, Sm, and Tb, Tm,Yb, Y).

4. RESULTS

4.1. RARE EARTH ELEMENT CONCENTRATIONS

The rare earth element (REE) concentrations of Kolakkudi Lake sediments were reported in Table 1. All analyzed sediments samples have similar concentrations of the REEs. The REE patterns exhibit variation typical of the average compositions of upper continental crust and Post-Archean Australian average shale (PAAS) and Chinese loess (Gromet et al., 1984; Taylor and McLennan, 1985; Gallet et al., 1996). The REE compositions are normalized to Post Archaean Average Australian Shale (PAAS) and to Upper Continental Crust (UCC) (Taylor and McLennan, 1985) in Figure 2. The PAAS and UCC normalized pattern of bottom sediment show no significant LREE enrichment and exhibit flat HREE patterns. The Eu anomaly in sedimentary rocks were usually interpreted as being inherited from igneous source rocks (McLennan and Taylor, 1991; Taylor and McLennan, 1985; Awwiller, 1993). Figure 2 illustrates that despite the difference in the absolute abundances, the samples show REE patterns that are similar to those of PAAS and UCC but differ in the HREE. Most sediment having slightly higher values than those of PAAS and UCC.

All the REE patterns are characterized by a differentiation between light REE (LREE) and heavy REE (HREE). The differences observed in the REE fractionation may be caused either by chemical weathering processes in the source area or by exchange reactions during transportation and/or deposition. The presence of Positive Eu anomaly patterns are characteristic features of the mafic source rocks. (Armstrong-Altrin and Machain-Castillo, 2016). Core sediments in the Kolakkudi Lake are characterized by REE concentrations in the range of 2.58 and 8.342 ppm (Table 1). In core sediments, the content of the REE follow the order Ce >Nd>La>Dy>Gd>Sm >Pr>Yb>Er> Ho >Eu>Tb > Lu and >Tm. The average values of LREE and HREE in core sediments of Kolakkudi Lake sediments are 117.85 and 26.101 ppm respectively. The ratio of LREE/HREE varies from 2.714 to 7.458 ppm which reveals the higher REE content in the core sediments samples from various locations which significance the plethora of clay and/or quartz with less significant effect caused by sedimentary sorting of their results.

The vertical variation in the total REE concentrations ranges along with ratio between LREE/ HREE Vs ΣREE are shown in Figures 3A and 3B. It exhibits the relatively high variation. The ratio of light REEs (from La to Sm) to heavy REEs (from Gd to

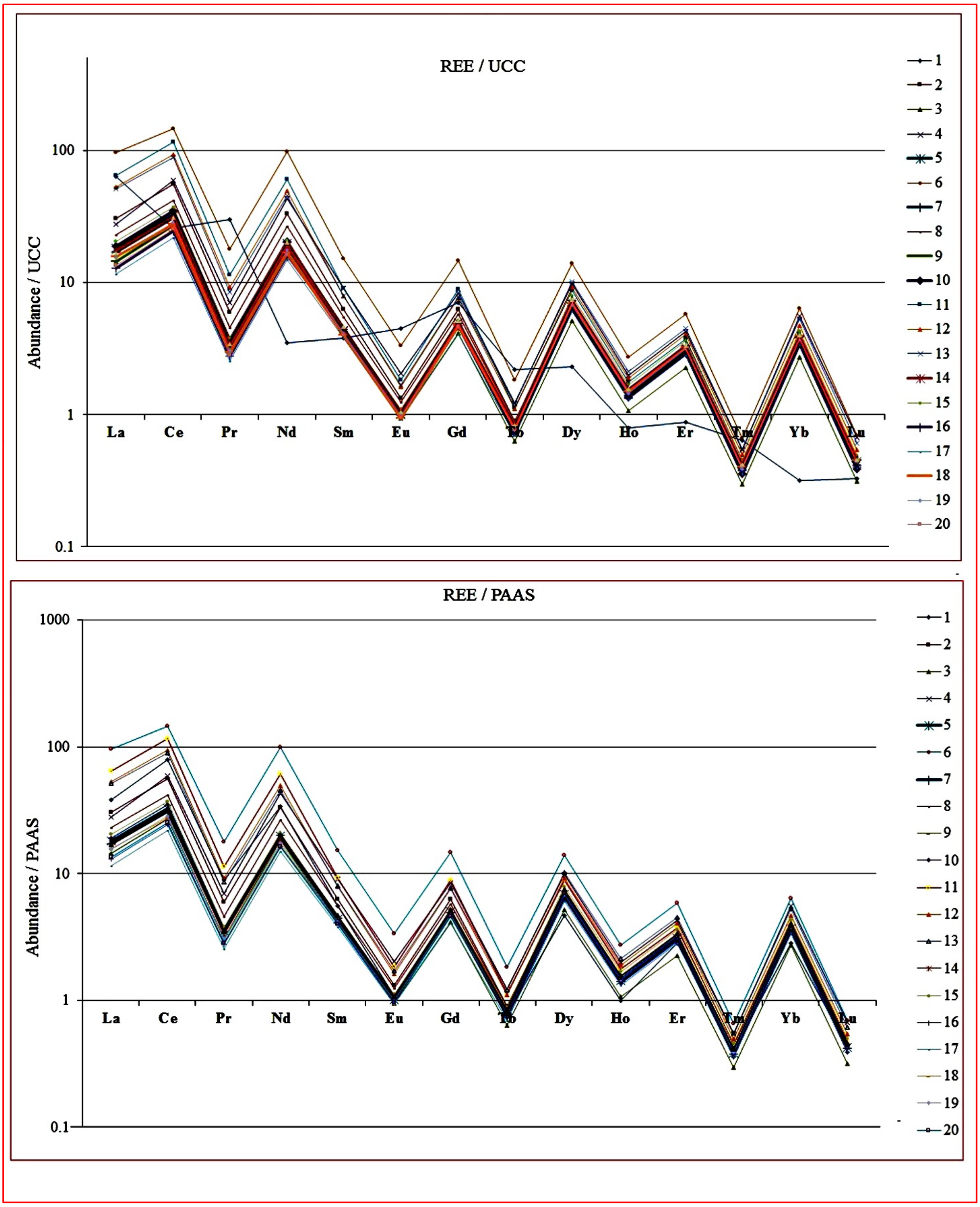

Fig. 2 Plot for normalized values of REE in core sediments of Kolakkudi Lake.

Lu), expressed as LREE/HREE, is used to indicate fractionation of total REE between light and heavy REEs. The element ratios of the immobile elements during sedimentation are good indicators of sediment sources (Bhatia and Crook, 1986; Yang et al., 2003; Lee et al., 2003; Tapia-Fernandez et al., 2017 and Hernández-Hinojosa et al., 2018). The core distributions of the La/Co, La/Sc, Th/Sc and Cr/Th ratios are shown in Figure 4 A-D. Similar distributional trends in the vertical changes in the REE fractionation parameters in the core were observed which signifying that grain size is dominant controlling factor of the ratios. At all on this basis, REEs are useful for identifying detrital sediment provenance (Munksgaard et al., 2003), monitoring climate change (Tanaka et al., 2007), investigating diagenetic processes (Caetano et al., 2009). The vertical distribution of REE in the base part (30 to 60 cm) of the core displays with low to moderate LREE / HREE fractionation (54.77 to 374.74).

Table 1 Concentration of REE in core sediments of Kolakkudi Lake.

S.No	Sampling Stations	Range of Depth (in cm)	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Y
1	KLKD-1	90-120	30.62	56.07	5.95	33.44	6.28	1.32	6.25	0.89	6.96	1.44	3.05	0.38	3.49	0.42	45.5
2	KLKD-2	60-90	14.35	26.98	3.09	18.48	4.07	0.95	4.11	0.63	5.18	1.07	2.26	0.30	2.72	0.31	33.8
3	KLKD-3	60-90	27.78	59.40	7.02	43.35	9.03	2.05	8.41	1.23	9.91	2.00	4.31	0.54	5.59	0.67	69.3
4	KLKD-4	120-150	18.13	32.68	3.52	19.95	4.35	1.01	4.98	0.79	6.88	1.43	3.06	0.38	3.68	0.43	47.7
5	KLKD-5	30-60	96.43	146.42	17.89	98.68	15.32	3.36	14.83	1.84	13.94	2.73	5.82	0.66	6.37	0.69	94.4
6	KLKD-6	30-60	17.11	31.30	3.45	20.14	4.45	1.07	4.93	0.77	6.68	1.41	3.06	0.38	3.62	0.42	45.7
7		240-270	23.02	41.89	4.61	26.65	5.52	1.25	5.80	0.88	7.37	1.54	3.27	0.41	3.86	0.45	49.9
8	KLKD-7	30-60	14.36	27.07	3.10	18.32	4.36	1.02	4.82	0.80	6.91	1.50	3.24	0.40	3.84	0.44	48.5
9	KLKD-8	60-90	18.95	35.03	3.70	20.43	4.24	1.00	4.75	0.73	6.39	1.36	2.94	0.36	3.43	0.39	43.6
10	KLKD-9	60-90	64.41	115.36	11.40	61.07	9.13	1.84	8.97	1.13	8.82	1.77	3.72	0.45	4.16	0.47	57.3
11		90-120	53.11	93.93	9.24	49.26	7.89	1.63	7.66	1.11	9.20	1.90	4.07	0.50	4.71	0.54	17.3
12	KLKD-10	90-120	51.14	88.98	8.53	45.49	7.99	1.70	7.75	1.21	10.26	2.14	4.51	0.55	5.32	0.61	63.7
13		30-60	17.62	31.52	3.32	19.08	4.31	1.02	4.70	0.79	7.06	1.47	3.22	0.40	3.78	0.44	71.8
14	KLKD-11	90-120	20.62	37.11	3.80	21.02	4.55	1.10	5.18	0.88	7.89	1.69	3.61	0.45	4.27	0.49	48.1
15		150-180	12.95	24.46	2.76	16.35	4.27	0.99	4.76	0.83	7.31	1.55	3.31	0.41	3.89	0.45	55.1
16		30-60	11.60	22.03	2.54	14.88	3.82	0.92	4.11	0.69	6.05	1.31	2.81	0.36	3.40	0.40	50.2
17		90-120	15.77	27.66	2.96	16.91	4.03	0.94	4.72	0.78	6.91	1.49	3.25	0.40	3.95	0.45	41.5
18	KLKD-12	150-180	15.39	28.60	3.09	17.57	4.13	0.99	4.69	0.77	6.84	1.46	3.18	0.39	3.77	0.44	48.9
19		210-240	13.43	25.36	2.83	16.27	4.03	0.96	4.62	0.77	7.01	1.50	3.22	0.40	3.89	0.44	47.1
20		240-270	16.92	31.38	3.47	20.05	4.65	1.06	5.19	0.84	7.42	1.58	3.34	0.42	4.01	0.46	48.5
		Min	**11.60**	**22.03**	**2.54**	**14.88**	**3.82**	**0.92**	**4.11**	**0.63**	**5.18**	**1.07**	**2.26**	**0.30**	**2.72**	**0.31**	**17.3**
		Max	**96.43**	**146.42**	**17.89**	**98.68**	**15.32**	**3.36**	**14.83**	**1.84**	**13.94**	**2.73**	**5.82**	**0.66**	**6.37**	**0.69**	**94.4**
		Mean	**27.69**	**49.16**	**5.31**	**29.87**	**5.82**	**1.31**	**6.06**	**0.92**	**7.75**	**1.62**	**3.46**	**0.43**	**4.09**	**0.47**	**51.5**

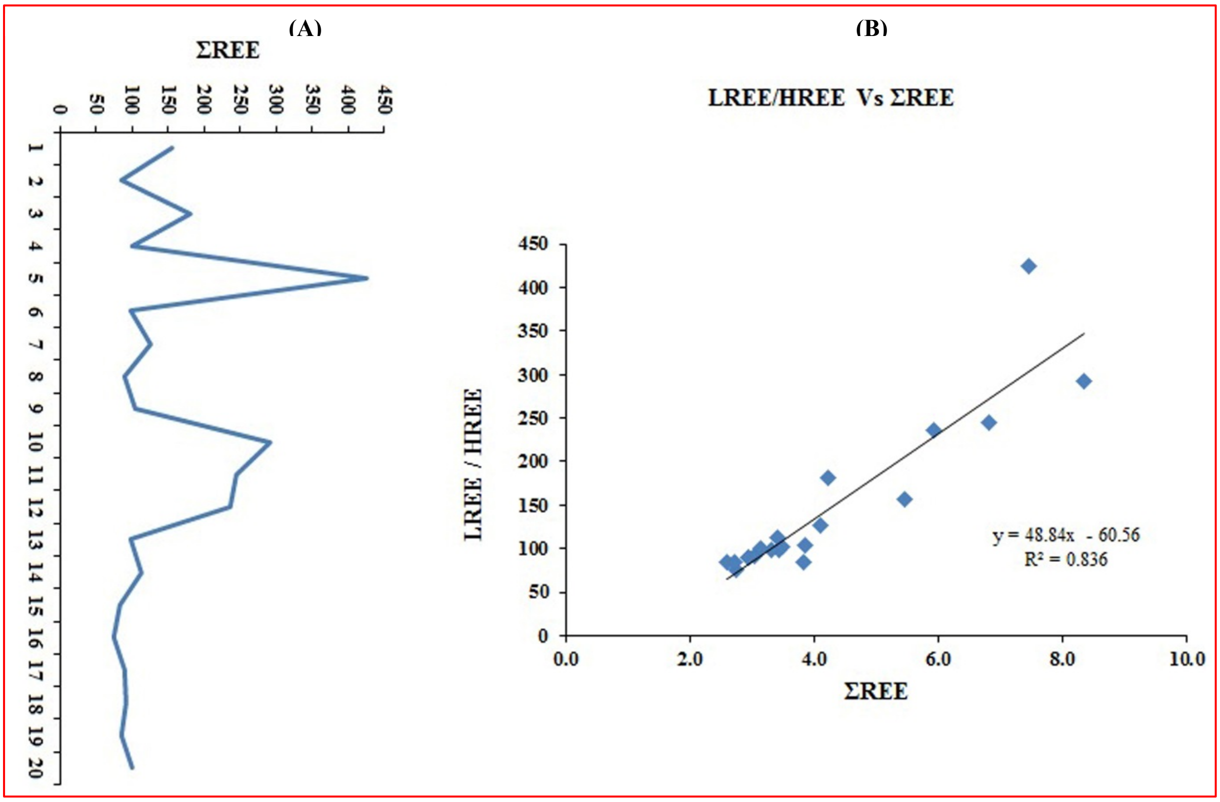

Fig. 3 (A) Vertical Distribution of ΣREE.
(B) Diagram of LREE/HREE Vs ΣREE.

4.2. PROVENANCE AND PROCESS OF REE

There is a significant enrichment of light REE (LREE) over heavy REE (HREE) relative to La/Sm ratios ranging from 3.03 to 7.05 with an average 4.38 for core sediments in the Kolakkudi Lake. Here the host rocks/sediments present in this area are interpreted by similar fractionation of LREE from HREE. The Rivers, which debouch into the lake carry through the gneisses and Charnockite formed by retrograde metamorphism in the hinterland followed by laterites and lateritic soils near lake. The REE usually provides a maximum range of trace elements in mineral with similar chemical properties but different mineral homogeneity. This makes them good traces for some geologic processes. In addition, preferential adsorption of LREE's relative to HREEs by clay minerals such as illite, kaolinite, montmorillonite, and chlorite (eg. Cullers et al., 1979) could be an important mechanism. Preferential sorting of heavy minerals such as zircon, sphene, monazite, garnet, allanite, hornblende, feldspar and mica (e.g. Frost et al., 1987) produce REE fractionation in some cases, but which may not hold good here, since our samples represent only the clay fraction. The HREE are concentrated in many heavy minerals of Kolakkudi lake sediments, e.g., zircon and garnet. The variations in Th and La indicate the felsic nature of source rock and Sc and Co is indicative of mafic source rock. These contents have been used to differentiate between felsic and mafic provenance by various authors (McLennan et al., 1980; Cullers, 2002; Nagarajan et al., 2007a, b; Kasanzu et al., 2008). In this connection, the bivariate diagram can provide information regarding the source rock characteristics. Also, the Th/Sc and La/Scvalues were suggest a basic source rocks in nature. The high abundance of REE in the sediments is probably due to the relatively high abundances of REE-bearing heavy minerals such as zircon, allanite, sphene, rutile, garnet, etc. (Das et al., 2006).

5. PROVENANCE OF LAKE SEDIMENTS

The provenance of the Kolakkudi Lake sediments were interpreted to be a high-grade metamorphic terrain as recorded by the dominance of specific heavy minerals as hornblende, epidote, garnet, chlorite, sillimanite, actinolite, biotite and muscovite. Garnet, a dominant constituent in lake sediments occurring together with Muscovite, sillimanite and epidote, rutile is of high - grade metamorphic origin. The studies of the heavy mineral assemblages have led to infer the dominant role of metamorphic source rocks.

6. SOURCE ROCK GEOCHEMISTRY

Trace elemental variations of lake sediments and source rocks of Talamalai hills are reported in Table 2. An enrichment of Cr and depletion in Ni, Sr, Zn, Co, Cu, V, Zr and Ba relative abundancies in samples were shown in their studied area (Fig. 5). The variation of high value in Cr because ilmenite and magnetite minerals are present in the Banded

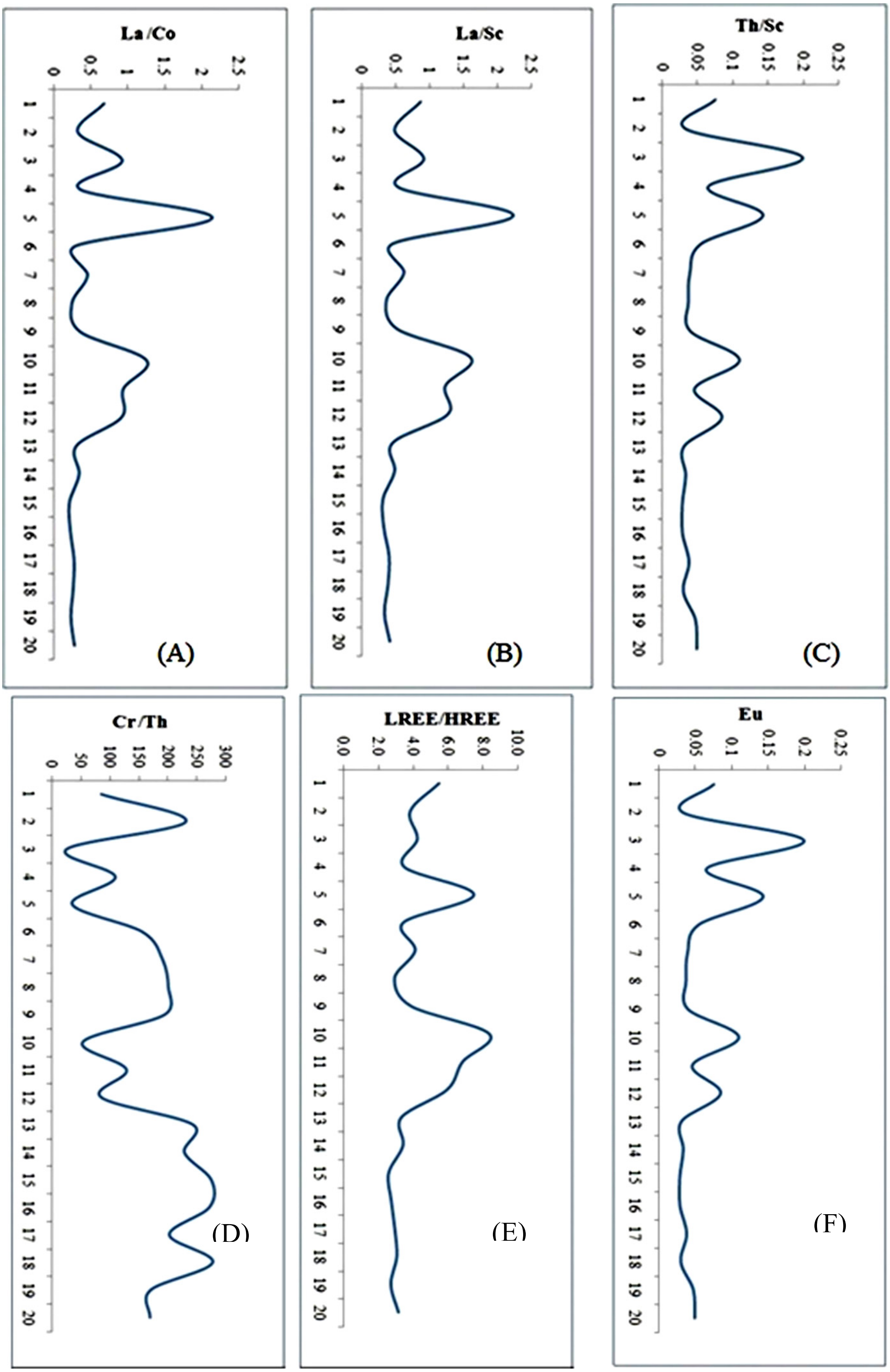

Fig. 4 Fractionation parameter and element ratios in core sediments of Kolakkudi Lake.

Table 2 Trace elemental variation of Kolakkudi Lake sediments and source rocks.

Samples	Ba	Cr	Ni	Sr	Zn	Co	Cu	V	Zr
Garnetiferous Gneiss	25.60	255.36	216.12	187.5	43	25.8	11.96	85.6	437.63
Garnet Pyroxene granulite	30.60	546.57	338.33	151.2	78.76	65.7	38.76	109.81	65.87
Pegmatite	204.70	533.08	336.28	25.4	30.77	BDL	12.68	BDL	105.16
Lake sediments (Kolakkudi)	139.08	275.84	97.56	235.47	627.37	52.7	179.77	223.24	211.18
PAAS	65.00	110.00	55.00	200.0	85.00	23.0	50.00	150.0	210.00
UCC	550.00	35.00	20.00	350.0	71.00	10.0	25.00	60.00	190.00

***BDL**- Below Detection Limit*

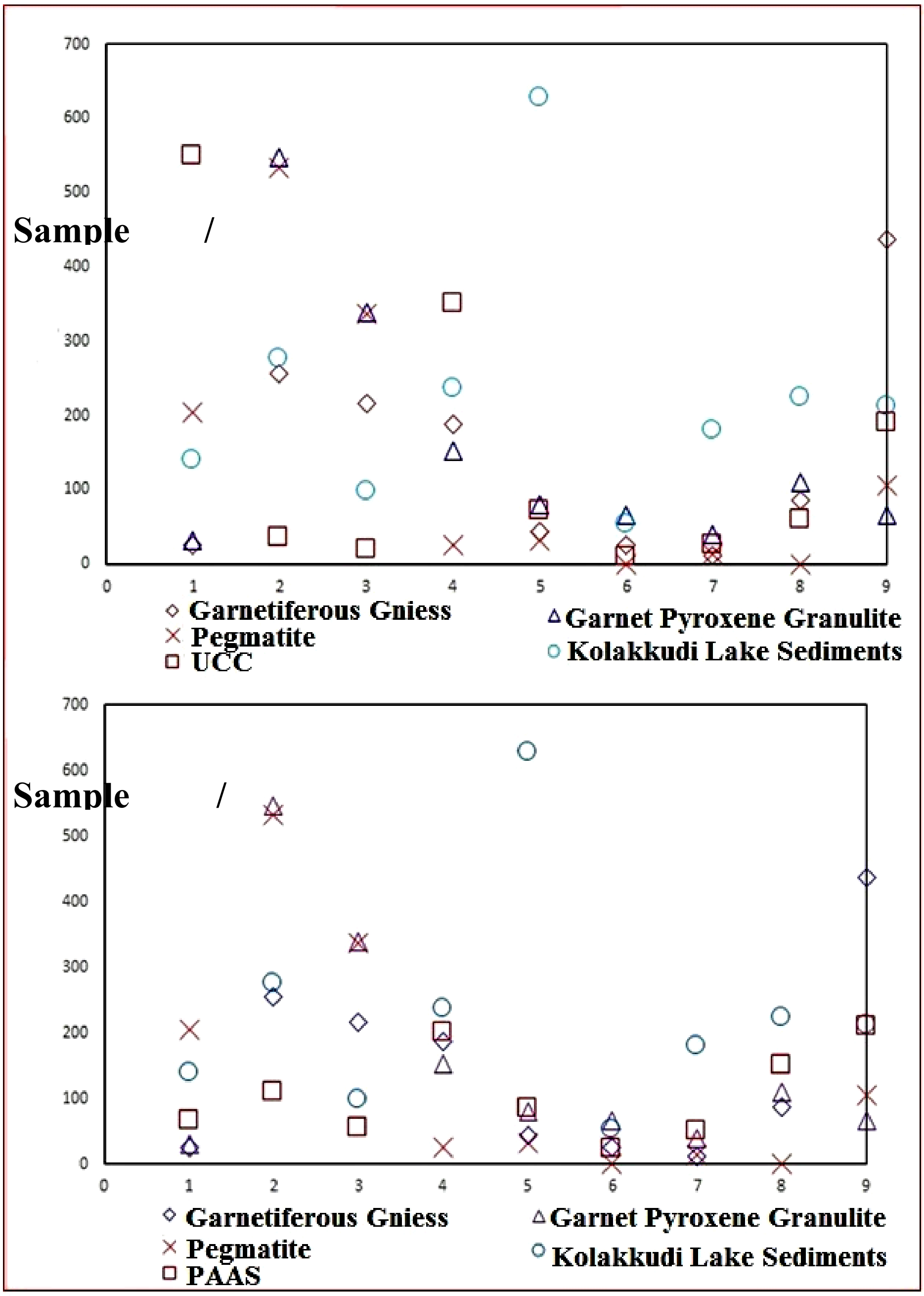

Fig. 5 Trace elemental variation for the source rock and Kolakkudi lake sediments.

A – Panoramic view of Talamalai Hills
B – Down stream side of the Hills
C – Exposed Pegmatite rocks

I – Gernetiferous Gniess
II – Banded Magnetide Quartzite
III – Garnet Pyroxene Granulite

Fig. 6 Source rock Area (Talamalai Hills).

magnetite quartzite rocks (Fig. 5). The banded iron formations and associated rocks of the study area had undergone granulite facies of metamorphism (Bavinton et al., 1980). Zn is very abundance in lake sediments compared to PAAS its value very high due to concentrations of zinc mainly governed by the source rocks and weathering conditions of Kolakkudi lake area. Zinc is generally soluble under humid weathering conditions, but may be adsorbed on manganese or iron oxides and clays or organic matter. Concentrations of zinc in soils are mainly governed by the source rocks (Kiekens, 1995). Zirconium from small well-rounded zircons observed in some of the samples and the Zr content in the lake sediments and source rocks varies between 211 and 437 ppm which is compared to value of PAAS (210 ppm). Sr and Ba value compared to lake sediments with UCC values due to the source of pegmatite rocks (Fig. 6). Strontium and Barium mostly reside in plagioclase and K-feldspar respectively (Puchelt, 1972; Bhat, 2017).

The variation of Cobalt is compared to lake sediments with PAAS and UCC which value is very high dependent on the texture of sediment and amount clay present. Zn is very high concentrations in lake sediments whereas sediments were widely spread source from Garnetiferous Gneiss and Garnet pyroxene granulite. Sediments formed from basic rocks are richer in Zn, whereas sediments from granites, gneisses, etc., (Vinogradov, 1959). Ba rich in sediments, one of these samples with higher plagioclase Ba concentration, several of which are pegmatites from metasedimentary exposures in Talamalai hills (Fig. 6).

7. Ce-ANOMALY

The samples with negative Ce anomalies are also having lower Ce concentrations. Ce relative to its neighboring REEs generally indicates a negative Ce-anomaly and this may be mainly from the presence of siliceous organisms. The Ce anomaly is calculated as Follows:

$$\text{Ce anomaly}=\frac{(\text{Ce})}{\text{Ce}^{*}}=\frac{(\text{Ce})\text{n}}{\sqrt{(\text{La})\text{n}(\text{Pr})\text{n}}}$$

The Ce anomalies of the studied area varies from 0.98 to 1.21 ppm in core sediments. This value plotted on the Ce anomaly Vs Nd concentration diagram (Fig. 6). Elderfield and Pagett (1986) set the Ce anomaly division as Oxic and anoxic conditions, whereas Wright et al. (1987) based on further evidence shifts this boundary tentatively to - 0.10 Ce anomaly measured in carbonates can be used to help understand Palaeo-redox conditions. Ce anomaly denotes the terrigenous source as origin and displayed Oxic environment that prevails along the study region.

8. CONCLUSIONS

REE concentrations in Kolakkudi lake sediments range from 0.43 ppm to 51.5 ppm, indicating a gradual increase towards the depth of sediment cores. The normalized pattern of La/Yb ratio ranges (3.33 to 15.4 ppm) that relative depletion in HREEs. The concentrations of most individual REEs in samples showed good correlation with each other. The normalized pattern of core sediments shows no significant LREE enrichment and exhibit flat HREE pattern. The core sediments show high ratio of LREE / HREE (3.14 to 8.34 ppm) which indicates that these sediments were derived from the basic source rocks (Table 3). The clustering of core sediments in the Th/Co Vs La/Sc bivariate plot suggests a basic nature of the source rocks. PAAS-normalized REE patterns are in agreement with source sediment REE in respective cores. Eu anomaly is inherited from ore material and controlled by sediment constituents. The Ce anomaly Vs Nd concentration bivariant plot for Kolakkudi Lake sediments fall in the field of slow sedimentation under Oxic condition and therefore, REE content in the sediments are not a consequence of anthropogenic activity. The positive correlation between Th and La suggests coherent behavior between REE (La) and Th and stronger grain size effect on sediments than that of provenance (Table 4). This implies that higher La resides in clays. Trace elemental studies of Kolakkudi lake sediments and its source rock result their high-grade metamorphic rocks. The strong association of Cr, Ni, Zn, Co, Cu, Pb, and V in sediments and high loading of these elements with clay content play a significant role in the distribution and sorption of these trace elements in sediments and the source rocks of lake sediments reveals that are metasedimentary origin.

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Table 3 REE concentration and ratios in core sediments of Kolakkudi Lake.

S.No	Sampling stations	Range of Depth (in cm)	LREE	HREE	LREE/HREE	ΣREE	La/Co	La/Sc	Th/Sc	Cr/Th	La/Sm	Gd/Yb
1	KLKD-1	90-120	132.4	24.2	5.47	156.6	0.68	0.87	0.08	85.3	4.88	1.79
2	KLKD-2	60-90	67.0	17.5	3.82	84.5	0.33	0.49	0.03	231.3	3.53	1.51
3	KLKD-3	60-90	146.6	34.7	4.22	181.3	0.93	0.92	0.20	25.3	3.08	1.51
4	KLKD-4	120-150	78.6	22.6	3.47	101.3	0.36	0.54	0.07	109.7	4.17	1.35
5	KLKD-5	30-60	374.7	50.2	7.46	425.0	2.15	2.23	0.14	35.3	6.30	2.33
6	KLKD-6	30-60	76.5	22.3	3.42	98.8	0.29	0.46	0.05	156.6	3.84	1.36
7		240-270	101.7	24.8	4.10	126.5	0.46	0.63	0.04	191.2	4.17	1.50
8	KLKD-7	30-60	67.2	23.0	2.93	90.2	0.25	0.37	0.04	201.2	3.29	1.25
9	KLKD-8	60-90	82.4	21.3	3.86	103.7	0.36	0.53	0.04	195.2	4.47	1.39
10	KLKD-9	60-90	261.4	31.3	8.34	292.7	1.26	1.60	0.11	53.2	7.05	2.16
11		90-120	213.4	31.3	6.81	244.7	0.95	1.23	0.05	129.0	6.73	1.63
12	KLKD-10	90-120	202.1	34.0	5.94	236.2	0.92	1.27	0.08	84.9	6.40	1.46
13	KLKD-11	30-60	75.8	22.9	3.31	98.7	0.31	0.46	0.03	244.1	4.09	1.24
14		90-120	87.1	25.6	3.41	112.7	0.35	0.49	0.03	229.0	4.53	1.21
15		150-180	60.8	23.5	2.59	84.3	0.21	0.32	0.03	275.4	3.03	1.23
16	KLKD-12	30-60	54.9	20.0	2.74	74.9	0.23	0.33	0.03	272.2	3.04	1.21
17		90-120	67.3	22.9	2.94	90.3	0.28	0.41	0.04	203.0	3.91	1.19
18		150-180	68.8	22.5	3.05	91.3	0.27	0.39	0.03	277.9	3.73	1.24
19		210-240	61.9	22.8	2.71	84.7	0.24	0.34	0.05	170.7	3.33	1.19
20		240-270	76.5	24.3	3.14	100.8	0.28	0.42	0.05	169.6	3.64	1.29
		Min.	**54.9**	**17.5**	**2.59**	**74.9**	**0.21**	**0.32**	**0.03**	**25.3**	**3.03**	**1.19**
		Max.	**374.7**	**50.2**	**8.34**	**425.0**	**2.15**	**2.23**	**0.20**	**277.9**	**7.05**	**2.33**
		Mean.	**117.9**	**26.1**	**4.19**	**144.0**	**0.56**	**0.71**	**0.06**	**167.0**	**4.36**	**1.45**

Table 4 Grain size data of Kolakkudi Lake Sediments.

		Mz	Verbal limit	(σ1)	Verbal limit	(Sk)	Verbal limit	(K_G)	Verbal limit
KLKD-1	90-120	1.6519	Medium grained	1.0525	Poorly sorted	-0.0339	Symmetrical	0.7337	Platykurtic
KLKD-2	60-90	2.1204	Fine grained	0.8815	Moderately sorted	-0.3917	Very coarse Skewed	1.3229	Leptokurtic
KLKD-3	60-90	0.9550	Coarse grained	0.7555	Moderately sorted	0.6641	Very Fine Skewed	0.7740	Platykurtic
KLKD-4	120-150	1.5437	Medium grained	0.9524	Moderately sorted	-0.0448	Symmetrical	0.6727	Platykurtic
KLKD-5	30-60	1.2234	Medium grained	0.9530	Moderately sorted	0.5662	Very Fine Skewed	0.7130	Platykurtic
KLKD-6	30-60	1.3592	Medium grained	0.8556	Moderately sorted	0.0692	Symmetrical	0.7274	Platykurtic
	240-270	1.4878	Medium grained	0.7591	Moderately sorted	-0.1552	Coarse skewed	1.0118	Mesokurtic
KLKD-7	30-60	1.2057	Medium grained	0.7381	Moderately sorted	0.1264	Fine skewed	0.7583	Platykurtic
KLKD-8	60-90	1.7243	Medium grained	0.9234	Moderately sorted	-0.1417	Coarse skewed	0.8502	Platykurtic
KLKD-9	60-90	2.2297	Fine grained	0.9737	Moderately sorted	-0.3444	Very Fine Skewed	1.1178	Leptokurtic
	90-120	1.7344	Medium grained	1.0783	Poorly sorted	-0.1048	Coarse skewed	0.6528	Very platykurtic
KLKD-10	90-120	1.3456	Medium grained	0.9465	Moderately sorted	-0.1615	Coarse symmetrical	0.6199	Very platykurtic
KLKD-11	30-60	2.4116	Fine grained	0.7846	Moderately well sorted	-0.0820	Symmetrical	1.1077	Mesokurtic
	90-120	2.4739	Fine grained	0.6756	Moderately well sorted	-0.0798	Symmetrical	0.8584	Platykurtic
	150-180	2.4330	Medium grained	0.6208	Moderately sorted	-0.1615	Coarse skewed	0.6199	Very platykurtic
KLKD-12	30-60	1.9998	Medium grained	0.6253	Moderately well sorted	0.1268	Fine skewed	1.1012	Mesokurtic
	90-120	2.1548	Fine grained	0.6010	Moderately well sorted	0.3458	Very fine skewed	1.2414	Leptokurtic
	150-180	2.2073	Fine grained	0.5111	Moderately well sorted	0.1842	Fine skewed	1.0040	Mesokurtic
	210-240	2.2590	Fine grained	0.5433	Moderately well sorted	0.1530	Fine skewed	0.9707	Mesokurtic
	240-270	2.2665	Fine grained	0.5254	Moderately well sorted	0.0535	Symmetrical	0.9791	Mesokurtic

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