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Research Article

RESOLVING DISCREPANCIES IN STRATIGRAPHIC NOMENCLATURE OF EOCENE LITHO UNITS OF AMEKI GROUP USING GEOCHEMISTRY

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ABSTRACT

The International Commission for Stratigraphic Classification (ICSC) has standard laid out procedures, policies, and rules for naming lithologic unit and these criteria do not include diagenetic changes as a basis for naming formation. The upper strata unit of the Ameki Group with respect to facies relation creates uncertainties in the stratigraphic nomenclature. This study using multi-element geochemistry of relatively immobile rare earth elements narrowed the knowledge gap by interpreting and unifying sediment source area of Upper Ameki Group. The "Nsugbe" sandstone is a diagenetic product of the "Nanka" sands and this further simplifies the stratigraphy of Upper Ameki Group. Consequently, this research identifies the need to synchronize or review the nomenclature in line with ICSC guidelines.

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INTRODUCTION

The International Commission for Stratigraphic Classification (ICSC) defines and recommends policy and rules governing stratigraphic nomenclature and classification. They describe units, specify type locality and provide guidance for designation or modification of formal and informal stratigraphic unit nomenclature based on boundaries, dimensions, shape, age, correlations, petrogenesis and historical background. The uncertainties in interpreting and defining lithologic units or in correlating them with near and far units have led to the creation of many local geological names which increases the number of lithostratigraphic units yearly (USGS, 1985). The modern Niger Delta petroleum province stratigraphic units can be grouped into outcropping and subsurface units (Nwajide, 2013). The outcropping series comprises of the Imo Formation through Ameki Group, the Ogwashi-Asaba Formation to the Benin Formation. The Akata Formation to Agbada Formation them to Benin Formation are the subsurface series. The Ameki Group is relatively well exposed and has received attention by the Geological Survey of Nigerian and many scholars like Nwajide (1979, 1980) and Reyment (1965). Nwajide (1980) described the Ameki Group to be made up of Ameki Formation, Nanka Formation and Nsugbe Formation using the bottom to top approach. The Nsugbe Formation is mainly consolidated Fe-sands which are undergoing intense weathering and underlain by unconsolidated sands. Insitu exposures along the Niger left bank some 100m upstream of the Nkisi River mouth as well as along the road through the Onitsha Prisons area. Nsugbe sandstone is overlaying the Nanka sands and has an unclear boundary. The Nanka Formation is made up of loose flaser bedded, fine to medium sand facies of the Ameki Group (Nwajide, 2013). The Nanka sands are best exposed in gullies and Nwajide (2013) described the approximate thickness to be 305m. Nwachukwu et al. (2011) described sedimentary control on reservoir sands properties of Eocene Nanka sands and emphasized its implication on deepwater studies. Generally, based on facies relations, the Nsugbe stones at Nsugbe town may be the result of diagenetic changes in Nanka sands and diagenetic change is not a criterion for defining lithologic units by ICSC. This research is aimed at applying the use of immobile rare earth element (REE) geochemistry to resolve discrepancies in the stratigraphy in the Upper Ameki Group.

Table 1. Outcropping Units of the Cenozoic Niger Delta. After Nwajide (2013)

Age	Lithostratigraphy Units	
Oligocene-Present	Benin Formation	
Oligocene-Miocene	Ogwashi to Asaba Formation	
Eocene-Early Oligocene	Ameki Group	Nsugbe Formation
		Nanka Formation
		Ameki Formation
Paleocene-Early Eocene	Imo Formation	

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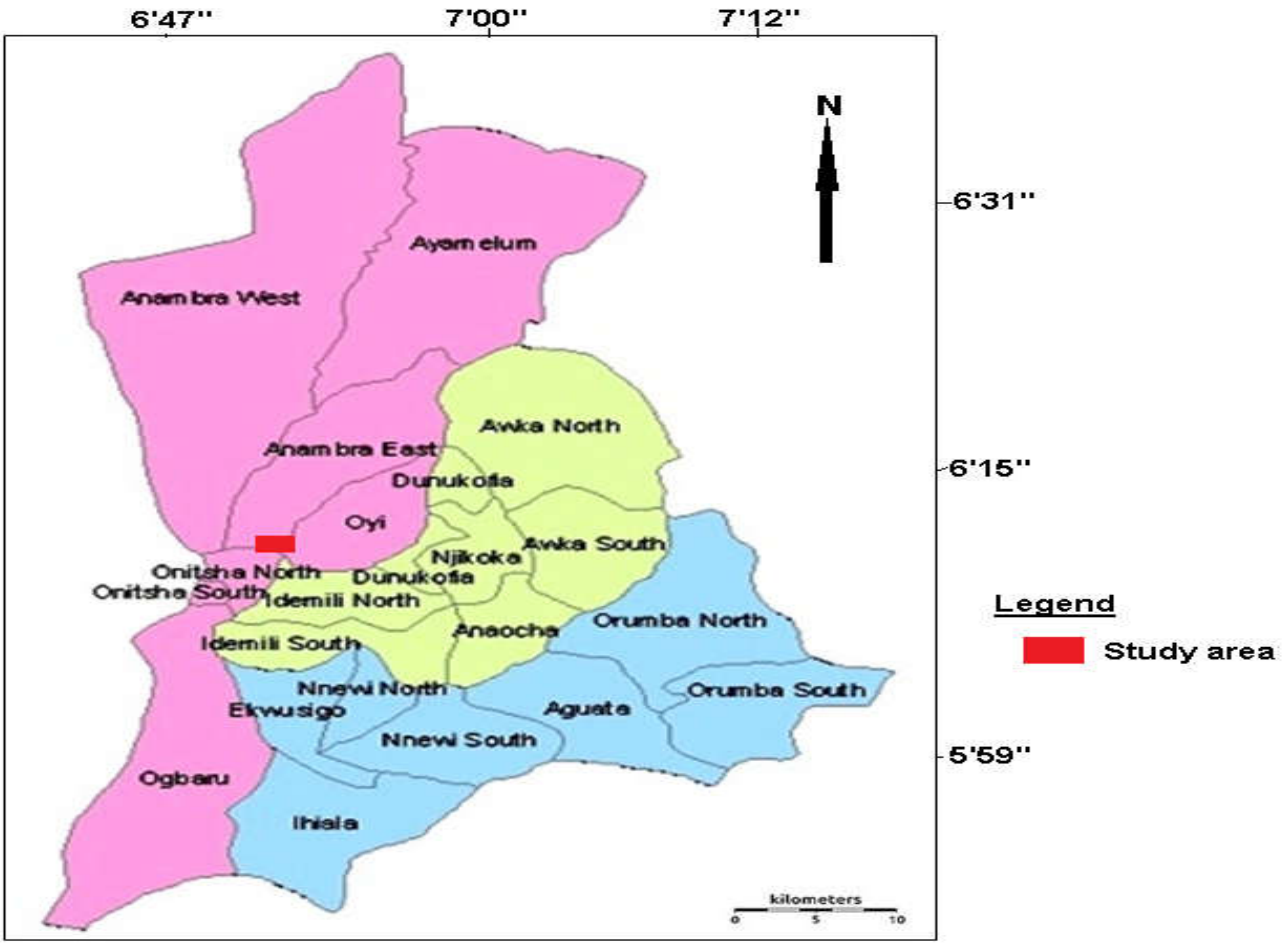

Figure 1. Map showing study area

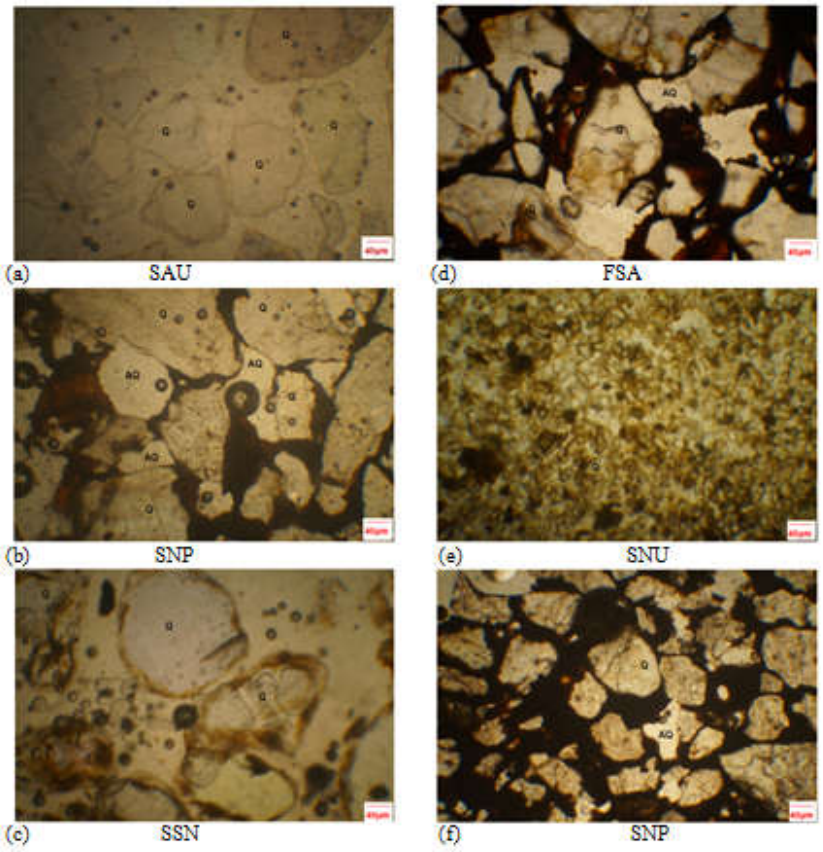

Figure 2. Photomicrograph of typical Eocene Sands of Ameki Group. (Note: Q=Quartz; AQ=Authigenic quartz; O=Opaque minerals)

Table 2. Rare earth element (REE) composition of Eocene litho-units of Upper Ameki Group

Sample	Unit	SAU								SSN					
Label Location		AZC2	AZB1	TKHC-1	AMD2	AVW2	AJJB-1	AVV2-1	AHB1-1	2-I	3-I	K-1	FRT-1	GGG-2	GH2-1
La	(ppm)	4.4	5.3	5.1	4.5	4.8	4.9	5.2	4.6	53.7	19.1	49.6	18.9	19.2	51.3
Ce	(ppm)	8.5	10.4	9.8	8.1	8.3	9.2	9.7	8.4	113	34.7	108	33.2	36.5	116
Pr	(ppm)	1.01	1.3	1.2	1.16	1.1	1.07	1	1.09	13.5	3.42	11.4	3.01	3.19	12.8
Nd	(ppm)	3.4	4.3	3.9	3.2	3.6	4.1	4	3.7	49.7	10.8	46.1	11.2	10.7	41.1
Sm	(ppm)	0.7	0.7	0.7	0.8	0.7	0.7	0.7	0.6	8.7	1.6	8.4	1.4	1.5	7.9
Eu	(ppm)	0.1	0.13	0.1	0.09	0.11	0.13	0.09	0.12	1.22	0.3	1.19	0.5	0.4	1.23
Gd	(ppm)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	5.6	1	5.3	1	1	4.9
Tb	(ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.8	0.1	0.7	0.3	0.2	0.6
Dy	(ppm)	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	4	0.8	2.8	0.7	0.6	3.4
Ho	(ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.7	0.2	0.6	0.1	0.2	0.7
Er	(ppm)	0.2	0.3	0.3	0.2	0.2	0.3	0.3	0.2	2.1	0.4	2.2	0.3	0.4	1.9
Tm	(ppm)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.33	0.06	0.29	0.07	0.08	0.31
Yb	(ppm)	0.3	0.2	0.2	0.3	0.3	0.2	0.2	0.3	2.4	0.4	2.3	0.5	0.4	2.1
Lu	(ppm)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.42	0.08	0.39	0.09	0.07	0.4
∑REE	(ppm)	19.9	23.92	22.59	19.74	20.4	21.89	22.48	20.3	256.17	72.96	239.27	71.27	74.44	244.64
∑LREE	(ppm)	18.01	22	20.7	17.76	18.5	19.97	20.6	18.39	238.6	69.62	223.5	67.71	71.09	229.1
∑HREE	(ppm)	1.79	1.79	1.79	1.89	1.79	1.79	1.79	1.79	16.35	3.04	14.58	3.06	2.95	14.31
∑LREE/HREE		10.061	12.291	11.564	9.397	10.335	11.156	11.508	10.274	14.593	22.901	15.329	22.127	24.098	16.010
La/Yb		14.667	26.500	25.500	15.000	16.000	24.500	26.000	15.333	22.375	47.750	21.565	37.800	48.000	24.429
La	(ppm)	10.8	12.9	11.1	12.2	11.7	3	3	23.8	2.8	21.7	2.8	22.1	11	12
Ce	(ppm)	25.7	32.2	24.9	31.8	25.1	6.4	7.1	51.8	6.7	47.9	6.6	45.8	42.1	40.9
Pr	(ppm)	3.54	5.45	3.57	5.22	4.05	0.99	1	6.38	0.82	6.23	0.79	0.91	5.95	5.38
Nd	(ppm)	12.4	21	11.9	19.8	13.2	3.9	3.9	25.4	3.2	23.5	3.3	3.1	25.8	26.1
Sm	(ppm)	2.2	3.5	2.2	3.7	3.4	1.2	1.1	5.9	0.8	5.8	0.8	0.7	6.6	6.4
Eu	(ppm)	0.42	0.67	0.4	0.65	0.61	0.26	0.24	1.32	0.14	1.29	0.11	0.13	1.36	1.37
Gd	(ppm)	1.4	1.6	1.3	1.5	1.4	1	1	5.5	0.5	5.1	0.5	0.6	5.8	5.5
Tb	(ppm)	0.2	0.2	0.3	0.2	0.2	0.2	0.1	0.8	<0.1	0.8	<0.1	<0.1	0.9	0.8
Dy	(ppm)	1.2	1.3	1.1	1.4	1.3	1.2	1.1	4.3	0.5	3.9	0.6	0.5	4.7	4.4
Ho	(ppm)	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.8	<0.1	0.5	<0.1	<0.1	0.8	0.8
Er	(ppm)	0.6	0.6	0.7	0.6	0.7	0.7	0.7	2	0.2	2	0.3	0.2	1.8	1.5
Tm	(ppm)	0.09	0.08	0.07	0.09	0.08	0.1	0.1	0.25	<0.05	0.25	<0.05	<0.05	0.23	0.24
Yb	(ppm)	0.6	0.6	0.6	0.7	0.6	0.7	0.8	1.6	0.2	1.6	0.2	1.7	1.5	1.3
Lu	(ppm)	0.09	0.08	0.08	0.09	0.07	0.1	0.1	0.25	<0.04	0.23	<0.04	0.21	0.24	0.21
∑REE	(ppm)	59.44	80.38	58.52	78.15	62.61	19.95	20.44	130.1	16.15	120.8	16.29	76.2	108.78	106.9
∑LREE	(ppm)	54.64	75.05	53.67	72.72	57.45	15.49	16.1	113.28	14.32	105.13	14.29	72.61	91.45	90.78
∑HREE	(ppm)	4.38	4.66	4.45	4.78	4.55	4.2	4.1	15.5	1.69	14.38	1.89	3.46	15.97	14.75
∑LREE/HREE		12.475	16.105	12.061	15.213	12.626	3.688	3.927	7.308	8.473	7.311	7.561	20.986	5.726	6.155
La/Yb		18.000	21.500	18.500	17.429	19.500	4.286	3.750	14.875	14.000	13.563	14.000	13.000	7.333	9.231

Study Area

The study area is located in Anambra State and cuts across Nsugbe, Nkwelle Ezunaka, Awkuzu, Ezinkeje, Nteje, Nneyi Umuleri, Onitsha Prison Area and some part of Umunya town in Anambra State (Figure 1).

MATERIALS AND METHODS

Samples were analyzed petrographically using a polarizing microscope to evaluate mineral composition. The rare earth element (REE) composition was evaluated using Fusion Inductive Couple-Plasma Mass Spectrometer.

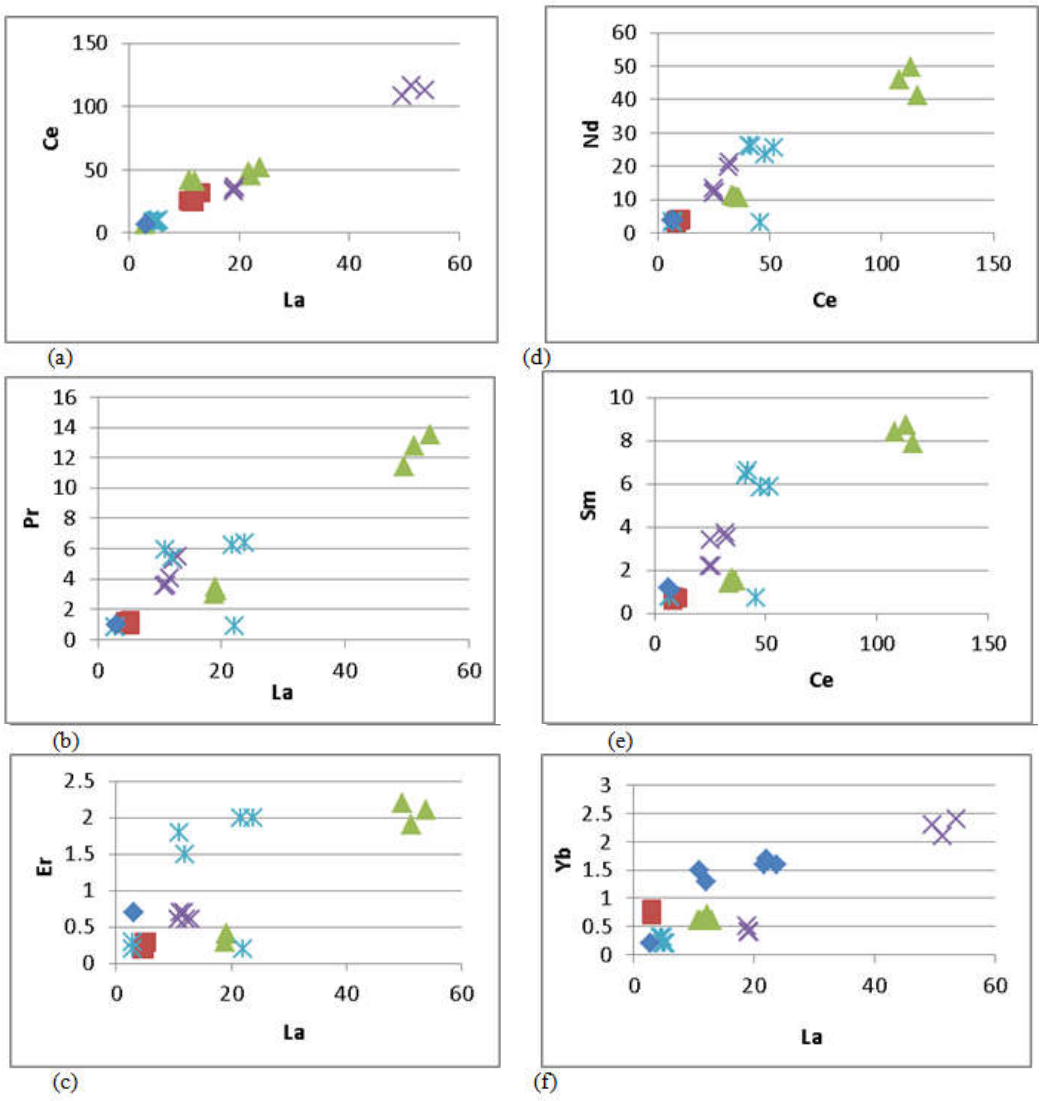

Figure 3. Inter-element plot of rare earth element composition in Nsugbe area

Results are analysis using statistical computations and graphical representation towards achieving research aim and objectives. The collected samples from outcrops are grouped based on localities into sands at Awkuzu-Umunya (SAU), sand pockets within sandstones in Nsugbe (SSN), sand at Nneyi Umuleri (SNU), ferruginized sandstones at Awkuzu (FSA) and sandstones of Nsugbe and Onitsha Prisons area (SNP).

RESULT AND DISCUSSION

They are no well-defined boundaries between the Nsugbe sandstone and Nanka sands and this supports Nwajide (2013). The sands at Awkuzu-Umunya (SAU) are exposed dominantly along burrow pits and are interbedded with ferruginized sandstones at Awkuzu (FSA). The sandstones at Nsugbe and Onitsha prison area (SNP) are highly affected by weathering and show increased tidal marine influence at Nsugbe. The grain sizes of these lithologic units are dominantly poorly to moderately sorted, fine to very coarse sands (Figure 2). The lithologic sands of SAU, SSN and SNU are unconsolidated and are rich in quartz grains that show opaque minerals probably iron oxide and/or oxyhydroxides, filling micro-fractures and coating grain edges. Generally, they have poorly to moderately sorted, subangular to subrounded, fine to very coarse grains.

The consolidated sands in the study area comprise of FSA and SNP and they are rich in quartz with opaque minerals probably iron oxides and oxyhydroxides, filling grains edges and intergranular pore spaces. The dominant pattern in the bilinear plot (Figure 3) of rare earth element (REE) is disseminated scattered with discrete cluster points. La shows a positive correlation with Ce, Pr, Nd, Sm, Eu, Er, Nb, Th and Yb in these sedimentary rocks. REE relative elements abundance is illustrated in Figure 4. $\sum REE$ Shows high values greater than 50ppm for sand pockets associated with sandstones but $\sum REE$ values are relatively low in sands at Awkuzu-Umunya and sandstones within the study area. $\sum LREE/HREE$ ratio shows the least values in FSA followed by SNP. Higher values of $\sum LREE/HREE$ are observed in SSN while SAU and SNU values are significant. Ce, La and Nd concentration in sediments is relatively higher in sand pockets within sandstone in Nsugbe and sandstones in Nsugbe and prison area. Using inter-elemental ratio plots the dominant pattern is disseminated scattered. The La/Yb ratio shows overlapping range in a composition which makes it less significant in discriminating provenance. The sands pockets within sandstones in Nsugbe (SSN) show relatively higher La/Yb ratio values. The multi-elemental plot (Figure 5) show very similar plot pattern and

trend for samples obtained and this probably implies a unified source for the lithologic units that make up the upper strata of the Ameki Group. The variation in immobile trace element is probably due to the interaction of sediment deposits with spatially heterogenic environmental conditions within polycyclic regimes. Consequently, the consolidated and highly weathered sandstones found at Nsugbe and Onitsha prison's area are products of diagenetic changes in "Nanka" sands.

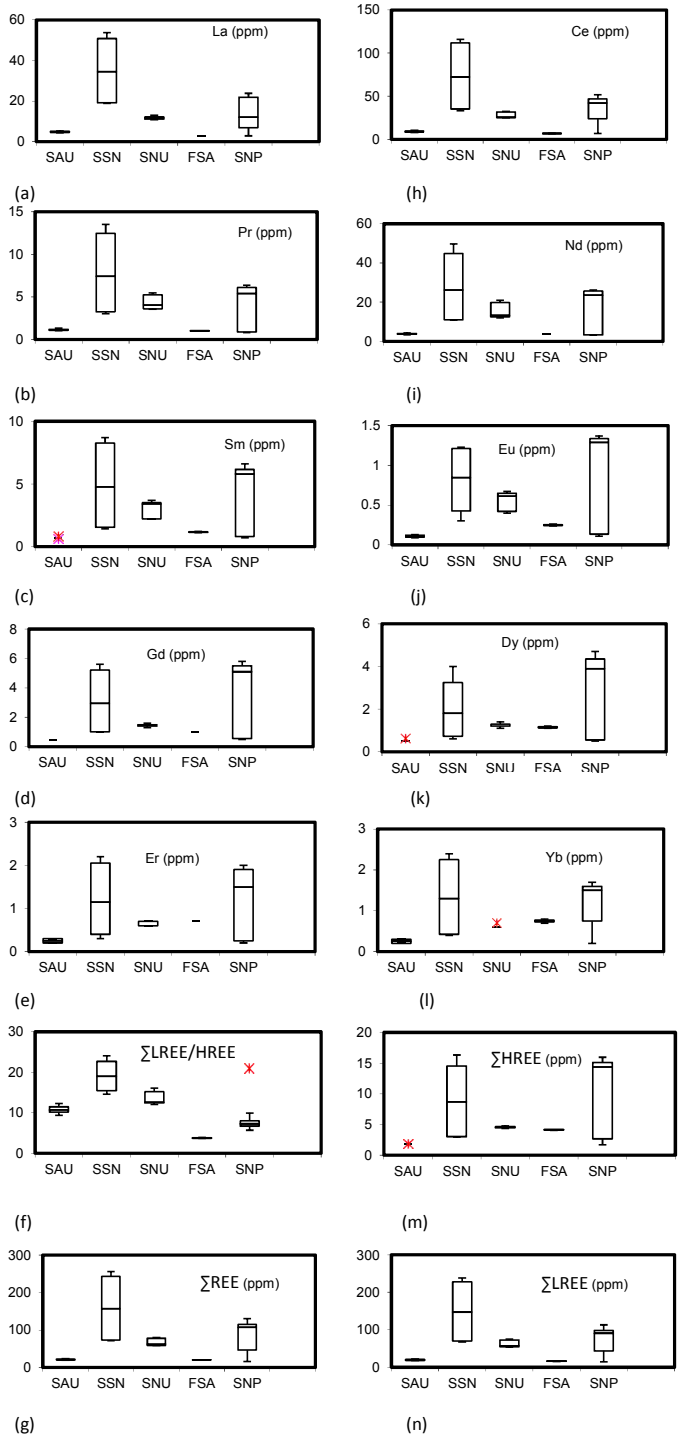

Figure 4. Relative abundance of REE in samples within the study area

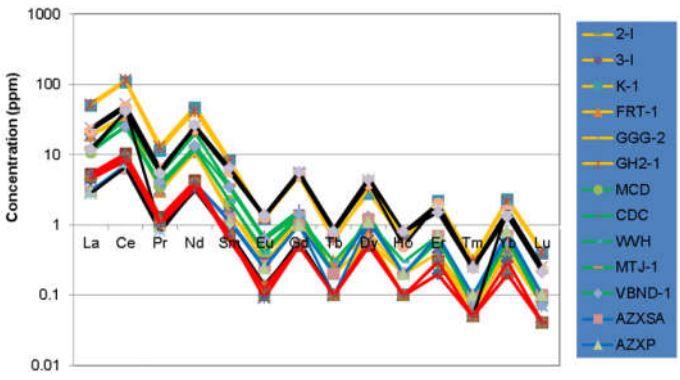

Figure 5. Multi-elemental plot of rare earth elements (REE) for Eocene litho-units of Ameki Group

Conclusion

REE composition proved a great tool for resolving stratigraphic disputes and consolidating present knowledge in provenance. This study has narrowed the knowledge gap by interpreting and unifying the sediment source of Eocene sand and sandstone units of upper Ameki Group, using immobile REE composition. This implies that the Nsugbe sandstones as described by Nwajide (2013) with same relative stratigraphic position, paleogeographic significance, lithological composition and limited lateral continuity are the product of diagenetic changes in Nanka sands. Since, diagenesis is not a criterion for naming stratigraphic nomenclature; consequently, this study justifies the need for a review of the nomenclature of these lithologic units in line with the International Commission for Stratigraphic Classification guidelines. This research further simplifies the stratigraphy of the Upper Ameki Group.

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