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RARE EARTH EVIDENCE FOR THE ORIGIN OF GNEISSES AROUND YARI BORI AND TSIGA AREA, PARTS OF MALUMFASHI SCHIST BELT, NIGERIA.

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Abstract

There is variability in the total Rare Earth Elements (REEs) abundance, their distribution patterns and degree of fractionation in the gneisses of Yari Bori and Tsiga area parts of Malumfashi schist belt of Nigeria. The variety of gneisses mapped includes granite gneisses, augen gneisses and the banded gneisses. Most of the gneisses investigated shows marked negative Eu anomalies. Also the REE distribution patterns are significantly fractionated with strong light REE enrichment (La, Ce, Pr, Nd, Sm and Gd,) and heavy REE depletion (Tb, Dy, Ho, Er, Tm, Yb, Lu); a suggestive of melt equilibration with residual garnet. La is in the range of 10.7-81.5 ppm, Ce (21.6-174.6 ppm) and Pr (2.39-20.29 ppm) while Tm is in the range of 0.05-0.73 ppm, Yb (0.30-4.62 ppm) and Lu (0.04-0.67 ppm). The gneisses of this area are interpreted as resulting from magmatic origin involving varying degree of partial melting of lower crust at different depths.

Key words: REE; gneisses; fractionation; chondrite; schist belt; Malumfashi.

Introduction

Rare earth elements are reliable petrogenetic indicators; they have unique properties such as strong electropositive character, constancy in valance state (3+) with exception of Eu and Yb showing additional (2+) and Ce and Tb showing additional (4+) valence; significant substitution especially of tetravalent cations in different minerals; and their systematic partitioning in the mineral/melt systems (Randive *et al.*, 2014). Their behaviour and content in metamorphic rocks depends on their protolith and pressure-temperature-composition conditions. This implies that the modal abundance of minerals present and the physicochemical conditions in which those minerals form will determine REEs distribution in metamorphic rocks. Overall, accessory minerals such as zircon, monazite, allanite, sphene, and apatite tend to concentrated REE much more than do the major rock forming minerals such as feldspars, micas, pyroxenes and amphiboles. Most scholars are of the view that the REE content of metamorphic rocks is assumed to be similar to that of their protolith; however, it is observed that REEs can be mobile or immobile depending on certain circumstances. Thus, the total REE abundance of metamorphic rocks may differ considerably from their protoliths.

The Precambrian basement of northwestern Nigeria consists largely of quartzofeldspathic gneisses, schists, quartzites and granitoids. The gneisses are reported to compose of relatively simple and monotonous mineralogy; quartz + plagioclase ± K-feldspar + biotite ± hornblende with garnet and zircon as accessory minerals. Recently, there has been a considerable revival of interest in the petrogenesis of basement rocks; gneisses in particular, and the relationship that exist amongst them. The most significant discovery has been the recognition of contrasting modes of evolution for the gneisses in the Nigeria basement terrain. This contrast varies from location to location (Elueze and Bolarinwa, 2004). Summary of the arguments for the different modes of origin of the basement gneisses can be found in the work of Elatikpo *et al.,* (2013). Most recent works still emphasise sedimentary protolith (Ayodele, 2015; Obioha *et al.,* 2015) or igneous protolith (Elatikpo *et al.,* 2013; Opara *et al.,* 2014; Obioha *et al.,* 2015) for the basement gneisses depending on their locations. But the greater number of these works was based on major elements geochemistry with little attention on trace and REEs geochemistry. The Malumfashi schist belt is not an exception, with works on the basement rocks mostly based on petrography, major and little trace elements geochemistry (e.g McCurry, 1976; Elatikpo *et al.,* 2013 amongst others) with most of the works on regional scale. This paper presents results of REEs geochemistry of the gneisses of some parts of Malumfashi schist belt (figure 1), the relationship that exist between them, clues about their origin and to improve on the existing knowledge.

Synopsis of Geology of the study area

The study area (Figure 1) covers part of the present political Katsina State of Nigeria and lies between Latitudes 11°30'00"N to 11°45'00"N and Longitudes 7°30'00"E to 7°45'00"E. This falls within the Federal Survey map of Nigeria, Malumfashi Sheet 79 SW. The area being part of northwestern basement complex is underlain by rocks of different lithological units; gneisses, medium-grained granites, granodiorites, schist, migmatites, aplites and pegmatites. The first detailed work carries out in northwestern Nigeria (Kusheriki area) was that of Truswell and Cope (1963), where they identified parallel structures and transitional contacts between the different metamorphic units (Ajibade et. al., 1989). McCurry (1970; 1976) then gave a systematic account of the geology of northern Nigeria, where she groups them into four main lithologies: Basement Complex, the Younger Metasediments (Schist belts), "Older Granites" series of

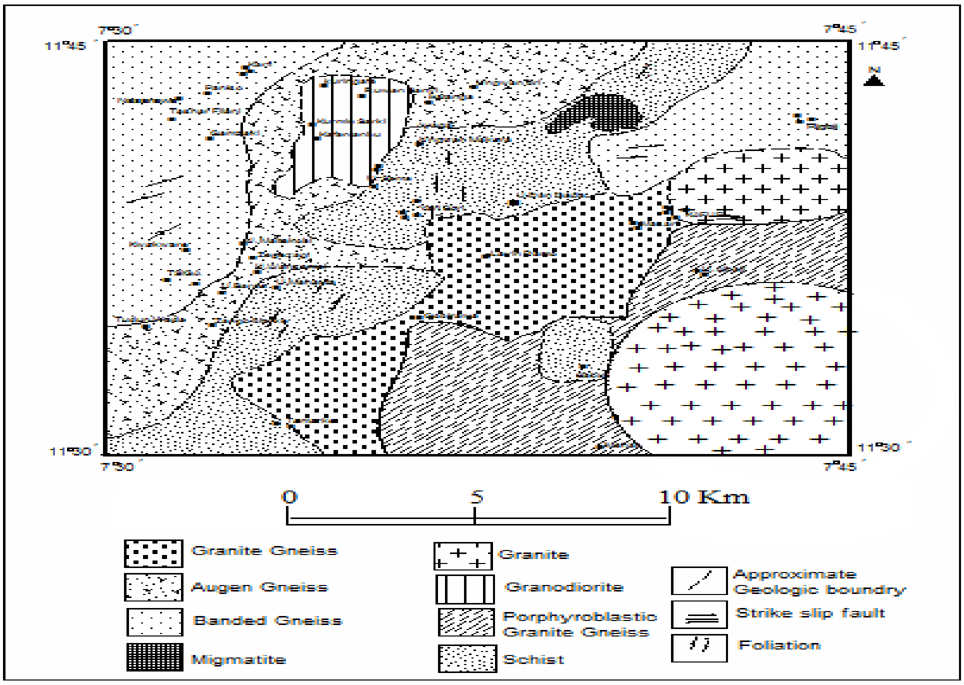

Figure 1: Geological map of Yari Bori and Tsiga area (modified from Elatikpo *et al.*, 2013)

Pan- African age and volcanic rocks. Other works in this area are those of Woakes (1981) on the basement metallogeny of northwestern Nigeria with emphasis on mineral potentials of this region and systematic geological mapping by undergraduate students of Ahmadu Bello University Zaria. More recent work in this area is that of Elatikpo *et al.*, (2013) where they discussed geochemistry and petrogenesis of the basement rocks of this belt. Structurally, the Pan-African tectonic trend (NE-SW) dominate most outcrops alignment while NW –SE and E- W structural trends abound.

Methodology

Different rock units within the study area were mapped using combine compass traverse and global position system (GPS) methods, with their locations plotted on the base map. Systematic sampling pattern was used to obtained a hand representative sample of each rock unit mapped.

The samples were then packed in a sample bag and convey to the laboratory for other physical treatments. Eight representative samples of gneisses which are the unit of interest were carefully selected for further investigated. The samples were jaw crushed and packed at the geochemical laboratory of the Department of Geology, Ahmadu Bello University Zaria, Nigeria.

Subsequent physical and chemical treatment as pulviration to <200 mesh (85%) and chemical analysis were carried out in ACME Analytical laboratories (now referred to as Bureau Veritas Minerals) in Vancouver Canada. REE concentrations were measured using 0.5g of sample pulp, analysed by ICP-MS following a Lithium borate fusion. Data obtained were analysed using spidergram normalised to REE chondrite of Boyton (1984).

Results and Discussions

Results of REE contents and their ratios for the gneisses of this study area are presented in tables 1 and 2 with the plots of chondrite normalised values showing the distribution patterns presented in figures 2-6. The analysis of the distribution patterns are outline below and presented in figures 2-6. Chondrite values used are those of Boynton, 1984.

Table 1: REE compositions (ppm) of gneisses of Yari Bori and Tsiga area

Analyte ppm	**Granite Gneiss**				**Augen Gneiss**		**Banded Gneiss**	
	2	4	5	8	3	7	6	9
La	81.5	56.2	38.4	61.5	30.7	60.4	25.1	10.7
Ce	174.6	117.9	88.3	128.1	62.5	103.7	47.8	21.6
Pr	20.29	13.36	8.76	15.38	7.67	12.25	5.18	2.39
Nd	76.6	43.1	30.9	57.4	26.7	38.9	17.6	8.2
Sm	14.99	9.45	5.39	11.83	5.66	6.92	3.02	2.08
Eu	2.54	0.48	1.33	1.28	1.06	1.04	0.78	0.30
Gd	12.97	8.38	3.28	11.78	4.21	5.09	2.44	2.26
Tb	1.90	1.37	0.37	1.97	0.66	0.74	0.36	0.44
Dy	9.76	6.91	1.43	11.41	2.82	3.60	1.91	2.80
Ho	1.90	1.18	0.17	2.15	0.46	0.62	0.31	0.62
Er	5.16	3.00	0.40	5.60	1.09	1.78	0.83	1.91
Tm	0.73	0.41	0.05	0.78	0.15	0.23	0.11	0.31
Yb	4.26	2.44	0.30	4.62	0.87	1.50	0.76	1.96
Lu	0.61	0.28	0.04	0.67	0.12	0.22	0.10	0.31
Total REE	407.81	264.46	314.47	179.12	144.67	236.99	106.30	55.88
Alumina and Sr contents of these gneisses								
Al_2O_3	14.68	14.09	16.05	12.77	14.41	15.08	15.45	13.99
Sr	245.5	58.0	740.7	50.6	198.1	249.0	319.4	104.4

Al_2O_3 and Sr data are from Elatikpo et al., (2013)

Table 2: Chondrite normalised REE ratio of gneisses of Yari Bori and Tsiga area

REE Ratio	**Granite Gneiss**				**Augen Gneiss**		**Banded Gneiss**	
	2	4	5	8	3	7	6	9
Eu/Eu*	0.56	0.17	0.97	0.33	0.67	0.54	0.88	0.43
$(La/Yb)_N$	12.75	15.36	85.33	8.87	23.52	26.84	22.02	3.64
$(La/Sm)_N$	3.42	3.74	3.27	4.48	3.41	5.49	5.23	3.24
$(Ce/Yb)_N$	10.60	12.50	7.17	76.13	18.58	17.88	16.27	2.85
$(Ce/Sm)_N$	2.81	3.01	2.61	3.95	2.66	3.62	3.82	2.51
$(Eu/Yb)_N$	1.70	0.56	0.79	12.61	3.46	1.97	2.92	0.44

The shape of the REE distribution patterns in all the variety of gneisses investigated is generally smooth as evident by the decrease in REE values from light REE to heavy REE (Figure 2). There is an enrichment of light REE and depletion of heavy REE in their distribution patterns. The plots of chondrite normalised values show significant negative Eu anomaly in the gneisses investigated except for one granite gneiss and banded gneiss. There are also relative positive anomalies of elements like Dy, Pr and Tb particularly in gneisses with no Eu anomaly (samples 5 and 6). The total REE abundance (Table 1) in the banded gneisses recorded the least values (55 and 106.30 ppm) among the gneisses investigated. On the contrary, granite gneisses show the highest total REE abundance (264.46-407.81 ppm).

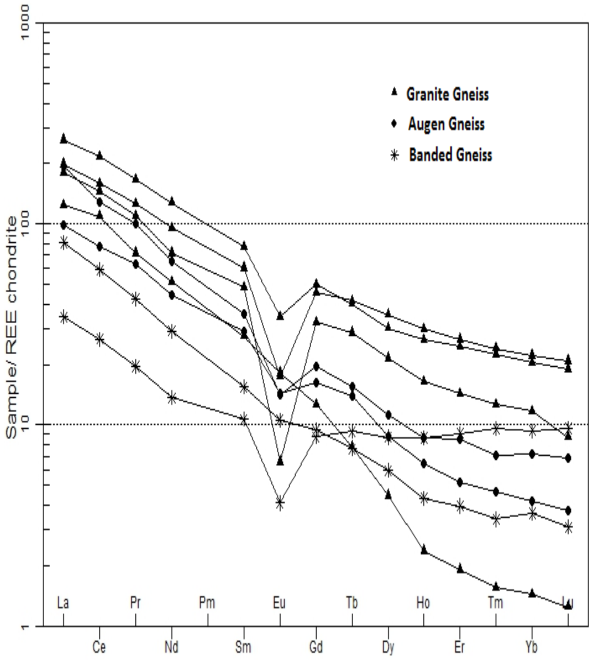

Figure 2: Chondrite normalised REE distribution patterns of gneisses in the Yari Bori and Tsiga area

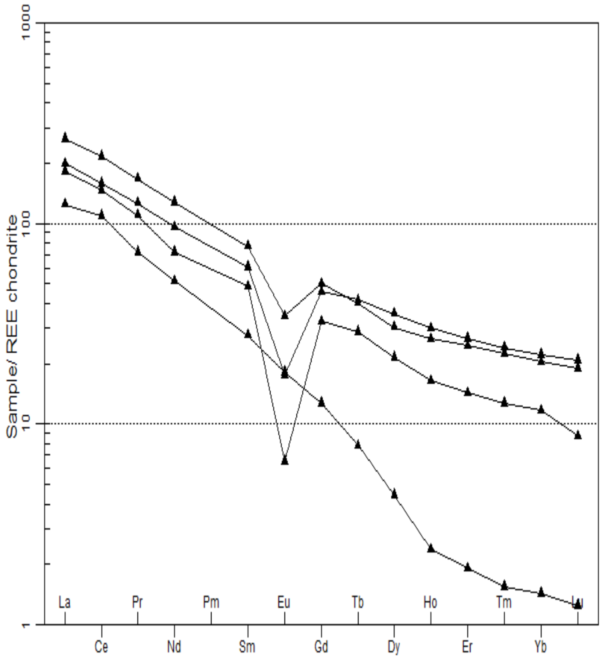

Figure 3: Distribution patterns of granite gneisses with negative Eu anomaly in all the samples except one.

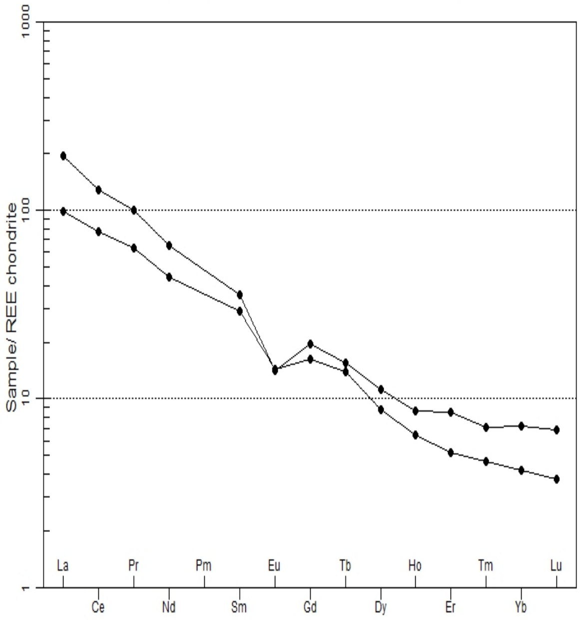

Figure 4: Distribution patterns of augen gneisses with negative Eu anomaly

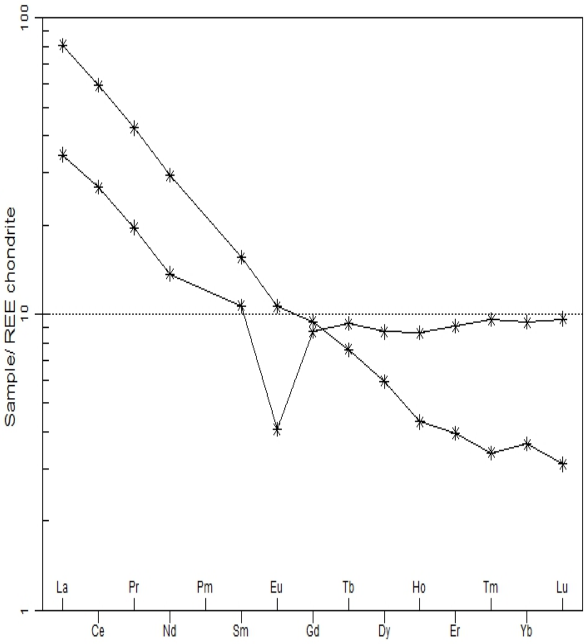

Figure 5: REE distribution patterns of banded gneisses

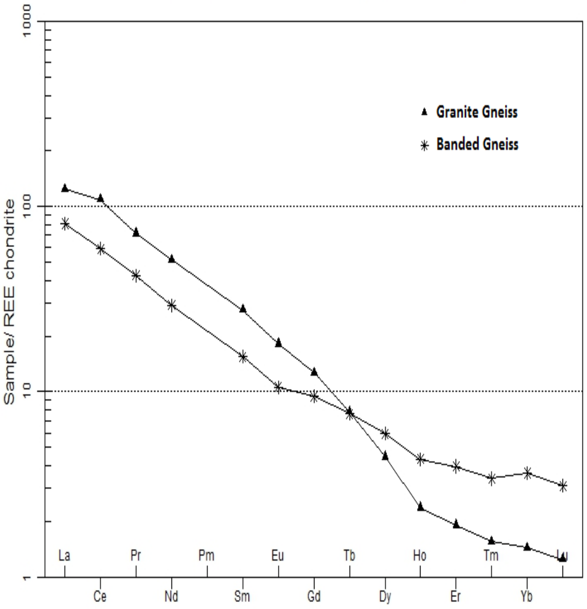

Figure 6: Granite gneiss and banded gneiss showing similar trend with no evidence of feldspar fractionated.

From table 1 it is also observe that, the REE abundance is not uniform in all the gneisses. While there is a preferential enrichment in light REE and heavy REE depletion in the gneisses, the two banded gneisses shows less light REE abundance relative to others but showed marked enrichment in heavy REE relative to the augen gneisses. The depletion of the heavy REE in most of these gneisses can be the result of their retention or concentration in garnet (an accessory component) and implies high degree of partial melting at a greater depth (>80 km). The presence of zircon in some of these gneisses as accessory phase may be responsible for heavy REE retention (Compton, 1978). The shape of the REE distribution patterns (figure 2) in this gneisses generally shows a smooth curves as evident by general decrease in concentrations from light REE to heavy REE. Although, there is a significant Eu anomaly in most of these gneisses, variability in the light of fractionation (there precursor) exist among them. In fact, there is little or no evidence of fractionation in two of the gneisses (sample 5 and 6); that is, neither positive nor negative Eu anomaly in them (figure 6). The precursor to these two unfractionated gneisses may be derived from multiple origins rather than differentiation from single parental magma. The negative Eu anomalies observed in most of these gneisses are suggestive of feldspar fractionation since feldspar are the only rock forming minerals, which are relatively enriched in Eu (Philpotts and Schnetzler, 1968). The degree of fractionation in these gneisses as expressed by $(La/Yb)_N$ in table 2 also varied; highest in granite gneiss (85.33) and lowest in banded gneiss (3.64). This variation in $(La/Yb)_N$ ratio is a suggestive of their alumina (Al_2O_3) and strontium (Sr) contents (Bor-Ming *et al.*, 1984), those with high degree of fractionation have higher Al_2O_3 and Sr contents (Table 1). Elatikpo *et al.*, (2013) earlier observed depletion in these gneisses of transition elements like vanadium (V) and chromium (Cr); a suggestive of their fractionation in spinel and imply moderate degree of partial melting at an intermediate depth (40-80 km). Again, lower concentration of Sr and low K/Rb ratios observed in two of the granite gneisses around Kafur (samples 4 and 8) were interpreted to have been derived from igneous precursor formed at relatively shallower depth (<40 km) by small degree of partial melting (Elatikpo *et al.*, 2013).

In the group fields' plots of chondrite normalized REEs patterns of these gneisses (Figure 7), it is evident that though the gneisses are from a common and related igneous source, they are not cogenetic due to the variability in light and the heavy REEs patterns.

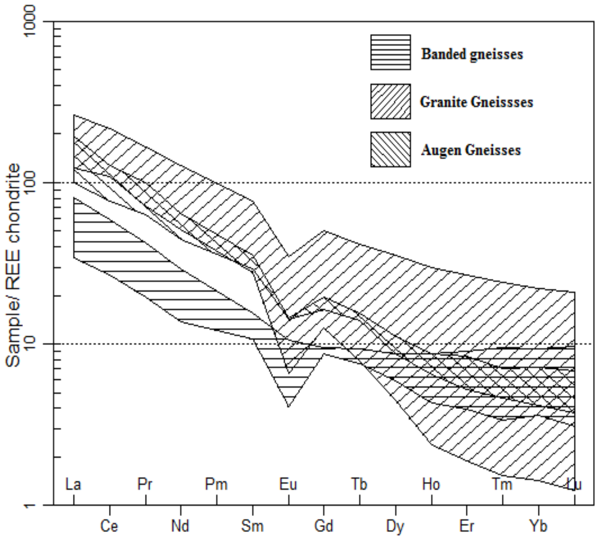

Figure 7: Group fields' plot of the chondrite normalized REEs patterns of the gneisses

Concluding Remarks

REE and their distribution patterns in the gneisses of Yari Bori and Tsiga area, of parts of the Malumfashi schist belt have been studied and analysed in this study. The gneisses shows high contents of total REE abundance and have been interpreted as to their concentrations in minerals like amphiboles, zircon and sphene (Olarewaju, 1981 and 1988) which forms major and minor minerals in these rocks. Abundance of REE in these rocks is an indication of partial melting of the lower crustal materials (Compton, 1978; Olarewaju, 1988). The depletion of Sr in two of the granite gneisses, depletion of V and Cr and heavy REE in most of the gneisses indicate partial melting at differing depths as genesis of the precursors of these gneisses. The enrichment of these gneisses in LREE is an indication of felsic rocks origin (Asiedu *et al.*, 2004). In view of all the aforementioned, a magmatic or igneous origin involving partial melting of lower crust is hereby considered the likely petrogenesis of the precursor to these gneisses.

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