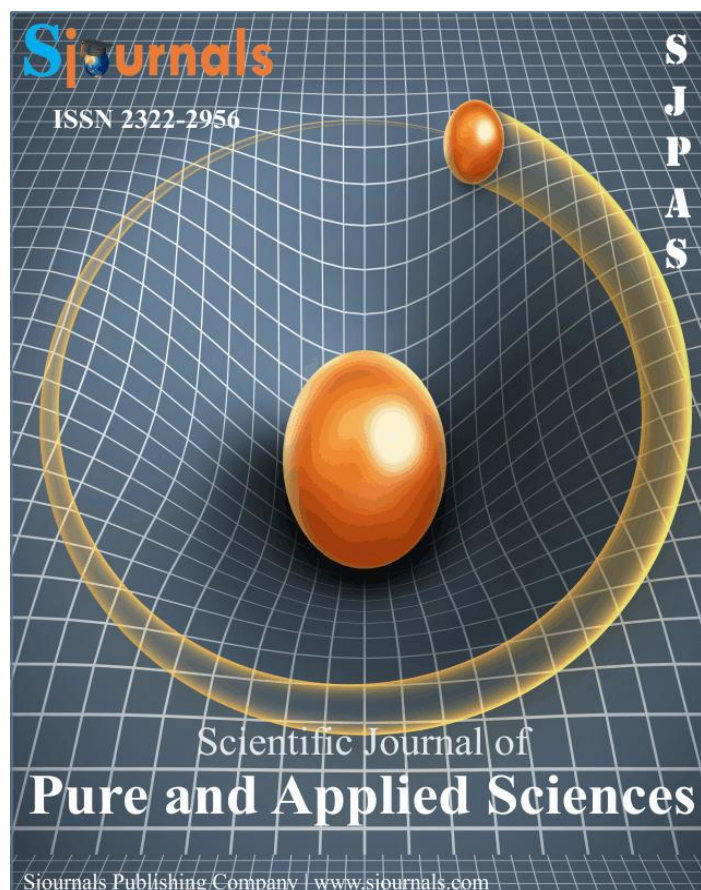


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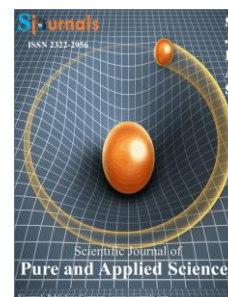
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### Case study

## Natural resources in the environment (A case study of basaltic rocks in Ameta, southern Benue Trough, Nigeria)

I.I. Dilioha, Josephine Nchekwube Onwualu-John\*

Department of Geology, University of Port Harcourt, Nigeria.

\*Corresponding author; Department of Geology, University of Port Harcourt, Nigeria.

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### ABSTRACT

Rare earth element (REE) Geochemistry of the basaltic rocks in Ameta were studied in order to determine the fractionation pattern of the magma that form the rocks and as well to determine the economic potential of the REE in the rocks. The field occurrence of the basaltic rock shows evidence of decrease in the thermal effects of the magma. Presence of phenocrysts of mafic minerals (biotite and olivine) in the rocks indicate slow rate of cooling of the magma that gave rise to the rocks. Field occurrence depicts that crystallization of the magma closed the vent through which the magma erupted thereby making the rocks to appear as plutons. The rare earth element geochemistry of the rocks shows the fractionating pattern of the magma. The REE is characterized by a sloping pattern which indicates the trend of the fractionation. There are enrichment of most of the light rare earth elements (LREE) and depletion of the heavy rare earth element (HREE). There are slight positive Eu anomalies in the rocks which defines the level of plagioclase fractionation. The concentration of REE in the rocks have shown the economic potentials of the rocks. REE is a useful natural resource for 21st century technology.

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## 1. Introduction

The Benue Trough is an aulacogen that occurred during the separation of South America from Africa in the Cretaceous time. The separation is associated with tectonism, accompanied by magmatism and this magmatism brought up lots of mineral resources (Rare Earth minerals) in the environment. Rare earth minerals are those minerals that consist of rare earth elements as major components. Rare earth elements can be regarded as oil boom of the twenty first century. Rare earth elements are seventeen metals, fifteen elements out of the metals occur in the lanthanide series while the two elements (Scandium (Sc) and Yttrium (Y)) are considered as non lanthanides rare earth elements and they share similar chemical properties with the lanthanides. The rare earth elements can be classified into light rare earth elements (LREE: Lanthanum, cerium, praseodymium, neodymium, and attimes samarium), the heavy rare earth elements (HREE: europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium), some studies include middle rare earth element (MREE: from Sa-Dy, samarium europium, gadolinium, terbium, dysprosium). In the Southern Benue trough, the magmatism resulted to emplacement of some igneous rocks that host fourteen of these rare earth elements. Rare earth elements are crucial tools in modern technology. This study is to determine the REE in the basaltic rocks of the study area (Fig 1) and as well to determine the economic potentials of the REE.

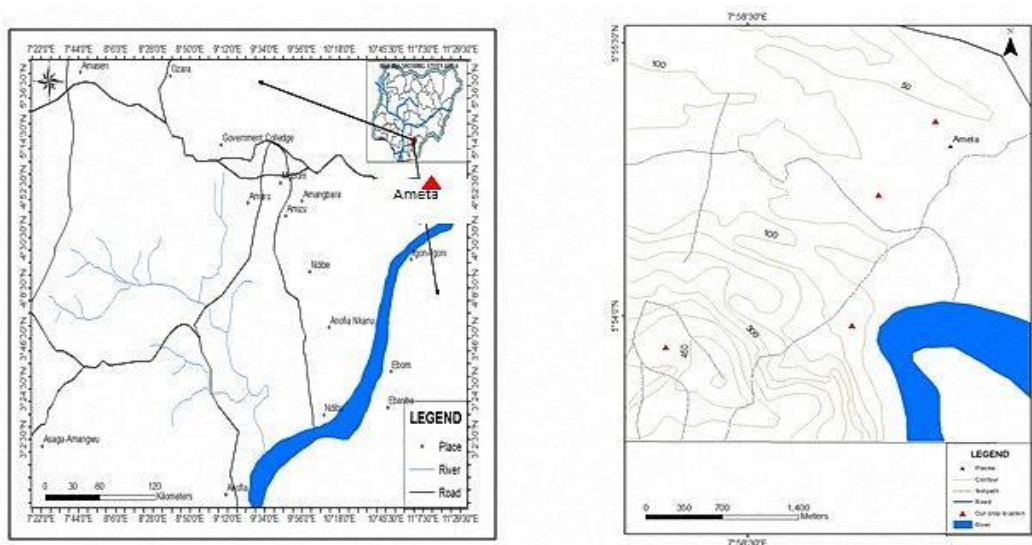


Fig. 1. Maps of the study.

## 2. Geologic setting

Southern Benue Trough is a segment of the failed arm of the triple rift that was formed in the Cretaceous when South America separated from Africa (Fairhead and Okereke, 1987). The southern Benue Trough is characterized by sediments of over 5000m in some places; these sediments were formed by series of marine transgressions and regressions. The sediments were deformed by Santonian tectonism and the deformation resulted to multiple fractures and folds on the sediments which are parallel to the fold axis (Ofoegbu, 1985; Nwachukwu, 1972), Santonian deformation produced the Abakaliki anticlinorium which has two basins/synclines units on its flanks (Anambra basin on the western flank and Afikpo basin on the eastern flank) (Kogbe, 1974). The sediment deposition and emplacement of the igneous rocks is structurally controlled by the Abakaliki Anticlinorium (Onwualu-John and Ukaegbu, 2009).

The field relation consists a sedimentary sequence of Asu River Group and Eze-aku Formation. The magmatic rock (gabbro) intruded the Asu River Group. The gabbro form a topographic high in the sedimentary sequence. Afikpo Basin is made up of Albian, Turonian - Coniacian and Campanian – Maastrichtian sediments and spans well over 2500km<sup>2</sup> (Odigi and Amajor, 2009).

### 3. Sampling techniques

Twelve fresh rock samples of gabbro were collected along the river channel in Ameta. Thin sections of the rocks were prepared using the thin section machine. The rocks were cut into slides and polished to acceptable thickness that will allow light to pass through. The descriptions and interpretations of the slides involved the use of petrological microscope. The rock samples were pulverised and sent to Activation laboratory Ontario for geochemical analysis. The geochemical analysis involved employed the use of ICP-MS diffusion method as described by Jarvis and Jarvis (1992) and Thompson and Walsh (1983). Interpretations of the REE employed the use of elemental abundances in the rocks.

### 4. Petrology and petrography

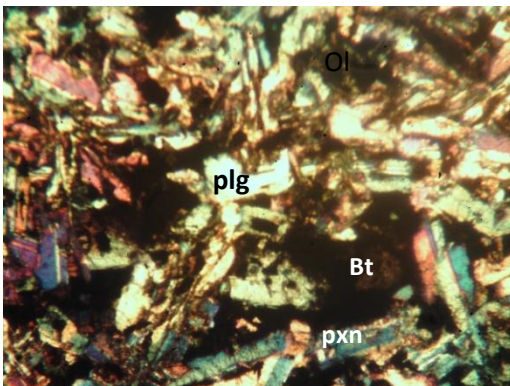
The basaltic rocks in Ameta are gabbroic in features; they are fresh and have phaneritic textures. The rocks are melanocratic in colour. There are phenocryst of biotites and olivine in the rocks. The rocks intruded the Asu River Group and crystallized at intrusive level. They are in situ crystallization with a lateral high relief (Plate 1) and few pluton shaped gabbroic rock in the study are (Plate 2). There are quartz veins which have healed the fracture in the rocks (Plate 1). Thin sections of the samples were described. The rocks contain mostly femic minerals and few felsic mineral. The average mineral compositions of the rocks as observed under cross polarized microscope are olivine (20%), pyroxene (10%), biotite (10%), iron oxide (5%) and plagioclase (55%), quartz occur as accessory mineral, (Plates 3 and 4). In thin section olivine exhibit euhedral form with pale green colour. The pyroxene is bluish with dark pleochroic colour. Biotite exhibit dark brown colour and subhedral crystal form. Plagioclase is dominant in the rock slides, the plagioclase are whitish in colour, strait shaped and exhibit black pleochroic colour.



**Plate 1.** Gabbroic outcrop in Ameta.



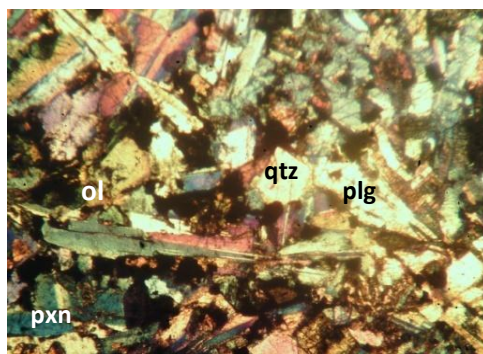
**Plate 2a.** The cross section of gabbroic outcrop having the shape of a pluton.



**Plate 3.** Mineral compositions in the gabbroic rocks; plg=plagioclase, Bt=biotite, Ol=olivine, Pxn=pyroxene.



**Plate 2b.** The gabbroic outcrop having the shape of a pluton.



**Plate 4.** Mineral compositions in the gabbroic rocks; plg=plagioclase, Bt=biotite, Ol=olivine, pxn=pyroxene, qtz=Quartz.

**Table 1**  
REE composition of the Gabbro in Ameta.

REE elements	Gabbro 1	Gabbro 2	Gabbro 3	Gabbro 5	Gabbro 6	Gabbro 7	Gabbro 8	Gabbro 9	Gabbro 10	Gabbro 11	Gabbro 12	Gabbro 13	av
La	10.9	8.3	9.1	8.8	9.1	8.4	8.7	8.3	38	25.2	14	13.7	13.54167
Ce	22.2	17.1	19.1	18.1	18.4	17.8	18.3	17.7	72.3	44.3	20.9	20.6	25.56667
Pr	3.06	2.46	2.7	2.55	2.69	2.55	2.6	2.57	8.54	5.17	2.18	2.24	3.275833
Nd	14.4	11.2	12.9	12.1	12.7	12.3	12.6	12.4	31.5	19.7	8	8.1	13.99167
Sm	4.2	3.5	4.2	3.8	4	3.9	3.9	3.9	6.1	3.5	1.5	1.5	3.666667
Eu	1.29	1.29	1.44	1.4	1.46	1.44	1.36	1.39	1.37	0.96	0.16	6.62	1.681667
Gd	4.5	4.2	4.5	4.4	4.5	4.4	4.3	4.4	4.5	2.9	1.3	1.2	3.758333
Tb	0.8	0.7	0.8	0.7	0.8	0.8	0.8	0.7	0.7	0.4	0.2	0.2	0.633333
Dy	4.6	4	4.4	4.2	4.5	4.4	4.4	4.4	3.8	2.4	1.2	1.3	3.854545
Ho	0.9	0.8	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.5	0.2	0.3	0.7
Er	2.4	2.1	2.2	2.1	2.3	2.2	2.2	2.2	2.3	1.3	0.7	0.8	1.9
Tm	0.36	0.29	0.32	0.3	0.32	0.31	0.32	0.32	0.37	0.2	0.11	0.12	0.278333
Yb	2.2	1.8	1.9	1.8	1.9	1.9	2	2	2.4	1.3	0.8	0.8	1.733333
Lu	0.3	0.25	0.26	0.25	0.28	0.27	0.28	0.29	0.36	0.19	0.12	0.13	0.248333
ΣLREE	43.86	34.26	38.9	36.55	37.79	36.55	37.4	36.57	118.44	72.67	32.58	32.44	46.50083
ΣHREE	17.35	15.43	16.72	15.95	16.86	16.52	16.46	16.5	16.6	10.15	4.79	10.17	14.45833

### 5. Rare earth element geochemistry

The rare earth element data of the gabbroic rocks are presented in Table 1, while the REE pattern is illustrated in Fig 2, The abundance of REE in the rocks are controlled by the evolutionary pattern of magma. The rocks are characterized by three basic pattern of the REE. There is sloping pattern in the REE which shows the level of fractionation of the magma. There are enrichment of light REE, and depletion of heavy REE in the rocks with slight negative Eu anomaly indicates the role of plagioclase probably the fractionation of plagioclase out of the magmatic melt was significant.

### 6. Petrogenesis and geotectonics

Partial melting of mantle and fractional crystallization results to REE enriched magma. Langmuir et al. (1977) suggested that the total abundances of incompatible REE in magma from a given source depend on the type of melting, and that each increment of melt inherits very different REEs during fractional melting. REE are incompatible elements and they are not fully absorbed in the rock forming silicates. They concentrate most in residual melts; this implies that they remain in the melt during fractional crystallization. Rare earth element minerals occur in low temperatures and late crystallization (Long et al., 2010).

The increase in LREEs enrichment in the rocks of the study area could be as a result of an inherent LREE in the continental crust. This phenomenon depicts the differentiation pattern of the magma that gave rise to the rocks. Castor and Hedrick (2006) mentioned the high concentrations of LREE in the continental crust. HREE depletion in the rocks could be due to the fact that HREE easily fit into the crystal lattice of the rock forming silicate, thereby being depleted in the crystallizing melt. REEs are coherent group in chemical characteristics. Trend of REE is in such a way that depletion of HREE activates enrichment of LREE. LREE always enriched relative to the HREE. In most cases presence of garnet in the magma leads to depletion of the HREE. The slight positive Eu anomaly in the rocks reflects the crystallization and abundance of plagioclase in the primary magma. REE are associated with late crystallization of magma.

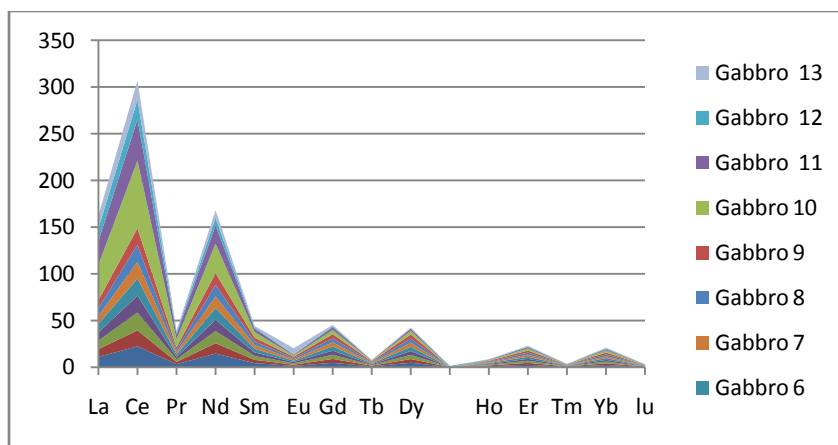


Fig. 2. Rare earth element pattern of the gabbros in Ameta.

### 7. Economic potentials of the REE

Rare earth elements have been extracted during mining operations in China, Canada, and Australia, at the end of the mining processes; the ores are processed to extract the REEs which are furnished into various uses. Rare earth elements can be used to monitor the effects of earthquakes and explosions on the ground, used in medicine and metrology, help to create lasers, used to create hard computer disks, assisting in treatment and diagnosis of cancer, it can kill cancer cells and is used for treatment of lung, prostate, breast and some forms of bone cancer, it is used in watches, used for sewage treatment and petroleum refining, used as a catalyst in catalytic converters of automotive exhaust systems in order to reduce emissions. Rare earth elements have been found useful in producing micro phones, head light glass of a car, catalyst for self cleaning oven, battery electrode, sparks plugs, energy efficient fluorescent bulbs, micro wave filters, ceramics, polishing powder, camera lenses, aerospace components, additives in metal –halide lamps, mercury vapour lamps, as well as radioactive tracing agents in oil refinery.

### 8. Conclusion

The cohesive nature of the REEs made it more technical to separate the rare earth elements into their individual entities. The processes of REEs separation involved the use of physical and chemical methods. The physical methods involves mining/quarrying of the ores, separation of the ores from the gangue, pulverisation of the rocks and froth floatations. The slight differences in the chemical behaviour of the REE are utilized in chemical separation which involved the ionic exchange, fractional precipitation, solvent extractions.

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