

# The Economic Potentials of the Rare Earth Elements in the Basaltic Rocks of Ameta, Southern Benue trough Nigeria

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## Abstract

Rare earth element (REE) geochemistry of the basaltic rocks (gabbro) 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 negative 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 useful natural resource for 21st century technology.

**Keywords:** Light rare earth elements; Heavy rare earth elements; Magmatism

## 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 environmental. 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 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 concentrations in the basaltic rocks of the study area (Figure 1). The knowledge of the REE in the rocks is crucial in determining the economic potentials of these REEs and the rocks.

## 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 [1]. The southern Benue Trough is characterized by sediments of over 5000 m 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 [2,3]. 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) [4]. The sediment deposition and emplacement of the igneous rocks is structurally controlled by the Abakaliki Anticlinorium [5,6].

The field relation consist 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 2500 km<sup>2</sup> [7].

## Methodology

### Sampling techniques

The field mapping involved studying the geomorphology of the rocks and taking recognisance of the contact relationship of the igneous rocks with the host rocks. Twelve fresh rock samples of gabbro were collected along the river channel in Ameta.

### Laboratory procedures

Thin sections of the rocks were prepared using thin section/cutting machine. The rocks were cut into slides and polished on a glass plate which contains mixture of carborundum and little water. The polishing was to reduce the thickness of the rock slides to 0.03 mm in order to allow light to pass through it during the optical interpretations of the component minerals in the rock thin sections. The polished rock and slides were placed on the hot plate for twenty minutes to dehydrate the water contents. Canada balsam were applied on another slide which then served as cover slip over the thin sectioned slides. 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 employed the use of ICP-MS diffusion method as described [8-10]. Interpretations of the REE employed the use of elemental abundances in the rocks.

## 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.

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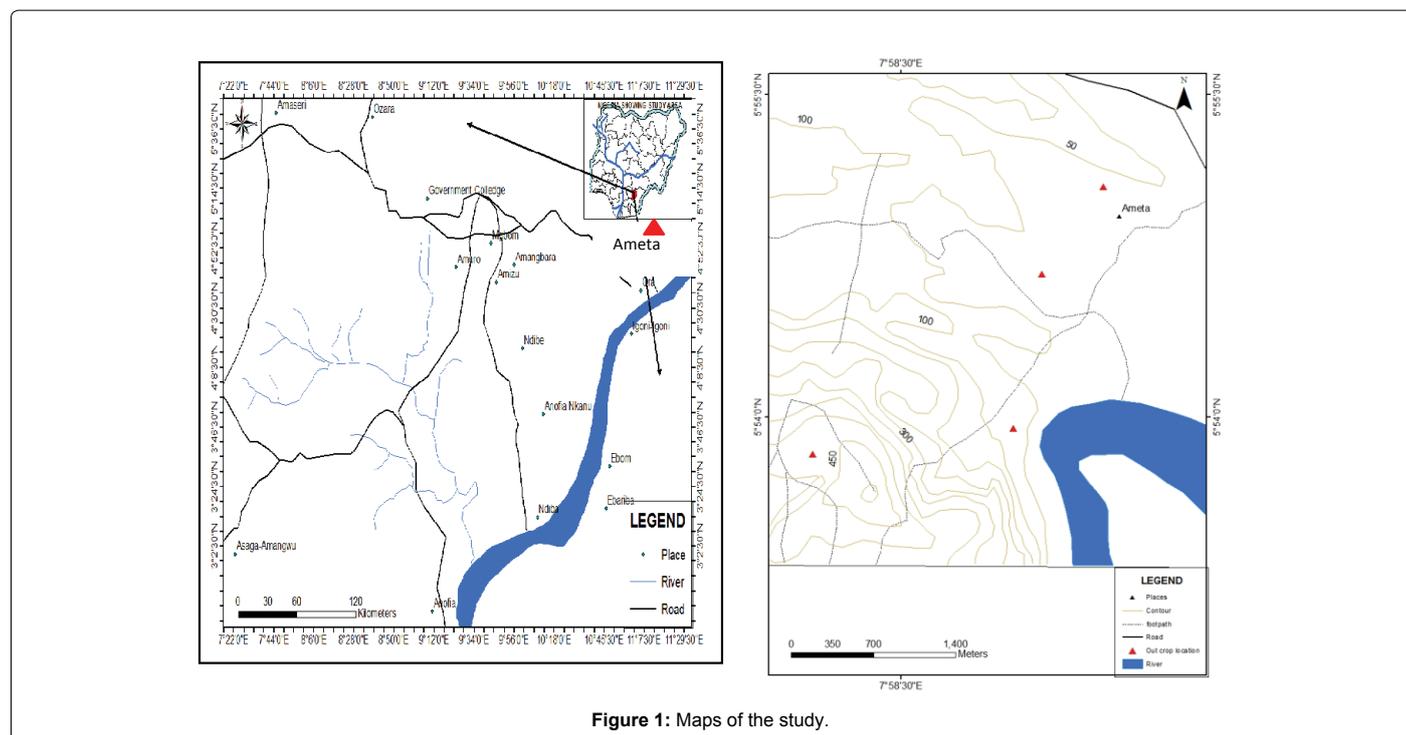


Figure 1: Maps of the study.

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 (Plate 2) occurred in the study area. 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.

### 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 Figure 2. The REE abundance 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 (Europium) anomaly. Plagioclase fractionation controls the anomalous nature of the Eu, probably the fractionation of plagioclase out of the magmatic melt was significant.

### Petrogenesis and Geotectonics

Partial melting of mantle and fractional crystallization results to REE enriched magma. Langmuir et al. [11] 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 [12].

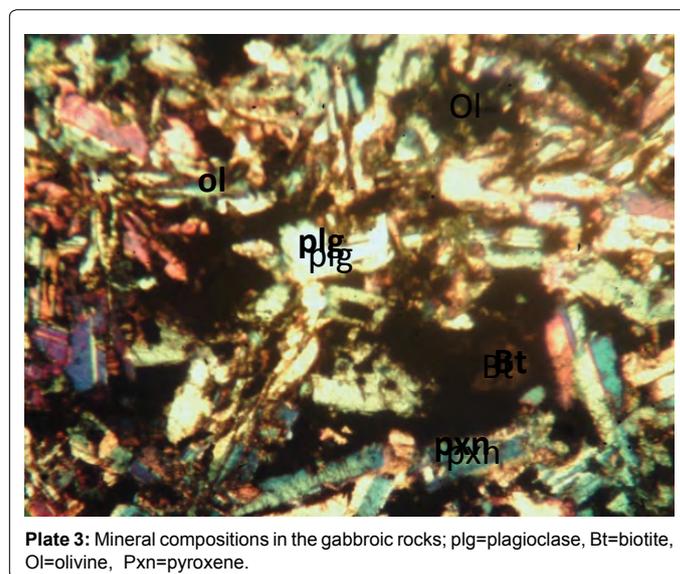
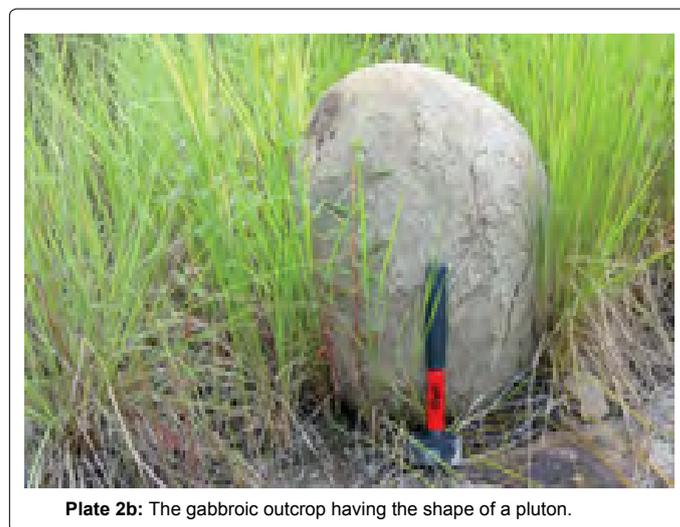
The increase in LREEs enrichment in the rocks of the study area could be as a result of an inherent LREE in the continental crust. This phenomenon depicts the differentiation pattern of the magma that gave rise to the rocks. Castor and Hedrick [13] mentioned the high concentrations of LREE in the continental 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 negative Eu anomaly in the rocks reflects the fractionation of plagioclase from the primary magma. REE abundances in rocks are associated with late crystallization of magma.

### REEs Separation

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. 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 flotation. The slight differences in the chemical behaviour of the REE are utilized in chemical separation which involved the ionic exchange, fractional precipitation, solvent extractions.

| 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       | 0.633333 |
| 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 |

Table 1: REE composition of the gabbro in Ameta.



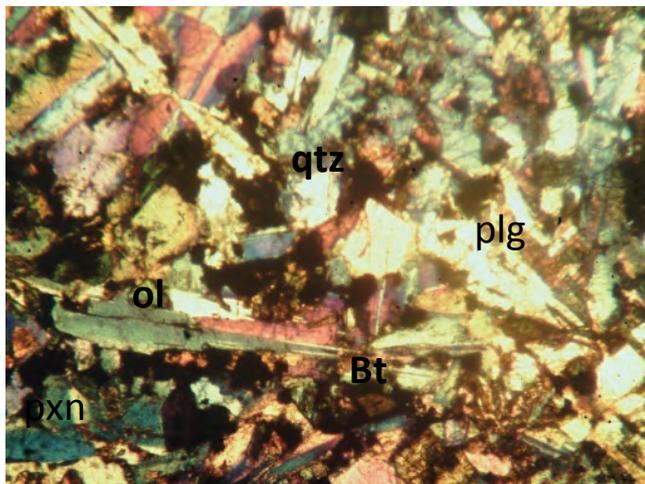


Plate 4: Mineral compositions in the gabbroic rocks; plg=plagioclase, Bt=biotite, Ol=olivine, pxn=pyroxene, qtz=Quartz.

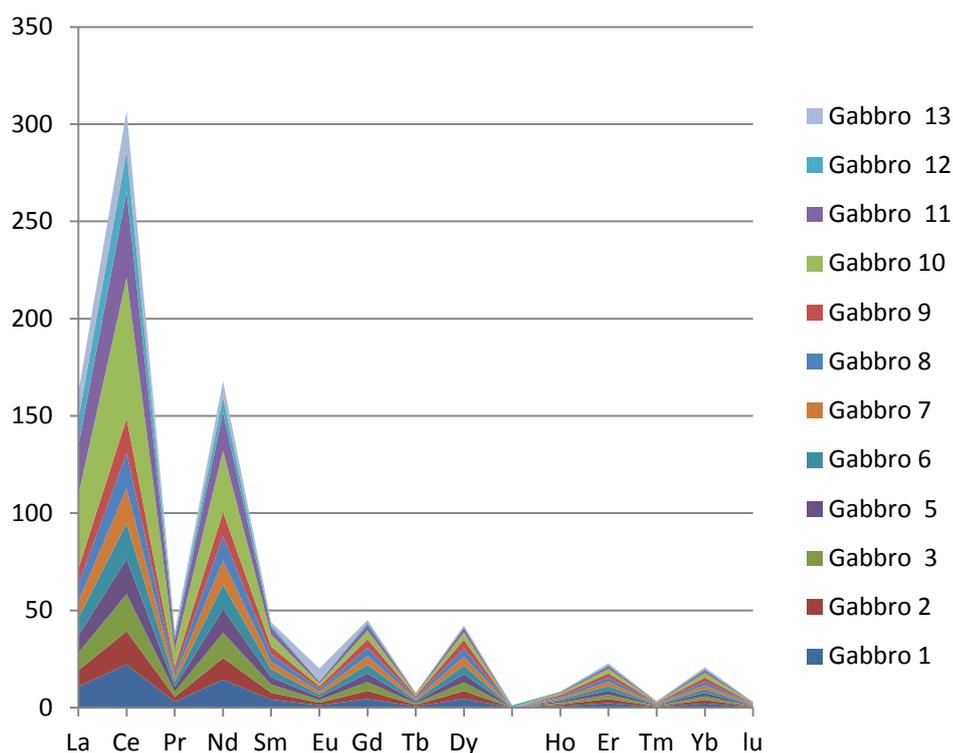


Figure 2: Rare earth element pattern of the gabbros in Ameta.

### Economic Potentials of the REE

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. REE can be used to design materials that 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. REE is 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.

### Conclusion

The economic potentials of REEs are highly tremendous and vast,

the abundances of these REEs in the magmatic rocks of Ameta has shown that evolution of magma played major roles on the occurrences of these elements. REEs which are also classified as incompatible elements are abundant in residual/fractionating melt rather than magma at its primary state. The contact relationship of the magmatic rocks (gabbros) with the host sedimentary has no significant input in the concentrations of the REEs in the gabbros of Ameta.

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