Journal of Geology & Geophysics
ISSN: 2381-8719
Ayodele, J Geol Geophys 2015, 4:4
DOI: 10.4172/2381-8719.1000212
Research Article
Open Access

# The Geology, Geochemistry and Petrogenetic Studies of the Precambrian Basement Rocks around Iworoko, Are and Afao Area, Southwestern Nigeria

**Olusiji Samuel Ayodele***

*Department of Geology, Ekiti State University, P.M.B. 5363, Ado-Ekiti, Nigeria*

## Abstract

The geology, geochemistry and petrogenetic studies of the Precambrian basement rocks around Iworoko, Are and Afao Ekiti were carried out to determine their geochemical and petrogenetic characteristics. Three lithologies including migmatite-gneiss, granite gneiss and banded gneiss with a pegmatite dyke that occurred as an intrusion were recognized in the study area. A total of seventeen rock samples were collected from the study area which were described based on their field relationships. Ten fresh rock samples were later selected for geochemical analysis. The result of the geochemical analysis revealed that silica ($SiO_2$) is the most abundant major oxide when compared with other oxides present in all the rock samples analyzed with an average percentage composition of 66.31%. The average percentage composition of other oxides present in all the rock samples are as follows; (16.41%) $Al_2O_3$, (3.67%) $Fe_2O_3$, (0.25%) CaO, (4.28%) $K_2O$, (3.53%) $Na_2O$, (1.75%) MgO, (0.78%) $P_2O_5$, (0.54%) $TiO_2$ and (0.061%) MnO. The results of the trace and rare earth elements analyses revealed that Barium (Ba) is the most abundant with an average value of 328.7 ppm compared to other trace and rare earth elements present in the rock samples. The high concentration of barium in the migmatite-gneisses of the study area revealed the radioactive nature of this lithology. Petrological and chemical data suggests a sedimentary protolith, probably greywacke for the migmatite gneiss, gneiss and banded gneiss in the study area which may have been derived from a continental environment.

## Introduction

Nigeria lies to the rest of the West Africa craton in the region of late Precambrian to Early Paleozoic orogenesis. The basement complex is made up of Precambrian rocks and the schist belts infolded in them. The Precambrian rocks of southwestern Nigeria is part of the Precambrian Basement complex of Nigeria, the Basement complex itself is made up of Gneiss-migmatite complex and the Pan African older Granite rocks. However, the lithologies in the study area include; migmatite-gneiss, granite-gneiss and banded gneiss. These rocks have undergone polycyclic deformation thereby causing the deformation of both the macro and micro structures. Secondary structures in rocks that can be used as clues to determine the geologic history of an area include; joints, folds, fractures and foliations etc. Some of these structures are not deformational but were formed at the same time the rocks were emplaced. A lot of literatures abound on the study of basement geology of Nigeria and its associated structures which include Geochemical dispersion of gold in stream sediments in Paleoproterozoic Nyong series, southern Cameroon undertaken by Mubfu and Nforba [1] in an attempt to explore for gold using stream sediments collected in the Ngo Vayang area of southern Cameroon, and revealed that the Au-Hf element association from the R-mode factor analysis indicated gold mineralization while U-Th-Pb-W, Nb-Ta-Co-V, Au-Hf-Cu associations reflected lithologic controls. Akintola et al., [2] carried out the petrography and stream sediment geochemistry of Ede and its environs in order to identify the rock units with their mineralogical appraisal and to determine the concentration and distribution of major and trace elements in the stream sediments with a view to elucidate the mineral potentials of the study area. Emmanuel et al., [3] also carried out geochemical investigation of the southern part of Ilesha with the aim of clarifying the potential source of mineralization in the area. Geologic mapping of the area revealed that the area is made up of different lithologies such as undifferenciated schists, gneisses and migmatites with pegmatites, schists and epidiorite complex, quartzite and quartz schist. Sixty-one soil samples were collected and analyzed for elements such as Pb, Fe, Ni, Cd, Cr, Cu, Zn and Mn, using multivariate analysis to obtain the coefficient of principal components. The elemental association ratio revealed high metallic concentrations which led to the mineralization trend in southern Ilesa. According to Okunlola and Akinola, the Precambrian pegmatites of Ijero area occur as steeply dipping intrusives into the other rocks of migmatite-gneiss complex and the schistose rocks. Thin section studies revealed that the pegmatite samples contain mainly quartz (37%), plagioclase (12%), and microcline (7%) with accessories such as biotite, hornblende and tourmaline. Geochemical analysis of muscovite extracts from the pegmatite using ICP-MS analytical method showed that the pegmatites is siliceous with average $SiO_2$ content of 71.79%. Trace element analysis using variation plots of Ta/ (Ta+Nb) versus Mn/ (Mn+Fe) revealed that the muscovite-quartz-microcline pegmatites of Ijero area is of rare element class, lepidolite subtype. Odeyem et al., [4] suggested that almost all the foliation exhibited by the rocks of southwestern Nigeria excluding the intrusive are tectonic in origin because pre-existing primary structures have been obliterated by subsequent deformation while Anifowose et al., [5] noted that joints ranging from minor to major ones are found in all the rock types, some of which are filled with quartz, feldspars or a combination of both. They lie generally in the NE-SW direction.

The study area lies in Irepodun/Ifelodun area, north east of Ekiti State, and falls within latitudes $07^0$ $41^1$ N - $07^0$ $43^1$ N and longitudes $05^0$ $15^1$ E – $05^0$ $18^1$ E respectively (Figure 1). These include Iworoko, Are and Afao-Ekiti, with an area coverage of about 242.6 km$^2$. The study area is generally accessible and motorable with availability of tarred and untarred roads which linked the towns and villages together in the area. Most of the outcrops are located in the thick forests in which the use of cutlass was essential in creating footpaths. The major towns around the study area include Ilokun, Ilupeju etc while the localities within Iworoko, Are and Afao-Ekiti were named after the features or events which occurred within each town amongst these include Ori oke Adura, Oke ode, oke iyanu etc. The settlement pattern in the study area is the nucleated type and the major occupation of the inhabitants are farming and trading.

***Corresponding author:** Olusiji Samuel Ayodele, Departmennt of Geology, Ekiti State University, P.M.B. 5363, Ado- Ekiti, Nigeria, E-mail: samuelayodeleolusiji@yhoo.com

**Received** September 29, 2015; **Accepted** July 13, 2015; **Published** July 18, 2015

**Citation:** Ayodele OS (2015) The Geology, Geochemistry and Petrogenetic Studies of the Precambrian Basement Rocks around Iworoko, Are and Afao Area, Southwestern Nigeria. J Geol Geophys 4: 212. doi:10.4172/2381-8719.1000212

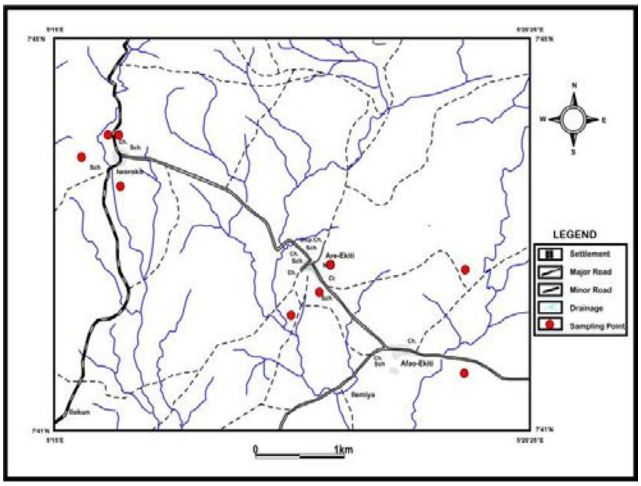


**Figure 1:** Location map of the study area showing rock sampling points.

## Geologic Setting of the Study Area

The study area is underlain by the Precambrian Basement Complex of Southwestern Nigeria, which is also part of the Basement Complex rocks of Nigeria. The basement complex is one of the three major litho-petrological components that make up the geology of Nigeria. The Nigerian basement complex forms a part of the Pan – African mobile belt and lies between the West African and Congo cratons and south of the Tuareg shield [6]. It is intruded by the Mesozoic Calc-alkaline ring complexes (Younger granites) of the Jos plateau and is unconformably overlain by Cretaceous and younger sediments. The Nigerian basement complex was affected by the 600 Ma Pan African orogeny and it occupies the reactivated region which resulted from plate collision between the passive continental margin of the West African craton and the active Pharusian continental margin [7]. The Basement rocks are believed to be the results of at least four major orogenic cycles of deformation, metamorphism and remobilization corresponding to the Liberian (2,700 Ma), the Eburrnean (2500 Ma), the kibaran (1,100 Ma), and the Pan-African cycles (600 Ma). The first three cycles were characterized by intense deformation and isoclinals folding accompanied by regional metamorphism, which was further followed by extensive migmatization. The Pan-African deformation was accompanied by a regional meta-induced syntectonic granites and homogenous gneisses. Late tectonic emplacement of granites and granodiorites and associated contact metamorphism accompanied the end stages of this last deformation. The end of the orogeny was marked by faulting and fracturing [8]. Anifowose [9] was of the opinion that the granitic emplacement was probably controlled by fractures within the basement, and also showed outcrop pattern indicating that the older granite cut across all other structures with sharp and chilled contact. Within the basement complex of Nigeria, four major petro-lithological units are distinguishable namely [7];

- The Migmatite – Gneiss-Quartzite Complex
- The schist belts
- The Pan African granitoids
- Under formed acid and basis dykes.

## Local geology of the study area

The study area is dominated by granite-gneiss, banded-gneiss and migmatite-gneiss respectively. These rocks are mostly metamorphic and belong to the Precambrian basement rocks of southwestern Nigeria, which itself is part of the basement rocks of Nigeria (Figure 2). The various lithologic units in the area are discussed below, while their field description and relationships are presented in Table 1.

### Migmatite-Gneiss-Quartzite complex

The migmatite-gneiss-quartzite complex occurs as ridges and highlands at Iworoko and Afao-Ekiti, but as valleys at Are Ekiti. Most of these rocks have been subjected to mechanical and chemical weathering. The migmatite-gneiss-quartzitecomplex is presumably the oldest group of rocks in the study area and the most widespread. Its occurrence is not restricted as it is found in the entire area of study. The texture of the migmatite-gneiss-quartzite complex in the study area varies from fine grained to medium grained while the structures observed on the outcrop include folds, joints, cracks and veins. The dominant mineral assemblages of this rock include quartz, mica, plagioclase, and hornblende. The field relationships between the migmatite-gneiss-quartzite complex rocks and other surrounding rocks could not be easily ascertained as a result of thick vegetation.

### Granite-gneiss

The granite-gneiss in the study area occurs as a hilly outcrop especially around Afao and Iworoko Ekiti. The texture of these rocks varies from fine to medium grained. The dominant mineral assemblages found in the granite-gneiss include quartz, feldspar, and mica, and the structures found on the outcrop are microfolds, veinlets and quartz veins. The surface of the outcrop has been subjected to exfoliation as a result of physical weathering. The granite-gneiss has a clear and sharp contact with the surrounding migmatite-gneiss-quartzite complex.

### Banded gneiss

The banded gneiss extends across some parts of the study area particularly Iworoko and Afao. In these areas, the rocks are medium to coarse grained texturally and occur as a hill in the study area. Also, the rock is characterized by banding in which there is mineral alignment. The banding varies from about 1 centimeter to 3 centimeters in the banded varieties found in Are and Afao Ekiti. The rock is typified by clear fine banding which shows alternating white and black (hornblende,

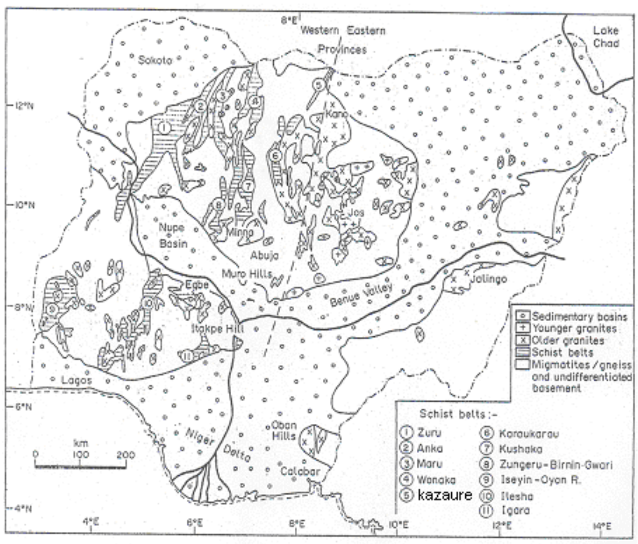


**Figure 2:** Generalized Geological Map of the Crystalline Rocks of Nigeria (After Rahaman [11]).

| S/N | Location | Longitude | Latitude | Lithology | Texture | Structure | Dip Angles |
|---|---|---|---|---|---|---|---|
| 1 | Ori-Oke Adura Iworoko | $07^0$ 43 494´ | $05^0$ 15 756´ | Granite Gneiss | Medium to fine grained | Cracks, Joints, Dykes, e.t.c. | |
| 2 | Behind Iworoko mosque | $07^0$ 44 018´ | $05^0$ 15 738´ | Granite Gneiss | Fine to medium grained | Veins, Veinlets, Folds e.t.c. | |
| 3 | Behind Iworoko Grammer School | $07^0$ 43 794´ | $05^0$ 15 315´ | Migmatite Gneiss | Medium to fine grained | Quartz Vein, Cracks, Folds, Dykes, Exfoliation | |
| 4 | Eniafe road | $07^0$ 44 020´ | $05^0$ 15 615´ | Granite Gneiss | Medium to coarse grain | Folds, veinlets, quartz veins | |
| 5 | Off Iworoko Are road | $07^0$ 44 058´ | $05^0$ 15 425´ | Granite Gneiss | Fine to medium grained | veins, dykes. | |
| 6 | Aba Sunday Are | $07^0$ 43 375´ | $05^0$ 17 114´ | Migmatite gneiss | Medium to coarse grained | Exfoliation, veinlet, fold, veins | |
| 7 | Behind OBA's Palace Are | $07^0$ 43 691´ | $05^0$ 18 147´ | Banded gneiss | Medium to coarse grained | Solution hole, banding, lineation, exfoliation | $42^0$ |
| 8 | Oke Ode Are | $07^0$ 42 174´ | $05^0$ 17 698´ | Migmatite gneiss | Medium to coarse grained | Exfoliation, lineation, solution hole | $42^0$ |
| 9 | Oke Isoro | $07^0$ 42 158´ | $05^0$ 17 410´ | Migmatite gneiss | Medium to coarse grained | Fold, Dyke, Veins, Xenolith | |
| 10 | Off Isara road | $07^0$ 42 410´ | $05^0$ 18 020´ | Migmatite Gneiss | Fine to medium grained | Fold, Dyke, Veinlets, | |
| 11 | Isara Are | $07^0$ 42 310´ | $05^0$ 17 512´ | Migmatite Gneiss | Fine to medium grained | Solution hole, fold, veinlets | |
| 12 | Afao round about | $07^0$ 41 647´ | $05^0$ 19 593´ | Granite Gneiss | Medium to coarse grained | folds, dyke, vein, solution hole | |
| 13 | Behind Oke iyanu Afao | $07^0$ 41 578´ | $05^0$ 19 669´ | Granite Gneiss | Medium to coarse grained | Folds, vein, cracks, solution hole | |
| 14 | Oke Iyanu Afao | $07^0$ 41 249´ | $05^0$ 19 405´ | Granite Gneiss | Coarse to fine grained | Folds, fracture, solution hole | |
| 15 | Igbemo road, Afao | $07^0$ 43 158´ | $05^0$ 20 684´ | Granite Gneiss | Coarse to fine grained | Vein, solution hole. | |
| 16 | Off Igbimo road, Afao | $07^0$ 43 206´ | $05^0$ 20 409´ | Granite gneiss | Fine to coarse grained | Dyke, vein, solution hole | |
| 17 | Ilemiya road, Afao | $07^0$ 42 640´ | $05^0$ 19 680´ | Migmatite gneiss | Medium to fine grained | Dyke, cracks, vein. | |

**Table 1:** Field data.

biotite) layers. Structures observed on this outcrop include folds, veins and pegmatite dyke, the pegmatite shows no zoning thus making it simple in nature with a width of about 32 centimeters. The present state of the rock is as a result of weathering.

## Method of Study

The method of study adopted for the different aspects of this work include field and laboratory operations. The field operations involve sample collection and the sampling method used is the grid-controlled type. In this method, the rock samples were picked at a sampling density of one sample per 4 $km^2$. A total of seventeen rock samples were collected from the study area which were lithologically described based on their field relationships after which were labeled properly and put in a sample bag for onward transmission to the laboratory. Ten (10) fresh samples were selected from the whole samples and were prepared for geochemical analysis for major, trace and rare earth elements determination (Table 2). The rocks were initially crushed, using the jaw crusher into fragments and were pulverized later using the agate mortar. The four acid method of digestion was adopted in preparing the samples for geochemical analysis using 0.5 g of each sample and the analysis were carried out using the Atomic Absorption Spectrophotometer (AAS) at the Central Laboratory, University of Ibadan, Nigeria.

## Discussion

The systematic geologic mapping, geochemical and petrogenetic studies of the Precambrian basement rocks in Iworoko, Are and Afao-Ekiti has been carried out and the overall results showed that $SiO_2$ (silica) is by far the most abundant mineral in all the rock types with the highest percentage present in the migmatites (66.2%) and the lowest in the banded gneisses (63.0%), while $TiO_2$ is the least abundant mineral with an average composition less than 1% in all the rock samples. The ferromagnesian compounds (FeO and MgO) have varying abundances in the rock samples. $Fe_2O_3$ value is higher in the migmatite gneisses(4.65%) while the lowest percentage is present in banded gneisses(2.67%), and the granite gneiss has percentage of 3.05%; MgO is mostly abundant in the granite gneiss(3.03%) because it contains more of mafic minerals than the other rocks. The banded gneisses have 1.81% while the migmatite gneisses have the lowest value of MgO (1.80%). From this it shows these rock samples (migmatites and granite gneisses) must have been emplaced in a continental environment as explained by the plots of $TiO_2$- $K_2O$- $P_2O_5$ (Figure 3). The results of the trace and rare earth elements show that Ba is the most abundant trace elements in the migmatite-gneiss. This indicated that the migmatite gneiss in the study area harbors some radioactive materials which are worth investigating. However, no mineral of economic importance has been reported in the area lately, but the migmatite gneisses in the study area could serve as a potential source of mineralization, especially radioactive minerals if well exploited. Also, the migmatite-gneiss in the study area could be chemically comparable to the metasediments of the south western Nigeria [10,11]. The plot of $SiO_2$ versus CaO for the samples fell within the field of Francisian greywacke (Figure 4) while the $Na_2O/Al_2O_3$ against $K_2O/Al_2O_3$ for the discrimination of sedimentary/metasedimentary and igneous series (Figure 5) by Garrels and Mackenzie [10] showed that majority of the samples plotted were within the sedimentary field [12]. Also, The $TiO_2$-$K_2O$-$P_2O_5$ plot (Figure 3) confirmed the continental nature of the sediments [13]. The range and mean concentration (ppm) of the trace and rare earth elements present (Table 3 and Figure 6) indicated that Barium (Ba) has the range of 36 – 458 ppm with an average value of 328.7 ppm. Migmatite gneiss has the highest concentration of Ba 458 ppm while the pegmatite has the lowest concentration of Ba 36 ppm. Chromium content ranges from 22 – 136 ppm with an average value of 70.8 ppm which is quite high. This high concentration in the samples could be responsible for the presence of some ultramafic bodies in the migmatite-gneiss. The pegmatite also contains fairly equal amounts of Cu, Ga, Cr, As and Pb compared to the migmatite-gneisses.

## Conclusion and Recommendation

The geochemical and geological studies (Figure 7) of the basement rocks in Iworoko, Are and Afao Ekiti, south western Nigeria has

| Major elements | Are-Ekiti | Are-Ekiti | Iworoko-Ekiti | Afao-Ekiti | Iworoko-Ekiti | Iworoko-Ekiti | Are-Ekiti | Are-Ekiti | Iworoko-Ekiti | Afao-Ekiti |
|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 74.97 | 65.46 | 64.85 | 66.36 | 60.30 | 70.07 | 65.20 | 64.30 | 69.90 | 61.66 |
| $Al_2O_5$ | 15.11 | 17.00 | 15.20 | 15.85 | 14.83 | 14.16 | 17.10 | 17.40 | 15.99 | 21.49 |
| $Fe_2O_3$ | 0.40 | 7.60 | 7.20 | 4.67 | 4.77 | 3.39 | 3.05 | 3.15 | 0.27 | 2.18 |
| $TiO_3$ | 0.01 | 1.08 | 0.76 | 0.58 | 0.74 | 0.01 | 0.53 | 0.75 | 0.01 | 0.95 |
| CaO | 0.27 | 1.72 | 2.90 | 3.02 | 4.75 | 0.09 | 3.08 | 5.88 | 0.26 | 3.68 |
| $P_2O_5$ | 0.22 | 0.06 | 0.17 | 1.21 | 1.36 | 0.29 | 1.02 | 0.95 | 0.96 | 1.24 |
| $K_2O$ | 3.53 | 4.25 | 2.82 | 2.91 | 3.47 | 8.42 | 3.75 | 1.75 | 8.30 | 3.56 |
| MnO | 0.04 | 0.02 | 0.15 | 0.10 | 0.09 | 0.06 | 0.05 | 0.03 | 0.05 | 0.02 |
| MgO | 0.11 | 1.40 | 2.45 | 2.32 | 4.35 | 0.10 | 3.03 | 2.20 | 0.10 | 1.41 |
| $Na_2O$ | 5.28 | 2.87 | 3.15 | 3.08 | 4.06 | 2.76 | 3.28 | 3.76 | 3.57 | 3.45 |
| Total | 99.94 | 101.46 | 99.65 | 100.1 | 98.72 | 99.35 | 100.09 | 100.1 | 99.41 | 99.64 |

**Table 2:** Major elements (wt %).

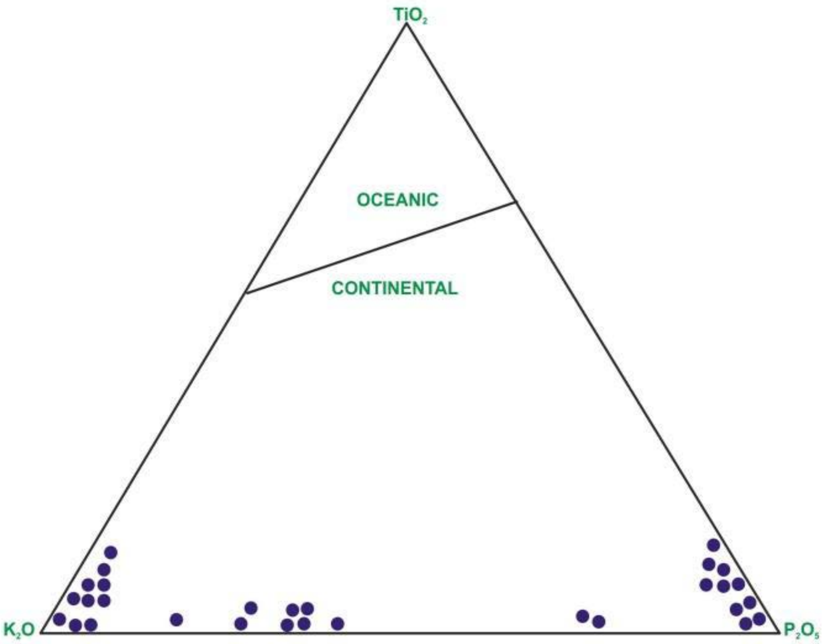


**Figure 3:** $TiO_2$-$K_2O$-$P_2O_5$ plot of the rocks from Iworoko, Are and Afao Ekiti (Pearce et al., [13]).

| Oxides | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | CaO | $P_2O_5$ | $K_2O$ | MnO | MgO | $Na_2O$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Migmatite gneiss | 66.2 | 15.5 | 4.65 | 0.53 | 2.12 | 0.68 | 5.0 | 0.078 | 1.80 | 3.24 |
| Granite gneiss | 65.20 | 17.10 | 3.05 | 0.53 | 3.08 | 1.02 | 3.75 | 0.05 | 3.03 | 3.28 |

**Table 3:** Average concentration of major elements (wt%).

| Trace and rare earth elements | Are-Ekiti | Are-Ekiti | Iworoko-Ekiti | Afao-Ekiti | Iworoko-Ekiti | Iworoko-Ekiti | Are-Ekiti | Are-Ekiti | Iworoko-Ekiti | Afao-Ekiti |
|---|---|---|---|---|---|---|---|---|---|---|
| Ba | 36 | 372 | 382 | 316 | 458 | 346 | 358 | 446 | 237 | 336 |
| Ga | 39 | 17 | 38 | 44 | 39 | 37 | 34 | 37 | 26 | 29 |
| Cu | 14 | 45 | 25 | 30 | 25 | 49 | 29 | 33 | 15 | 29 |
| Cr | 52 | 131 | 109 | 96 | 48 | 136 | 42 | 46 | 22 | 26 |
| As | 62 | 57 | 4 | 6 | 61 | 52 | 4 | 3 | 6 | 3 |
| Pb | 61 | 88 | 15 | 18 | 36 | 28 | 246 | 78 | 60 | 86 |

**Table 4:** Trace and rare-earth elements (ppm).

**Citation:** Ayodele OS (2015) The Geology, Geochemistry and Petrogenetic Studies of the Precambrian Basement Rocks around Iworoko, Are and Afao Area, Southwestern Nigeria. J Geol Geophys 4: 212. doi:10.4172/2381-8719.1000212



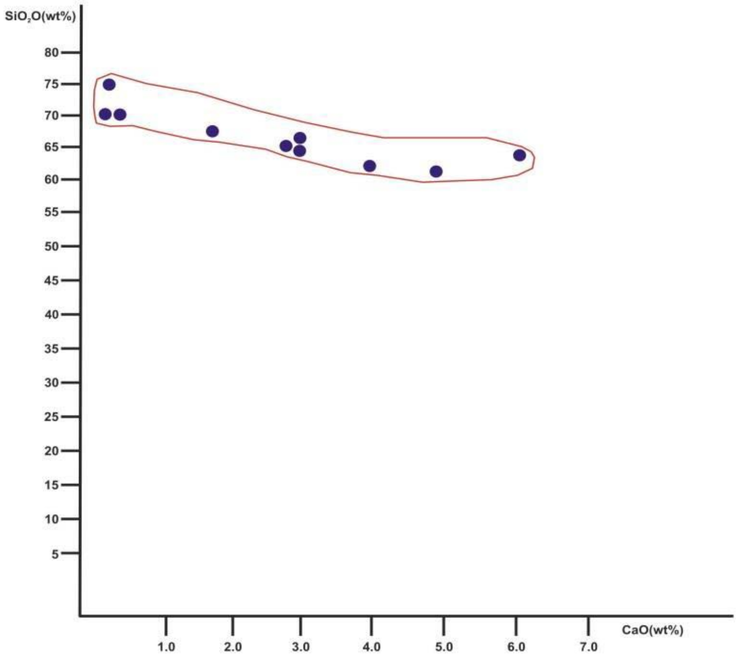


**Figure 4:** $SiO_2$-CaO Plot for Iworoko Are and Afao Ekiti Gneisses (Field of Francisian Greywacke after Brown et al., [12]).

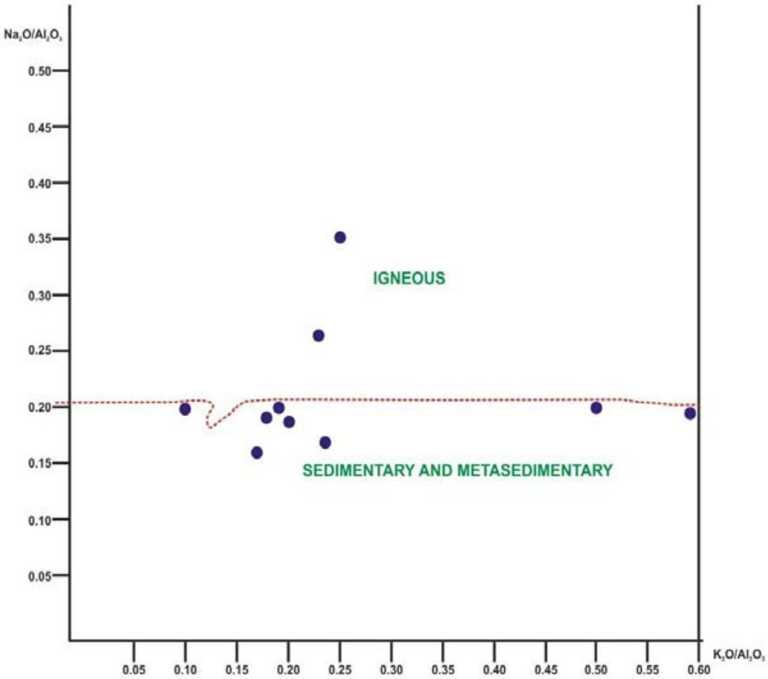


**Figure 5:** $Na_2O/Al_2O_3$ Vs $K_2O/Al_2O_3$ Variation diagram fields of igneous and sedimentary/metasedimentry rocks (After Garrels and Mackenzie [10]).

**Citation:** Ayodele OS (2015) The Geology, Geochemistry and Petrogenetic Studies of the Precambrian Basement Rocks around Iworoko, Are and Afao Area, Southwestern Nigeria. J Geol Geophys 4: 212. doi:10.4172/2381-8719.1000212



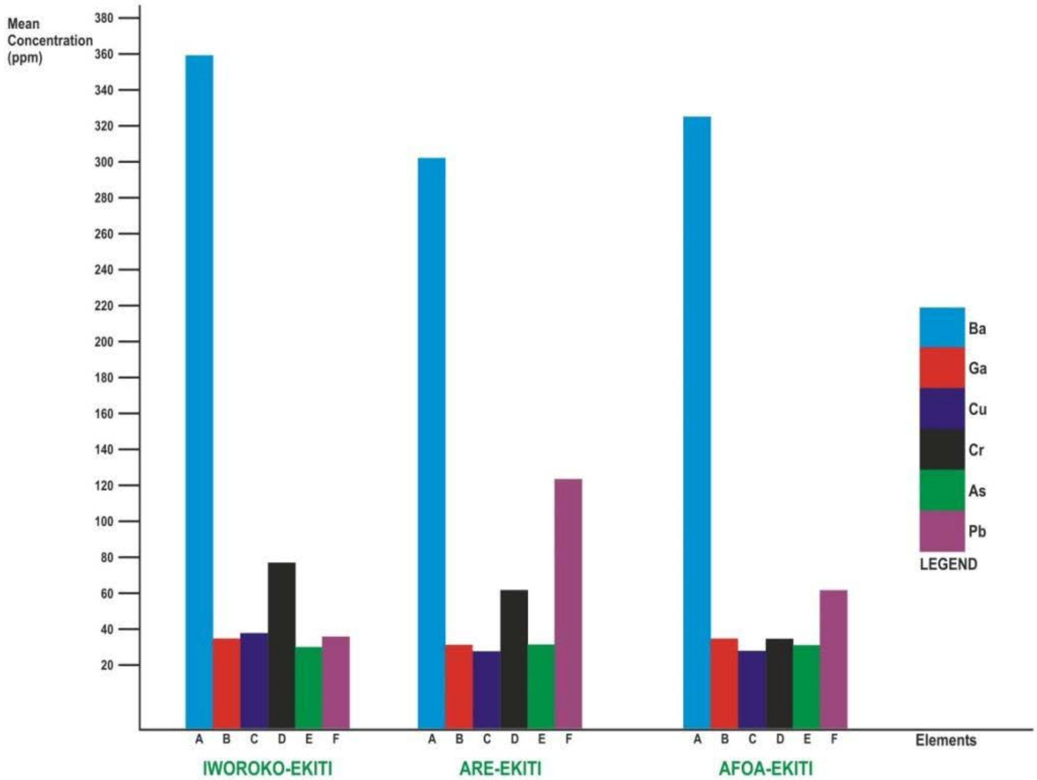


**Figure 6:** Histogram of mean concentration of the trace and rare-earth elements in the study area.

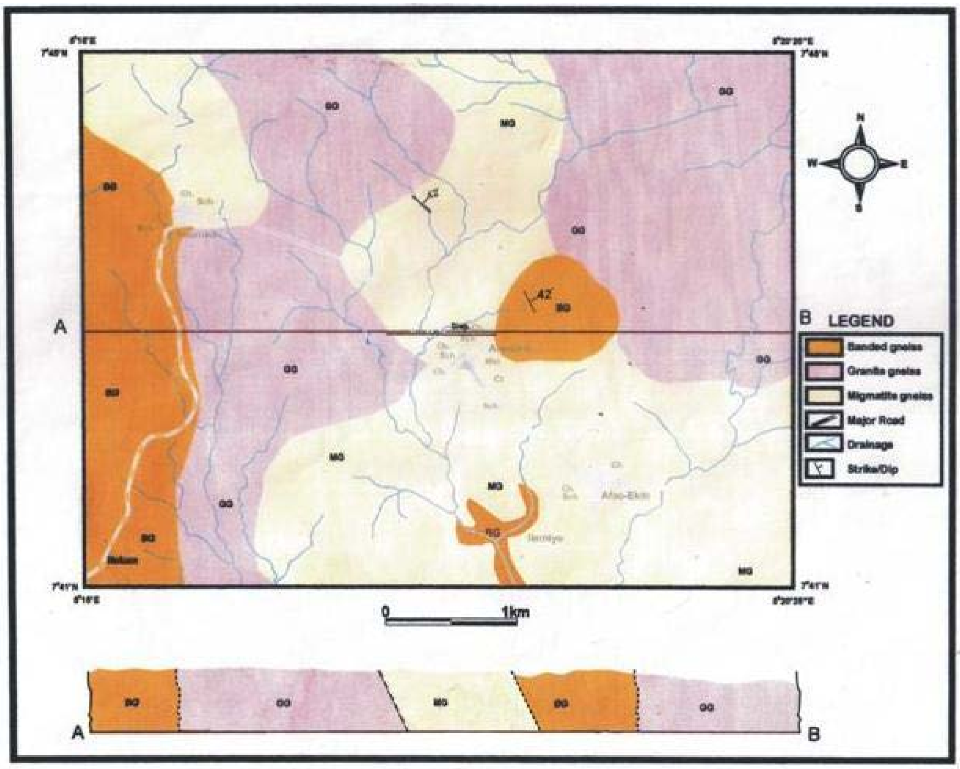


**Figure 7:** Geologic and cross-section map of the study area.

been studied. Through the results acquired from this analysis, it can be concluded that some of the trace and rare earth elements detected are radioactive in nature (Table 4). Petrological and geochemical data interpreted strongly indicated a sedimentary protolith, probably greywacke for the migmatite gneisses, granite gneiss and banded gneisses of the Iworoko, Are and Afao Ektit area. The greywacke sediments may have been derived from continental source. It is recommended that the inhabitants should be quarantined against possible exposure to radioactive elements which could cause infant mortality, mutations, and carcinogenic radiations emanating from the area. Furthermore, the level of radioactivity of the migmatite gneiss in the area should be ascertained by carrying out radioactive survey program of the entire area.

## Aknowledgement

I hereby acknowledge the efforts of Akinniyi Richard Akinwale, who assisted me during the geologic field mapping exercise of this research and whose immense contribution to this work is highly appreciated. Thank you very much.

## Refreneces

1. Mumbfu EM, Forba NMT, Cheo ES (2014) Geochemical dispersion of gold in stream sediment in Paleoproterozoic Nyong Series, Southern Cameroon. Science Research 2: 155-165.
2. Akintola AI, Ikhane PR, Bankole SI, Adeokurolere DN (2013) Petrography and Stream sediment geochemistry of Ede and its environs, southwestern Nigeria. International Research Journal of Geology and Mining 3: 2276-6618.
3. Emmanuel A, Samuel A, Folami L, Bankole D, Taye A, et al. (2011) Applications of the principal component analysis on geochemical data; A case study in the basement complex of southern Ilesa area, Nigeria. Arab Journal of Geoscience 4: 239-247.
4. Odeyemi IB, Anifowose AYB, Asiwaju-Bello YA (1999) Multi-technique graphical analysis of fractures from remotely-sensed images of basement region of Nigeria. Journal of Mining and Geology 35: 9-21.
5. Anifowose AYB, Borode AM (2007) Photogeological study of the fold structure in Okemesi area, southwestern Nigeria. Journal of Mining and Geology 43: 125-130.
6. Black R (1980) Precambrian of West African Episodes. International Journal of Geosciences 4: 3-8.
7. Dada SS (2006) Crust forming ages and Proterozoic crustal evolution in Nigeria, a reappraisal of current interpretations. *Precambrian Research* 87: 65-74.
8. Gandu AH, Ojo SB, Ajakaye DE (1986) A gravity study of the Precambrian in the Malufashi area of Kaduna State, Nigeria. Tectonophysics 126: 181-194.
9. Anifowose AYB (2004) An integrated Remote Sensing Analysis of the Ifewara-Zungeru Megalinear in Nigeria. Ph.D Thesis, Federal University of Technology, Akure, Nigeria.
10. Garrels RM, Mackenzie FT (1971) Evolution of sedimentary rocks. W.W. Norton and Company, Incorporated New York.
11. Rahaman MA, Ocan O (1978) On relationships in the Precambrian Migmatite-gneiss of Nigeria. Niger Journal of Mineral Geology 15: 23-32.
12. Brown EH, Babcock RS, Clark MD, Livingstone DE (1979) Geology of the older Precambrian rocks of the Grand Canyon 1. Petrology and Structure of the Vishnu Complex. Precambrian Research 8: 219-241.
13. Pearce M, Gorman BE, Birkett TC (1975) The relationship between major element chemistry and tectonic environment of basic and intermediate volcanic rocks. Journal of Earth Science letters 36: 121-132.