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Geology and Petro-chemistry of the Precambrian Rocks around Ipoti and Oke-Ila Area, Southwest Nigeria: A Preliminary Investigation for Mineral Exploration

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Abstract

Geology and petro-chemistry of the underlying lithologic units in Ipoti, and Oke-ila area, southwestern Nigeria was carried out with the aim of evaluating the mineral potentials of the studied area. Thirty rock samples were collected using a grid-controlled sampling method after which ten fresh rock samples were carefully selected for geochemical analysis followed by partial digestion of the rock samples and subsequent geochemical analysis using Inductively Coupled Plasma Spectrophotometry (ICP-MS) to determine the major oxides and trace elements geochemistry. The result of the geological mapping of the area revealed six lithologic units such as granite, gneiss, pegmatite, massive and schistose quartzite and amphibolite with well delineated boundaries. The analytical geochemical results revealed that silica (SiO_2) is the most abundant major oxide with average percentage composition of 65.17%. These indicated that the rocks are siliceous and have abundant aluminosilicate minerals. Also, the results of the trace elements analyses revealed that Mn is the most abundant in the rocks, with an average concentration of 1784.9ppm. The average percentage concentrations of other trace elements in all the rock samples are as follows: Ba (865.2ppm), Zr (727.87ppm), Sr (274.5ppm) and Zn (33.74ppm). Conclusively, metallic mineral association of Mn-Co-Zn-Pb-Cu-Fe-As is highly suspected in the studied area, while the weathering indices of the rock's ranges from 50%-75%, indicating that the rocks are fresh to moderately weathered, therefore suitable for mineral exploration.

Keywords: *Ipoti; Oke-Ila; Petro-chemistry; Lithologies; Mineralization*

Introduction

Some areas in our environment are endowed with economically important resources whose exploitation can contribute greatly to the economic growth of any nation. The occurrence, localization and availability of these mineral resources can only be discovered through geological investigations which subsequently set the stage for exploration. Geological field mapping is the selection of a area of interest, identifying the geological aspects of that area with the intention of preparing a geological report that can be used for further geological investigations. The geological map which is superimposed on a topographic map with a scale will show the various rock types in the area of study, the structures, age relationships, geological formations, distribution of mineral deposits etc. Geochemistry as a branch of Earth Science applies chemical principles to deepen the understanding of the Earth system and systems of other planets. Geochemists consider the Earth as composed of discrete spheres (rocks, fluids and gases) that exchange matter and energy over a range of time scales. An appreciation for rates of reactions and the range of physical conditions responsible for the chemical expressions of each sphere provides the framework to study the evolution of the solid Earth, its oceans, atmosphere, biosphere, and climate. Analytical instrumentation such as inductively-coupled plasma and stable-isotope mass spectrometers, constitute an indispensable tool in understanding the geochemical make up rocks and other earth materials.

Geological Setting

Ipoti and Oke-Ila, which is the study area, are two localities within Ekiti and Osun states respectively. The study area is part of the Basement Complex of south western Nigeria (Figure 1). The area is bounded by latitudes 7°52'0"N and 7°57'0"N, and longitudes 4°59'0"E and 5°5'0"E respectively. This area is part of the larger Pan-African mobile belt that lies between the West-African and Congo Cratons and South of the Tourareg Shield (Figure 2). The dominant rocks in the area are the meta-sediments which include quartzite, schist and amphibolite. These rock units are underlain by variably migmatised granodioritic-tonalitic and granitic gneisses with which they possess co-eval fabrics. Members of Late- to Post-Pan African granitoids intruded and cut the fabrics of both the gneisses and the meta-sediments. This scenario has also been reported from other parts of southwestern Nigerian schist belt [1]. The Nigerian Basement Complex consists of three broad lithological groups. The first is the polymetamorphic migmatite-gneiss complex which is composed largely of migmatite and gneisses of various compositions and amphibolites. Also, part of these are the relics of metasedimentary rocks represented by medium to high grade calcareous pelitic and quartzitic rocks occurring within the migmatites and gneisses and they have been described as "Ancient Metasediments", [2]. Isotopic ages varying from Liberian to Pan – African have been obtained from the rocks.

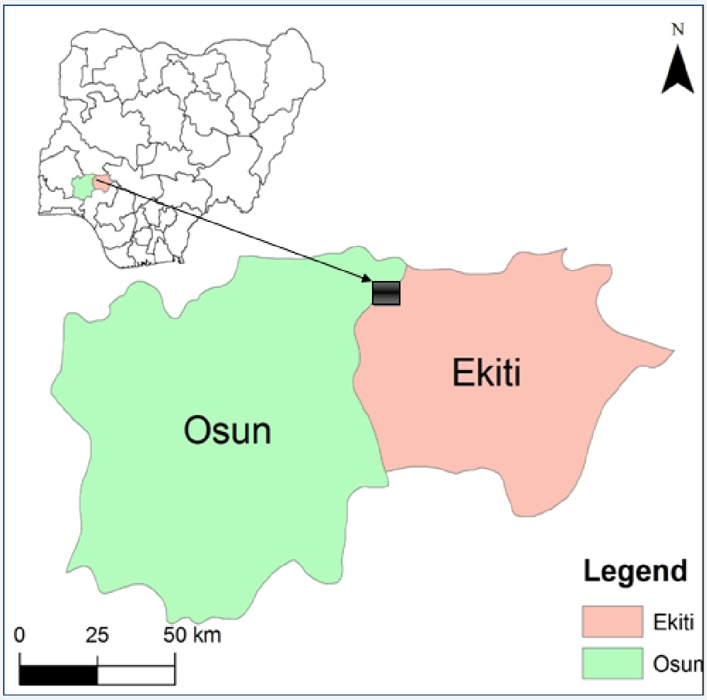

Figure 1: Map of the study area located within Ekiti and Osun States inset: Map of Nigeria showing the study area.

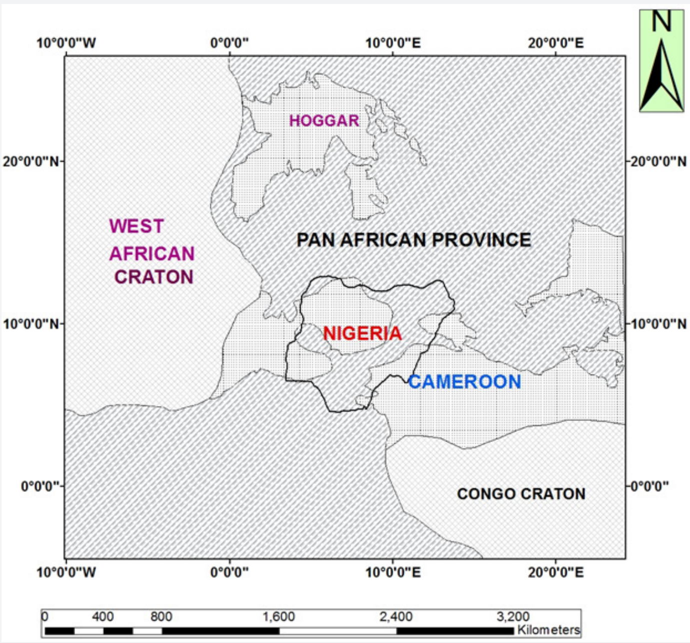

Figure 2: Nigeria within the Pan African Province (Modified after Ajibade and Fitches, 1988).

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The second suit of rocks are the low-grade sediment-dominated schists which form narrow belts in the western half of the country (Figure 2) have been described as "newer meta-sediments" [3] and unmigmatized to slightly migmatised shists; [4]. The schist belts are believed to be relics of a supracrustal cover which was folded into the migmatite gneiss complex [5,6] which was intruded by pan-African granitoids. The third but no less significant group of rocks is the syntectonic to late tectonic granitic rocks which cut both the migmatite gneiss complex and schist belts. The granitoids include rocks varying in composition from granite to tonalite and charnockite with smaller bodies of syenite and gabbro. Radiometric ages of the granitoids range from 750-500Ma which lie within the Pan - African age spectrum. These pan-African granitoids are granite to tonalite and charnockite with smaller bodies of syenite and gabbro. Radiometric ages of the granitoids range from 750-500Ma which lie within the Pan -African age spectrum. These pan-African granitoids are called older granites in Nigeria to distinguish them from the Mesozoic tin bearing granite complexes of central Nigeria which are referred to as the Younger granites (Figure 2). The geology of the South-Western part of Nigeria has been documented by several workers including [7-9] amongst others. In Southwestern Nigeria, the Precambrian suite is represented by the migmatite-gneiss rocks, the schist belt and Pan-African intrusive (Older Granite). They outcrop over 70% of the entire area [8]. Within the migmatite-gneiss, banded and melanocratic gneiss are the major rocks types. The meta-sediments comprise rocks whose earliest and metamorphic fabrics are co-eval with those of the gneisses upon which they lie. They grade imperceptibly into and are often intercalated with each other. Foliated and massive varieties of quartzites are the most dominant meta-sediments. They occupy the central, southwestern and the north western parts. Quartzite is in contact with mica schist, amphibolite, gneisses, marble, granite and pegmatite. The regional rock in the mapped area is migmatite gneiss complex comprising relics of ancient Metasedimentary sequences of quartzite quartz schist and pegmatite.

Method of Study

The methods adopted in carrying out the research include field examination of the outcrops, sampling and geochemical analysis of the rocks. Geological mapping of the study area was done on scale 1:25,000 using grid-controlled sampling method and at a sampling density of one sample per 100sqkm^2.

The field method entails proper in-situ observation, identification and systematic description of the outcrops. The geological mapping of the study area was done by traversing the area essentially on foot through existing roads and footpaths with the aid of the global positioning system (GPS) which assisted in determining the accurate geographical positions of the outcrops. Also, detailed study of the structural features in the rocks such as folds, joints, dyke, foliation and physical characteristics of the rocks such as color, textures and various features were recorded for each locality. Thirty rock samples were collected on the field while ten fresh samples were carefully selected for this research. The rocks were prepared for thin section studies using the standard procedures as well as for geochemical analysis (Major Oxides & Trace elements determinations).

The samples were crushed and packed at the geochemical laboratory of the Department of Geology, Obafemi Awolowo University (OAU) Ile-Ife, Nigeria. Subsequent physical and chemical treatment such as pulverizing to 200 mesh (85%) and chemical analysis were carried out in ACME Analytical Laboratories East Vancouver, Canada using Inductively Coupled Plasma Mass Spectrometer (ICP-MS) and Inductively Coupled Plasma Emission Spectrometer (ICP-ES). Total abundances of the major oxides were measured using 0.5g of sample pulp, analyzed by ICP-Emission Spectrometry following a Lithium metaborate/tetraborate (LIBO2/LI2B4O7) fusion and dilute nitric digestion [10]. The trace elements which are basically base and precious metals were measured using 0.5g of sample pulp digested in Aqua Regia and analyzed by ICP-Mass Spectrometry. The analytical procedure involved addition of 5ml each of perchloric acid (HCL04), trioxonitrate (V) HN03 and 15ml hydrofluoric acid (HF) to 0.5g of sample, the solution was stirred properly and allowed to evaporate to dryness after it was warmed at a low temperature for some hours. Four (4) ml of hydrochloric acid (HCL) was then added to the cooled solution and warmed to dissolve the salts. The solution was cooled; and then diluted to 50ml with distilled water. The solution was then introduced into the ICP torch as aqueous - aerosol. The emitted light by the ions in the ICP was converted to an electrical signal by a photo multiplier in the spectrometer, the intensity of the electrical signal produced by emitted light from the ions were compared to a standard (a previously measured intensity of a known concentration of the elements) and the concentrations were then computed. Analytical precisions vary from 0.1% to 0.04% for major elements.

Results and Discussions

Field occurrences

The major rock type that occurred in the study area are the gneisses, while there are relatively minor occurrences of pegmatite, quartzite, amphibolite and granite, (Figure 3). They are well exposed with mostly flat lying outcrop and were seen cutting across rivers and stream channels as well as road cuts. The gneisses occupied 60% of the entire area and are the banded types. They exhibited light and dark streaks of minerals (banding) which may be continuous or discontinuous, (Figure 4a). Contact between each band may be sharp or gradational. They outcrop as massive exposures that are fractured in places. Fracture and joints are principally in the north-south direction. The exposed part of the outcrop is generally dark grey in appearance. Other structural features observed are veins and joints. The texture of the gneisses is medium grained in hand specimens. Minerals identified in the rocks are biotite, quartz and plagioclase feldspar. The pegmatites are located within the south-eastern part of the

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study area and they account for about 20% of the study area (Figure 4b). They have an average strike value of 315° NW-SE and are exposed along stream channels and road cuts. The pegmatites are coarse grained and are predominantly grey with a shade of pink in colour due high content of feldspar. It occurs as low-lying outcrop with characteristic porphyritic texture. The pegmatite is composed of very coarse potassium-feldspar, coarse quartz constituting the phenocryst while micas, both muscovite and biotite dominate the matrix, they are the simple types with common mineralization. Quartzites are found in the western part of the study area within the gneisses, it runs from south west to the north east striking roughly NE-SW; the Quartzite occurred as low-lying outcrop which shared boundary with the gneisses. In hand specimens, observable minerals are quartz and muscovite chips. Most of the quartzite are buried under thick vegetation making them very difficult to see but their presence is recognized by the quartz rubble seen along footpaths and ridges. Two varieties of quartzite were found in the study area: a massive granular variety and a schistose quartzite, (Figures 4c & 4d). The massive variety of the quartzites are dominant with medium-grained texture and light greyed colour. The schistose quartzites, a minor occurrence, (occurring in just one location), have medium-grained texture, light greyed and found as channel exposure. It has minerals such as quartz and muscovite which are aligned and weathered.

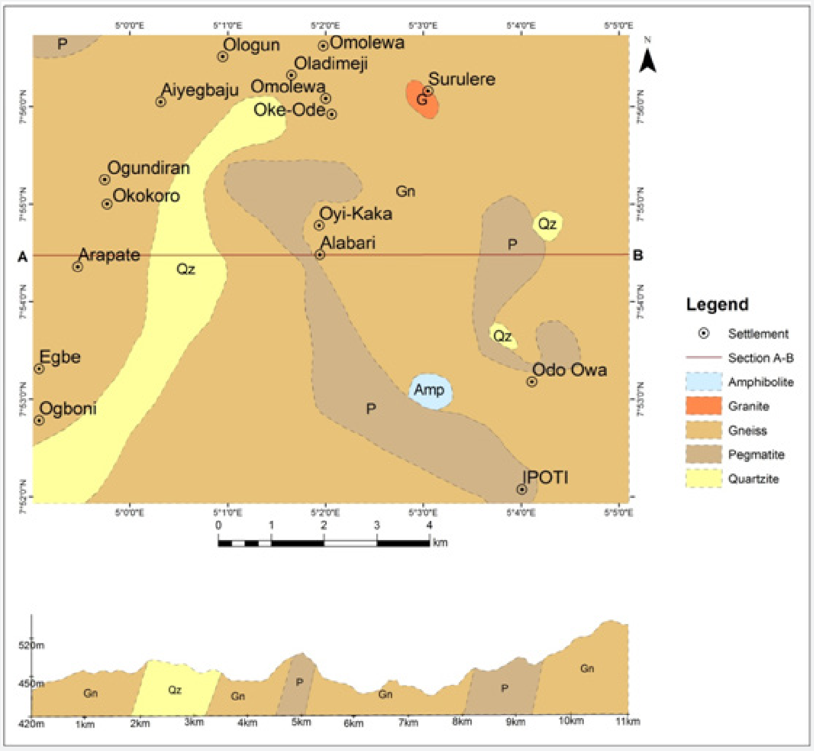

Figure 3: Geologic and X-section map of the study area.

Granites and the amphibolite schists are very minor units occurring to the northern and southern part of the study area. The granites observed in the study area occurred as an isolated hilly outcrop. The outcrop exposure had undergone intense weathering. The granite texture is medium-grained, slightly porphyritic and grey in colour, (Figure 4e). This rock was mapped only in one location on the field especially around Surulere. It contains xenolithic fragments of the older parent rock and exhibited minerals such as quartz, biotite, plagioclase and microcline feldspars in hand specimen. The amphibolite observed in the study area occurs as low-lying outcrop; it has fine-grained texture and are dark grey in colour, (Figure 4f). This rock was mapped only in one location on the field around Iparuku. The various lithologic units are represented in the geologic and cross-section map of the study area (Figure 3).

Petrographic analysis

The result of the petrographic analysis is presented in Table 1. The identification of minerals was done using their different optical properties under plane and cross polarized light. This analysis gave information that led to the determination of modal analysis (Table 1) of minerals in the rocks. A sample of the gneiss is characterized by coarse-medium interlocking grains of quartz with microcline feldspar, biotite and hornblende, (Figures 5a & 5b) and perthites are also evident in the sample. Also, some of the samples contain interlocks of biotite, strained quartz and feldspar of medium-fine grain at one end to the other with coarse-medium grained quartz and feldspar with specks of muscovite. The granites displayed minerals such as quartz, biotite, hornblende, augite, microcline, plagioclase and orthoclase feldspars (Figure 5c). The orthoclase feldspars present are

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subhedral, partially altered to sericite with strings of pethites of the feldspar, quartz, and microcline. Hornblende appears brownish to dark green in colour and has two distinct cleavages while Orthoclase exhibits Carlsbad twinning. The amphibolites predominantly contained hornblende, and a little of quartz and plagioclase feldspar, (Figure 5d). Hornblende makes up 57.1% of the sample and is pale green under plane polarized light. It is massive and elongated under cross polar. Quartz and plagioclase feldspar are almost covered by the amphiboles while plagioclase is typically identified by its albite twinning. The pegmatite in the study area are the simple types which were found to contain large amount of quartz, muscovite and tourmaline. Tourmaline is interlocked with quartz with pegmatitic texture (Figure 5e).

Figure 4: Field occurrences of: (a) Gneis (b) Pegmatite (c) Quartzite (d) Quart schist (e) Granite (f) Amphibolite.

Table 1: Modal analysis of the minerals constituting the samples.

Sample	Quartz (%)	Biotite (%)	Microcline (%)	Plagioclase (%)	Orthoclase (%)	Hornblende (%)	Muscovite (%)	Tourmaline (%)	Augite (%)
Gneiss	27	20	45	_	_	8	_	_	_
Amphibolite	20	_	_	23	_	57	_	_	_
Quartzite	100	_	_	_	_	_	_	_	_
Gneiss	38	33	13	3	_	8	_	_	5
Gneiss	34	40	_	9	_	_	17	_	_
Pegmatite	94	_	_	_	_	_	6	_	_
Pegmatite	48	_	_	_	¬¬_	_	52	¬_	_
Gneiss	38	19	23	8	_	12	_	_	_
Pegmatite	33	_	_	_	_	_	_	67	_
Schistose quartzite	75	_	_	_	_	_	15	_	_

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Granite	44	13	22	4	0	11	_	_	4
Gneiss	32	27	24	¬_	_	_	16	_	_

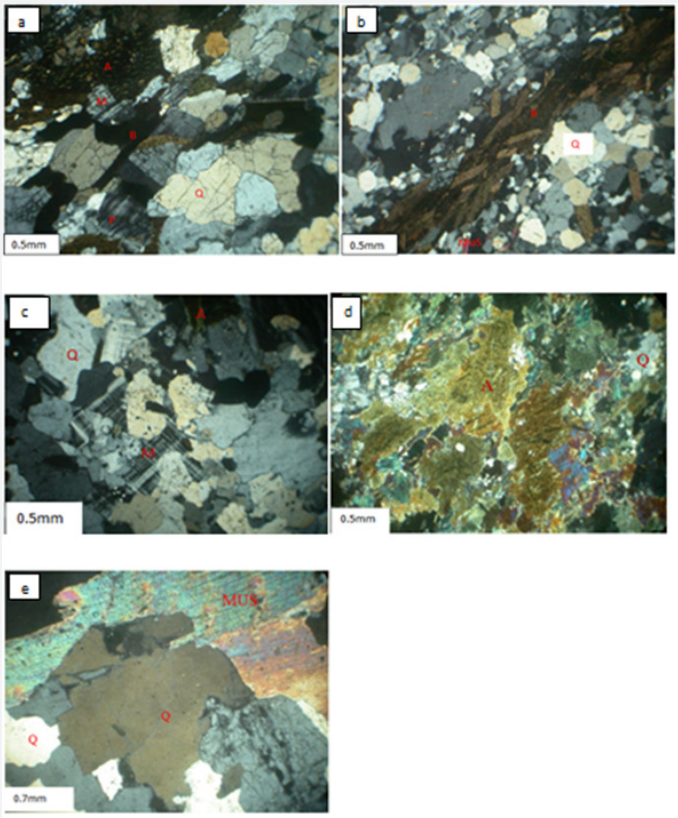

Figure 5: Photomicrographs of (a&b) Gneiss; (c) Granite (d) Amphibolite and (e) Pegmatite.

Structures

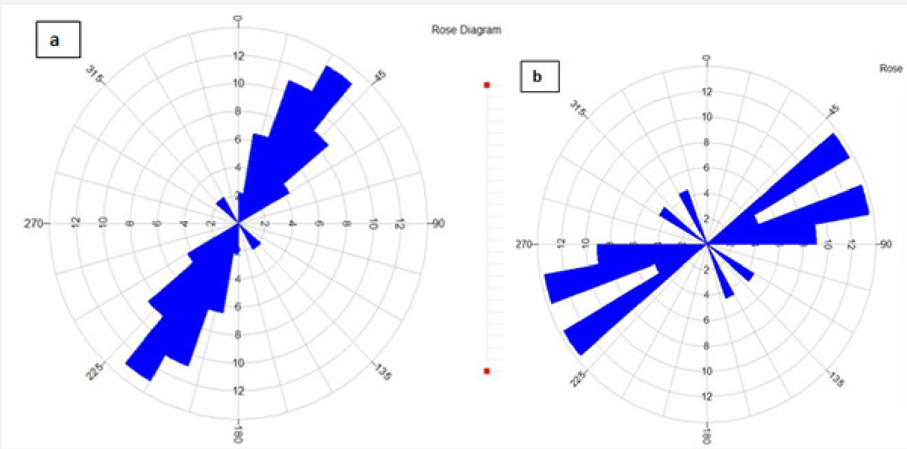

Figure 6: Rose plot of (a) Foliation (b) Joint

The structures identified and mapped in the study area are manifested as folds, fractures and even land forms such as mountains. Repeated application of these forces on already folded or fractured rocks can cause difficulty in geological interpretation. The following structures were observed on the field: folds, joints, faults, veins pinch and swell and dyke. The structures were examined and measured on the field and rosette diagrams were plotted using the data obtained in order to determine the general trend of deformation of the rocks. Compressional forces from opposite sides of the rock usually leads to shortening of initially parallel layers which become contorted following plastic or ductile deformation. Due to the degree of polycyclic deformation in the basement complex, styles of folding were seen to vary. Several folds were observed on the outcrops level such as ptygmatic, recumbent, gentle, open etc. Major or dominant foliation trend in the study area is in the

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NE-SW direction (Figure 6a), while several joints observed and measured on the outcrops (some being concordant to the strike of the outcrop while others were discordant) trend in the ENE-WSW direction (Figure 6b). Quartzo-feldspathic and pegmatitic veins occur at different lengths and widths on the outcrops and are present in most of the outcrops where the outcrop surfaces have not been too weathered especially on the gneisses.

Presentation of geochemical analytical results

Major oxides geochemistry

Table 2: Major Oxide geochemistry of the study area (values in Wt%).

Sample ID	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cr_2O_3	Total
Surulere	75.47	11.5	5.4	2.88	0.5	0.68	2.14	0.21	0.02	0.05	0.003	98.853
Oyi-Kaka	64.47	11.19	8.4	2.3	2.34	1.53	1.16	2.02	0.16	0.71	0.018	94.298
Oyi-Alabari	58.67	16.62	6.3	3.04	4.91	3.5	4.65	0.93	0.43	0.1	0.012	99.162
Iparuku	59.36	6.1	5.43	23.72	1.34	1.14	1.05	0.36	0.03	0.08	0.322	98.932
Odo-Owa 1	64.27	12.19	8.4	1.3	1.34	1.23	2.16	2.02	0.16	0.71	0.018	93.798
Odo-Owa 2	60.7	12.83	10.62	3.59	2.97	3	2.24	2.35	0.13	0.48	0.014	98.924
Aiyegbaju	65.93	13.56	4.85	0.36	2.65	2.63	5.13	0.72	0.17	0.11	<0.002	96.11
Oko-Eskinkin	74.57	12.68	6.4	2.9	0.7	0.7	0.46	0.22	0.02	0.05	0.003	98.703
Ipoti	60.47	14.62	5.7	3.06	5.01	2.89	4.78	0.9	0.51	0.2	0.0018	98.1418
Oke-Ode	67.82	16.22	3.15	1.26	4.3	3.8	2.15	0.85	0.2	0.06	0.002	99.812
Average	65.173	12.751	6.465	4.441	2.606	2.11	2.592	1.058	0.183	0.255	0.043	97.67

The analytical geochemical result of the Major oxides is presented in Table 2. The overall results of the major oxidesshowed that SiO_2 (silica) is by far the most abundant mineral in all the rock types with the highest percentage present in the Granite (75.4%) and the lowest in the gneisses and amphibolites of 61% & 57% respectively. Pegmatite and Quartzite has SiO_2 content of 66% and 63% respectively.Alumina (Al_2O_3) contents generally exhibited high molecular trend of the order: Al_2O_3 > (CaO + Na_2O + K_2O), the highest concentration is found in the gneiss and schistose quartzite which are 16% and 17%, while the lowest concentration was found in the amphibolite (6.1%). The ferromagnesian compounds (FeO and MgO) have varying abundances in the rock samples. Fe_2O_3 value is highest in the gneiss (10.62%) while the lowest percentage is present in the schistose quartzite (3.15%); the pegmatite and quartzite have average percentage of 8.40%, while granite has average percentage of 5.4%. MgO has relatively high abundant in the amphibolite (23.72%), this is because of the basic to ultramafic composition of the rocks in the studied area. Its content in the other rocks are in the range of (4-1%). The pegmatite have the lowest value of MgO (0.36%). Generally, the P_2O_5, MnO and Cr_2O_3 are low. CaO, k_2O and NaO are very low and this could be attributed to weathering and cyclic metamorphism that must have taken place in the rocks thereby forming new minerals. TiO_2 value is highest in the gneiss (2.35%) while the lowest percentage is present in Amphibolite (0.36%); pegmatite and quartzite have averagepercentage of 2.02%, while the other rocks are in the of range of 0.1 - 1%.

Trace elements geochemistry of the rocks

Table 3: Trace Element geochemistry of the study area (ppm).

Sample ID	Ba	Ni	Sr	Zr	Y	Nb	Sc	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	U	Au	Th
Surulere	20	50	132	<5	<3	<5	13	1.4	15.3	1.4	17	<0.1	17.4	4.8	256	1.5	1	<0.1	<0.1	0.2
Oyi-Kaka	591	41	64	1629	75	43	13	1.3	31.6	34.8	91	<0.1	33.3	72.3	5740	6.04	3	7	<0.1	26.5
Oyi-Alabari	1736	30	683	326	20	16	12	0.7	38.4	24.7	72	<0.1	27.3	18.3	746	4.33	1	0.7	<0.1	7.1
Iparuku	10	548	28	12	5	18	9	<0.1	6.8	1.8	81	<0.1	50.6	70.6	300	3.42	3	1.8	<0.1	0.5
Odo-owa 1	591	41	64	1629	75	43	13	1.3	31.6	34.8	91	<0.1	33.3	72.3	5740	6.04	3	7	<0.1	26.5
Odo-owa 2	1324	87	237	672	42	32	17	1.2	50.8	42.6	207	<0.1	50	60.6	2789	6.4	3	2.5	<0.1	16
Aiyegbaju	2164	<20	251	913	70	34	17	1.3	20.1	32	148	<0.1	2.2	3.2	669	5.12	1	1.1	<0.1	12.4

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Oko-Esinkin	21	52	128	<5	<3	<5	16	1.4	15.6	1.4	16	<0.1	17.8	4.6	302	1.5	1	<0.1	<0.1	0.3
Ipoti	1801	32	689	337	24	15	12	1.1	39.2	26.1	74	<0.1	26.9	18.7	784	4.86	1	0.7	<0.1	7.3
Oke-Ode	394	<20	469	305	32	26	4	2.4	23.2	22.4	71	<0.1	8.9	12	523	3.26	2	5.3	<0.1	31.3
AVE-RAGE	865.2	110.12	274.5	727.87	42.87	28.37	12.6	1.34	27.26	22.2	86.8	0.1	26.77	33.74	1784.9	4.247	1.9	3.2625	0.1	12.81

The trace elements analyticalresults are presented in Table 3. The results indicated thatBa is high and considered as the dominant trace element found in the rock samples having a wide range value of 10-2164ppm with an average value of 865ppm. It is exceptionally high because the study area is underlain by older granitoids. This unusual characteristic may be attributed to the initial composition of thee magma that form the granite or dissolution of the country rocks to which the magma was injected because the high values cut across almost the entire area. The pegmatites have high value of Ba concentration of 2164ppm while Amphibolite has the lowest value of Ba (10.20ppm). Quartzites and gneisses have average Ba value of 1324ppm and 1736ppm respectively. Au and Ag have values less than 0.1 in all the sample location. Iron (Fe) range from (6.4-1.5)ppm with an average value of 4.25ppm. Fe is high in some of the Pegmatite but low in the Granite around Surulere area and Gneiss in Oko-Esinkin area. Mo is extremely low in the Amphibolite in Iparuku with value less than 1ppm. Values of Mo in other sample locations are in the range of (2.4-0.7)ppm. It has an average value of 1.344ppm. Cu range from 6-51ppm with an average value of 27.26. The highest value of Cu occurred in the Gneiss in Odo-Owa 2 (50.8ppm). Cu is low in the Amphibolite in Iparuku with a value of 6.8ppm. Lead (Pb) ranges from (43-1) ppm having an average value of 22.2ppm. Pb is high in the Quartzite in Odo-Owa 1 and the Gneiss in Odo-Owa 2 having values of 34.8ppm and 42.6ppm respectively. Pb is very low in Granite(surulere) and Gneiss(Oko-Esinkin) withan average value of 1.4ppm. Pb is one of the most important decay products of U, and Th; Pb content may indicate that the samples are made up of minerals that have the tendency to be radioactive. Zinc(Zn) value ranges from 17ppm-207ppm with an average value of 86.8ppm, zinc is high in the Gneiss in Odo-owa 2 and Pegmatite in Aiyegbaju, having values of (207 and 148)ppm respectively.Zn has a lower value in Gneiss in Oke-Esinkin and Granite in Surulere having values of (16 and 17)ppm respectively. Values of Zn in other locations are in the range of (91-71)ppm. Zircon(Zr) has a very wide value ranging from (5.0-1629)ppm with an average value of 727.875ppm. Zircon(Zr) is very high in Gneisses in Odo-Owa 1 and Pegmatite in Oyi-Kaka with an average value of 1629ppm. Zircon(Zr) is low in the Granite in Surulere and Gneiss in Oko-Esinkin with value less than 5 ppm.

Weathering Indices of the rocks

Table 4: Weathering indices of rock samples rocks in the study area.

Sample ID	CIA	PIA	CIW
Surulere	75.862	101.317	101.317
Oyi-Kaka	67.471	104.06	104.06
Oyi-Alabari	54.904	108.452	108.452
Iparuku	63.204	102.368	102.368
Odo-owa 1	72.348	102.277	102.276
Odo-owa 2	62.4	105.204	105.204
Aiyegbaju	56.955	104.605	104.605
Oko-Esinkin	87.832	101.234	101.234
Ipoti	51.232	108.575	108.575
Oke-Ode	61.857	107.527	107.527

Note: CIA = Chemical index of weathering, PIA= Plagioclase index of alteration, CIW = Chemical index of Weathering.

The result of the weathering indices of the rocks is presented in Table 4. The Chemical Index of Alteration, developed by [11], is a useful index of the degree of weathering basement rocks. The measure of the degree of weathering of basement rocks in Ipoti, Odo-Owa, Oke-Ila is obtained by calculation of the chemical index of alteration (CIA) using molecular proportions where CIA= $[Al_2O_3/ (Al_2O_3+CaO^*+ Na_2O+ K_2O)]x100$. The CIA range of rocks in the study area is 50-75% indicating freshly to moderately weathered rock (Table 4). These showed that the rocks in the studied area are suitable for geochemical/ mineral exploration.

Variation plots

The variation plots of all metallic oxides exhibited negative corellation with SiO_2 (Figure 7). This is an indication of its depletion within the geochemical distribution framework .

Descriptive statistics

Correlation

The correlation relationship between Ba with the following metals such as As, Mn, Co and Cr are negative (Table 5). Very strong positive correlation exists between the following pairs

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of elements Zn, Fe, V and Cu whilethe correlation relationships between Cr with other metalssuch as Mn, Cu, Fe and Ba are negative. Very strong positive correlation exists between the following pairs of elements Zn, As, V and Co. The correlation relationship between Zn with other trace elements is very strong positive correlation (Table 5). However, the positive correlation of Zinc with with As, is an indication of gold showings or sulphide mineralization. The correlation relationship between Ag with the other trace element is constant while the correlation relationship between Pb with the trace other element is insignificant.The descriptive statistics of the major oxides and trace metals are shown in Tables 6 & 7 respectively. An interesting deduction from this table is a likely mineral association of Mn-Co-Zn-Pb-Cu-Fe-As mineralization suspected in the studied area.

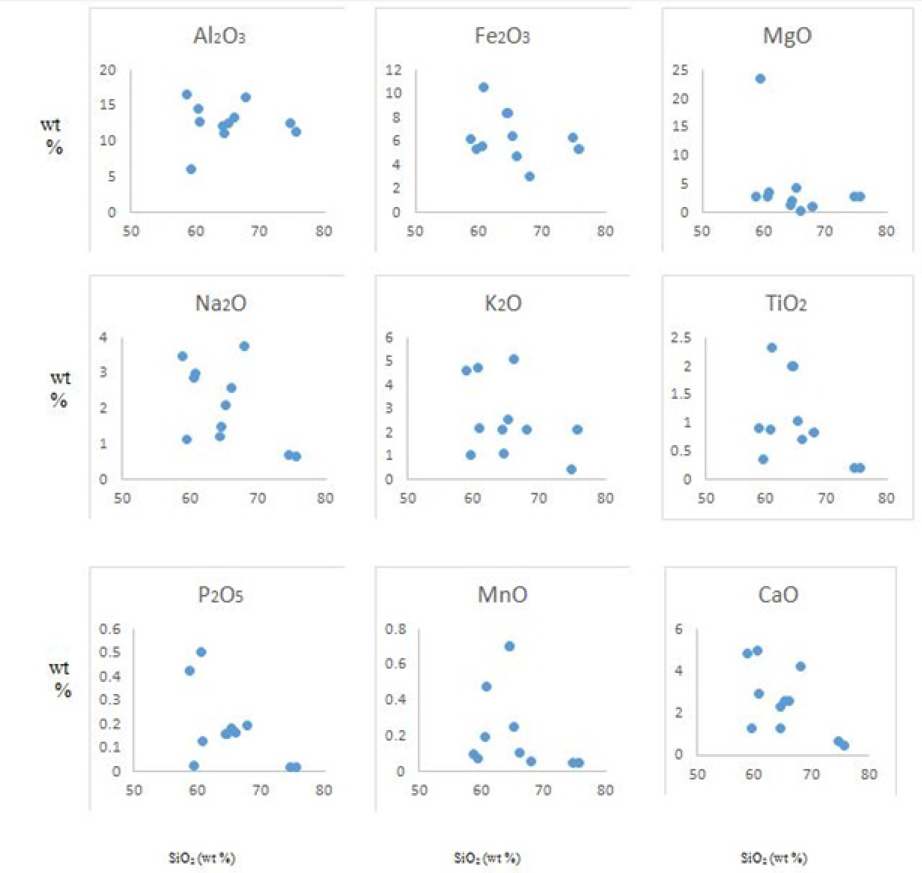

Figure 7: Variation plots of the major oxides with SiO_2.

Table 5: Correlation showing interrelationship of the trace element in the study area.

	Ba	Cu	Pb	Zn	Co	Mn	Fe	AS	V	Cr
Ba	1									
Cu	0.598	1								
Pb	0.646	0.807	1							
Zn	0.571	0.578	0.78	1						
Co	-0.211	0.228	0.367	0.401	1					
Mn	-0.036	0.424	0.638	0.314	0.743	1				
Fe	0.573	0.71	0.93	0.794	0.619	0.712	1			
AS	-0.321	0.161	0.367	0.454	0.939	0.687	0.55	1		
V	0.26	0.862	0.708	0.39	0.548	0.637	0.707	0.482	1	
Cr	-0.336	-0.441	-0.386	0.034	0.505	-0.157	-0.07	0.462	-0.189	1

Table 6: Descriptive statistics of the Major Oxides in the study area.

Oxides	Minimum	Maximum	Mean	Standard Deviation	Variance	Skewness	Kurtosis
SiO_2	58.67	75.47	65.173	5.976	35.71	0.829	-0.419
Al_2O_3	6.1	16.62	12.751	2.976	8.857	-1.0192	2.189

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Fe_2O_3	3.15	10.62	6.465	2.138	4.574	0.6076	0.42
MgO	0.36	23.72	4.441	6.85	46.92	3.0295	9.405
CaO	0.5	5.01	2.606	1.681	2.8262	0.3125	-1.392
Na_2O	0.68	3.8	2.11	1.181	1.3937	0.111	-1.789
K_2O	0.46	5.13	2.592	1.671	2.7942	0.5632	-1.18
TiO_2	0.21	2.35	1.058	0.791	0.6253	0.6587	-1.122
P_2O_5	0.02	0.51	0.183	0.166	0.0276	1.1367	0.55
MnO	0.05	0.71	0.255	0.271	0.0739	1.1249	-0.537
Cr_2O_3	0	0.322	0.03938	0.099	0.0099	3.1331	9.864

Table 7: Descriptive statistics of the Trace Element geochemistry of the study area (values in ppm).

Metals	Range	Minimum	Maximum	Mean	Standard Deviation	Variance	Skewness	Kurtosis
Cu	44	6.8	50.8	27.26	13.432	180.425	0.229	-0.581
Pb	41.2	1.4	42.6	22.2	15.393	236.962	-0.494	-1.305
Zn	191	16	207	86.8	56.548	3197.733	0.969	1.462
Ag	0	0	0	0	0	0		
Co	69.1	3.2	72.3	33.74	30.93	956.716	0.419	-2.095
Mn	5484	256	5740	1784.9		4883783	1.404	0.344
Fe	4.9	1.5	6.4	4.247	1.793	3.217	-0.4952	-1.004
AS	2	1	3	1.9	0.994	0.989	0.237	-2.3
V	125	5	130	73	47.004	2209.333	-0.31	-1.893
Cr	1257	8	1265	178.5	384.413	147773.4	3.081	9.623

Conclusion

Six varieties of rocks exist in the study area which are granite, gneiss, pegmatite, quartzite, quartz schist and amphibolite with their structural trends in ENE-WSW direction. The result of the geochemical analysis for the major oxides revealed that SiO_2 and Al_2O_3 are the most abundant major oxides in the rocks. SiO_2 indicated that the rocks are siliceous while Al_2O_3 indicated presence of aluminosilicate-bearing minerals such as feldspar, micas, and feldspathoids while other oxides such as CaO, Fe_2O_3, K2O, MgO, MnO, Na2O, $P2O_5$, and TiO_2 are present in minor to trace amounts in the rocks due to their mode of occurrence. The weathering index shows that the rocks in the study area are fresh to moderately weathered this implies that the rocks can be used for geochemical or mineralogical exploration. From the variation plots, it can be concluded that the basement rocks in the study area (Ipoti, Odo-owa, Oke-ila) are derived from crustal materials having high silica (felsic) content. Considering the geochemical properties of the rocks in the study area, we can deduce that Mn-Co-Zn-Pb-Cu-Fe-As mineralization which is indicative of sulphide mineralization and gold showings in the studied area is suspected. Although, detailed geochemical investigation is desirable to confirm these discoveries and other types of deposits inherent. Also, the Pb-Sr-Ba-Zr association could also point to the radioactive nature of the rocks.

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