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Research Article

THE GEOLOGY, STREAM SEDIMENT GEOCHEMICAL SURVEY AND GROUND WATER QUALITY EVALUATION OF OKEMESI AREA, SOUTHWESTERN NIGERIA

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ABSTRACT
The geology, stream sediment geochemical survey and groundwater quality evaluation of Okemesi and environs, southwestern, Nigeria was carried out. The lithologies mapped in the study areas include banded-gneiss, biotite-gneiss, quartzite, biotite-schist, quartz-biotite schist and pegmatite with various structures found on the outcrops such as joints, fractures, solution holes, microfolds, banding and above all, the presence of an asymmetric fold was also detected from the cross-section of the geologic map produced. A total of ten active stream sediment samples and four borehole (water) samples were collected over an area of 138.45km^2. Stream sediment samples were digested in aqua regia solution and analyzed by ICP-MS method while borehole (water) samples were analyzed by spectrophotometer and ICP-MS methods. The analyses revealed that the stream sediment samples have concentration of elements between Al(0.18 – 2.42%), Ca (0.01 – 0.16%), Fe (0.27 – 6.98%), k (0.01 – 0.13%), Mg (0.01 – 0.14%), Na (0.01 – 0.02%), As (0.1 – 6ppm), Ba (20 – 90ppm), Co (0.8 – 10.3ppm), Cr. (5 – 69ppm), Cu (4.8 – 38.4ppm), P (50 – 350ppm), Pb (3.8 -15.1ppm), Sr (1 – 15.8ppm), Zn (5 – 35ppm), Ce (14.2 – 72.8ppm), Ga (0.91 – 13.75ppm), La (6.3 – 29ppm), Rb (3.5 – 52.8ppm), Th (*1.6 – 10ppm), V (5 – 142ppm) and Y (2.2 – 13ppm**)** while the concentrations of anions and cations in the borehole (water) samples are; Cl- (7.97 – 24.90mg/l), No_3- (<1.0 – 8.53mg/l) HCO_3- (16 - 278mg/l), SO_4^{2-} (9 - 16 mg/l), PO_4^{3-} (0.43 – 5.90 mg/l), Ca^{2+} (2.24 – 109.57 mg/l), K^+ (1.02 – 5.75 mg/l), Mg^{2+} (0.63 – 5.56 mg/l) and Na^+ (4.54 – 23.87 mg/l). Comparison of the results by plots of concentration of elements against sample locations and statistical description for both sampled media showed that most of the elements have high concentration around Ikange, Ayegunle and Makanju area respectively, which all lie in the western part of the study area. The underlying lithology (quartzite) probably played a major role in the distribution of these elements.

Key Words: *Okemesi; Lithologies; Stream Sediments; Geochemistry; Statistics*

INTRODUCTION
Geologic mapping on the field is one of the main functions of a geologist, which is the basis of understanding the geologic history of an area. Rocks after formation are subjected to weathering be it physical or chemical from which disintegrated minerals pass through to the surface or underground water into streams rivers etc. and then co-precipitated as heavy minerals in sediments. Geochemical mapping of stream sediments gives a clearer picture that allows minerals/ elements to be examined in the area drained by stream. Therefore, stream sediment samples are collected from first order streams in order to represent the weathered rocks in the drainage system. Also, examination of groundwater chemistry enables the determination of the extent of mixing of rare earth elements, trace / minor elements and major elements within the environment owing to their solubility rates.
The study area is underlain by rocks of the Precambrian basement complex which have conformable field relationship and they occur as outcrops mainly in the western part. The rocks show great variations in grain size and mineral composition. The rocks are banded-gneiss, biotite-gneiss, quartzite, biotite-schist, quartz-biotite schist and pegmatite. In grain size and structure, the rocks vary from very coarse grained pegmatites, medium grained gneisses to equigranular quartzites. Some of the rocks in the study area are foliated while others are not. A lot of studies have been carried out by various workers on the study area which includes Ayodele (2010) who worked on the remote sensing and geological studies of the fold belt around okemesi area, and revealed the existence of fractures, faults and folds on the Landsat^{TM} imagery of

the study area, and that the rocks in the area from the imagery bear imprints of different generations of folding. The ground truth also confirmed the presence of overturned antiformal and asymmetric folds. Okunlola and Jimba (2006) carried out petrographic and geochemical evaluation of pegmatite bodies around aramoko, ara and ijero area and concluded that majority of the samples are lepidolite subclass and magmatic pegmatite while some pegmatite bodies may have undergone mild post magmatic alternation especially those outcropping around ijero area. Also okunlola and Richard (2009) studied the schistose rocks around the okemesi fold belt, ife-ilesha schist belt therefore is a view to evaluate their compositional feature and petrogenetic affinities and to contribute further to the understanding of the geodynamic evolution of nigerian's schist belt. Anifowose and Borode (2007) carried out photogeological studies of the fold structure in okemesi area and indicated the existence of isoclinal limbs of a megafold in association with other minor folds and subsequent fracturing which resulted in the plunging of the fold generally towards the north and south. Elueze et al., (2007) carried out hydrogeochemical assessment of surface and ground water quality in Agbowo-Orogun area of ibadan and found out that the water is slightly basic. Other literature exists on the development and application of index methods for water quality assessment. Some of these include the work of Joung et al, (1979), Nishidia et al (1982), and Prasad and Boesse, J.M. (2001). Ajayi (1995) interpreted regional soil and active stream sediments by using moving average and trend surface technique from Ilesha gold field and concluded that the techniques are useful for interpreting geochemical data and applicable where anomalous/background contrasts are generally low. Ajayi (1981) also carried out statistical geochemical exploration in ife/ilesha of 176 stream sediment samples from an area of 1800km^2 for copper, zinc, manganese, nickel and cobalt and found out that all the elements have density distribution closely approaching lognormal. The factor analysis for cu-co-ni correlates spatially with area underlain by amphibolite complex, thus reflecting the parent rock as the influencing factor.

This research attempts to unravel the underlying lithologic units; as well as assist in understanding the geological and geochemical characteristics of the major rock units by studying the rocks and analyzing stream sediment and borehole (water) in order to obtain baseline geological and geochemical information about the study area.

Location, Accessibility And Human Settlement : The study area lies within latitudes 07^{0}50'10"N and 08^{0}00'N and longitudes 004^{0}56'30"E and 05^{0}01'E respectively. It covers part of the topographic map sheet No. 243 (Ilesha N.E, 1:50,000) and sheet No 244 {Ado sheet, N.W. 1:50,000). The study area covers part of Ekiti and Osun States, southwestern Nigeria, with a total surface area of 138.45km^2. The major towns in the area include; Oke-Ila, Ilupeju, Soso, Oba-Sinkin, Ayegunle, Kajola and Ajindo (Figure.1).

The study areas which fall within Osun State can be rated moderate due to interconnectivity of roads while areas within Ekiti State can be rated poor, because there are only minor roads and footpaths, which are not motorable but trekable. The research work was carried out during the dry season, thereby making accessibility to the outcrops less difficult. Areas within Ekiti State are mainly small villages with linear settlements and in Osun State, towns with nucleated settlement predominates. Generally, most rocks encountered are moderately weathered to weathered with few exposures usually along stream channels and road cuts. Vegetation in most part of the area is derived savannah due to human activities such as deforestation and perennial bush burning while other parts are underlain by thick vegetation and soil cover.

Topographyand Drainage: The study area is underlain by a prominent northwest to southwest trending ridge known as the Effon Psammite Formation, which covers towns like Oke-Ila, Ilupeju, Oba-Sinkin, Ayegunle to eastern parts of Okemesi, with a gorge around Ayikunnugba (Oke-Ila), while other part of the areas are underlain by low-lying outcrops and isolated hills with an estimated height of about 2000metres above sea level. The pattern of drainage within the study area is mainly dendritic, and trellis drainage pattern along the jointed and fractured rocks. The drainage pattern is structurally controlled with a prominent river called River Oyi which flows in a southerly direction (Figure.2).

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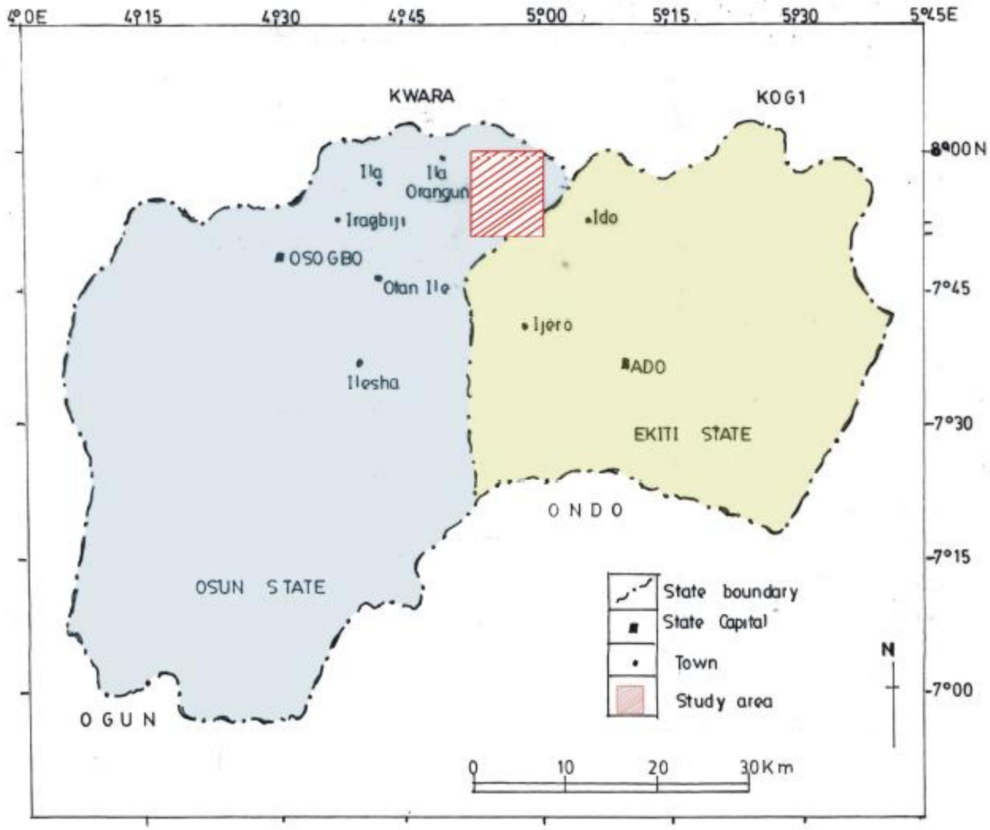

Figure 1: Location Map of the Study Area

A water fall was encountered around Oke-Ila called Ayikunnugba waterfall. Most streams in the area are actively flowing while some are stagnant and others have dried channels owing to dry season especially from November to April. The disposition of rivers and streams within the area is controlled by the following factors such as the gradient / slope of the highland, the prevailing climatic condition, the structural features e.g. joint, fracture, vein, foliation etc, geomorphology and physiology of the area and lastly, the lithology of the area.

Regional Geologic Setting: The study area is underlain by crystalline rocks of Precambrian Basement Complex of southwestern Nigeria, which is also part of the Basement Complex rocks of Nigeria. The study area is also part of the regional Dahomeyide fold belt defined by Affaton et al. (1991), and so it is not an exception to the structural and deformational episodes that pervaded Nigeria's Precambrian Basement Complex. Within the basement complex, tectonic deformation has completely obliterated primary structures (Oluyide, 1988) except in a few places where they survived deformation (Okonkwo, 1992). The study area is also an extension of the Ife-Ilesha schist belt, which is made up of different lithologic units. The major rock units within the belt are the amphibolite complex, the schists and the quartzitic sequence (Elueze, 1988). The Ifewara fracture zone separates the rock of Ilesha schist belt into two structural units of contrasting lithologies (Hubbard, 1975; Ako et al., 1978, Folami, 1992; Odeyemi, 1993). Other workers (Klemm et al., 1984; Wright et al., 1985; Oyinloye and Odeyemi, 2001; Anifowose, 2004) have provided evidences in support of the existence of the structure as well as its significance in terms of tectonic movements.

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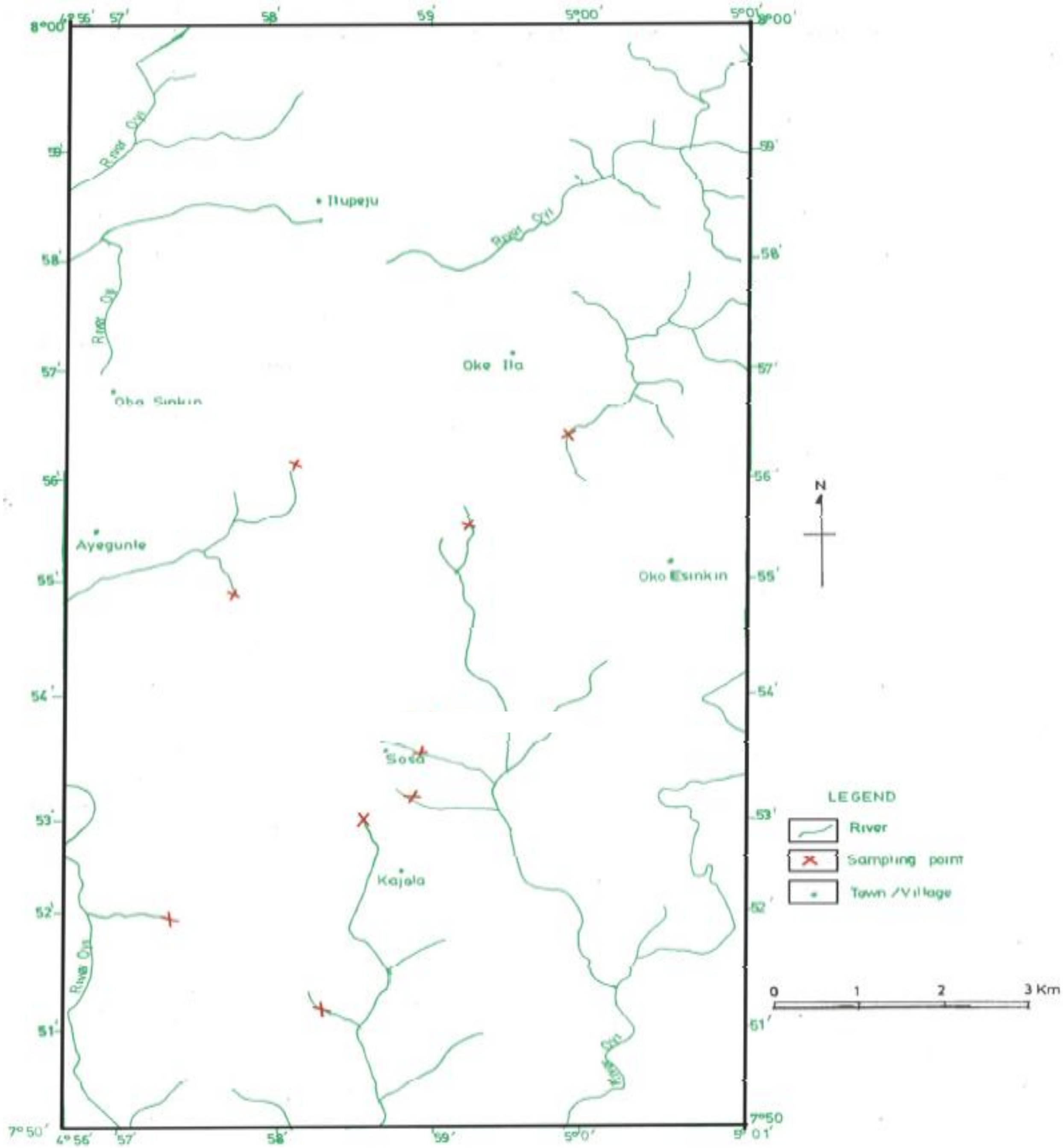

Figure 2: Drainage Map of the Study Area

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 (Black, 1980). 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 600Ma 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 (Burke and Dewey, 1972; Dada, 2006). 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 (2,700Ma), the Eburnean (2500Ma), the kibaran (1,100Ma), and the Pan-African cycles (600Ma). 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 (Gandu et al 1986). Anifowose (2004) 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 (Dada 2006), namely;

- 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 part of the basement complex of southwestern which itself is part of the basement complex of Nigeria. The study area is underlain by gneisses, migmatites and metasediments ranging from Precambrian to Paleozoic age. The lithologies vary considerably, with the following rock units such as banded gneiss, Quartzite, biotite gneiss, biotite schist, quartz-biotite-schist and pegmatite.

Banded Gneiss: This unit covers the southwestern part of the study area around Okokoro, Aba Francis and Aba-Ori-Apata near Ikoro-Ekiti. Texturally, they are medium to coarse grained with alternating bands of light and dark coloured portions with complete gradation between them. They occur as low lying outcrops which have been intruded by pegmatite in the southeastern corner of the area

Quartzite: These tend to form good topographic features which rise up to about 400 metres above the surrounding terrains forming ridges. Quartzites cover the northern part around Oke-Ila, Ilupeju areas to central, western (Ayegunle), extending to the southwestern and southern parts (Ajindo) of the study area. Around the study area, the varieties of quartzite encountered are massive, milky, smoky, sugary and schistose quartzites, however, schistose and smoky varieties occur chiefly in the area. The rocks have varying textures from equigranular, medium grained to coarse grained. The varieties of quartzites are so closely related that, often, it is impossible to indicate them as separate units on the map. The quartzites consist of mainly quartz which is usually more than 90% with minor amounts of interlocking grains of muscovite and biotite. Structurally, the quartzites are highly jointed, with some having joint sets around Ayikunnugba (Oke-Ila) area and others are foliated by the presence of micaceous streaks. Dips ranging between 40^0W – 66^0W were measured around Soso and Oko Ajindo areas.

Biotite Gneiss: This is a medium grained dark to almost black coloured rock composed chiefly of biotite and little quartz with foliation. A band of biotite gneiss concordantly lies within the quartzites around Ajindo area. The rock have been weathered and covered mostly on all sides by sand, thereby making field observation difficult to carry out.

Biotite Schist: These outcrops occur around Arapate Erigbe area as a lenticular body within quartzites and it is exposed due to stream activity as low lying outcrop. Structurally, foliation is present thereby making the name biotite schist" appended to the rock as confirmed by petrographic studies. There is also the presence of microfolds and joints which control the flow of the stream. Field observation shows that the rock unit dips at 48^0W to the surrounding rocks. The rock is found to be medium grained.

Quartz-Biotite Schist: This occurs in low land areas between quartzite and banded-gneiss around Oko-Esinkin area (eastern part) where it has been exposed by stream channel and road cut. The foliation on the outcrop is defined by biotite streaks. The rock is coarse grained and contains mainly biotite and quartz.

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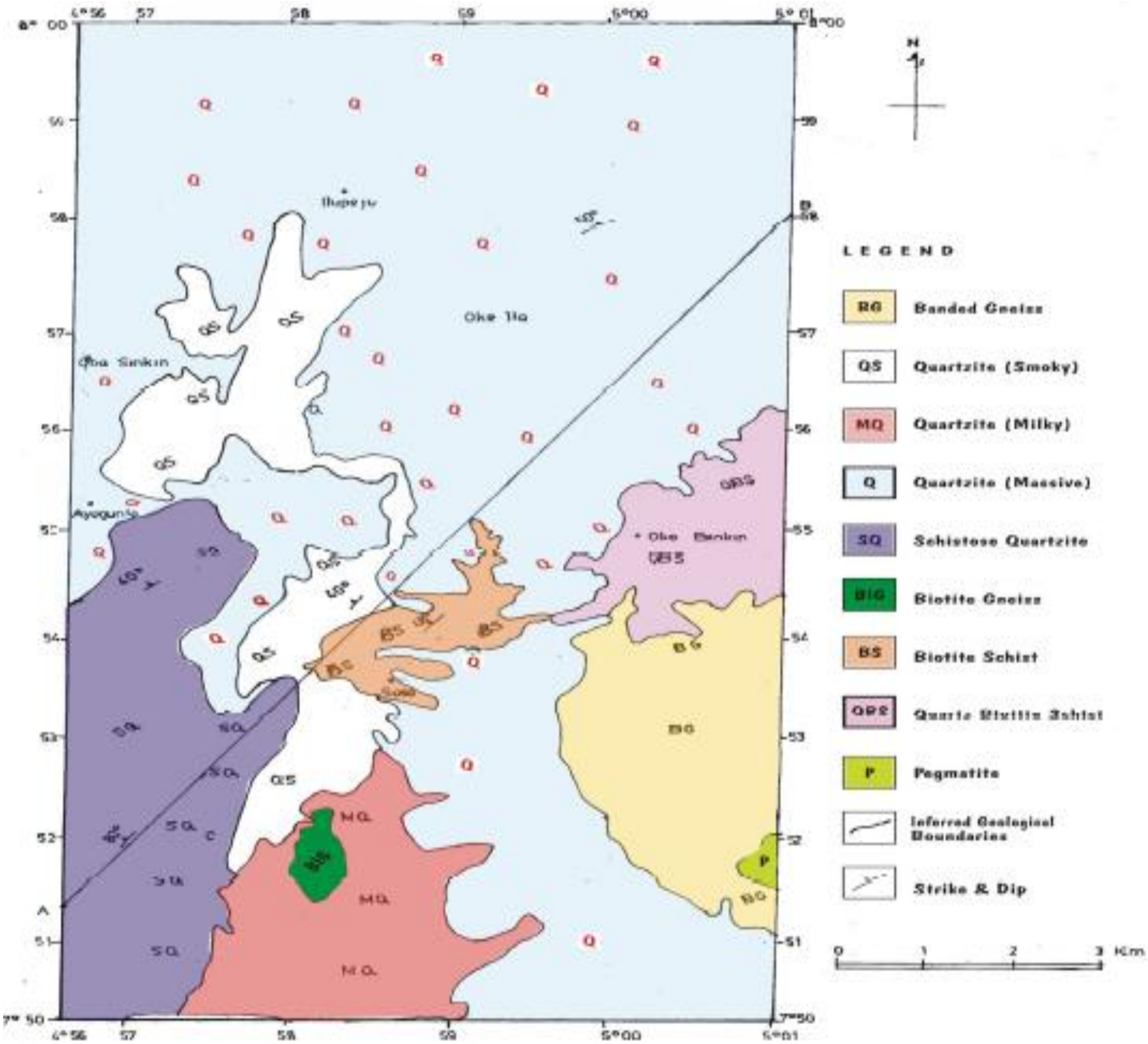

Figure 3a: Geologic Map of Study Area

Pegmatite: This lithologic unit ranges from a few meters in length and it is concentrated in the southeastern corner of the study area where it intrudes banded gneiss around Aba-Francis, Ikoro area as an isolated hill. Texturally, it is extremely coarse grained with quartz, feldspar and muscovite as distinguished mineral component. Quartz vein and veinlets were noticed on the outcrop.Based on field observation; the pegmatite is complex in nature with distinct textural and mineralogical variations. The geologic and cross-sectional maps of the study area are presented (Figure 3a & b).

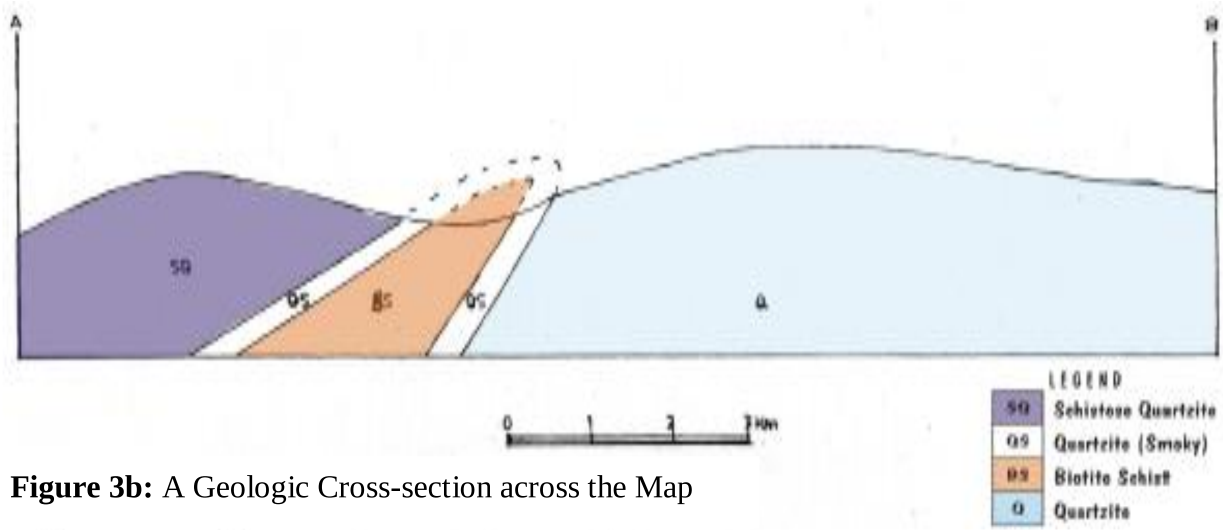

Figure 3b: A Geologic Cross-section across the Map

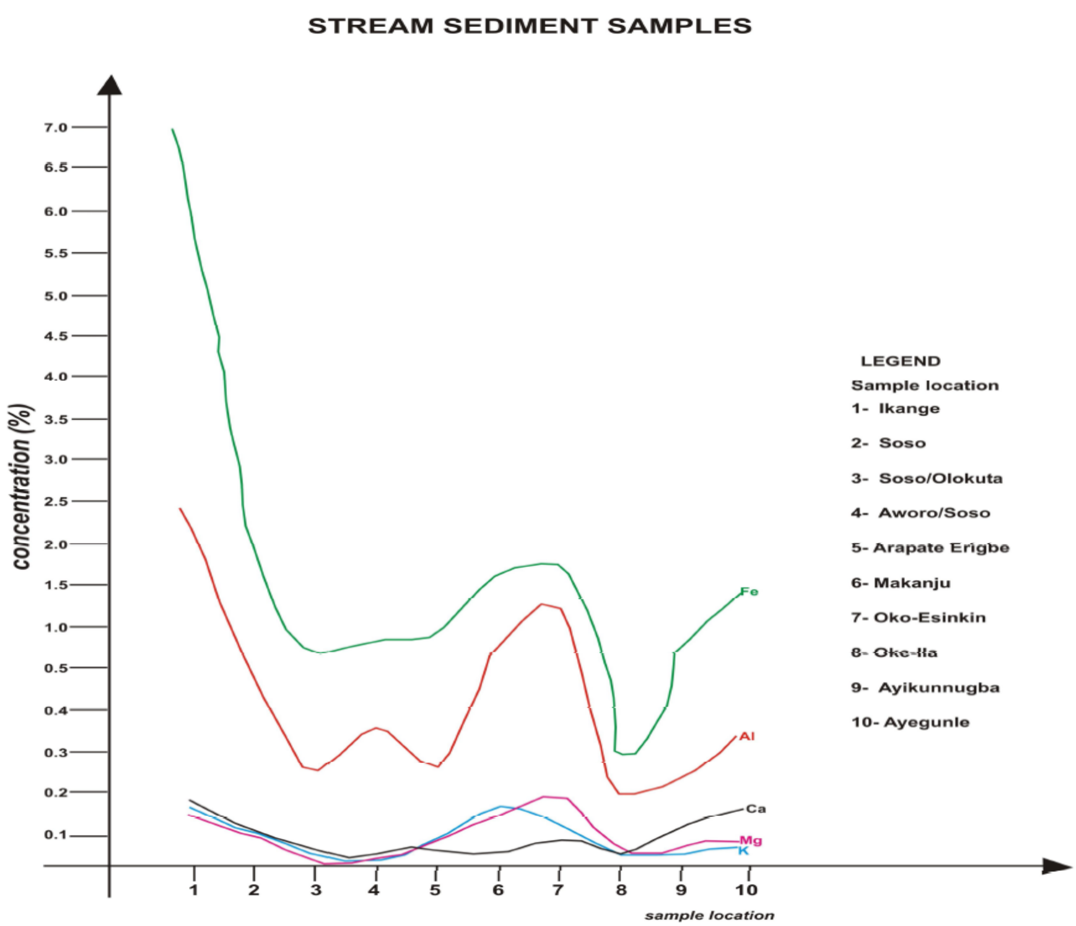

Figure 4: Plot Concentration against Sample Location for Al, Ca, Fe, K and Mg

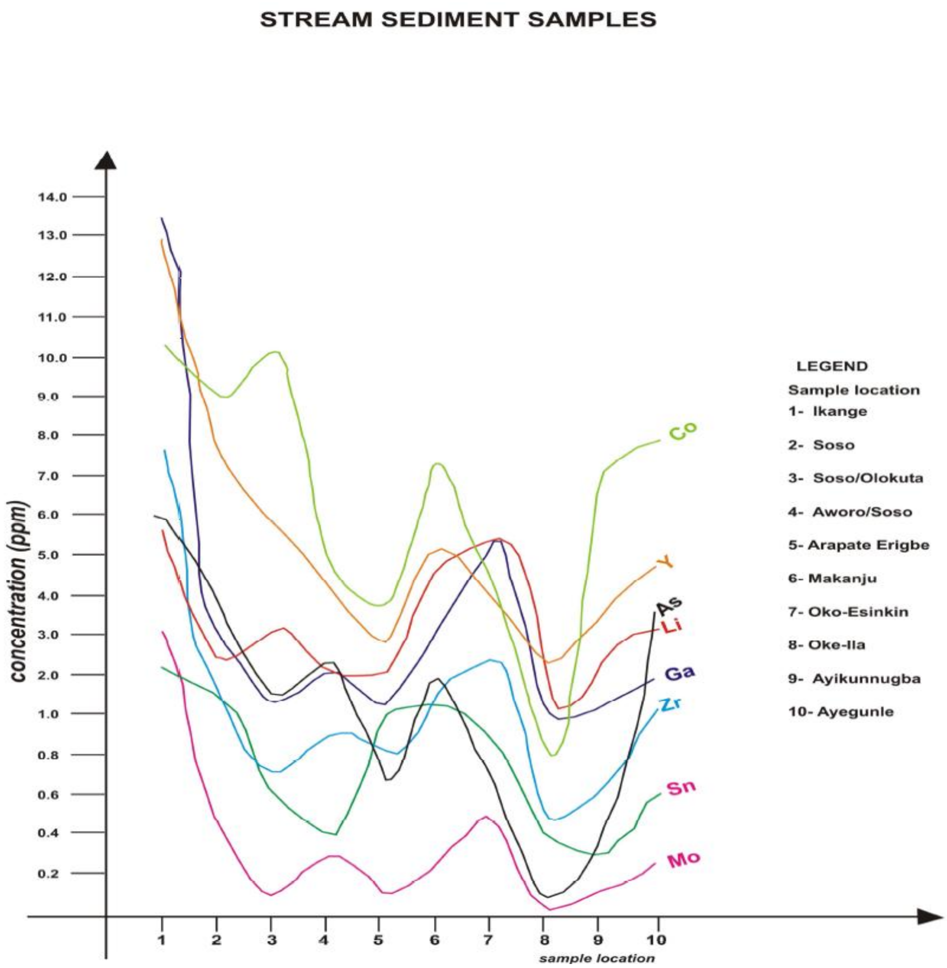

Figure 5: Plot Concentration against Sample Location for As, Co, Li, Mo,Y and Zr

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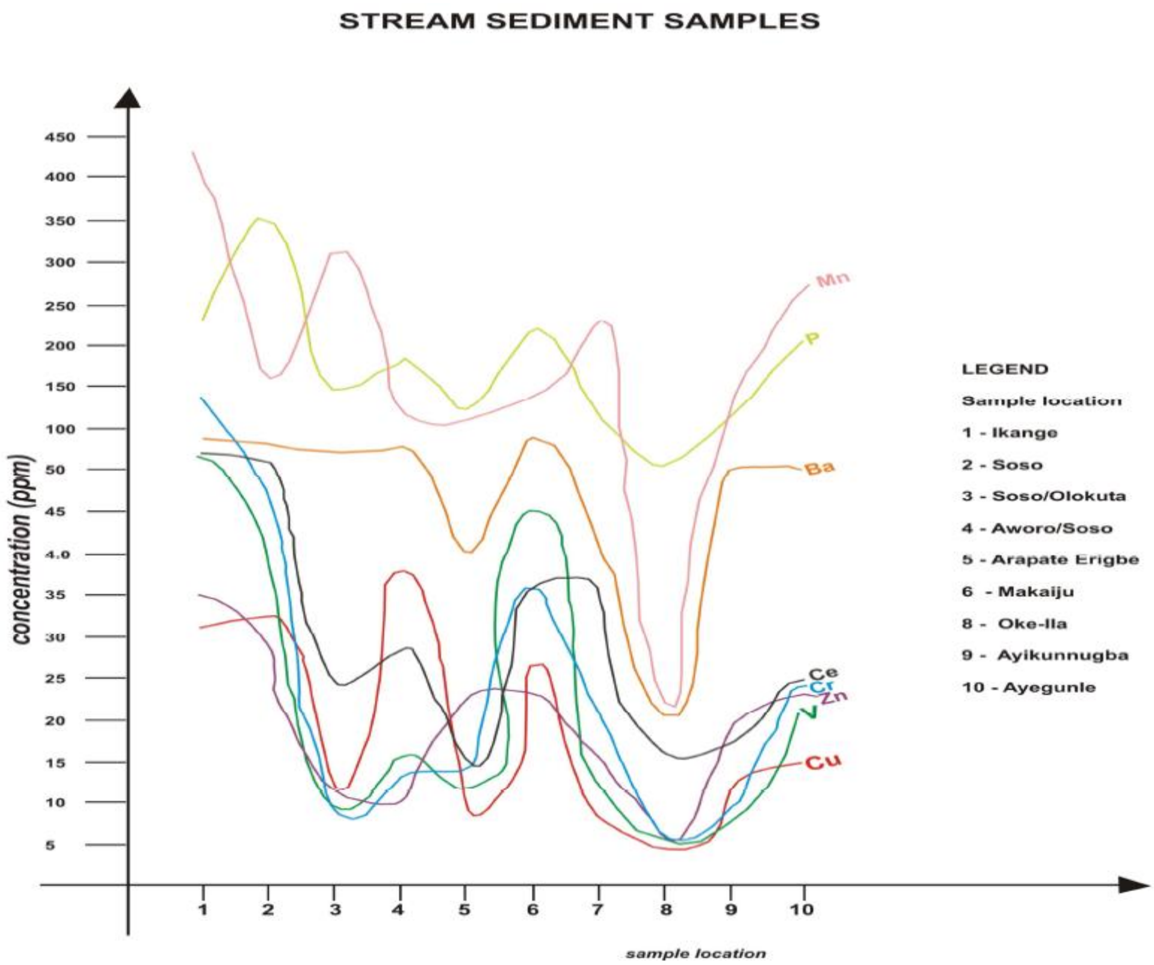

Figure 6: Plot of Concentration (PPM) against Sample Location for Ba, Ce,Cr, Cu, Mn, P, V and Zn

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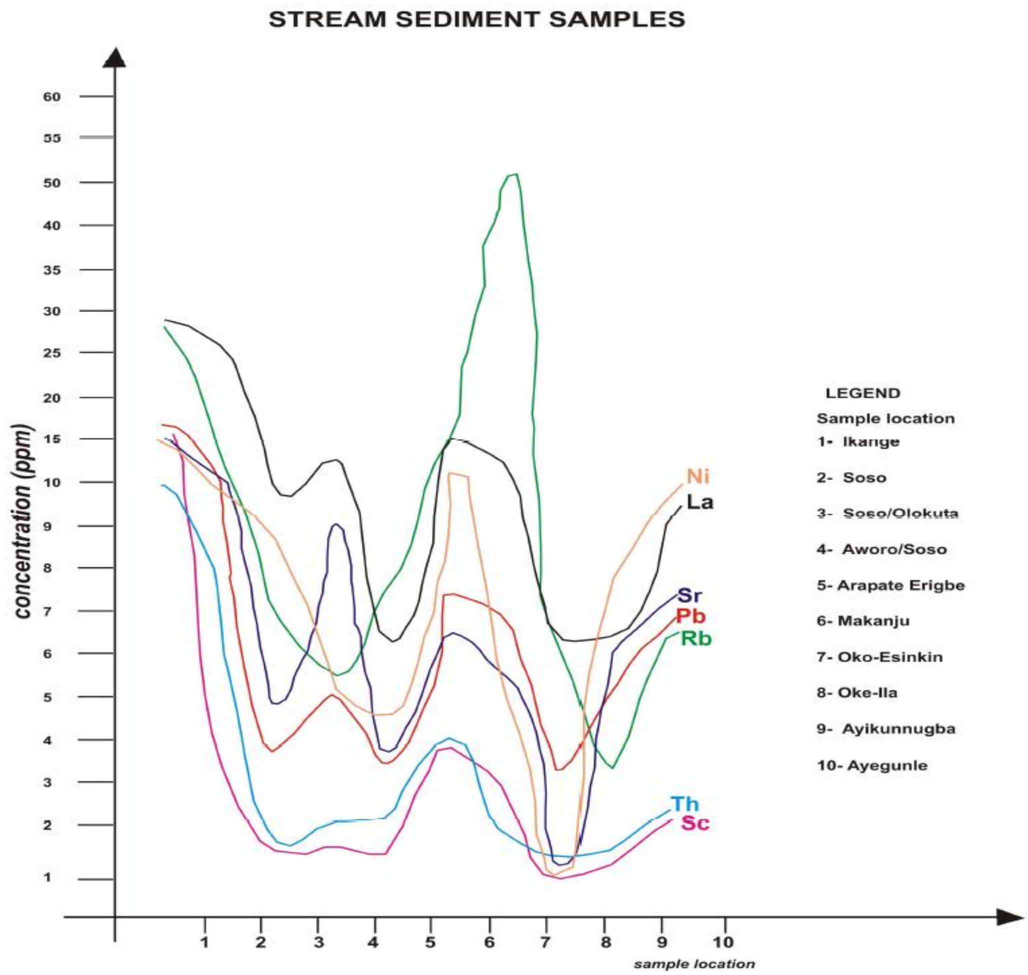

Figure 7: Plots of Anions Concentration against Sample Location for Ni, La, Sr, Pb, Rb, Th and Sc

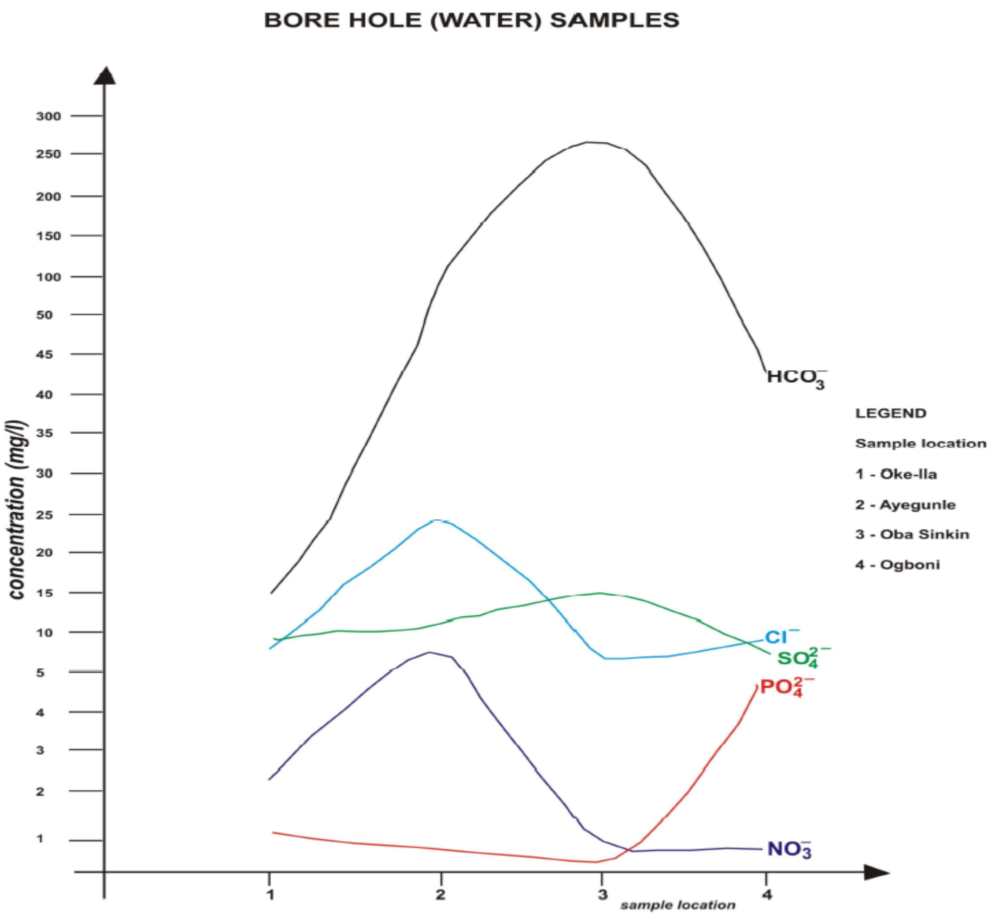

Figure 8: Plots of Anions Concentration against Sample Location

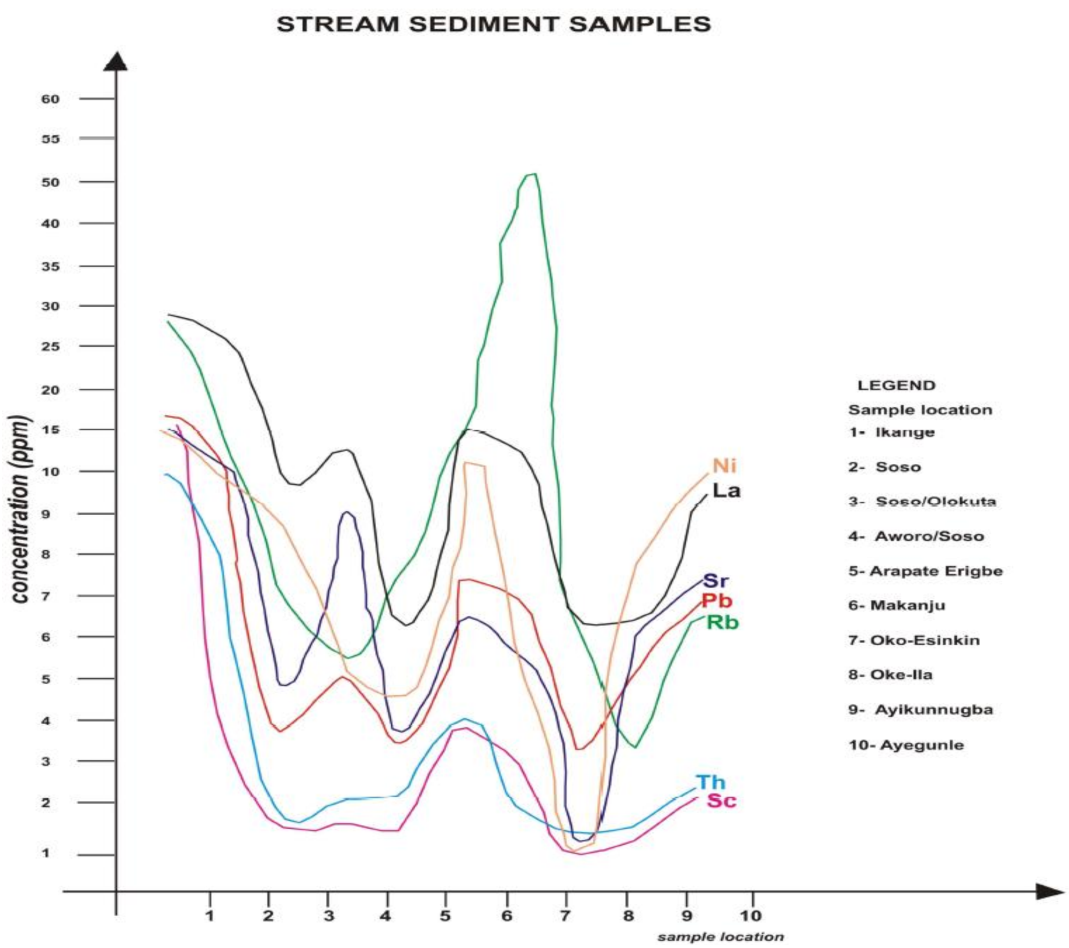

Figure 9: Plot of Concentration against Sample Location for La, Ni, Pb,Sc, Sr, and Th

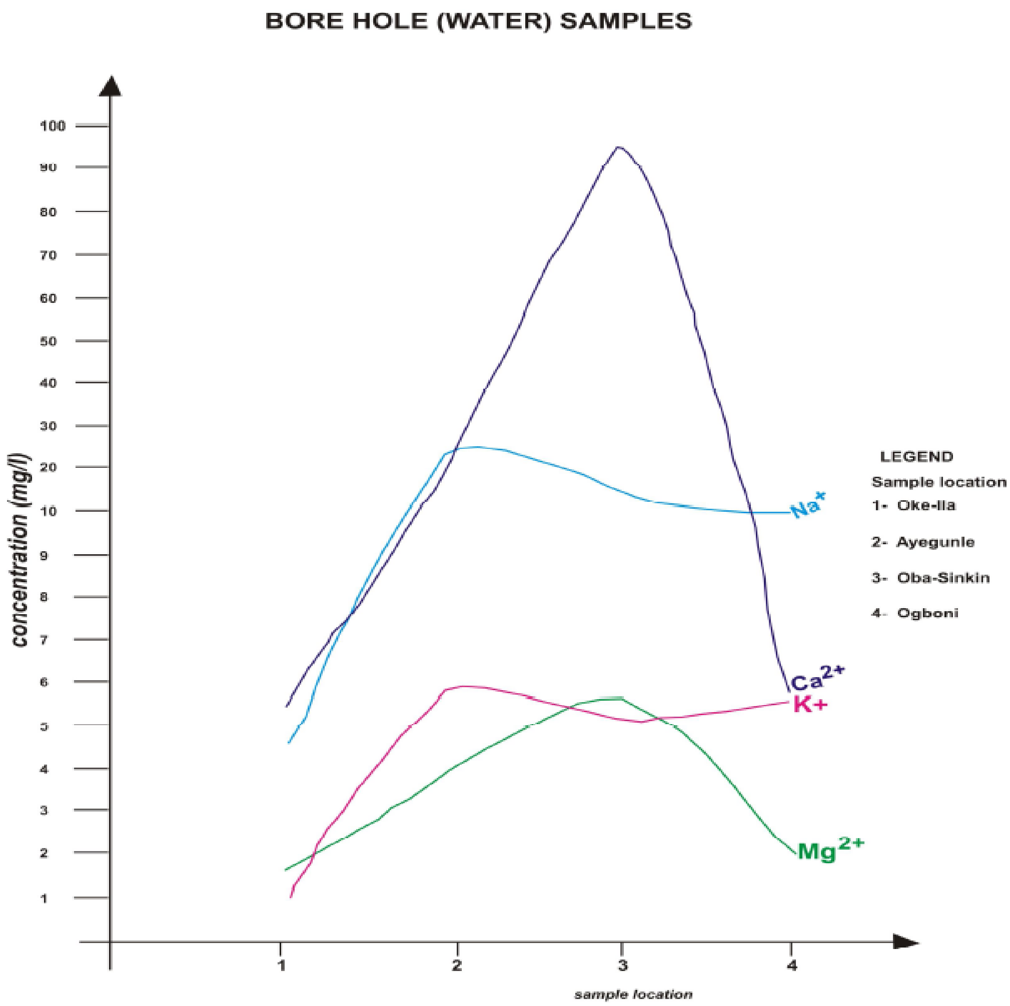

Figure 10: Plots of Cations Concentration against the Sample Location

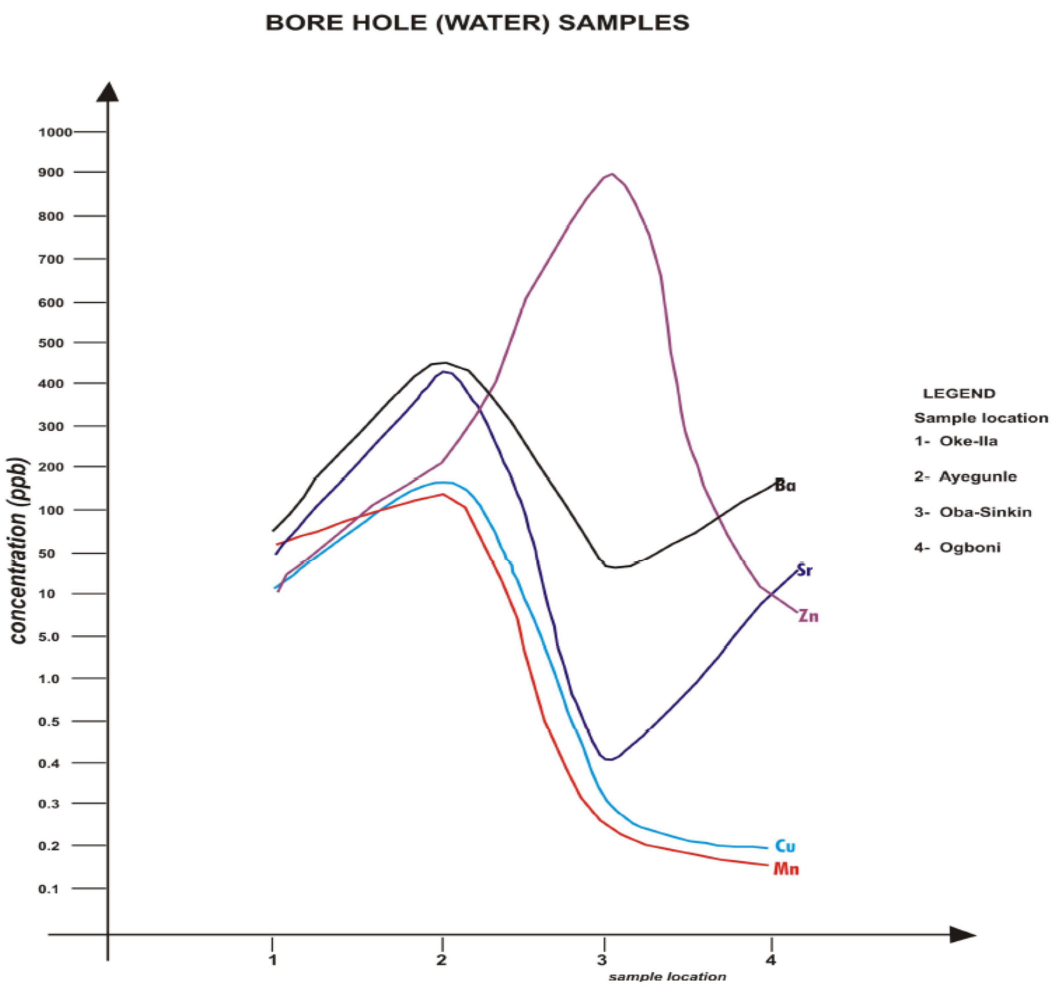

Figure 11: Plots of Concentration against the Sample Location for Ba, Cu, Mn, Sr, and Zn

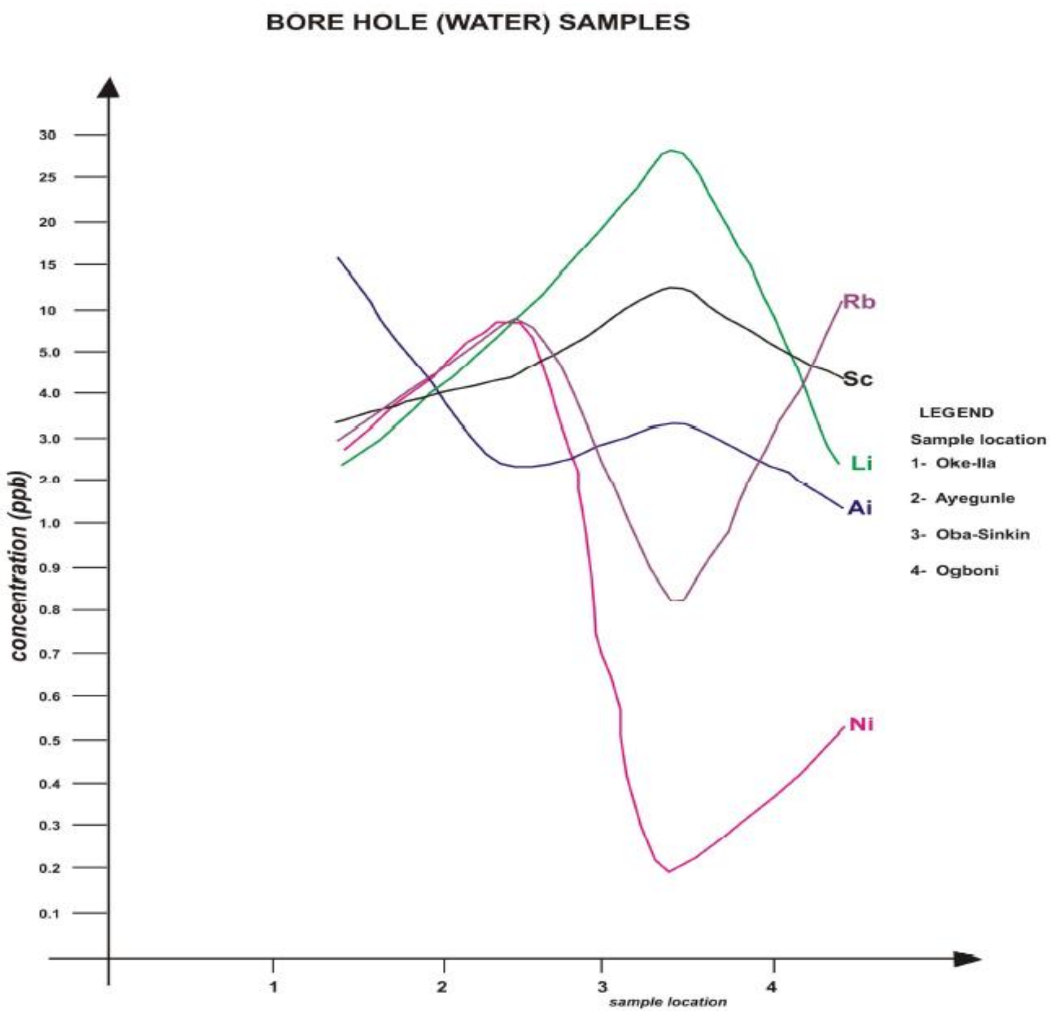

Figure 12: Plots of Concentration against the Sample Location for Al, I, Ni, Rb, and Sc.

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MATERIALS AND METHODS

Various materials were used for the different aspect of this work, some of the materials include; sample bags used in storing rocks and stream sediment samples before it was transported to the laboratory. The samples were carefully labeled with permanent markers to avoid mix up. A set of sieves with perforations of different sizes were also used. The first sieve has 0.150mm as its aperture size while the second has 2mm aperture size. These were used in separating sediments of 2mm and 0.150 fraction sizes from the bulk samples. Other materials included compass clinometers, global positioning system (GPS). The method adopted for this work involves systematic geologic mapping of the basement rocks and also systematic sampling of the stream sediments along stream channels. It involves both field work and laboratory exercises.

The field work is essentially geologic mapping. Systematic geological mapping was carried out on a scale of 1:50,000 using grid-controlled sampling of the stream sediment channels. Fifteen stream sediment samples were initially obtained while ten which were representative of the different stream channels were eventually analysed. The stream sediment samples were taken at a depth of 20-25cm, bagged and transported to the laboratory. The process of sample preparation involves pulverizing and homogenizing the stream sediment samples in order to allow it for geochemical analysis. The jaw crusher was used to crush the samples to tiny bits until it became very fine. Methylated spirit was used to cleaning the milling machine after each crushing to avoid contamination; the samples were later digested using aqua regia method and placed in a sample container which was properly labeled. The samples were transferred to the laboratory for major, trace and rare earth elements determination. The analyses were carried out at ACME Laboratories East Vancouver, Canada. The analysis involves the use of aqua regia method for the major element analysis, spectrophotometer for the borehole/well water samples and the use of Multi-collector High Resolution inductively coupled Plasma-Mass Spectrometry (ICP-MS) for the trace and rare earth elements.

RESULTS AND DISCUSSION

The data collected from the field for the rocks, stream sediment and borehole (water) samples are presented in Table 1-3.

Table 1 presents the field description of the different lithological units mapped in the study area; table 2 shows the field data for the stream sediment samples, while table 3 presents the field data for borehole (water) samples collected in the study area. Table 4 presents the condensed descriptive statistics for the concentration of elements in stream sediment samples, which include minimum and maximum values, mean, median, standard deviation, skewness and kurtosis, while table 5 presents the minimum and maximum values, mean and World Health Organization (WHO) limits for borehole (water) samples. From Table 4 and 5, statistical analysis characterizes the location and variability of data set. The data distribution is generally positively skewed except for cadmium, which indicates that the data is skewed to the right that is the right tail of the graph (Figures 4–12) is long relative to the left tail which means that the elements have higher close values around left of the western part of the study area, which is mainly underlain by quartzites of varying composition than the eastern part. Values of Kurtosis for the data set is positive indicating a peaked distribution (Figures 4 –12) for the elements around Ikange, Makanju and Ayegunle areas respectively. The sample locations also fell in the western part of the study area that is mainly underlain by quartzites (smoky), which play a role as the major influencing factor. Fe/Ca/Mg has been used as a lithological index reflecting the geology of the underlying rocks (Ojo, 1988). Low concentration of the major elements Fe, Ca, Mg, Al, K, Na, S, Ti, observed in the stream sediment samples is attributed to the fact that the area is underlain by rocks that are low in olivine, pyroxene, amphibole and other minerals that bear the elements.

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Table 1: Field Data for Rock Samples

Sam No	Location	Latitude/ longitude	Rock type	Texture	Structure	Colour	Mineralogy	Lithology	Strike /Dip	Remark
1	Aba Ori-Apata (Okemesi road)	07^{0}51^{1}49.1N 005^{0}01^{1}04^{1}.1E	Metamorphic	Medium grained	Banding	Grey	Quart, biotite feldspar	Banded Gneiss	-	Alternation of felsic and mafic mineral,
2	Aba Francis (Ikoro-Okemesi)	07^{0}51^{1}49.9N 005^{0}01^{1}05^{1}.1E	Igneous	Very coarse	-	Impure white	Quartz muscovite, feldspar	pegmatite	-	Extremely coarse grained due to slow cooling rate
3	Ajindo	07^{0}52^{1}193N 004^{0}58240^{1}.1E	Metamorphic	Equigramular	Micro-joint	Milky	Quartz	Quartzite (milky)	-	-
4	Aworo	07^{0}51^{1}527^{1}N 004^{0}58007^{1}E	“	Medium	“	Dark to green black	Biotite, quartz	Biotite gneiss	-	Weathered outcrop
5	Makanju	07^{0}52^{1}579^{1}N 004^{0}57,698^{1}E	“	“	Joint	Silvery grey	Quartz, mica	Quartzite	-	
6	Olutoki (Okemesi)	07^{0}52^{1}335^{1}N 004^{0}57.468^{1}E	“	“	Foliation	Pink	Quartz, mica, feldspar	Schistose quartzite	024^{0} 80^{0}W	Tiny specks, of micaceous, mineral
7	Oko Ajindo	07^{0}52^{1}912^{1}N 004^{0}57.561^{1}E	“	“	Joints, fracture	Pink	Quartz, mica, feldspar	Schistose quartzite	034^{0} 40^{0}W	“
8	Aworo (Soso)	07^{0}54^{1}380^{1}N 004^{0}58.380^{1}E	“	Equigranular	-	Smoky	Quartz	Quartzite (Smoky)	“	Exposed by a stream
9	Olokuta (Soso)	07^{0}51^{1}527^{1}N 004^{0}58007^{1}E	Metamorphic	Equigranular	Foliation	Smoky	Quartz	Quartizite	028^{0} 40^{0}N	Exposed by a stream
10	Arapate Erigbe	07^{0}54^{1}474^{1}N 004^{0}58.064^{1}E	“	Coarse	-	Smoky	Quartz, mica	Quartzite	0.28^{0} 40^{0}N	Shiny surface due to the presence of mica
11	Arapate / Soso	07^{0}54^{1}380^{1}N 004^{0}58.087^{1}E	“	Medium	Foliation, microfold	Dark grey	Quartz biotite	Biotite schist	032^{0} 48^{0}W	Presence of microfold
12	Oke Jewoese	07^{0}54.474^{1}N 004^{0}57.931^{1}E	“	“	Foliation	Pink	Quartz, mica feldspar	Schistose quartzite	046^{0} 66^{0}W	An isolated hill
13	Okokoro	07^{0}55^{1}28.3^{1}N 005^{0}001^{1}10.6^{1}E	“	Coarse	Fracture	Light grey	Quartz, mica	Massive quartzite	-	Shiny surface due to micaceous flakes
14	Oko Esinkin (1)	07^{0}55^{1}14.6^{11}N 005^{0}001^{1}42.4^{1}E	“	Medium	Banding	Light grey	Quartz biotite	Banded gneiss	-	-
15	Oko Esinkin (2)	07^{0}54^{1}48.5^{1}N 005^{0}001^{1}22.3^{1}E	“	Coarse	Fracture, foliation	Grey to dark	Quartz, biotite, muscovite	Quartz-Biotite schist	-	Well foliated outcrop with distinct mineralogy
16	Oke-Ila 1	07^{0}56^{1}89.4^{1}N 004^{0}58.59.9^{1}E	Metamorphic	Medium	Solution hole	Light grey	Quartz, feldspar muscovite	Massive quartzite	-	Parts of the outcrop have pegmatitic intrusion
17	Oke-Ila 2	07^{0}57^{1}53.8^{11}N 004^{0}57^{1} 45.2^{11}E	“	Granular	Fracture	Sugary white	Quartz muscovite	Quartzite	-	Muscovite specks sandwiched in the quartzite
18	Ayikunnugba waterfall	07^{0}55^{1}40.2^{11}N 004^{0}57.55.7^{11}E	“	Granular	Joint set, caves, solution hole	Sugary white	Quartz muscovite	Quartzite	-	“
19	Ayegunle	07^{0}55^{1}14.6^{11}N 004^{0}57.02.0^{11}E	“	Coarse	Joint	Smoky	Quartz	-	-	-
20	Ayegbaju	07^{0}55^{1}08.4^{11}N 005^{0}01^{1}06.3^{11}E	“	“	-	“	“	“	-	-
21	Ilupeju	07^{0}58^{1}54.2^{11}N 004^{0}57^{1}31.0^{11}E	“	“	-	Impure white	“	Quartzite	-	-

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Table 2: Field Data for Stream Sediment Samples

Sample No	Location	Latitude /Longitude	Lithology	Texture	Remarks
1	Ikange	07^{0}52.007^{11}N 004^{0}58^1.416^{11}E	Quartzite	Fine & coarse	Lithology exposed due to stream flow
2	Soso	07^{0}53.415^{1}N 004^{0}58.302^{1}E	-	”	High energy stream
3	Soso / Olokuta	07^{0}54.519^{1}N 004^{0}58.135^{1}E	Quartzite (Smoky)	”	The joints on the lithology control the drainage
4	Aworo / Soso	07^{0}54.380^{1}N 004^{0}58.089^{1}E	Quartzite (Smoky)	“	“
5	Arapate Erigbe	07^{0}53.775^{1}N 004^{0}58.210^{1}E	Biotite schist	“	Lithology exposed due to stream flow
6	Makanju	07^{0}53.775^{1}N 004^{0}58.064^{1}E	Quartzite (smoky)	“	Low energy stream
7	Oko-Esinkin	07^{0}54^{1}48.5^{11}N 005^{0}01^{1}22.3^{11}E	Quartz-Biotite schist	“	Lithology exposed due to stream action
8	Oke-Ila	07^{0}56^{1}39.5^{11}N 004^{0}59.552^{1}E	Quartzite	“	Stream water has laached out some soluble minerals forming solution holes on the outcrop
9	Ayinkunnugba	07^{0}53^{1}40.2^{11}N 004^{0}57^{1}55.7^{1}E	Quartzite (smoky)	“	Presence of water fall with a very high energy.
10	Ayegunle	07^{0}55^{1}13.5^{11}N 004^{0}57.01^{1}E	-	“	No lithology exposed by stream

Table 3: Field Data for Borehole (water) samples

Sample No	Location	Latitude / Longitude	Lithology	Type of Wells	Remarks
1	Oke-Ila	07^{0}57^{1}007N 004^{0}58.58.5E	Quartzite	Borehole	-
2	Ayegunle	07^{0}55^{1}13.5^{11}N 004^{0}57^{1}01.2^{11}E	Quartzite	Borehole	-
3	Oba Sinkin	07^{0}56^{1}36.5^{11}N 004^{0}56^{1}41.5^{11}E	Quartzite	Borehole	-
4	Ogboni	07^{0}52$^.$820^{1}N 004^{0}58.241^{1}E	Quartzite	Borehole	This is the only well in the area

Table 4: Condensed Descriptive Statistics for Stream Sediment Samples

S/n	Element	Unit	Min	Max	Mean	Median	Standard Deviation	Skewness	kurtosis
1	Al	%	0.18	2.42	0.636	0.335	1.50	0.06	0.22
2	Ca	%	0.01	0.16	0.063	0.05	0.11	0.08	0.07
3	Fe	%	0.27	6.98	1.698	1.08	3.72	0.32	0.45
4	K	%	0.01	0.13	0.065	0.04	0.145	0.01	0.004
5	Mg	%	0.01	0.14	0.061	0.045	0.124	0.03	0.02
6	Na	%	0.01	0.02	0.012	0.01	0.006	0.26	0.35
7	S	%	0.01	0.02	0.013	0.01	0.009	0.004	0.01
8	Ti	%	0.007	0.057	0.029	0.021	0.061	0.01	0.005
9	Ag	ppm	0.01	0.08	0.039	0.035	0.05	0.001	0.0002
10	As	ppm	0.1	6	2.09	1.7	4.04	0.1	0.097
11	Au	ppm	<0.2	-	<0.2	<0.2	0	0	0
12	P	ppm	<10	-	<10	<10	0	0	0
13	Ba	ppm	20	90	61	60	66.4	0.009	0.004
14	Be	ppm	0.07	1.1	0.531	0.55	1.02	0.0007	0.0001
15	Bi	ppm	0.02	0.99	0.146	0.055	0.534	0.44	0.69
16	Cd	ppm	0.01	0.06	0.037	0.04	0.056	-0.003	0.001
17	Ce	ppm	14.2	72.8	32.82	26.85	43.90	0.08	0.08
18	Co	ppm	0.8	10.3	6.54	7.15	7.82	0.01	0.006
19	Cr	ppm	5	69	24.1	14	51.67	0.07	0.06
20	Cs	ppm	0.47	1.29	0.083	0.04	0.89	0.009	0.004
21	Cu	ppm	4.8	38.4	19.04	13.2	34.75	0.005	0.002
22	Ga	ppm	0.91	13.75	3.43	2.07	7.65	0.27	0.37
23	Ge	ppm	<0.05	0.14	0.069	0.055	0.06	0.18	0.22
24	Hf	ppm	<0.02	0.2	0.053	0.04	0.097	0.39	0.58
25	Hg	ppm	0.01	0.03	0.021	0.02	0.017	0.016	0.008
26	In	ppm	0.006	0.01	0.021	0.01	0.053	0.35	0.52
27	La	ppm	6.3	29	13.56	11.45	18.75	0.06	0.05
28	Li	Ppm	1.1	5.6	3.21	2.8	3.84	0.03	0.02
29	Mn	ppm	21	432	190.5	150	306.11	0.05	0.04
30	Mo	ppm	0.12	3.31	0.55	0.0255	1.75	0.44	0.69
31	Nb	ppm	0.21	1.66	0.623	0.43	1.12	0.001	0.0002
32	Ni	ppm	1	15.6	8.65	8.55	9.96	0.04	0.03
33	P	ppm	50	350	171	160	199.2	0.003	0.001
34	Pb	ppm	3.8	15.1	7.4	7.0	8.10	0.09	0.09
35	Rb	ppm	3.5	52.8	14.63	7.35	33.72	0.008	0.003
36	Re	ppm	<0.01	-	<0.001	<0.001	0	0	0
37	Sb	ppm	<0.05	0.52	0.252	0.165	0.43	0.03	0.02
38	Sc	ppm	1	15.8	3.57	1.95	8.09	0.38	0.58
39	Se	Ppm	<0.2	0.7	0.38	0.35	0.38	0.07	0.055
40	Sn	ppm	0.3	2.2	0.9	0.75	1.52	0.07	0.06
41	Sr	ppm	1.2	17.1	6.76	6.1	9.44	0.15	0.16
42	Ta	ppm	<0.01	-	<0.01	<0.01	0	0	0
43	Te	ppm	<0.01	0.06	0.015	0.01	0.04	0.16	0.18
44	Th	ppm	1.6	10	3.45	2.25	6.55	0.11	0.11
45	Tl	ppm	0.06	0.31	0.115	0.08	0.21	0.03	0.02
46	U	ppm	0.29	3.02	0.81	0.54	1.48	0.41	0.63
47	V	ppm	5	142	31.8	17.5	82.60	0.26	0.35
48	W	ppm	<0.05	0.34	0.112	0.065	0.23	0.11	0.11
49	Y	ppm	2.2	13	6.131	5.0	8.98	0.05	0.04
50	Zn	ppm	5	35	19.2	21	23.4	0.03	0.02
51	Zr	ppm	<0.5	7.7	1.77	1.0	4.12	0.33	0.48

Table 5: Condensed Descriptive Statistics for Borehole (water) samples

S/n	Measured parameter	Unit	Min	Max	Mean	WHO General Standard (mg/l)	Max permissible (mg/l)
1	Total Hardness	mg/l$CaCO_3$	12	272	93.25	100	500
2	Total Alkalinity	mg/l$CaCO_3$	16	278	107.25	100	100
3	Chloride	mg/l$CaCO_3$	7.97	24.90	12.95	200	250
4	Nitrate	mg/l$CaCO_3$	<1.0	8.53	3.27	10	50
5	Bicarbonate	mg/l$CaCO_3$	16	278	107.25		
6	Sulphate	mg/l	9	16	11.75	250	500
7	Phosphate	mg/l	0.43	5.90	2.1		
8	Ca^{2+}	mg/l	2.24	109.57	32.07	NS	NS
9	K^{+}	mg/l	1.02	5.75	4.32	NS	NS
10	Mg^{2+}	mg/l	0.63	5.56	3.25	20	20
11	Na^{+}	mg/l	4.54	23.87	12.96		
12	Ag	Ppb	<0.05	-	<0.05	NS	NS
13	Al	Ppb	1	14	5.0	0.2	0.2
14	As	Ppb	<0.5	1.7	1.03	0.01	0.01
15	Au	Ppb	<0.05	-	<0.05		
16	B	Ppb	<5	6	5.25		
17	Ba	Ppb	29.19	448.07	184.16	0.05	0.07
18	Be	Ppb	<0.05	0.44	0.20		
19	Bi	Ppb	<0.05	-	<0.05		
20	Br	Ppb	22	126	93.5		
21	Cd	Ppb	<0.05	0.12	0.06	0.003	0.003
22	Ce	Ppb	<0.01	0.11	0.04		
23	Co	Ppb	<0.02	6.58	2.12		
24	Cr	Ppb	<0.5	9.9	3.0	0.05	0.07
25	Cs	Ppb	<0.01	0.79	0.24		
26	Cu	Ppb	0.2	169.7	46.53	200	250
27	Fe	Ppb	<10	-	<10	1	3
28	Ga	Ppb	<0.05	-	<0.05		
29	Ge	Ppb	0.18	0.27	0.24		
30	Hf	Ppb	<0.02	-	<0.02		
31	Hg	Ppb	<0.1	-	<0.1	0.001	0.001
32	In	Ppb	<0.01	-	<0.01		
33	La	Ppb	<0.01	-	<0.01		
34	Li	Ppb	2	26.9	9.23		
35	Mn	Ppb	0.16	146.01	51.94	0.1	0.4
36	Mo	Ppb	<0.1	-	<0.1		
37	Nb	Ppb	<0.01	-	<0.01		
38	Ni	Ppb	<0.2	6.9	2.48		
39	Pb	Ppb	<0.1	0.3	0.25	0.01	0.01
40	Rb	Ppb	0.79	9.81	4.96		
41	Re	Ppb	<0.01	-	<0.01		
42	Sb	Ppb	0.6	1.57	1.07		
43	Sc	Ppb	3	11	5.5		
44	Si	Ppb	7666	31334	14778.25		
45	Sn	Ppb	<0.05	-	<0.05		
46	Sr	Ppb	10.71	901.98	283.92		
47	Ta	Ppb	<0.02	-	<0.02		
48	Te	Ppb	<0.05	-	<0.05		
49	Th	Ppb	<0.05	-	<0.05		
50	Ti	Ppb	<10	-	<10		
51	Tl	Ppb	<0.1	0.1	0.04		
52	U	Ppb	<0.02	0.14	0.05		
53	V	Ppb	<0.2	0.8	0.3		
54	W	Ppb	<0.02	0.14	0.04		
55	Y	Ppb	<0.01	1.24	0.33		
56	Zn	Ppb	<0.5	436.8	125.0	0.01	0.07
57	Zr	Ppb	<0.02	-	<0.02		

The average concentration of the minor / trace element varies. Ba, Cr, Cu, Mn and Zn have diagnostic high values with respect to other elements. Their values are related to the bedrock lithology and suggest the absence of basic and ultrabasic rocks in the entire study area. Cu – Zn belong to the chalcophile group of elements, which are liberated from Cu / Zn bearing mineral in the country rocks as a soluble sulphate under acid to near natural condition and co-precipitated to stream particles (Boyle et al., 1996). Cu has its highest concentration around Ajindo (Aworo) where biotite-gneiss was encountered within the quartzites. Ni – Co – Pb have close values and are mostly concentrated in biotite of intermediate and acid rocks (Beus and Grigorian, 1977). As a result of weathering, these elements are released and pass directly through underground water into stream as sediments. Mn occurs in significant amounts in the areas especially in Ikange and other areas which quartzite is the main lithologic unit. Cr/As have values rather low for it to have been an indicator element for gold mineralization in the area. The rare earth elements that have conspicuous value in the area include Ce, Ga, La, Rb, Th, U, V, Mo and Y, which are all influenced by the underlying lithologic units. The concentration of cations in the samples is in the order $Na^+ > Ca^{2+} > Mg^+ > K^+$. Ca^{2+} which is one of the most common ions in subsurface water (David and Dewiest, 1966) with high values around Ayegunle and Obasinkin areas which is underlain by quartzite. Ca / Mg / Na are mainly released as weathering product of feldspars and amphiboles associated with basement complex while K is mainly controlled by plant uptake. The concentration of anions in the samples is in the order HCO_3- > SO_4^{2-} > Cl^- > NO_3- > PO_4^{3-} > Cl^- may occur as $MgCl_2$, $NaCl_2$ and $CaCl_2$. Its presence in natural water may be associated with environmental and atmospheric precipitation (Elueze et al., 2001). HCO_3- is the dominant anion in the water sample with a range 16 – 278mg/l. It is abnormally high at Obasinkin (location 3). Its concentration may be due to seasonal changes associated with chemical reactions during rainstorm. SO_4^{2-} has concentration that varies from 9 – 16mg/l. It is a major constituent of atmospheric precipitation (Davies and Dewiest, 1966) as well as dissolution of silicate minerals in the bedrock and aluminosilicates in the weathered regolith. No_3- and PO_4^{3-} has low concentration in the area and it is mainly controlled by plant uptake. Elements in water samples include minor / trace elements, rare earth element and heavy metals. Ba, Mn, Sr, Zn, Cu and Li have high concentration within the area which samples are collected. The area is mainly underlain by quartzites of Precambrian age which plays a major role in the borehole (water) chemistry. The mean values for As, Cr, Mn and Pb falls slightly above the World Health Organization (WHO, 2003) standard and permissible limits, which makes the water unfit for drinking.

The results from both stream sediment and borehole (water) sample plots reveal consistent high concentration patterns of element (major, trace and rare earth) around Ikange, Makanju, Ayegunle and Soso which are underlain by quartzite (smoky) with low values of concentration for gold and its pathfinder element.

The elemental concentration of stream sediment samples were given as percentages and parts per million (ppm) while borehole (water) samples are in parts per million (ppm) and part per billion (ppb). Inspite of their contrasting units of concentration, the results show an interesting trend. From the results, some elements that are not well represented in stream sediment sample tend to be more detectable in borehole (water) sample in the same area, which may be linked to the solubility of the elements. For instance, around Ayegunle in Osun State (Borehole sample 2 / stream sample 10), As, Co, La, Ga, Cr, Mn, Ni, Pb, Th, V, and Y are more conspicuous in water sample while Ba, Cu, Sc, Li and Zn have high values in stream sediment than water. The results of the stream sediment samples (Figures 4 –8) and borehole (water) samples (Figures 9 –12) are presented as plots of concentration against sample location for ease of comparison.

Geologically, the study area falls within the Precambrian Basement rocks of southwestern Nigeria with six major lithologic units namely; Quartzite, Banded-gneiss, Biotite-gneiss, Biotite-Schist, Quartz-Biotite Schist and Pegmatite. Structures encountered in the area include joint (Figure 13), solution hole (Figure 14), Microfold on Biotite Schist (Figure 15), Fracture (Figure 16), Foliation and banding. Generally, the strike values range from $024^0 – 046^0$ while dip values range between 40^0W – 80^0W in the area. Also, the more brittle nature of quartzites manifested in the presence of fractures and joints in greater number which controls the drainage pattern in the area. In the Ife-Ilesha area, (Ajayi, 1988) showed that the trace element in the stream sediment fall dominantly into background population in their statistical distribution. In effect, they only show variations in their background level without large differences characteristic of areas where surface expression of mineralization is subtle and contrasts weakly with the background. In this type of environment, Haruna et al. (2008) expressed the view that errors inherent in geochemical data plus local environment factors have profound effects on the migration and distribution of trace and major elements in the sampled media.

Figure 13: Joint on the Rock

Figure 14: Solution hole caused by differential weathering

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Figure 15: Fracture due to brittle nature of the rock

Figure 16: Microfolds due to compressive deformation

In conclusion, the results of the geochemical studies of both stream sediment and borehole (water) samples combined with intensive field mapping shows that there is high concentration of elements in the western part of the study area. Both samples modified their chemistry through weathering of the associated rocks and precipitation in the area. Comparison of results by plots showed that most of the elements have peak values around Ikange, Makanju and Ayegunle, which are underlain by quartzites of Precambrian age. The abundances of cations and anions fell within the maximum permissible limit of World Health Organization (WHO, 2003) and the borehole (water) is slightly alkaline.

After carrying out an intensive research on the geology, stream sediment geochemical survey and ground water quality evaluation of the study area, the following recommendations are suggested;

- The area is a manifestation of Precambrian deformation, hence, recommended as a good training ground for upcoming geologist.
- More intensive field studies are required to map out nappe structures in the area.

- A detailed and elaborate geochemical research should be carried out in the area in order to reveal the origin/Petrogenesis of the rocks.
- High concentration of some elements like Cu, Zn, Mn etc. in the quartzites as shown by the sampled media are thereby, recommended for exploration and exploitation by government.
- On the other hand, due to the different lithologies observed in the area, the rocks can be quarried for various economic and industrial purposes such as building and construction.

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