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Integrated Geology and Geochemical Analysis of Eruku Basement Complex, Southwestern Nigeria

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ABSTRACT
Eruku, located within Osi which is part of the southwestern Nigerian Basement Complex plays host to principal exposures of Precambrian – Paleozoic crystalline rocks in the region. Detailed geological mapping revealed the area to comprise essentially of migmatite – banded gneiss complex and diorites and minor rock types that include pegmatite and quartz veins with associated superficial stream deposits occurring proximally along channels in the vicinity. While efforts have been committed to regional mapping, petrography and geochemistry of rocks in the region, little attention was paid to detail delineations and integrating the observed associated stream sediments. This study employs detailed geological mapping, granulometric analysis and the use of XRF and ICP – MS to establish the geology and geochemical properties of the rocks and surrounding deposits in the area. Migmatitic rocks predominates the southwestern and part of the northwest, while the granite gneisses with some occurrence of diorite are mainly confined to the northeastern part of the study area. Granulometry of the sediments revealed a predominantly medium – coarse grained, poorly sorted leptokurtic sands, indicating products of in-situ weathering of host rocks. Geochemical analysis supports a strong correlation between the rocks and the sediments. The study is useful as guide to regional mapping and is applicable in geochemical prospecting of minerals.
Keywords: Basement complex, migmatite – gneiss complex, stream sediments, granulometric analysis, elemental abundance, southwestern Nigeria

INTRODUCTION
The Basement complex of Nigeria, which is part of the West African Precambrian to Early Paleozoic orogeny, comprises of Precambrian crystalline rocks with associated infolded Schist belts. The Southwestern Nigeria (Figure 1) that hosts the study area (Eruku) is generally represented by series of older metasediments and gneisses that are known to be of Precambrian to Lower Paleozoic age (Oyawoye, 1972). Eruku is located in the Osi area sheet 224 SE (1:27,000) of Southwestern Nigeria covering approximately 65.54km2 (Figure 2). It is situated within latitudes $8^0 04^1$N and $8^0 09^1$N and longitudes $5^0 25^1$E and $5^0 29^1$E, and is essentially made up of migmatites and granite gneisses with some miscellaneous superficial deposits. The migmatitic rocks predominate in the northwestern and southwestern parts, while the granite gneisses with some occurrence of diorite dominate the northeastern part of the study area.

The geology and geochemistry of the Southwestern Nigerian Basement complex have been reported by many researchers (Oyawoye, 1972; Rahaman; 1976; Anifowose, 2007; Ayodele, 2015). Oyawoye (1972) classification typifies the rocks in this region as older granites, migmatitic complex, metasedimentary series of schists, amphibolites, marble and calc silicates, as well as miscellaneous rocks that include charnockite, diorite, gabbro and metagabbro, potassic syenites and dolerite. General trend of north-east and south-west have been established for the region. Foliations in the region are predominantly tectonic in origin with evidence of pre-existing structures being replaced by deformational structures (Odeyemi et al., 1999).

Most of the studies carried out in the area focused on outcrops, petrography, geochemistry and structural analysis of the rocks with less regard for the linkage between the crystalline outcrops and the surrounding superficial deposits. Therefore this study attempts to provide detailed geological mapping, granulometric analysis of the superficial and geochemical properties of the rocks and surrounding deposits in the Eruku area.

Geologic setting

The Basement complex of Nigeria is part of the West African craton of Precambrian to Early Paleozoic orogeny (Oyawoye, 1972) that has been affected by supracrustal plutonics. The area lies between 6^0N and 12^0N latitudes and 4^0E and 12^0E longitudes. It extends westwards and into the Dahomey superbasin that includes the Togo and Ghana regions. It also extends Northward into Niger Republic, eastward into the Cameroon, and is overlain by a Mesozoic – Recent rocks of the coastal basins of Dahomey and Niger (Grant, 1969; Ajibade and Wright, 1989). The Nigerian Basement complex (Figure 1) is generally outcropped in the North-central region where it occurs as continuous shields, and in the Southwest and the Eastern Nigeria where they are separated by sedimentary deposits (Ayodele, 2015). The outcropped crystalline rocks observed today are resting on pre-pan african ancient basement of sialic crust.

The crystalline rocks constitute the basement complex of Nigeria covering about half of the country's landmass; the rest of the country is covered by sedimentary deposit. The basement complex is classified broadly into three; the gneiss-migmatite complex, the metasedimetary schist belt and the older granite. The gneiss-migmatite complex are composed of Archean (3000Ma) and Earliest Proterozoic (2000Ma) ages (Oversby, 1975; Dada et al., 1995) and forms the base upon which the metasedimentary Schist belt is deposited. The gneiss-migmatite complex together with the schist sequences were affected by the Pan African tectonic deformation of 600 Ma to produce the observed conformable relationships (Annor, 1986 and Ajibade, 1987 in Ayodele, 2015), thereby making relative dating and origin of these rocks difficult to ascertain. Hence the older granites which are essentially suites of discordant granitoids including granites, granodiorites, syenites and adamellites were emplaced due the Pan African orogeny (Kennedy, 1964). The Nigerian Basement complex suffered series of tectonic events that transformed them into rocks that were classified into six lithological groups by Rahman (1988) as follows: (i) migmatite-gneiss-quartzite complex, (ii) the schist belts, (iii) the charnokitic rocks, (iv) the older granites, (v) Volcanic, gabbroic and dioritic rocks and (vi) the unmetamorphosed miscellaneous rocks including dolerite, syenites and dykes.

The Eruku area in Osi region of Southwestern Nigeria Basement complex exhibited three classes of rocks (Figure 3) – (i) major rock types comprising of migmatite – banded gneiss complex and diorites and (ii) minor rock types that include pegmatite and quartz veins, and (iii) a set of basically superficial deposits also occur in the area. The banded gneiss complex consists of isolated domes low-lying ridges composed of an assemblage mainly of quartz, biotite, muscovite and hornblende. The Diorites are plutonic composed essentially of oligoclase or andesine, biotite, hornblende and / or pyroxene and are occurring as undeformed small bodies of rocks or stocks with the dark minerals such as andesine, biotite, and hornblende predominating. The pegmatitic rocks occur as simple veins and dykes and situated mostly within the gneisses. Most of the pegmatite veins, which comprise of coarse-grained quartz and feldspar minerals with some biotite, averaged about 8m in length and 30 cm in width, and are believed to be members of the older granites (Rahaman, 1976). The quartz veins and lenses occur in almost all the major rock types in the area and vary in thickness from a few millimetres to a metre, showing great irregularities in their morphologies. The superficial deposits refers to the unconsolidated and loosely consolidated deposits that often occurring proximal to the base of the Basement complex outcrops. They appear as by-products of denudation of pre-existing rocks; they consist mainly of gravely, sandy, silty, clay and lateritic materials occurring mainly in major valleys. These deposits are dominated by quartz and feldspar.

Most of the outcrops have been deformed. Associated structures are believed to be of tectonic origin with predominantly quartzose and feldspathic intrusive rocks with varying degree of jointing (Anifowose et al., 2007). General trend of north-east and south-west have been established for the region. Foliations in the region are predominantly tectonic in origin with evidence of pre-existing structures being replaced by deformational structures (Odeyemi et al., 1999).

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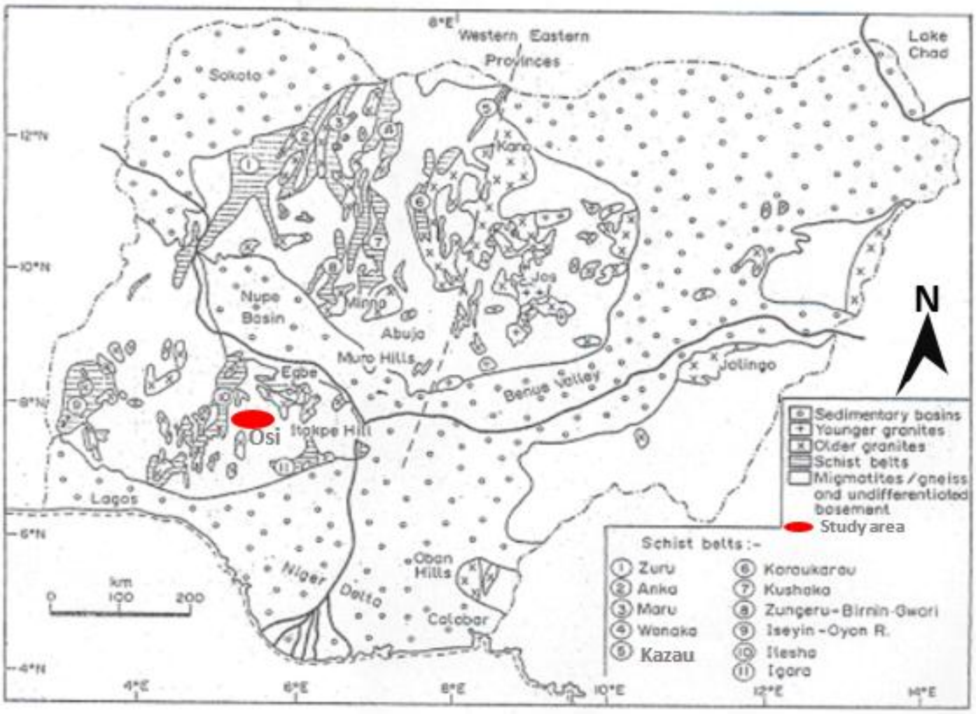


Figure 1. Generalized geological map of Nigeria showing the Basement Complex rocks provinces and the study location, Osi (modified after Rahaman, 1988)

MATERIALS AND METHODS

This study employed field observations, petrographic analysis and granulometric analysis to establish the geology, geochemical properties of the rocks, and the relationship between the rocks and the superficial deposits. Outcrop mapping and descriptions and collection of representative samples (Figure 2) from the exposed rocks was carried out in the area. Thin sections of 10 rock samples were carefully prepared and studied under petrological microscope in order to realise the mineralogy and fabrics of the rocks. While X-ray Fluorescence (XRF) spectrometry and inductively coupled Plasma Mass Spectrometry (ICP - MS) (for quantitative elemental abundance analysis) and granulometric analysis was performed on 12 soil samples that were collected mainly from the base of rock outcrops and from some accessible river channels in the area using set of sieve pans.

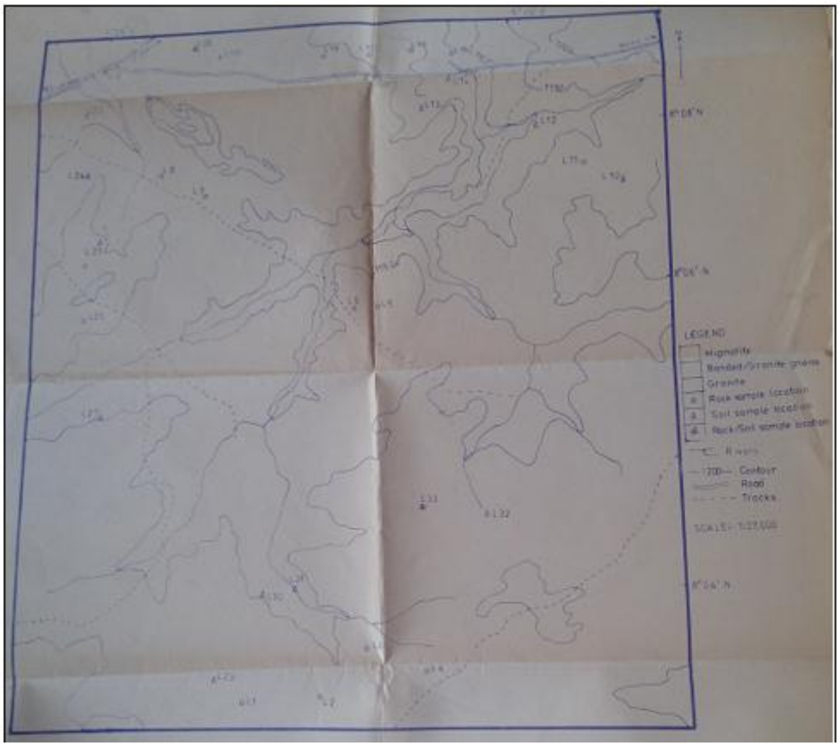


Figure 2. Topographical map of part of Osi SE (Sheet 224, Southwestern Nigeria) showing sample locations

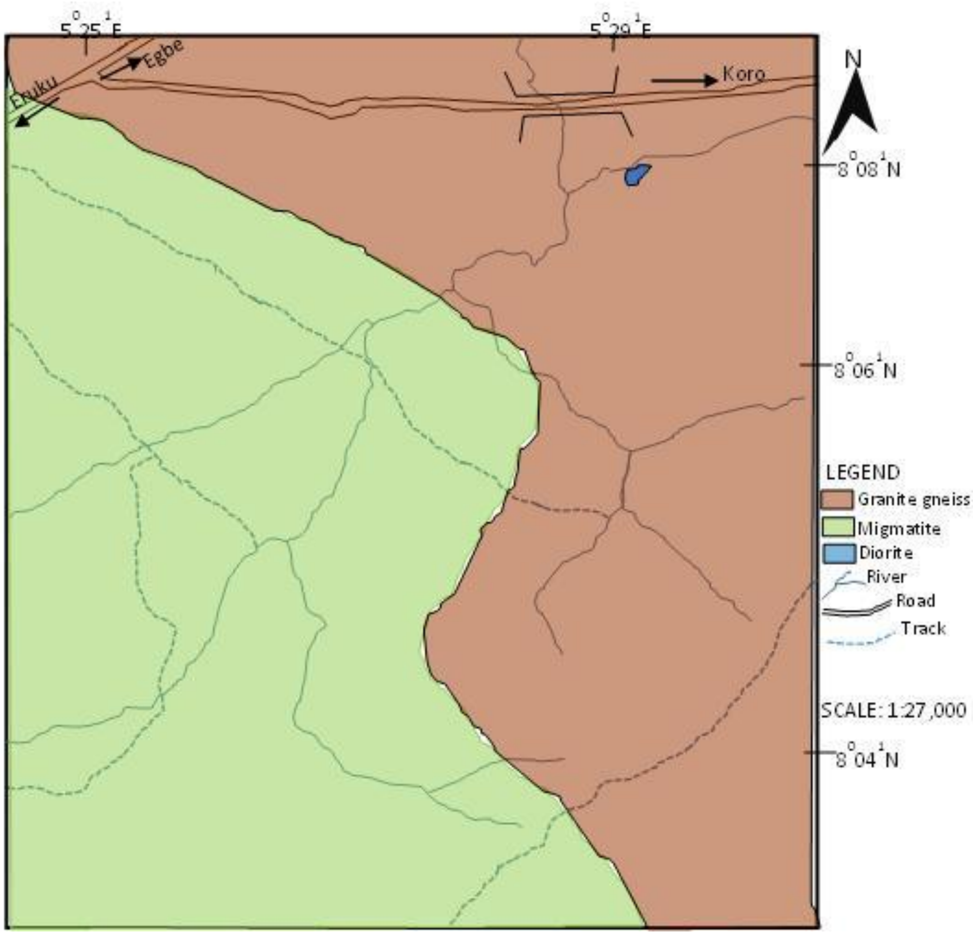


Figure 3: Geological map of part of Osi (Sheet 224, Southwestern Nigeria)

RESULTS AND DISCUSSION

The results of the thin section study conducted are presented in Figure 4. The most common rock types in the study area include migmatite, banded gneiss, granite and an isolated diorite (Figure 3) ridge. A representative display of the petrography of the rocks in the study area is presented in figure 4. The main components are quartz, Feldspar (Microcline and Plagioclase), Mica, Hornblende and some opaque minerals. From the analysis, quartz represents the predominant mineral component of the rocks occurring with the highest percentage in granite (>40%) and lowest in the diorite where it averages 10% in aggregate rock composition. Microcline are most dominant in the migmatites and granite gneisses ranging from 25% – 40%; they likely indicate granite origin (Imaseun et al., 2013). This class of mineral assemblage indicates emplacement in continental environment (Ayodele, 2015).

The soil samples and stream sediments analysed are characteristically brown to dark-brown in colour and are micaceous. They contain predominantly quartz and varying degree of feldspar. Rock fragments were also common in the stream sediments.

The results of the sieve analysis of the stream sediments (Tables 1, 2 and 3) were used to create the histogram plots (Figure 5) and cumulative frequency curves (not shown in this paper) from which Phi values were derived for evaluating the graphic means, sorting and the kurtosis that were used for the grain size analysis of the sediments in the immediate vicinity of the crystalline outcrops. Most of the samples (see Figure 5) have their modal classes between grain sizes 0.075mm to 0.25mm and between 0.25mm to 0.5mm which correlate with medium – coarse grained sands. From the tables and plots, a graphic mean of range of -0.37 – 1.40 (Table 2) interpreted using the Udden – Wentworth scale (1922) indicated medium sand to very coarse sediments. The grains generally range between very poorly sorted to poorly sorted, and mostly very leptokurtic to leptokurtic with a few showing platy kurtosis. About 35% of the grains are nearly symmetrically skewed, 25% negatively skewed, another 35% are positively skewed while 5% are strongly coarse skewed. This skewness indicates that sediments are products of in-situ weathering that were deposited proximal to the source.

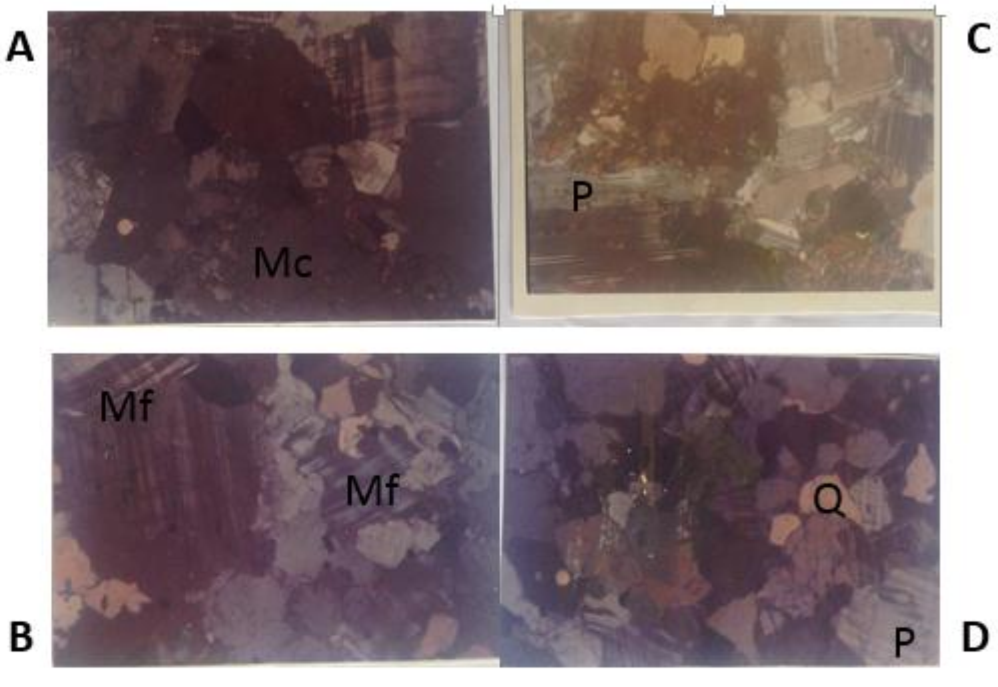


Figure 4. Petrography of some of the rocks in the study area (magnification x40): A and B represent migmatite-gneiss rocks; C = Diorite; D = Granite. Mc = muscovite; Mf = Microcline feldspar; P = Plagioclase; Q = Quartz

Table 1. Results of sieve analysis conducted on 12 stream sediment samples collected from the area

Sample/Retained weight(%)	1mm	0.5mm	0.25mm	0.075mm	<0.075mm	Total (%)
SS 10	14.8	26.5	33	22.5	3	99.8
SS13	9	24	39	26	1	99
SS 14	24	57	17	1	0.5	99.5
SS 20	35	25	21	15.5	3	99.5
SS 24	11.5	28	34	22	4	99.5
SS 25	20.5	32.3	24	18	5	99.8
SS 27	34.7	24	22	15	4.2	99.9
SS 29	8.5	22	32	30	6	98.5
SS 30	23	28.5	27.5	18	2.5	99.5
SS 31	31	23	25	19	1	99
SS 32	37	19	15.7	23	5	99.7
SS 33	24	14.3	25	29	7.5	99.8

Key: SS = Stream sediments

Table 2. Left: Calculated graphic properties of the stream sediments; Right: Estimated Phi values from cumulative frequency curves

Sample	Mean	Sorting	Skewness	Kurtosis
SS 10	1.12	1.26	-0.01	1.66
SS 13	1.27	1.16	0.12	1.3
SS 14	-0.37	1.33	-0.29	1.88
SS 20	0.52	1.8	0.09	0.53
SS 24	1.4	1.36	0.14	1.44
SS 25	0.95	1.73	0.06	1.21
SS 27	0.45	1.94	-0.2	1.01
SS 29	1.57	1.51	0.27	1.16
SS 30	1.03	1.56	-0.49	1.24
SS 31	0.65	1.84	-0.01	1.15
SS 32	0.58	2.04	0.04	0.17
SS 33	0.92	1.8	-0.14	0.8

Sample	ø5	ø16	ø25	ø50	ø75	ø84	ø95
SS 10	-1.5	0.1	0.55	0.9	1.95	2.35	3.05
SS 13	-1.2	0.4	0.6	1.1	1.75	2.3	3.3
SS 14	-2.5	-1.5	-0.85	0.25	0.7	1.15	1.85
SS 20	-2.3	-1.35	-0.8	0.3	1.85	2.6	3.05
SS 24	-1.25	0.25	0.7	1.15	2.05	2.8	3.5
SS 25	-2.05	-0.65	0.15	0.8	2.15	2.7	3.85
SS 27	-2.55	-1.8	-0.8	0.85	1.7	2.3	3.6
SS 29	-1.2	0.35	0.8	1.15	2.65	3.2	4.05
SS 30	-2.15	-0.8	0.5	1.8	1.85	2.1	3.3
SS 31	-2.6	-1.15	-0.75	0.6	1.5	2.35	3.74
SS 32	-2.45	-1.65	-0.95	0.5	2.5	2.9	3.55
SS 33	-2.2	-1	-0.9	1.1	2.1	2.65	3.68

Table 3. Grain size characteristics and interpretation of the analysed stream sediments and soil samples in the area

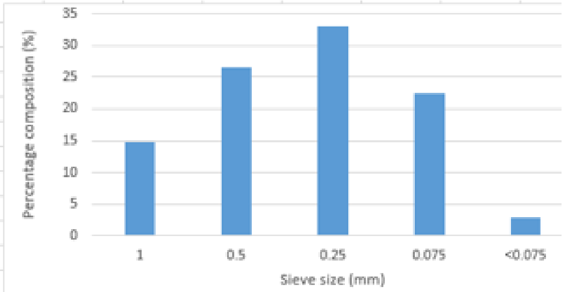
Sample	Graphic mean	Inclusive standard deviation	Inclusive graphic skewness	Graphic kurtosis
SS 10	Medium sand	Poorly sorted	Nearly symmetrical	Very leptokurtic
SS13	Medium sand	Poorly sorted	Positively skewed	Very leptokurtic
SS 14	Very coarse sand	Poorly sorted	Negatively skewed	Very leptokurtic
SS 20	Coarse sand	Poorly sorted	Nearly symmetrical	very platykurtic
SS 24	Medium sand	Poorly sorted	Positively skewed	Leptokurtic
SS 25	Coarse sand	Poorly sorted	Nearly symmetrical	Leptokurtic
SS 27	Coarse sand	Poorly sorted	Negatively skewed	Mesokurtic
SS 29	Medium sand	Poorly sorted	Positively skewed	Leptokurtic
SS 30	Medium sand	Poorly sorted	Strongly coarse skewed	Leptokurtic
SS 31	Coarse sand	Poorly sorted	Nearly symmetrical	Leptokurtic
SS 32	Coarse sand	Very poorly sorted	very positively skewed	Platykurtic
SS 33	Coarse sand	Poorly sorted	Negatively skewed	Platykurtic

Table 4. Comparison of elemental abundance of the samples (A = rocks / samples; B = the crust's composition)

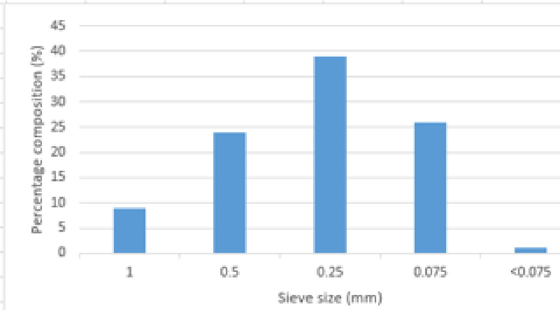
Element	A (ppm)	B (ppm)	B/A		Element	A (PPM)	B (PPM)	B/A
K	23900	19420	0.81		K	17200	19420	1.13
Ca	23700	49960	2.11		Ca	14000	49960	3.57
Ti	3810	5040	1.32		Ti	12100	5040	0.42
Cr	907	102	0.11		Mn	773	1240	1.6
Mn	873	1240	1.42		Fe	32700	50880	1.56
Fe	32000	50880	1.59		Cu	149	68	0.46
Cu	162	68	0.42		Pb	95.3	13	0.14
Zn	131	76	0.42		Rb	94.2	78	0.83
Pb	74.1	13	0.18		Sr	31.1	384	12.3
Rb	247	78	0.32		Y	57.6	3.1	0.54
Sr	264	384	1.45		Zr	500	162	0.32
Th	35.6	8.1	0.23		Nb	14	20	1.43
Y	22.7	31	1.37					
U	35.1	2.7	0.08					
Zr	241	162	0.67					
Nb	30.3	20	0.66					

Table 5. ICP – MS analysis of some samples digested with acids (2 L35 PS = pegmatite; 2 L29 SS = soil sample; 2 L 11M = Muscovite; 2 L 21F = Feldspar

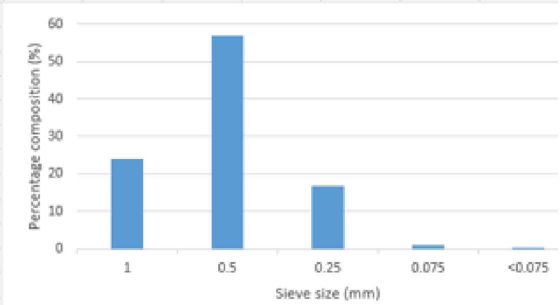
Element	Conc (ppm) (2 L35 PS)	Conc (ppm) (2 L29 SS)	Conc (ppm) (2 L11 M)	Conc (ppm) (2 L21 F)
Y	14.9	7.8	0.7	2
Ce	59.54	69.69	3.64	0.59
Pr	4.9	6.6	0.3	0.1
Nd	17.6	23.9	1.2	0.3
Sm	3.8	5.2	0.3	0.1
Eu	0.7	0.5	<0.1	0.2
Gd	2.5	3.2	0.3	0.1
Tb	0.4	0.4	0.08	0.09
Dy	2.5	1.9	0.2	0.3
Ho	0.5	0.3	0.1	<0.1
Er	2.2	0.8	0.1	0.5
Tm	0.3	0.1	0.09	0.08
Yb	2.7	0.8	0.1	0.5
Lu	0.4	0.1	0.09	0.1
Hf	3.14	2.33	0.64	0.09
Li	30.2	3.9	121	15.7
Rb	195.4	126.1	954.7	576.1
Ta	2	1.1	29.3	0.8
Nb	13.4	9.86	227.84	2.11
Cs	4.9	1.8	49.9	3.6
Ga	17.35	8.48	101	19.18
Ca	1.48	0.22	0.04	0.17
P	0.021	0.015	0.013	0.003
Mg	0.45	0.06	0.47	0.01
Fe	2.27	0.85	1.85	0.05
Ba	755	954	95	226
Ti	0.253	0.331	0.188	0.001
Al	5.84	4.32	18.39	8.86
Na	1.81	0.408	0.567	1.802
K	2.59	3.68	9.71	11



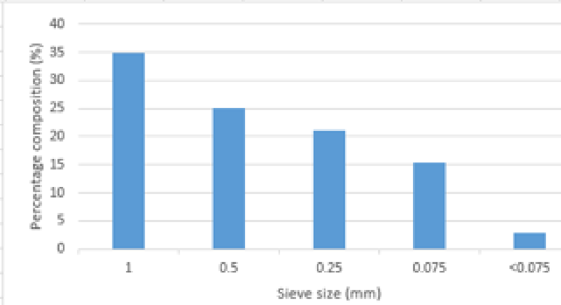
Histogram for stream sediment 10



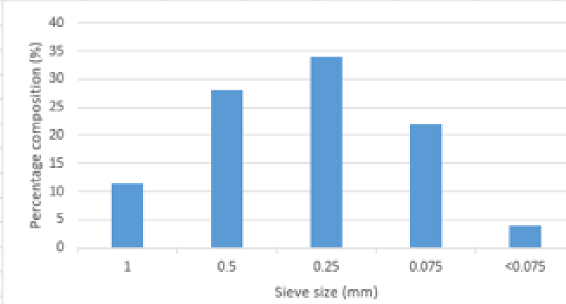
Histogram for stream sediment 13



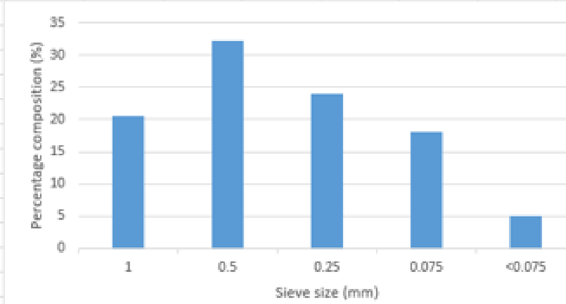
Histogram for stream sediment 14



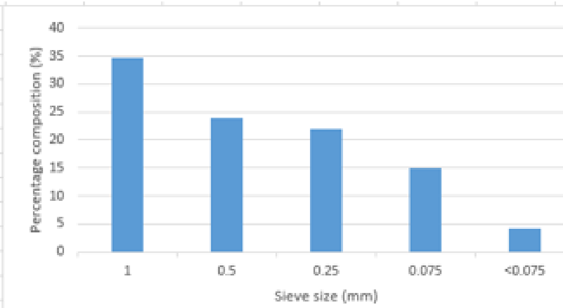
Histogram for stream sediment 20



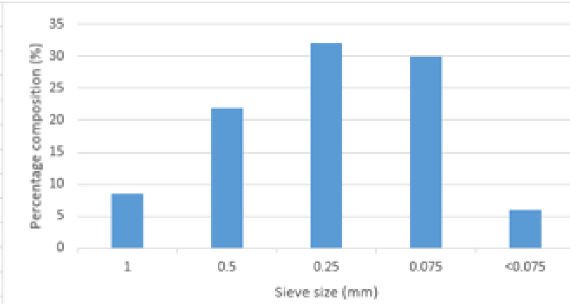
Histogram for stream sediment 24



Histogram for stream sediment 25



Histogram for stream sediment 27



Histogram for stream sediment 29

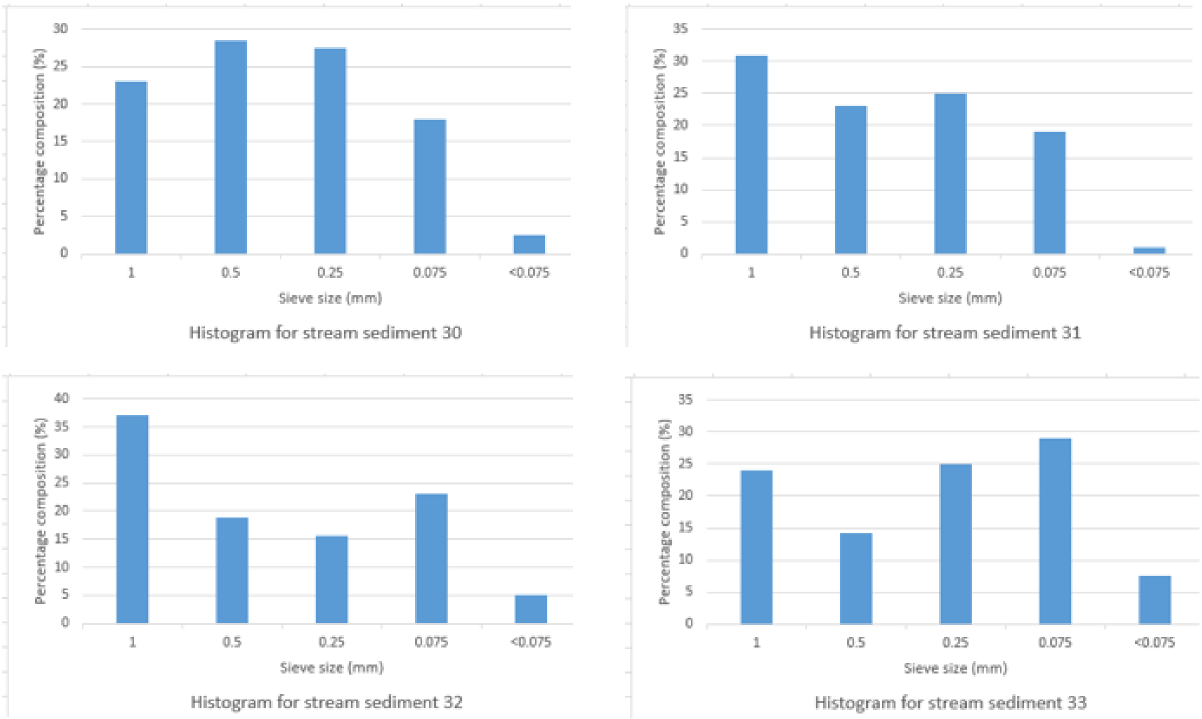


Figure 5. Histogram plots of the grain size analysis of the selected stream sediments in the area. The predominant grain sizes is 0.25 – 0.5 mm indicating coarse – very coarse grained deposits; the least common grain size is <0.075 – 0.075 mm.

Representative XRF results (Tables 4 and 5) and the ICP-MS, whose results are presented in Table 5, is a quantitative technique that assists in subdivision of the elements as major, minor and trace elements and it agrees with Goldschmidts (1954) division of elemental compositions of rocks into major elements (those that have their elemental composition greater than their presence in the crust) and minor elements (referring those elements whose sample composition is greater than their presence in the crust). The major elements in the analysed samples include Fe, Ca, Mg, Al, Ti, Na, K and S; these are present in concentrations >1000 ppm i.e. >1%. Also noticed is relatively elevated level of Ba and Rb. The method is useful as guide to regional mapping, applicable to Basement complex geochemistry (e.g., Ayodele, 2015) and in geochemical prospecting of minerals like gold, platinum, etc. (Rose, 1974).

CONCLUSION

Eruku area of Osi, Southwestern Nigeria exhibited typical geology of the Nigerian Basement complex characterized by the predominance of migmatite - gneiss complex that indicated continental origin. Combination of petrography, granulometry and the ICP-MS techniques were applied to describe the geology and elemental composition of the rocks in the area. Granulometric analysis of adjacent stream sediments showed coarse – very coarse sediments with very poorly to poorly sorted grains. This indicated sediment derivation from proximal weathering of the parent crystalline rocks.

The XRF and ICP-MS analysis divided the elemental abundance of the rocks major and minor elements. This integrated analysis is not only complementary to and useful in regional mapping of the Nigerian Basement complex but also applicable to geochemical mineral exploration.

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