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Base Metal Mineralization in the Precambrian Rocks of Okemesi-Ijero Area, Southwestern Nigeria

Ayodele O.S.* Department of Geology and Applied Geophysics, Ekiti State University, P.M.B. 5363 Ado Ekiti, Nigeria

Madukwe Y. Henry Department of Geology and Applied Geophysics, Ekiti State University, P.M.B. 5363 Ado Ekiti, Nigeria

Azeez M.A. Department of Chemistry, Ekiti State University, P.M.B. 5363 Ado Ekiti, Nigeria

Awokunmi E.E. Department of Chemistry, Ekiti State University, P.M.B. 5363 Ado Ekiti, Nigeria

Abstract: The evaluation of base metals in the bedrocks of Okemesi / Ijero area, southwestern Nigeria has been carried out to assess their potentials, level of accumulation and enrichment. The methodology included systematic geological and geochemical mapping of the rocks using grid-controlled sampling method at a sampling density of one sample per 500m. Ten rock samples were collected at different locations of the study area. The results obtained showed that the major oxides such as SiO_2, Al_2O_3, TiO_2, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O and P_2O_5 were detected in variable proportions. While SiO_2 varied between 70.59% and 98.70%, Al_2O_3 ranged between 15.73% and 0.61%. There is abundance of barium (Ba), silver (Ag) and gold (Au) with concentration values of 1.6-9.8, 1.24-7.1 and 0.05-10.00 ppm respectively. Base metals such as Cu, Zn, Pb, Bi and Cr enrichment factors and their geo-accumulation index indicates moderately significance to very high enrichment of Cu (10 – 70%) , Pb (20 – 40%) and Bi (10 – 40%). The geo-accumulation indices suggest geogenic concentration of the base metals in the host rocks rather than anthropogenic inputs. The PCA elements loaded Au, As, Ag, Pt and Os on the same factor and they are pathfinder elements of Gold. Correlation coefficients indicate strong positive correlations between the elements. This implies that they are strongly related and therefore of the same source, also suggesting geogenic sources.

Keywords: Bedrocks; Mineralization; Base metals; Enrichment factor; Index of geo-accumulation.

1. Introduction

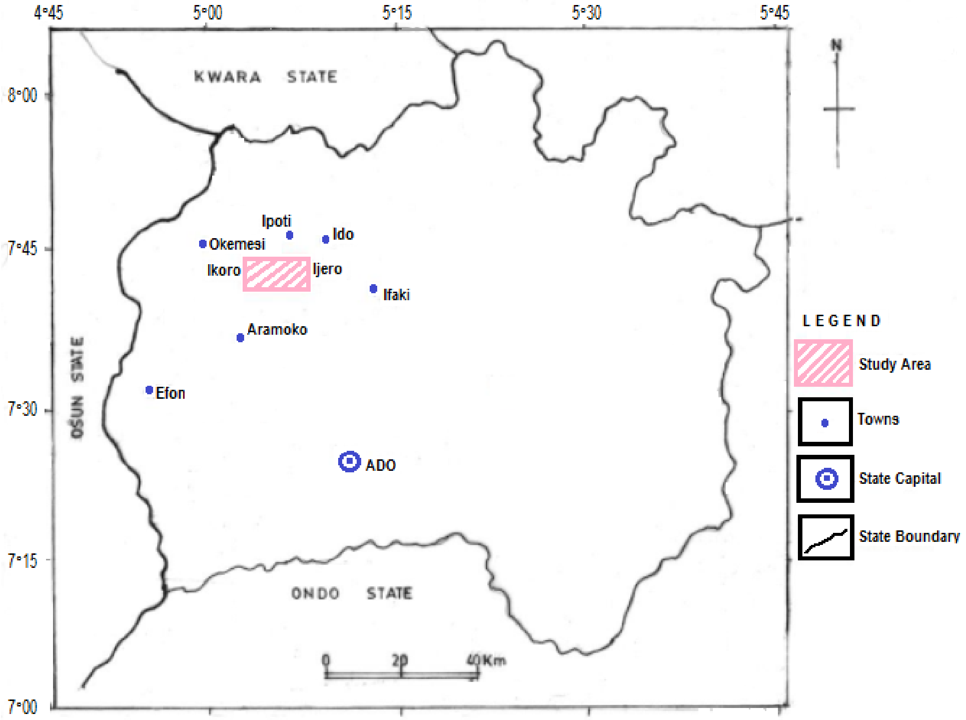
The search for concealed mineral deposits has led to the development of numerous sampling media that can unravel such hidden mineral deposits. Some of the important geochemical sampling media that have been used successfully in the recent past include soil, stream sediment, and termitarium or termite mound [1, 2] Rock as a medium for reconnaissance geochemical prospecting for mineral deposits is not used as much as soil and stream sediments. This is because of the difficulty involved in sampling representative rocks and the pattern of distribution of outcrops within an area [3]. Whole rock sample analysis can however, provide important information concerning the range of trace elements present, their primary dispersion in rock and the mineralogical relationships [4]. Putman and Burnham [5] used whole-rock analyses in a regional study of a part of the Arizona copper province. The Geological Survey of Canada, according to Sakrison [6] carried out regional geochemical survey using whole-rock samples.

The understanding of 'base metals' differs in different disciplines. While an electrochemist explains them in reference to metals in the lower end of the electrochemical series [7] while metallurgist understands them as the bases on which other elements are coated [8]. To geologist, base metal refers to high volume, low-value metallic elements such as copper, lead and zinc. Mumbfu, *et al.* [9] explored for gold using stream sediments from the Ngo Vayang area of southern Cameroon. The study revealed that the Au-Hf element association from the R-mode factor analysis indicated gold mineralization while U-Th-Pb-W, Nb-Ta-Co-V, Au-Hf-Cu associations reflected lithologic controls. Emmanuel, *et al.* [10] carried out geochemical investigation of the southern part of Ilesha using multivariate analysis to obtain the coefficient of principal components. The elemental association ratio revealed high metallic concentrations, which led to the mineralization trend in southern Ilesa [10]. Okunlola and Okorojafor [11], studied the geochemical and petrogenetic features of the schistose rocks of the Okemesi fold belt, and revealed that the metasedimentary assemblages which form the inner portion of the Okemesi antiform are continental post

*Corresponding Author

Archean supracrustals. Stream sediment geochemistry can aid in recognizing variations in upstream geology in several high grade metamorphic litho-tectonic units having different metamorphic and tectonic histories [12]. The aim of this research is to evaluate the base metal potentials in the bedrocks of Okemesi/Ijero Area, southwestern Nigeria with the objectives of harnessing it for economic and industrial development of Ekiti State. The study areas (Okemesi and Ijero) lies between latitudes 7°46′N to 7°53 ′N and longitudes 5°00′E to 5°07′E (Figure 1).

Figure-1. Map of Ekiti State showing the study area



2. Geologic Setting

The study area is located within Ekiti State and is underlain by crystalline rocks of Precambrian basement complex of southwestern Nigeria, which is also part of the basement complex rocks of Nigeria. The rocks in the area have different textural classes ranging from coarse to fine grained. Structural complexity is a common feature of the basement complex of Nigeria [13]. The rocks in the study area are most likely products of multiple folding, igneous and metamorphic activities and polycyclic deformation [14]. All the rocks encountered during field examination of the area have been compiled to produce a working geological map of the study area (Figure 2).The study area is also part of the regional Dahomeyide fold belt defined by Affaton, *et al.* [15] and 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 [16] except in a few places where they survived deformation [14]. The Ifewara fracture zone separates the rock of Ilesha schist belt into two structural units of contrasting lithologies [17-20]. Other researchers [21-24] have provided evidences in support of the existence of the structure as well as its significance in terms of tectonic movements. Also, sutures have been proposed along the two transcurrent fault zones, and in particular within the Ife-Ilesha schist belt, which has been interpreted as a back-arc marginal basin [13], and east-verging nappes [25]. It is worthy of note that the Ilesha schist belt hitherto thought to be devoid of iron ore deposits has been reported to host some deposits of "banded iron formation" [26]. The Nigerian basement complex forms part of the Pan – African mobile belt and lies between the West African and Congo cratons and south of the Tuareg shield [27]. 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 [28, 29]. 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 (1100Ma), 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 [30]. Anifowose [24] 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 [29], namely; the migmatite – gneiss-quartzite complex, the schist belts, the Pan African granitoids and under formed acid and basis dykes. Major rivers in the study area include river Osun found along Okemesi road, river Oyi, which flows in a southerly direction. A waterfall was encountered around Oke-Ila called Ayikunnugba waterfalls and river Isa etc. The streams spread out from a central point, forming dendritic drainage pattern as a result of its branching (Figure 3).

Figure-2. Geological map of the study area [31]

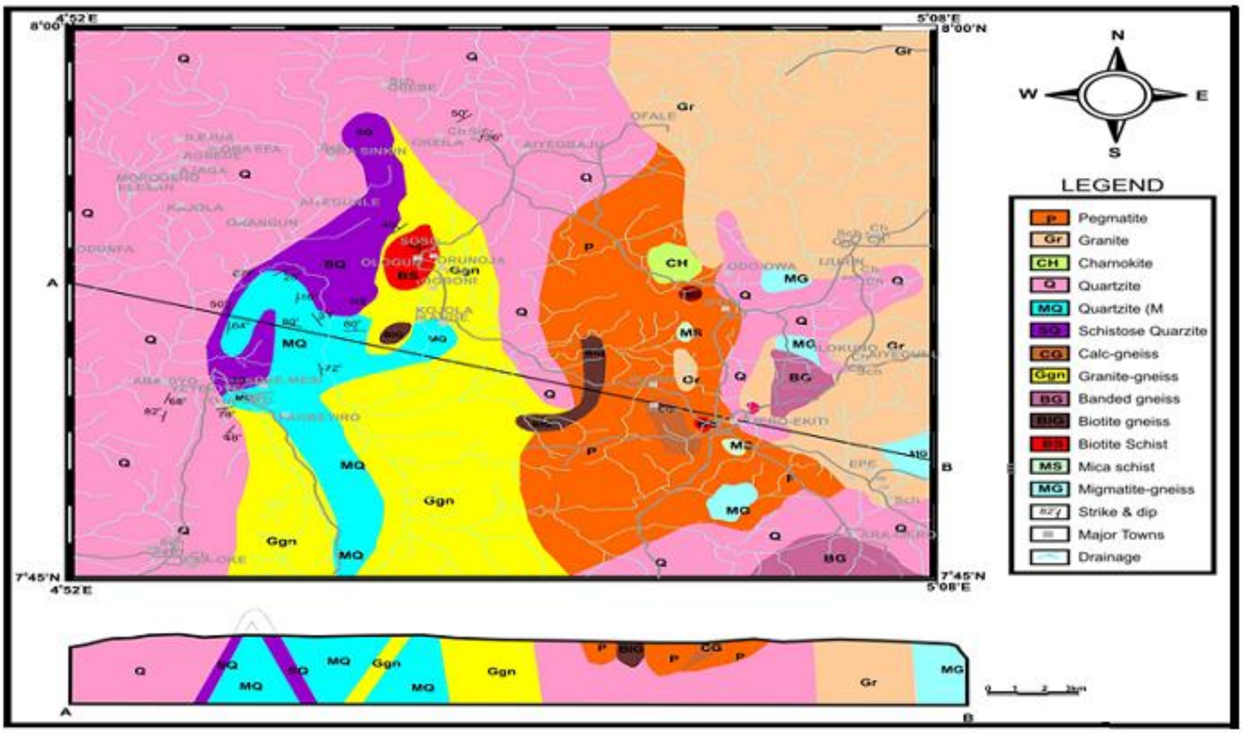
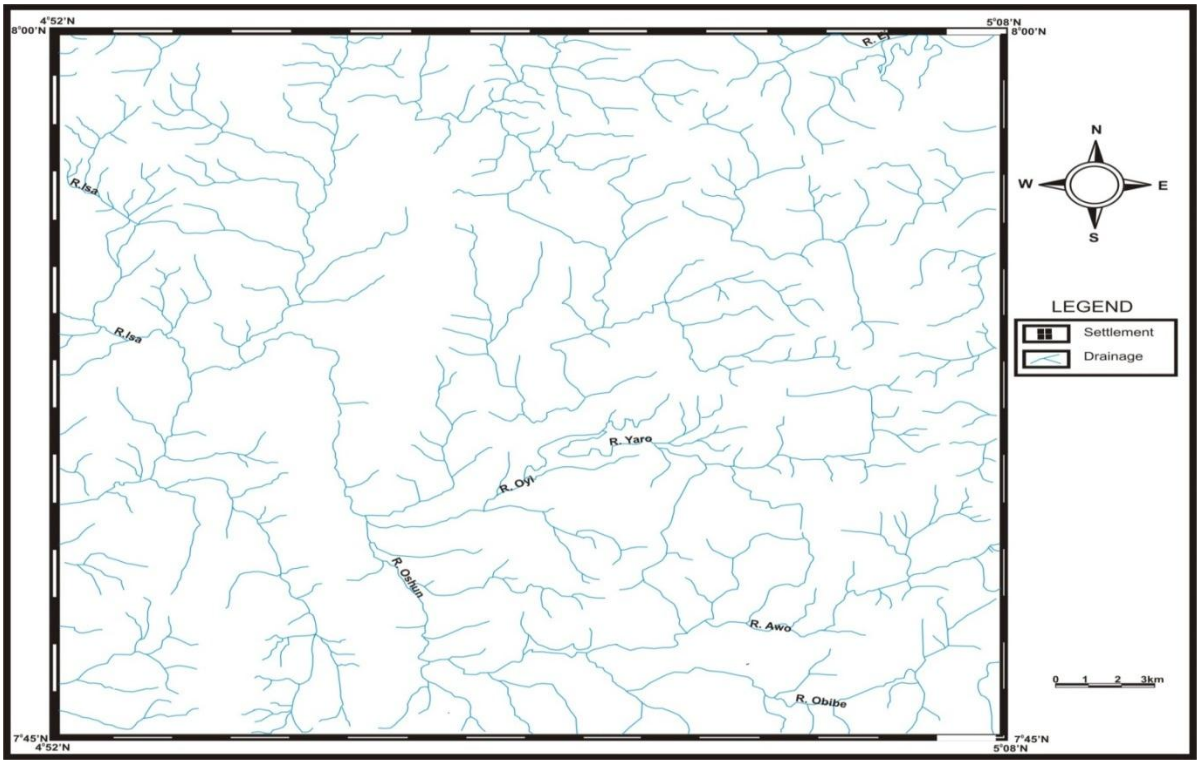


Figure-3. Drainage map of the study area [31]



3. Method of Study

The field operation was essentially geologic mapping of the study area, to determine the underlying bedrock units. The geologic mapping was carried out at a scale of 1:50,000 using grid-controlled sampling method at a sampling density of one sample per 4sq km^2 for the collection of rock samples. Ten rock samples were obtained. The rock samples were collected from different localities within the study area, after which they were labeled accordingly to avoid mix up. The location of each outcrops were determined with the aid of a Global Positioning Systems (GPS) and the lithologic and field description of each samples were correctly recorded. The samples were bagged and transported to Petroc Laboratory, Ibadan, where it was pulverized and crushed using standard procedures. The samples were later digested using the total digestion method. 40g of the digested samples were introduced into containers provided and properly labeled, and were sent to ACME Laboratories, East Vancouver, Canada for geochemical analysis to determine the major oxides using atomic absorption spectroscopy (AES). Trace and rare earth elements were determined using inductively-coupled-plasma mass spectrometry (ICP-MS). Bivariate and multivariate statistical analysis was applied on the geochemical data using SPSS statistical software package to obtain elemental correlation coefficients, base metal and gold paragenesis,. The Pearson linear correlation coefficient [32] is a statistical method of checking for linear relationships between two variables. A value of 1 indicates a perfect positive or direct relationship between two variables. A value of -1 indicates a perfect negative or inverse relationship, while a value of zero indicates a lack of any correlation.

4. Results and Discussion

4.1. Geological Field Mapping

The field description and characteristics of the various rock units mapped in the study area have been compiled a geological map (Figure 3). The geological map revealed the dispositions of the various rock units in the area. Also, from the geological map, migmatites are the oldest rocks in the study area, a few lithologies such as the pegmatites, mica schists, charnockites and granites occur as intrusive bodies within the migmatite-gneiss, and others such as granite-gneiss, calc-gneiss etc. form discrete, disseminated and linear bodies within the massive quartzites and the schistose types. The strike values of the quartzite (schistose and massive) range from 024°-046° in some places. Also, the rocks dip in the western direction, with values such as 40°W - 80°W in some areas of study, while other areas also dip in the eastern direction with dips such as 72°E - 80°E respectively. The high dip values could be attributed to several episodes of deformation that characterize the rocks in the area, which is manifested in the brittle nature of the quartzites. These display several joints and fracture sets and control the drainage pattern in the area. Also, there is existence of structures in the area as can be seen on the cross-section map. This confirmed the presence of folding on the rocks especially on the schistose quartzites; this type of fold is an antiform.

4.2. Major Oxide Geochemistry

The analytical geochemical results of the various rocks mapped are presented in Table 1. From the result obtained, the most prominent oxides in the samples are SiO_2, Al_2O_3, Na_2O and K_2O with average values of 80.58%, 14.78%, 2.73%, and 2.52% respectively. The SiO_2 content of the sample from the study area ranges between 70.59% and 98.70%) with an average value of 80.57%. Also, from the result presented, SiO_2 has the highest concentration in all the rocks analysed. Al_2O_3 content is moderate in all the samples analyzed except in Ajindo sample which is relatively higher than others. The values range from 0.71% to 46.22% with an average value of 14.78%. The TiO_2 values vary between 0.01% and 1.21% with an average value of 0.22% and are considerably very low in all the analysed samples. Its concentration is highest in the samples

Table-1. The major oxides in the rocks (%)

Oxides%	Okemesi 1 Qtz	Okemesi 2 Qtz	Ijero Quarry A	Ijero Quarry B	Ijero Quarry C	Itawure 1 Qtz	Itawure 2 Qtz	Ajindo Qtz	Ipoti Quarry	Odo-Owa Quarry	MDL
SiO_2	74.14	72.18	74.25	73.72	70.59	83.67	87.00	73.00	98.52	98.70	0.01
Al_2O_3	13.27	12.96	14.80	16.42	19.01	13.89	10.26	46.22	0.84	0.71	0.01
TiO_2	0.43	0.28	0.02	0.01	0.01	0.12	0.07	1.21	0.01	0.01	0.01
Fe_2O_3	0.95	0.82	0.41	0.20	1.42	0.63	0.46	3.19	0.01	0.02	0.01
MnO	0.08	0.05	0.02	0.02	0.04	0.01	<0.01	<0.01	<0.01	<0.01	0.01
MgO	0.22	0.24	0.39	0.17	0.09	0.44	0.23	0.06	<0.01	<0.01	0.01
CaO	2.01	1.46	0.22	0.39	0.20	0.21	0.32	0.13	0.12	0.14	0.01
Na_2O	3.42	1.04	6.43	8.24	7.86	0.13	0.07	0.04	<0.01	<0.01	0.01
K_2O	5.04	9.52	2.85	0.35	0.27	0.23	0.95	5.78	0.01	<0.01	0.01
P_2O_5	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01
LOI	0.43	0.55	0.61	0.48	0.51	0.67	0.54	0.36	0.49	0.42	0.01

from Ajindo. The Fe_2O_3 values range between 0.01% and 3.19% with an average value of 0.81% of the total rock content. The highest concentration (3.19%) is detected from Ajindo which is underlain by ferruginous quartzite. MnO and MgO values ranges between (<0.01%-0.08%) and (<0.01%-0.44%) respectively with average values of 0.06% and 0.19% respectively. Other oxides such as CaO, P_2O_5, Na_2O and K_2O have fair to low concentration in all the rocks analysed.

4.3. Trace Elements Geochemistry

The trace elements analysed in the rocks are as follows: Cu, Zn, *As, *Pb, Rb, *Ir, Sr, *Pt, Zr, *Os, *Ag, Ba, Re, Eu, Au, V, Cr and Bi (Table 2). The results revealed that the concentrations of *Ag, Au, V are considerably high when compared with other trace elements and rare earth metals. Barium (Ba) and Gold (Au) have high concentrations in the range (1.60-9.80) and (0.05-10.00) in all the locations. The concentrations of the metals present in ppm are: Cu (0.02-0.33); Zn (0.004-0.01); Rb (0.01 and 0.021) and Sr (0.042-0.94); *As and*Pb (0.01- 0.04). The latter elements are pathfinder elements for Au, the values indicate low Au potential in the areas under investigation.*Ir, *Pt and *Os concentration ranges between 0.0050 and 0.024) respectively. Pt shows minimum presence in samples from Ipoti and Odo-Owa while Os is only present in the

Table-2. Concentration of Trace and Rare Earth Metals in the rocks (ppm)

Elements	Okemesi 1 Qtz	Okemesi 2 Qtz	Ijero Quarry A	Ijero Quarry B	Ijero Quarry C	Itawure 1 Qtz	Itawure 2 Qtz	Ajindu Qtz	Ipoti Quarry	Odo-Owa Quarry	MDL
Cu	0.210	0.220	0.180	0.038	0.330	0.019	0.230	0.020	0.029	0.020	0.002
Zn	0.060	0.040	0.031	0.004	0.009	0.030	0.020	0.004	0.020	0.022	0.002
*As	0.130	0.011	0.022	0.06	0.040	0.010	0.040	0.020	0.100	0.080	0.002
*Pb	0.030	0.042	0.040	0.007	0.030	0.005	0.008	0.005	0.009	0.040	0.002
Rb	0.007	0.008	0.012	0.016	0.012	0.021	0.006	0.007	0.005	0.011	0.001
*Ir	0.011	0.005	0.007	0.005	0.021	0.008	0.041	0.006	0.043	0.007	0.002
Sr	0.940	0.101	0.420	0.210	0.090	0.470	0.080	0.300	0.042	0.310	0.001
*Pt	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.020	0.020	0.001
Zr	0.023	0.022	0.028	0.009	0.016	0.024	0.021	0.005	0.019	0.014	0.002
*Os	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.024	BDL	0.001
*Ag	1.380	1.430	3.200	2.180	1.840	2.290	1.410	1.240	6.200	7.100	0.002
Ba	3.200	4.710	9.800	6.000	4.200	2.600	2.500	3.850	1.900	1.600	0.001
Re	0.350	0.490	0.700	0.600	0.620	0.800	0.060	0.040	0.400	0.030	0.002
Eu	0.030	0.017	0.005	0.040	0.030	0.006	0.004	0.030	0.020	0.002	0.002
Au	0.050	1.000	0.300	4.000	2.000	4.000	6.000	0.700	9.000	10.000	0.001
V	2.000	3.200	0.400	1.100	0.600	2.000	0.220	0.420	0.050	0.090	0.001
Cr	0.040	0.003	0.002	0.040	0.007	0.040	0.005	0.017	0.030	0.040	0.001
Bi	0.490	0.120	0.068	0.008	0.110	0.020	0.020	0.010	0.020	0.004	0.004

BDL- below Detection Limit, MDL- Mean Detection Limit, (*)-pathfinder elements of gold Sample from Ipoti. Zr, Re, and Eu have average values of 0.018 ppm, 0.41Lppm and 0.018 ppm respectively. Rhanium, established more pronounced presence in almost all the samples than Zr and Eu. Cr and Bi values range from 0.002 to 0.04 ppm and 0.004 to 0.49 ppm with average values of 0.022ppm and 0.087ppm respectively. Cr is of relatively high concentration in Okemesi.

Particularly useful ratios include K_2O/Na_2O, SiO_2/CO_2, and SiO_2/total volatiles; the volatiles commonly include H_2O, CO_2, S, as and B [33]. According to Horsnail [33], many types of mineral deposits are characterized by a consistent increase in the ratio K_2O/Na_2O, which is essentially a manifestation of increasing potassic alteration. Similarly, a number of mineral deposits, particularly those enriched in gold and silver, are marked by a consistent decrease in the ratio SiO_2/CO_2 as ore is approached. The ratio SiO_2/total volatiles exhibits considerable variation among the various types of mineral deposits; in most cases, skarns excepted, there is a consistent decrease in the ratio as mineralization is approached [33]. The K_2O/Na_2O ratio for the samples range between 0.03 and 144.5, the highest value came from Ajindo while the lowest are from Ijero quarries. The Ajindo due to its high potassic alteration might be a good area for mineralization. The correlation plot of K_2O vs. Na_2O (fig. 4) gives a negative correlation an indication of potassic alteration. The ratio SiO_2/total volatiles for the samples range from 122 to 235; this is high which suggests that the areas are far from mineralization and a plot of SiO_2 against the volatiles indicates negative correlation (fig.5).

Figure-4. Correlation plot of K_2O vs. Na_2O

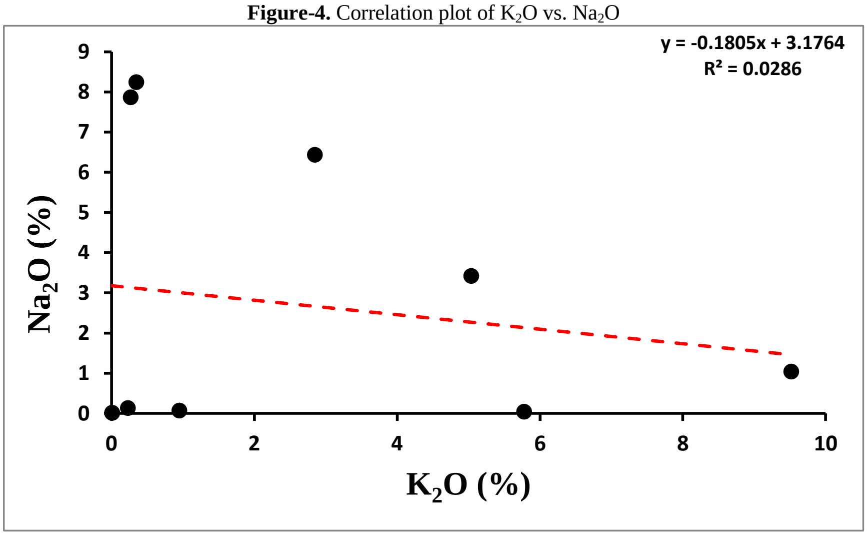
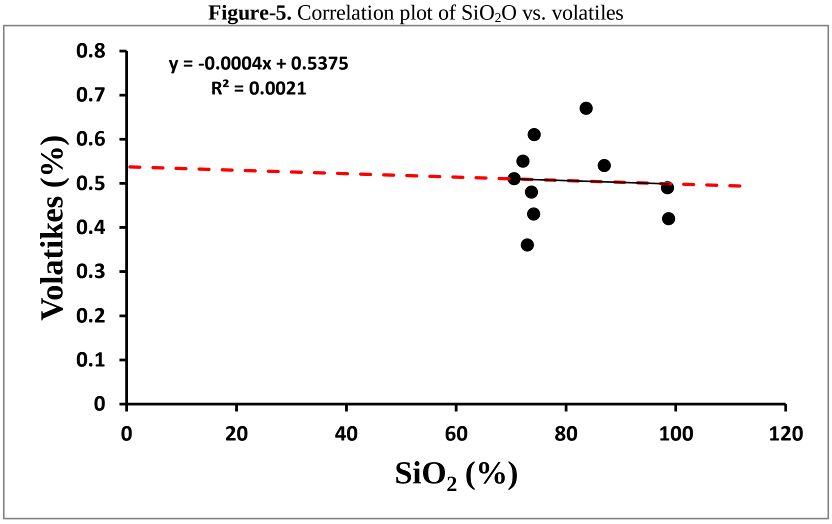


Figure-5. Correlation plot of SiO_2O vs. volatiles



4.4. Correlation Coefficients and Principal Component Analysis

The interrelationship between elements in the rocks is presented in Table.3. The result shows a strong positive correlation between the elements. This implies that they are strongly related and therefore of the same source, suggesting geogenic sources.

With regards to the PCA, the concentration dataset is divided into subsets, represented by different factors. The elements in each subset are correlated with one another and are largely independent of the elements in the other subsets (Table 4). According to Deng, *et al.* [34] factors should be representative of the underlying geological and metallogenical process that created the correlations among these variables. Based on PCA, the elements were classified into two factors. The second factor is important because Au, As, Ag, Pt and Os are situated on this factor and they are pathfinder elements of Gold. Figure 6 is a plot of the components showing metallic affinities.

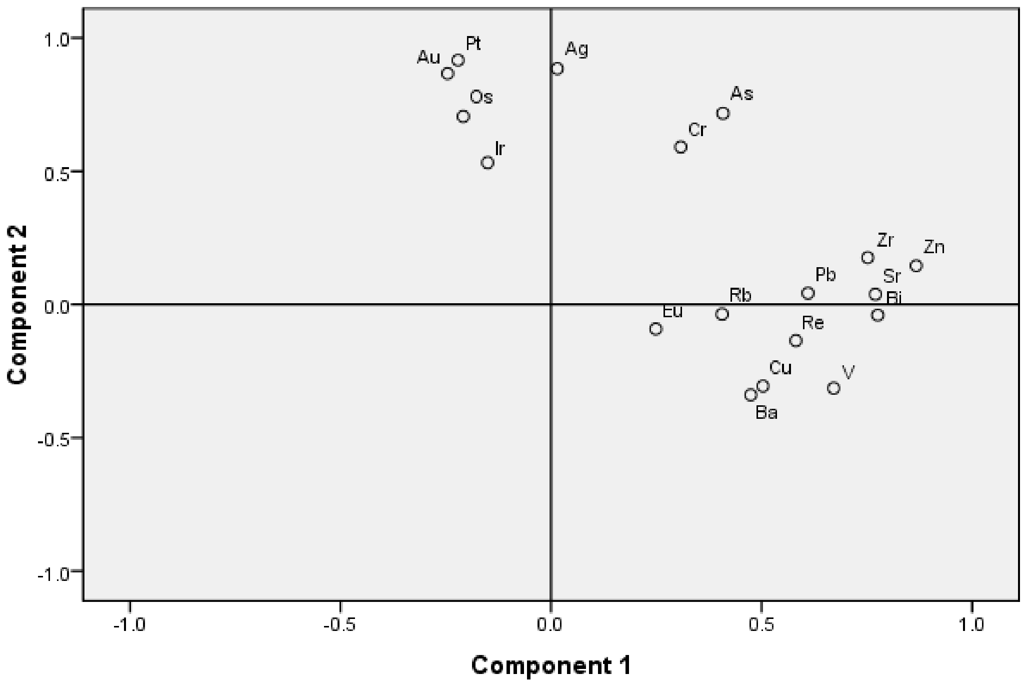
Table-3. Bivariate and multivariate statistical analysis of trace and rare metals using Spearman correlation coefficients

	Cu	*Zn*	*As*	*Pb*	*Rb*	*Ir*	*Sr*	*Pt*	*Zr*	*Os*	*Ag*	*Ba*	*Fe*	*Eu*	*Au*	*V*	*Cr*	*Bi*
Cu	1																	
Zn	0.999523	1																
As	0.99923	0.999619	1															
Pb	0.999634	0.999723	0.999441	1														
Rb	0.999369	0.999574	0.999423	0.999559	1													
Ir	0.999293	0.999174	0.999441	0.998991	0.999179	1												
Sr	0.999138	0.999634	0.999592	0.999418	0.999196	0.998581	1											
Pt	0.99997	0.999999	0.999969	0.999929	0.999986	0.99979	0.999958	1										
Zr	0.999664	0.99987	0.999602	0.99976	0.999821	0.999512	0.999403	0.999997	1									
Os	0.999977	0.999999	0.999965	0.999987	0.99999	0.999873	0.999974	1	1	1								
Ag	0.998989	0.999409	0.999646	0.999548	0.999584	0.999401	0.99903	0.999912	0.999639	0.999945	1							
Ba	0.999551	0.999551	0.999322	0.999686	0.999767	0.999104	0.99935	0.999985	0.999794	0.999989	0.999409	1						
Fe	0.99945	0.999566	0.999288	0.999516	0.999867	0.99912	0.999065	0.999962	0.999805	1	0.999379	0.99979	1					
Eu	0.999355	0.99933	0.999566	0.999302	0.999584	0.999143	0.99932	0.99996	0.99948	1	0.999228	0.999588	0.999539	1				
Au	0.998709	0.999064	0.999466	0.999101	0.999384	0.999519	0.9985	0.999884	0.999389	0.999921	0.999835	0.998985	0.999039	0.998966	1			
V	0.999241	0.999637	0.998977	0.999356	0.99945	0.998502	0.999028	0.999961	0.999505	0.999966	0.998781	0.999308	0.999507	0.999291	0.998458	1		
Cr	0.998846	0.999502	0.99974	0.999254	0.999723	0.999089	0.999358	0.999979	0.999557	0.999996	0.999642	0.999314	0.99946	0.999536	0.999527	0.999186	1	
Bi	0.998853	0.999252	0.998995	0.99873	0.998231	0.997868	0.999481	0.999966	0.998712	0.999977	0.997854	0.998368	0.998378	0.998668	0.997261	0.998816	0.998462	1

Table-4. Principal Component Analysis (PCA) of trace and rare metals

	Component	
	1	2
Zn	0.867	0.145
Bi	0.776	-0.04
Sr	0.77	0.039
Zr	0.752	0.176
V	0.671	-0.314
*Pb	0.61	0.043
Re	0.581	-0.136
Cu	0.503	-0.306
Ba	0.474	-0.339
Rb	0.406	-0.037
Eu	0.249	-0.092
*Pt	-0.221	**0.916**
*Ag	0.015	**0.885**
Au	-0.246	**0.867**
*As	0.408	**0.717**
*Os	-0.209	**0.706**
Cr	0.308	0.591
*Ir	-0.151	0.532

Figure-6. Component plot in rotated space of the studied samples



4.5. Enrichment Factor

The results of the enrichment factor on the base metals, statistical summary and percentage enrichment factor are shown in Tables 5, 6 and 7 respectively while the histogram of distribution of the base and precious metals in the rocks is shown in Figure 7.

A common approach to estimate how much rocks and sediments are impacted (naturally and anthropogenically) with metal is by calculating the Enrichment Factor (EF). According to Sutherland [35], EF of a metal in sediment can be calculated using the expression:

$$EF = \frac{[C_{sample/C_{normalizer}}]Al}{[C_{metal/C_{normalizer}}]}$$

where C_{metal} and $C_{normalizer}$ are the concentrations of metal and normalizer in sample and in unpolluted control. Al has a constant value of 1 throughout the analysis which showed that it is the base element for the analysis. Minerals like Cu, Pb and Bi showed moderately to extremely high enrichment (10 – 70%, 20 – 40% and 10 – 40%), while Ti was noted to exhibit extremely high enrichment of 100%.

4.6. Index of Geoaccumulation (Igeo)

The index of geo-accumulation of the base metals is shown in Table 8 while the statistical summary is presented in Table 9. The fact that all the value indicated in the geo-accumulative statistics table is below 1 implies that the metals are from geogenic sources (they are all naturally occurring elements). Therefore, all the base metals are from geogenic sources with little or no anthropogenic contribution.

Table-5. Enrichment Factors (EF) for the base metals

Sample ID	EF (Cu)	EF (Pb)	EF (Zn)	EF (Ag)	EF (Bi)	EF (Cr)	EF (Ti)	EF (Al)
Okemesi 1 Qtz	83.755	11.965	2.393	0.55039	97.7142	0.31907	5721.39	1
Okemesi 2 Qtz	89.8421	17.152	1.63349	0.58397	24.5024	0.0245	3814.67	1
Ijero Quarry A	64.3685	14.304	1.10857	1.14433	12.1585	0.0143	238.601	1
Ijero Quarry B	12.2482	2.2563	0.12893	0.70266	1.28929	0.25786	107.53	1
Ijero Quarry C	91.8743	8.3522	0.25057	0.51227	15.3124	0.03898	92.8799	1
Itawure 1 Qtz	7.23958	1.9051	1.14309	0.87256	3.81031	0.30482	1525.4	1
Itawure 2 Qtz	118.643	4.1267	1.03168	0.72733	5.1584	0.05158	1204.63	1
Ajindo Qtz	2.29014	0.5725	0.0458	0.14199	0.57254	0.03893	4622.31	1
Ipoti Quarry	182.718	56.705	12.6012	39.0638	63.0062	3.78037	2101.96	1
Odo-Owa Quarry	149.085	298.170	16.3993	52.9252	14.9085	5.9634	2486.83	1

Table-6. Statistical Summary for the Enrichment Factor

Enrichment Factor	MIN	MAX	AVER	STDEV
EF (Cu)	2.2901	182.718	80.206	60.769
EF (Pb)	0.5725	298.17	41.550	91.647
EF (Zn)	0.0458	16.399	3.6735	5.8200
EF (Ag)	0.1419	52.925	9.7224	19.395
EF (Bi	0.5725	97.714	23.843	31.764
EF (Cr)	0.0143	5.963	1.0793	2.0674
EF (Ti)	92.879	5721.39	2191.62	1974.21
EF (Al)	1	1	1	0

Table-7. Percentage Enrichment of the base metals

Class	Sediment Quality	Cu	Pb	Zn	Ag	Bi	Cr	Ti
		Percent						
EF <2	Deficiency to Mineral Enrichment	0	20	70	80	20	80	0
EF= 2- 5	Moderate Enrichment	10	20	10	0	10	10	0
EF=5-20	Significant Enrichment	20	40		0	40	10	0
EF = 20-40	Very High Enrichment	0	0	0	0	10	0	0
EF >40	Extremely High Enrichment	70	20	0	20	20	0	100

Figure-7. Histogram showing Base metal distribution in the rocks

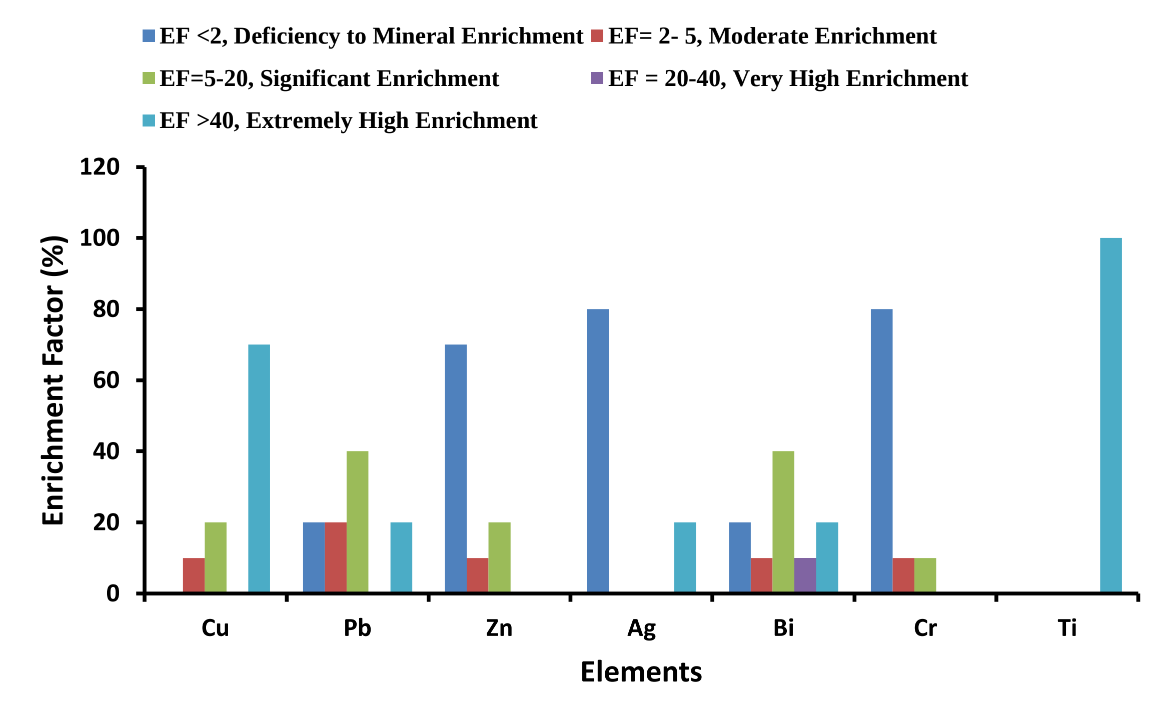


Table-8. Index of geo-accumulation of the base metals

ELEMENTS	Cu	Pb	Zn	Ag	Bi	Cr	Ti	Al
Okemesi 1 Qtz	-2.553	-3.397	-2.096	1.264	-2.185	-1.574	-3.320	-0.475
Okemesi 2 Qtz	-2.533	-3.251	-2.273	1.280	-2.796	-2.699	-3.507	-0.486
Ijero Quarry A	-2.619	-3.273	-2.383	1.630	-3.043	-2.875	-4.652	-0.428
Ijero Quarry B	-3.295	-4.03	-3.273	1.463	-3.972	-1.574	-4.953	-0.383
Ijero Quarry C	-2.356	-3.397	-2.921	1.389	-2.834	-2.331	-4.953	-0.319
Itawure 1 Qtz	-3.596	-4.176	-2.398	1.484	-3.574	-1.574	-3.874	-0.456
Itawure 2 Qtz	-2.513	-3.972	-2.574	1.274	-3.574	-2.477	-4.108	-0.587
Ajindu Qtz	-3.574	-4.176	-3.273	1.218	-3.875	-1.945	-2.871	0.066
Ipoti Quarry	-3.412	-3.920	-2.574	1.917	-3.574	-1.699	-4.953	-1.674
Odo-Owa Quarry	-3.574	-3.273	-2.533	1.9762	-4.273	-1.574	-4.953	-1.747

Table-9. Statistical Summary of Index of Geo-accumulation for the base metals

Geo-accum	MIN	MAX	AVER	STDEV
Igeo Cu	-3.596	-2.356	-3.003	0.525
Igeo Pb	-4.176	-3.252	-3.686	0.398
Igeo Zn	-3.273	-2.096	-2.629	0.401
Igeo Ag	1.218	1.976	1.489	0.271
Igeo Bi	-4.273	-2.184	-3.369	0.640
Igeo Cr	-2.875	-1.574	-2.032	0.516
Igeo Ti	-4.954	-2.871	-4.215	0.789
Igeo Al	-1.748	0.066	-0.649	0.586

5. Conclusion

This study has provided useful information on the lithological characteristics and geochemical background values of the various base metals present in the bedrocks of Okemesi/Ijero area, which serves as a useful guide in exploration and exploitation of these metallic resources. The rocks contain high silicon content and moderate aluminum, sodium and potassium oxide contents. This high content of silica is responsible for their hardness and their high resistance to weathering, which could make them useful construction raw materials. Also, the enrichment factor result showed that Cu, Pb and Bi has moderate to extremely high enrichment, while Ti has extremely high enrichment. Also, there is structurally-controlled type of mineralization as observed in the pattern of emplacement of the bedrocks. The results also suggest possible showings of gold mineralization in the studied area, though a further geochemical assertion is still required to delineate the auriferous zones. It can however be concluded that the base metals analyzed are from geogenic sources, as there no trace of anthropogenic inputs in their geo-accumulation index. Radiometric dating of the rocks to determine its petrogenetic characteristics and detailed structural mapping of the studied area to identify nappe structures are recommended. The Correlation coefficients indicate strong positive correlations between the elements. The PCA elements loaded Au, As, Ag, Pt and Os on the same factor and they are pathfinder elements of Gold.

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