

Statistical Analyses from Geochemical Investigations of Basement Rocks in Ila Orangun Area, Southwestern Nigeria

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Abstract: *Ila Orangun is located within the basement complex and specifically on the north of Okemesi and falls within latitude 7°54' and 8°00' N and longitudes 4° 53' and 5° 00' E respectively. In the study area six (6) lithological units were identified to be common around the study area which includes quartzites, granites, granite gneiss, porphyritic granites, amphibolite and pegmatites. This study focuses on statistical analyses of geochemical datasets obtained from the geochemical investigations of basement rocks in Ila Orangun area, Southwestern Nigeria with the aim of ascertaining the elemental association of their chemical components targeted at validating the mineralization potentials of basement rocks in the area. For the purpose of this study involving statistical analyses, the use of relevant statistical software packages such as IBM SPSS, Statistics 28 was employed so as to obtain useful and reliable information on the geochemical attributes of the rocks in the area. Statistical analysis was carried out with the aid of available geochemical data which were statistically processed using descriptive statistics, principal component analysis (PCA), analysis of variance (ANOVA), correlation coefficient and factor analysis. Results from statistical analysis showed that correlation matrix using Pearson method displayed positive and negative values. From factor analysis, five component groups were extracted from the analysis with each component group showing the various elemental associations. Component 1 show Ag-As-Ba-Cd-Co elemental association suggesting sulphide mineralization. Component 2 show Cr-Cu-Ni elemental association which are pathfinder elements while component 3 show Pb-Rb elemental association, Component 4 reveal Zn-Fe-V elemental association and Component 5 show U-Mn elemental association. However, Components 3, 4 and 5 suggest weathered and dispersed elements. Hence, it is recommended that subsequent researchers who may intend to work on the study area should consider the geochemical characteristics of pegmatites in the study area to unravel its mineralization potential.*

Keywords: statistical, mineralization, elemental association, factor analysis, Ila Orangun

INTRODUCTION

The integration of accurate and reliable geoscience information in form of geological, geochemical and statistical studies have been found to be very important for the purpose of mineral resources exploration, development and production across the globe (Jayeola, et.al., 2023). The combination of these research methods has played vital roles in affirming the elemental association of mineral and chemical components

of rocks in the study area for the purpose of mineral exploration. The study area, Ila Orangun falls within the basement complex of southwestern Nigeria. It is noted to be the headquarter of Ila Local Government Area in the present-day Osun State. The study area occupies an area of about 143.745 km² between 7° 54' and 8° 001' N latitude and between 4° 53' and 5° 00' E longitude. However, with the continuously growing availability of geoscience data acquired by field and laboratory methods, there is an increasing demand to interpret and analyze such multivariate data sets in a spatially consistent and integrated manner. These study techniques have over the previous centuries proven to be highly suitable in complementing conventional geological mapping, identifying targets for mineral and hydrocarbon exploration (Drury, 1992) and there is increasing awareness that they provide invaluable information to monitor the environment (Bennett and Doyle, 1997). Increasingly however, the goal of the earth scientist in investigating a region of interest is to integrate and spatially link all the available data to gain insight into the geological phenomena and processes in a study area. The line of reasoning is that each data type potentially provides complementary information and that if such data are adequately integrated more insight in the geology of an area is better understood. Ground-truthing which involves field observations became necessary so as to validate needed information on the geology of the study area with the motive of conducting geochemical analyses on rocks which describes the underlying lithology of the area. This will allow for comparisons between information obtained from the field study and that read from literatures reviewed for the area. Geochemical details of rock samples were processed and analysed with results being interpreted and subjected to statistical analyses so as to validate the geochemical attributes and elemental associations of basement rocks in the area for the purpose of mineral exploration for predictive modelling and mineral potential prediction (Ayodele, 2015).

The Study Area

The study area is located within Osun state in the southwestern part of Nigeria. It falls within latitudes 7°54' and 8° 001'N and longitudes 4°53' and 5°00'E covering a total estimated area of about 143.745km². The various camps and settlements within the area are accessible through footpaths, minor road networks and motorable tracks which are all interconnected (Figure 1 and 2). Ila Orangun falls within the tropical rain forest and has a humid tropical climate characterized by distinct wet and dry seasons.

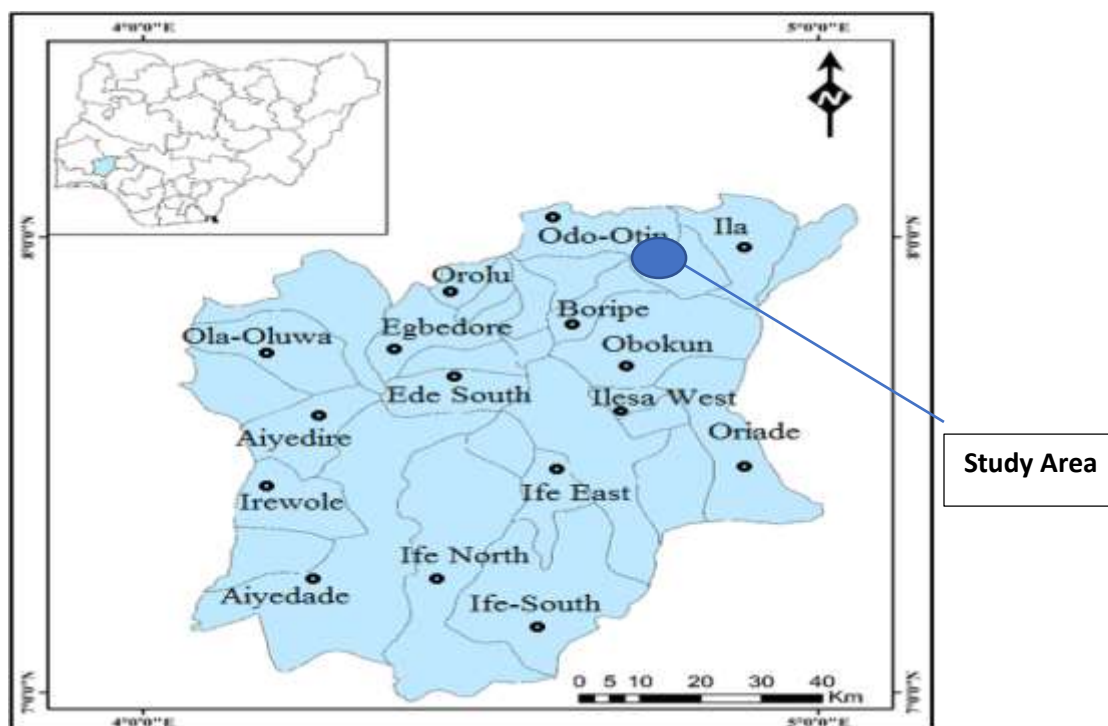


Figure 1: Map of Osun State showing the study area (Inset: Map of Nigeria)

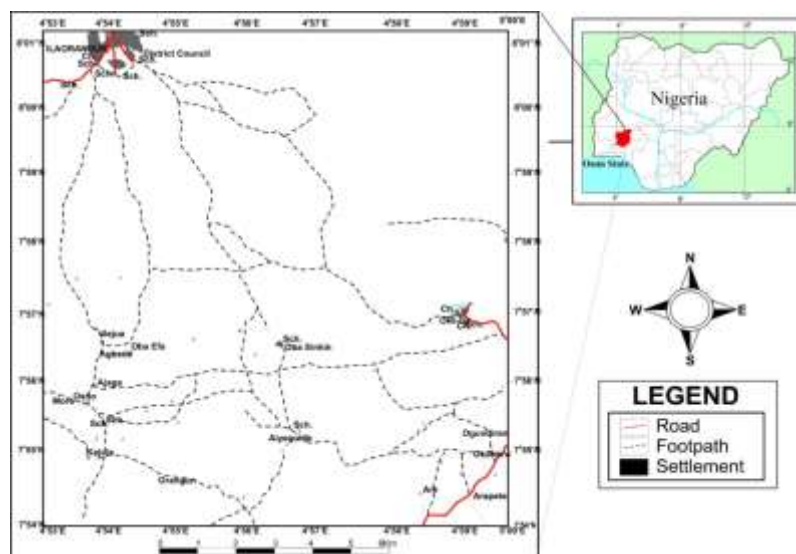


Figure 2: Interconnectivity and accessibility map of the study area (Inset: Map of Nigeria)

Geologic Settings: Regional and Local

The study area being part of the Ilesha Schist belt, the Nigerian schist belts are exposed predominantly west of longitude 8° within a North-South trending (Figure 3). The lithology of schist belts generally consists of pelitic and semi-pelitic schist, phyllites, quartzites, polymict meta-conglomerate, iron formation, marbles, calcsilicate rocks and subordinate igneous rocks. These rock types occur in varying proportions in different schist belts across Nigeria (Rahaman, 1976; King and De Swardt, 1949; Elueze, 1981; Odeyemi, 1988; Adekoya, 1996). The local geology revealed that six (6) lithological units were identified in the study area which includes quartzites, granites, granite gneiss, porphyritic granites, amphibolite schists and pegmatites thus describing the local geology of the area (Figure 4).

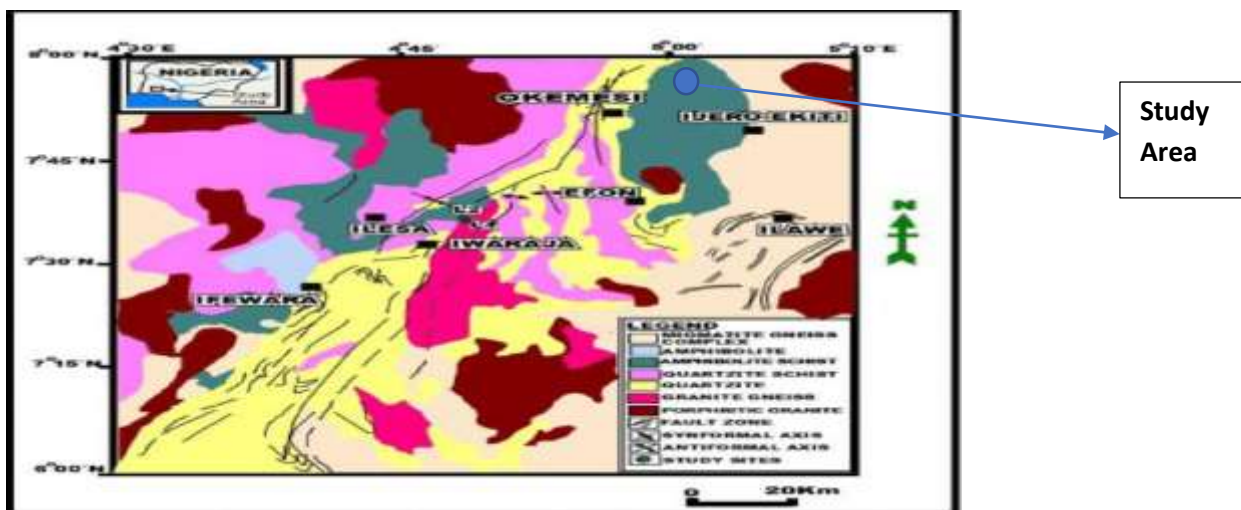


Figure 3: Geological Map of Ilesha Schist Belt Showing the Study Area (Modified After Odeyemi,1993)

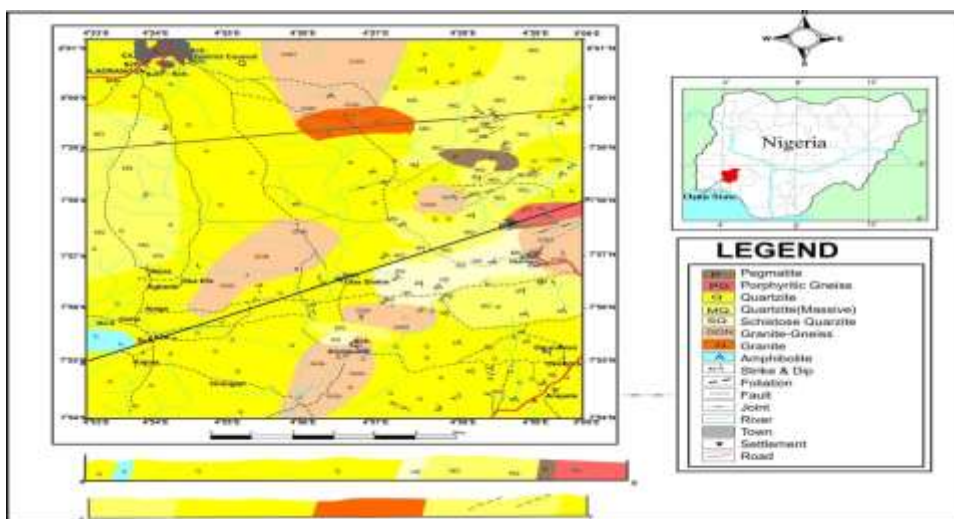


Figure 4: Geological Map of the study area with cross sections

MATERIALS AND METHODS

Very vital research material used for this research is software-enabled computer with relevant Microsoft Word suites including excel sheets. These research materials were required for the purpose of this study so as to effectively utilize relevant statistical software packages such as IBM SPSS and Statistics 28. Statistical analysis was carried out with the aid of available geochemical datasets which were statistically processed using descriptive statistics, principal component analysis (PCA), analysis of variance (ANOVA), correlation coefficient and factor analysis.

RESULTS AND DISCUSSION

Statistical analyses were conducted using available geochemical datasets which were processed adopting descriptive statistics, correlation coefficient and factor analysis statistical methods. Hence, the results of these statistical analyses were carefully presented in Tables 1 - 6 below and succinctly discussed so as to clearly extract useful information from available geochemical datasets as well as relate the useful information with the geochemical attributes of rocks in the study area.

For the descriptive statistical analysis, the descriptive variables used are mainly heavy metals which include Ag, As, Ba, Cd, Co, Cr, Cu, Ni, Pb, Rb, U and Zn. Results were obtained and presented on the descriptive statistics table showing the range values, minimum and maximum values, mean, standard deviation and variance (Table 1). Trace elements in the forty (40) samples were considered which are denoted by 'N'. The range here implies the difference between the maximum and minimum values obtained from the bulk of geochemical data obtained as concentration of the trace elements in parts per million. Hence, the range values obtained reveals that the difference between the Maximum and Minimum values for Ag is 0.64, As (0.23), Ba (0.11), Cd (1.35), Co (0.62), Cr (0.90), Cu (0.73), Ni (1.38), Pb (1.74), Rb (0.90), U (0.50) and Zn (0.82). The highest maximum values of 1.20 was observed in Nickel (Ni) and the least maximum value is 0.08 was observed in Ba. The highest minimum value 0.02 was observed in Zinc (Zn) while the least minimum value 0.00 was observed in Uranium (U). Mean (Average) values show Ag (0.0346), As (0.0571), Ba (0.0419), Cd (-0.0108), Co (-0.0425), Cr (0.0632), Cu (0.0068), Ni (0.1052), Pb (0.0911), Rb (0.0441), U (0.0735) and Zn (0.4110). The difference between the Maximum and Minimum values for Ag is 0.64, As (0.23), Ba (0.11), Cd (1.35), Co (0.62), Cr (0.90), Cu (0.73), Ni (1.38), Pb (1.74), Rb (0.90), U (0.50) and Zn (0.82). The highest maximum values of 1.20 was observed in Nickel (Ni) and the least maximum value is 0.08 was observed in Ba. The highest minimum value 0.02 was observed in Zinc (Zn) while the least minimum value 0.00 was observed in Uranium (U). Values obtained for the standard deviation are all observed to be less than 1 showing perfect positive correlation.

Table 1: Descriptive statistics of heavy metals in the study area

	N	Range	Minimum	Maximum	Mean	Std. deviation	Variance
Ag	40	.64	-.08	.56	.0346	.11150	.012
As	40	.23	.01	.24	.0571	.03872	.001
Ba	40	.11	-.03	.08	.0419	.02606	.001
Cd	40	1.35	.72	.63	-.0108	.21270	.045
Co	40	.62	-.24	.38	-.0425	.12545	.016
Cr	40	.90	-.14	.76	.0632	.17656	.031
Cu	40	.73	-.35	.38	.0068	.15831	.025
Ni	40	1.38	-.18	1.20	.1052	.34206	.117
Pb	40	1.74	-.82	.92	.0911	.30619	.094
Rb	40	.90	-.08	.82	.0441	.15513	.024
U	40	.50	.00	.50	.0735	.07491	.006
Zn	40	.82	.02	.84	.4110	.17859	.032
Valid N (listwise)	40						

Results of correlation coefficient using Pearson Correlation Coefficient show Cu and Cr (0.162,0.319), Ba and Ag (0.116,0.475), Cd and As (-0.018, 0.913), Co and Ba (0.157,0.333), Cr and Cd (-0.020,0.901), Cu and Co (0.290,0.069), Ni and Cr (0.389,0.013), Cd and Ag (0.192,0.235), Co and As (0.134,0.409), Cr and Ba (-0.263,0.101), Cu and Cd (0.461, 0.003), Ni and Co (-0.023,0.887). Correlation coefficient of the trace elements compared show a perfect strong positive correlation which shows an established relationship between the trace elements which are possibly obtained from the same source, describing same geogenic sources while correlation coefficient values for trace elements showing negative (-ve)

values implies a perfect weak negative correlation showing little or no established relationship between the trace elements suggesting that they are of heterogeneous geogenic sources (Table 2)

Table 2: Correlation Coefficient of Trace Elements as Variables

	Cu	Ni	Pb	Rb	U	Zn
Ag Pearson Correlation	.392	.196	.097	.188	.246	.245
Sig. (2-tailed)	.012	.225	.551	.244	.126	.127
N	40	40	40	40	40	40
As Pearson Correlation	.248	.089	.028	.006	.070	.022
Sig. (2-tailed)	.124	.585	.866	.972	.669	.894
N	40	40	40	40	40	40
Ba Pearson Correlation	.072	.142	.029	.213	.094	.351
Sig. (2-tailed)	.660	.381	.858	.187	.563	.026
N	40	40	40	40	40	40
Cd Pearson Correlation	.461	-.019	.201	.154	.102	-.031
Sig. (2-tailed)	.003	.907	.213	.341	.532	.850
N	40	40	40	40	40	40
Co Pearson Correlation	.290	.023	.292	.178	.171	.231
Sig. (2-tailed)	.069	.887	.068	.272	.291	.152
N	40	40	40	40	40	40
Cr Pearson Correlation	.162	.389	-.058	-.074	.011	.262
Sig. (2-tailed)	.319	.013	.722	.652	.945	.103
N	40	40	40	40	40	40
Cu Pearson Correlation	1	-.010	.145	.266	.196	.127
Sig. (2-tailed)		.952	.373	.097	.225	.434
N	40	40	40	40	40	40
Ni Pearson Correlation	-.010	1	.085	.537	-.003	-.142
Sig. (2-tailed)	.952		.603	.000	.986	.382
N	40	40	40	40	40	40
Pb Pearson Correlation	.145	-.085	1	.023	-.440	-.012
Sig. (2-tailed)	.373	.603		.886	.005	.942
N	40	40	40	40	40	40
Rb Pearson Correlation	.286	.537	.023	1	.150	.162
Sig. (2-tailed)	.097	.000	.886		.356	.319
N	40	40	40	40	40	40
U Pearson Correlation	.196	.003	-.440	.150	1	.057
Sig. (2-tailed)	.225	.986	.005	.356		.727
N	40	40	40	40	40	40
Zn Pearson Correlation	.127	-.142	-.012	.162	.057	1
Sig. (2-tailed)	.434	.382	.942	.319	.727	
N	40	40	40	40	40	40

▪ Correlation is significant at the 0.05 level (2-tailed)

▪▪ Correlation is significant at the 0.01 level (2-tailed)

For the factor analysis, 12 variables were considered to include Ag, As, Cd, Co, Cr, Cu, Ni, Pb, Zn, Hg, Fe and Sn. Five component groups otherwise known as Factors were extracted from the analysis identified as Group I, Group II, Group III, Group IV and Group V with each component group serving specific purpose in the analysis. Elements noted to be variables in Group I show values of Ag (.374), Cr (.779), Ni (.731) with a variance of 16.611 and covariance of 16.611. Group II show values of As (.663), Ni (.340), Hg (.510), Fe (.431), Sn (.837) with a variance of 14.835 and covariance of 31.446. Group III show values of Co (.537), Pb (.854), Hg (.752) with a variance of 14.116 and covariance of 45.562. Group IV show values of Cd (.853) and Cu (.773) with a variance of 13.311 and covariance of 58.873. Group V show values of Ag (.669), Co (.470) and Zn (.805) with a variance of 12.318 and covariance of 71.192. The result of factor analysis shows five component groups derived from the analysis. **Group 1** consists of Ag-Cr-Ni elemental associations with 16.611% variance of the total. However, there is likelihood of Ag, Cr, and Ni mineralization in the study area. These elements are hosted by lithologies such as quartzite suggesting sulphide mineralization. **Group II and III** consist of As-Ni-Hg-Fe-Sn-Co-Pb-Hg element association which could be pathfinder element to the mineralization (especially gold) that characterize the study area with a variance of 28.951% of the total. **Group IV and V** consist of Cd-Cu-Ag-Co-Zn which concentrations are significant to elemental associations and mineralization with a variance of 25.629% (Table 3).

Table 3: Factor Analysis involving Five Component Group

	Component				
	1	2	3	4	5
Ag	.374				.669
As		.663			
Cd				.853	
Co			.537		.470
Cr	.779				
Cu				.773	
Ni	.731	.340			
Pb			.854		
Zn					.805
Hg		.510	.752		
Fe		.431			
Sn		.837			
VAR	16.611	14.835	14.116	13.311	12.318
CVAR	16.611	31.446	45.562	58.873	71.192

Table 4: Principal Component Analysis for the Five Component Group Showing Eigen Values for the Variables

Component	Initial Eigen Values			Extraction Sums of Squared Loadings		
	Total	% Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.504	20.865	20.865	2.504	20.865	20.865
2	1.725	14.377	35.242	1.725	14.377	35.242
3	1.531	12.755	47.997	1.531	12.755	47.997
4	1.410	11.746	59.743	1.410	11.746	59.743
5	1.070	8.913	68.656	1.070	8.913	68.656
6	0.925	7.705	76.361	0.925	7.705	76.361
7	0.730	6.083	82.444	0.730	6.083	82.444
8	0.649	5.406	87.850	0.649	5.406	87.850
9	0.567	4.723	92.572	0.567	4.723	92.572
10	0.437	3.643	96.215	0.437	3.643	96.215
11	0.286	2.383	98.598	0.286	2.383	98.598
12	0.168	1.402	100.00	0.168	1.402	100.00

Geochemical results using statistical analysis show that rocks in the area are mineralized with these heavy metals, hence could be obtained in reasonable commercial quantity if large quantities of the rocks are collected for processing as the results for five (5) component factor analysis depicts the possibilities of Ag (Silver), Chromium (Cr) and Nickel (Ni) elemental associations suggesting the presence of sulphide rich-rock. Also suspected are the presence of Mercury (Hg), Iron (Fe), Tin (Sn) and Arsenic (As) elemental

associations identified as pathfinder elements for the possibility of gold mineralization in rocks within the study area.

CONCLUSION AND RECOMMENDATION

Evidence from geochemical analyses using statistical study approach show vividly that rocks within the study area are mineralized as they play host to sulphide-bearing rocks and some heavy metals which are identified as pathfinders to gold mineralization with the pegmatites as intrusives noted to host substantive amount of these mineral suites. From the various geochemical plots, it is confirmed that the geochemical classification of rocks within the area is of the peraluminous and peralkaline metaluminous while the granite tectonic discrimination (Pearce et al.,1984), suggest that the rocks straddle between the VAG (Volcanic Arch Granites) and the WPG (Within Plate Granites) with most of the samples confined to the VAG field. It is therefore recommended that subsequent researcher who may intend to work on the study area should consider stream sediments analysis as a way to further establish more facts on the geochemistry of sediments in rivers within the environ as they are possibly sourced from the surrounding rocks.

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