# Geochemical Treatment of Stream Sediment Data from River Ipala Drainage Basin, Guguruji, Southwestern Nigeria: Implication for Mineralization

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***Abstract*: Metallic mineralization has been suspected within an extensive drainage basin of River Ipala, Guguruji, of Egbe-Isanlu schist belt, Southwestern Nigeria. The area which has not been subjected to modern methods of mineral exploration as at the time of this research has no information available on the concentration and dispersion pattern of minerals in the basin. This study therefore focuses on the statistical treatment of the stream sediments data and its metallic prospects. Twenty-five composited stream sediments samples were analyzed for trace element concentrations. The statistical treatment of the data provided parameters such as descriptive statistic, correlation matrix and factor analysis of the variables. The Descriptive statistics provided mean, standard deviation and skewness of the distribution, while correlation matrix identified Au, As, Br, Cr, Sb, Sc, Cu, Ni, Zn, S, Ag, and Pb as associates with various loadings. Factor analysis yielded a five-factor model high loadings that accounted for 83.69% cumulative variance; four of which are mineralization related: Sc-Ni-Zn and Cu-Pb on one hand and single ore metals such as Au and Ag on the other, while the Br-S is lithology related. The study therefore identified areas with high elemental concentrations, and metallic associations that holds potential for Au and base metal deposits in the basin.**

***Keywords*: Factor loading, geochemical, pathfinder, standard deviation**

## I. INTRODUCTION

Metallic mineralization has been suspected within an extensive drainage basin of River Ipala and its tributaries around Guguruji in Egbe - Isanlu schist belt of Southwestern Nigeria. Guguruji is probably one of the areas identified by the Geological Survey of Nigeria (GSN) under Falconer (1911) leadership when its activities in tin fields and geological mapping in Nigeria was intensified to discover mineral occurrences and deposits as they are known today. The history of mining in the area has been linked with the operations of mining activities in Jos in the fifties which field observations, such as old mining sites, long trenches used for water control and relics of worked pegmatites seemingly confirm. Okolom, Egbe, Isanlu and Dogondaji are prominent gold districts within this schist belt. Garba, (1985 and 1987) carried out stream sediments and geochemical prospecting for gold in Isanlu area. Gold mineralization in Guguruji area was first documented by the Nigeria Mining Corporation (NMC) in the eighties (Dada, 1983). Guguriji is about 72km and 40km, northeast of Egbe and Isanlu respectively, and 35km southeast of Okolom. These communities are within the same Egbe -Isanlu schist belt and hence Guguruji can be considered an eastern extension of the Egbe -Isanlu -Okolom gold field.

An extensive part of Guguruji environ is covered by thick superficial overburden presumably deposited unconformably on loose and unconsolidated conglomeratic materials,which rest on the basement rocks. The basement consists of lithologic units which include migmatized biotite gneiss, carbonate rocks, mafic metavolcanics, the schistose and the plutonic rocks. These are the biotite gneiss, calc-silicate gneiss, amphibolite, the quartz-mica schist and granitc rocks. The drainage system of Guguruji area is characterized by irregular joining of the main river (River Ipala) by tributaries at nearly acute angles forming open V shape and then Y shape channels downstream, consequently defining dendritic pattern (Fig.1).

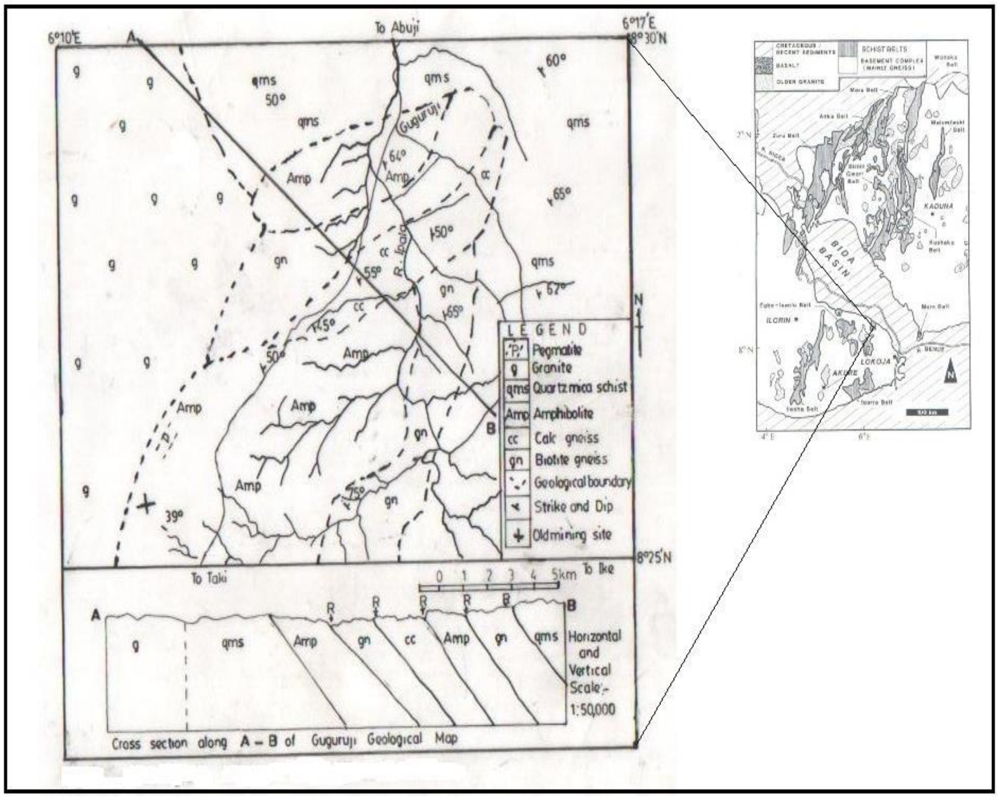

Fig. 1: Map of Guguruji area showing River Ipala drainage basin

(Inset is map of Egbe-Isanlu Schist belt)

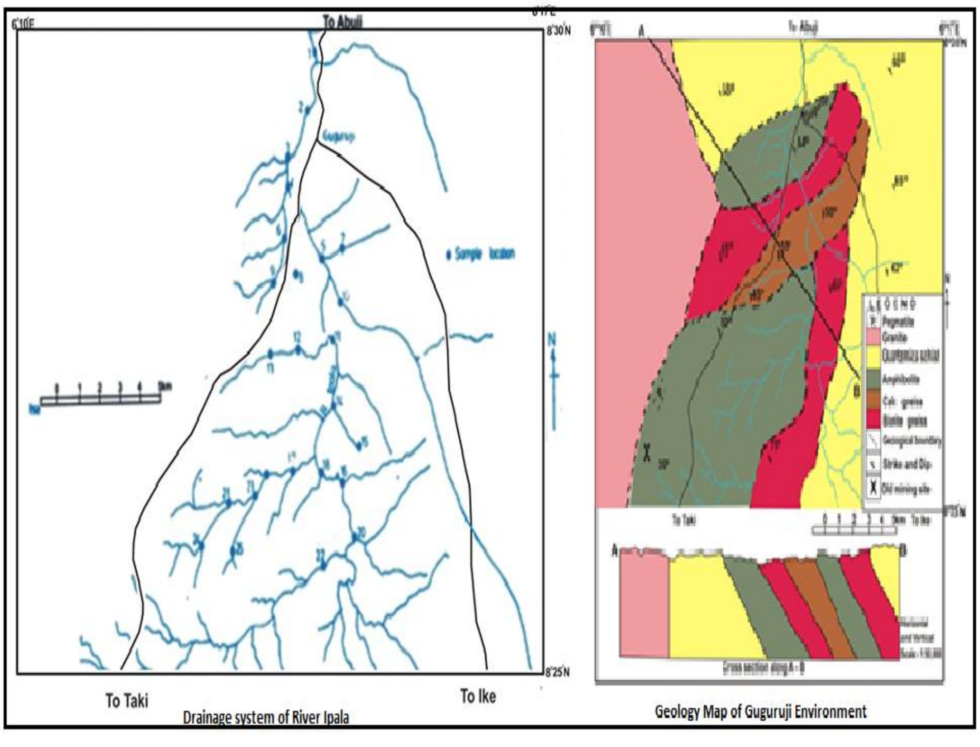

Fig.2: The drainage pattern and the geological Map of Guguruji Area

This pattern is attributable to the geology and geomophological history of the area. River Ipala and tributaries now drains a uniformly erodible regolith, resulting in the dendritic drainage pattern. The river gradient is gentle and the valley width ranges between 20 to 50metres.Following the reported mineralization in the area, annual gathering of droves of men for informal artisanal mining activities along the course of the rivers is a common sight. The area having not been subjected to modern methods of mineral exploration, no information is available on the distribution and dispersion pattern of minerals. The current study focuses on the statistical treatment of its stream sediments data and possibility of metallic prospects. The use of stream sediments geochemistry in prospecting for ore deposits has been successfully employed in many parts of the world (e.g. Naseem et al., 2002; Ali *et al.*,2006; Bölücek and Kalender, 2009; Knights, *et al.*,2010). And in Nigeria, Ajayi (1981); Elueze and Olade (1985); Ojo, (1988); Bammeke (1992);Adepoju and Adekoya (2008); and Bamigboye and Adekeye (2011) have also conducted various geochemical surveys.

## II. MATERIALS AND METHODS

Dry samples were collected from the channels along the winding course of the river and its tributaries (Fig.2). At each point and at depths of between 10 to 15cm, 5kg of stream sediments were collected and composited for between 2 and 10 pits across the river channel (depending on the width) to minimize within site heterogeneity (Bölücek and Kalender, 2009),and sampling was at every 100 to 150 metre interval. Appropriate precautions were observed to prevent contaminants. There is the preponderance of fine-medium grained sediments, in which case fine fractions are moderate in proportion. Many studies (e.g. Rose *et al.*,1979, Beeson, 1984, 1995), have shown that elemental values in anomalous sediments must be sufficiently distinctive for them to be distinguished from the regional background in the fine fractions of the sediments. Each sample was therefore disaggregated and sieved with an improvised nylon sieve on site to reduce the weight and the fraction packaged into pre-labelled nylon bag for further treatment in the laboratory. A total of twenty-five composited samples were collected comprising of samples from the main stream and its tributaries. The samples were sieved through 75µm mesh, and sent to Activation Laboratory in Ancaster, Canada for analysis to determine its trace element composition. Total Digestion Inductively Coupled Plasma (TD-ICP) package which runs on Perkin Elmer-Sciex ELAN 9000, where 0.25g aliquot of each sample was digested with HF and then HCIO4–HNO3at 260oC to fuming, and subsequently mixed with dilute Aqua Regia (AR) to leach sulphides, oxides and silicates. The resulting solution was now fed into Varian 735ESICP for interpretation. FA-MS and INAA methods were used for gold analysis following the steps outlined by Hoffman *et al.*,(1998). This was supplemented by a subset of each sample analyzed for Ag, Cd, Cu, Mn, Mo, Ni, Pb, Zn, and S by additional procedure of Aqua Regia (AR-ICP).

## III. RESULTS

### *3.1 Dispersion*

The results of the full range of elements detected by the analysis are as presented in Table 1(OlaOlorun, 2014). The table shows that gold ranges between 0.002 and 0.34 ppm with a mean of 0.06 ppm. Arsenic (As) vary from 0.50 to 7.40 pm with a mean value of 3.51 ppm. Bromine, a member of the halogen group has a mean concentration of 0.66 ppm and range from 0.2 to 3.50 ppm. Chromium (Cr) was detected in all samples with enhanced concentrations well above its detection limit(5) and concentrations range from 123.0to 198 ppm with an average of 145.4 ppm. Antimony (0.61 ppm), which belongs to the same group with As in the periodic table has a range between 0.1 and 0.90 ppm. Scandium (Sc) has a mean value of 11.75 ppm and ranges between 8.30 to 16.50 ppm. The base metals Cu, Zn and Ni, have means of 103.3, 40.68 and 30.4 ppm with ranges from 48.0 to 174.0 ppm, 27.0 to 71.0 ppm and 24.0 to 43.0 ppm respectively. Sulphur (S), Ag and Pb range from 10.0 to 50.0 ppm, 0.3 to 1.00ppm and 12.0, 0.33 to 27.0 ppm with mean values of 20.8 and 20.8 ppm respectively.

### *3.2 Data Analysis*

The descriptive statistics of the data is presented in Table2. The quantitative multivariate statistical treatment of geochemical data has been described as a useful necessary technique in geochemical nterpretation, and widely acceptable and practiced (Ajayi, 1981; David, 1986; Ojo 1988; Weber and Davis, 1990; Saffarini and Lahawani, 1992; Grunfeld, 2003 and Ariyibi *et al.*,2010). The application of factor analysis in geochemical prospecting data has also been used in the interpretation of stream sediment and soil surveys. Recently, Naseem *et al.*,(2002); Reimann *et al.*,(2002); Shiva and Atkin (2004) and Bamigboye and Adekeye (2011) applied factor analysis to interpret the result of various geochemical data sets. To investigate simultaneous variation in geochemical elements, multivariate statistical techniques, such as correlation coefficient and factor analysis are often applied. These techniques compress a large number of variables into small number of independent linear combinations. The statistical parameters of the data under review show inter element correlation (Table 3) for the correlation matrix of the stream sediment data. The strong and positive correlation of Sc with Ni (0.566) and Zn (0.886); Ni with Zn (0.728) on one hand as well as Cu with Pb (0.714), Ni with Pb (0.514) and Zn with Pb (0.551) on the other hand are instructive for mineralization. A critical look at Table 4 reveals a varimax rotated factor matrix which yielded a five-factor model with a cumulative variance of 83.69% for the data. Correlation Matrix for Stream sediment.

Table 1: Elemental Concentration of Stream Sediment Samples

| Elts (ppm) | IP01 | IP02 | IP03 | IP04 | IP05 | IP06 | IP07 | IP08 | IP09 | IP10 | IP11 | IP12 | IP13 | IP14 | IP15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Au(2) | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.0224 | 0.002 | 0.002 | 0.002 | 0.34 | 0.002 | 0.002 |
| As (0.5) | 4.7 | 5.1 | 6.2 | 5.6 | 4.9 | 5.1 | 3.7 | 6.8 | 6.8 | 7.4 | 2.7 | 3.0 | 0.2 | 3.9 | 3.9 |
| Br(0.5) | 0.3 | 0.2 | 0.4 | 0.3 | 0.2 | 0.3 | 0.4 | 0.3 | 0.3 | 2.0 | 0.3 | 0.4 | 0.2 | 0.4 | 0.3 |
| Cr (5) | 132 | 154 | 165 | 198 | 143 | 165 | 165 | 133 | 130 | 149 | 133 | 145 | 125 | 140 | 152 |
| Sb(0.2) | 0.7 | 0.9 | 0.8 | 0.8 | 0.7 | 0.6 | 0.8 | 0.7 | 0.4 | 0.5 | 0.8 | 0.6 | 0.4 | 0.7 | 0.7 |
| Sc(0.1) | 9.1 | 9.9 | 9.2 | 10 | 8.6 | 8.5 | 10.2 | 9.6 | 8.3 | 8.4 | 15.6 | 13.6 | 12.3 | 12.8 | 11.4 |
| Cu(1) | 174 | 56 | 87 | 48 | 85 | 87 | 79 | 144 | 132 | 109 | 92 | 99 | 89 | 99 | 85 |
| Ni(1) | 24 | 27 | 26 | 32 | 25 | 25 | 26 | 26 | 25 | 27 | 28 | 28 | 25 | 28 | 28 |
| Zn(1) | 31 | 30 | 28 | 33 | 27 | 28 | 31 | 30 | 30 | 27 | 49 | 42 | 40 | 42 | 37 |
| S(10) | 10 | 10 | 30 | 20 | 10 | 40 | 30 | 20 | 10 | 30 | 10 | 10 | 10 | 10 | 20 |
| Ag(0.3) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Pb(5) | 25 | 16 | 17 | 12 | 16 | 16 | 13 | 23 | 22 | 19 | 19 | 19 | 18 | 18 | 17 |

Table 1(continues)

| Elts (ppm) | IP16 | IP17 | IP18 | IP19 | IP20 | IP21 | IP22 | IP23 | IP24 | IP25 | AV | Range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Au(2) | 0.002 | 0.002 | 0.12 | 0.002 | 0.32 | 0.002 | 0.10 | 0.28 | 0.002 | 0.01 | 0.06 | 0.002-0.34 |
| As (0.5) | 3.0 | 3.2 | 0.4 | 3.0 | 0.3 | 2.7 | 2.0 | 0.3 | 0.3 | 2.5 | 3.5 | 0.5 -7.4 |
| Br(0.5) | 0.4 | 0.3 | 0.4 | 0.2 | 2.8 | 3.5 | 0.3 | 0.2 | 0.4 | 1.7 | 0.7 | 0.2 -3.5 |
| Cr (5) | 137 | 19 | 139 | 141 | 126 | 123 | 140 | 123 | 161 | 172 | 145 | 19 -172 |
| Sb(0.2) | 0.1 | 0.4 | 0.3 | 0.6 | 0.8 | 0.7 | 0.6 | 0.6 | 0.6 | 0.4 | 0.6 | 0.1 -0.9 |
| Sc(0.1) | 14.4 | 16.0 | 13.9 | 14.5 | 10.0 | 12.1 | 13.0 | 12.8 | 15.0 | 12.5 | 12.0 | 8.3 -16.5 |
| Cu(1) | 108 | 10 | 100 | 104 | 146 | 127 | 10 | 89 | 124 | 108 | 103.0 | 48 -144 |
| Ni(1) | 30 | 34 | 34 | 35 | 39 | 33 | 43 | 34 | 39 | 38 | 30 | 24 - 43 |
| Zn(1) | 45 | 54 | 53 | 55 | 36 | 51 | 51 | 47 | 71 | 49 | 41 | 27-71 |
| S(10) | 30 | 10 | 10 | 30 | 10 | 40 | 30 | 20 | 20 | 50 | 20.8 | 10-50 |
| Ag(0.3) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Pb(5) | 15 | 24 | 21 | 22 | 24 | 27 | 24 | 26 | 27 | 21 | 20.0 | 12-27 |

All values in ppm except Au

Table 2: Descriptive Statistics for Stream sediment

| **Elements (ppm)** | **Min.** | **Max** | **Mean** | **Std. Dev.** | **Threshold** | **Variance** | **Skewness** | **Kurtosis** |
|---|---|---|---|---|---|---|---|---|
| Au | 0.00 | 0.34 | 0.06 | .11 | 0.28 | 0.01 | 1.70 | 1.49 |
| As | 0.20 | 7.40 | 3.51 | 2.18 | 7.87 | 4.76 | 0.00 | -0.83 |
| Br | 0.20 | 3.50 | 0.66 | 0.87 | 2.40 | 0.76 | 2.41 | 5.02 |
| Cr | 123.00 | 198.00 | 145.44 | 17.92 | 181.27 | 321.01 | 1.11 | 1.57 |
| Sb | 0.10 | 0.90 | 0.61 | 0.19 | 0.97 | 0.04 | -0.89 | 0.67 |
| Sc | 8.30 | 16.50 | 11.75 | 2.47 | 16.69 | 6.12 | 0.17 | -1.13 |
| Cu | 48.00 | 174.00 | 103.28 | 27.44 | 158.17 | 753.13 | 0.50 | 1.06 |
| Ni | 24.00 | 43.00 | 30.36 | 5.38 | 41.13 | 28.99 | 0.80 | -0.39 |
| Zn | 27.00 | 71.00 | 40.68 | 11.52 | 63.73 | 132.81 | 0.69 | 0.10 |
| S | 10.00 | 50.00 | 20.80 | 11.87 | 44.55 | 141.00 | 0.81 | -0.21 |
| Ag | 0.30 | 1.00 | 0.33 | 0.14 | 0.61 | 0.02 | 5.00 | 25.00 |
| Pb | 12.00 | 27.00 | 20.04 | 4.29 | 28.63 | 18.37 | -0.02 | -0.93 |

Table 3: Correlation Matrix for Stream sediment

| **Elements** | Au1.000 | As | Br | Cr | Sb | **Sc** | **Cu** | **Ni** | **Zn** | S | Ag | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Au<br>As<br>Br<br>Cr<br>Sb<br>Sc<br>Cu<br>**Ni**<br>**Zn**<br>S<br>Ag<br>**Pb** | -<br>0.103<br>-<br>-<br>0.009<br>0.152<br>0.243<br>0.045<br>- 0.114<br>0.314 | 1.000<br>- 0.320<br>0.234<br>-<br>-<br>-<br>- 0.099<br>-<br>- | 1.000<br>- 0.063<br>- 0.358<br>0.315<br>0.053<br>0.374<br>- 0.345 | 1.000<br>0.218<br>-<br>- 0.034<br>- 0.372<br>-<br>- | 1.000<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>- | 1.000<br>-<br>**0.566**<br>**0.886**<br>- 0.181<br>0.304 | 1.000<br>0.109<br>0.128<br>-0.060<br>-0.025<br>**0.714** | 1.000<br>**0.728**<br>0.256<br>0.141<br>**0.514** | 1.000<br>0.081<br>0.223<br>**0.551** | 1.000<br>-<br>- | 1.000<br>0.047 | 1.000 |

Table 4: Factor analysis (Rotated Component Matrix)

| **Elts(ppm)** | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Au** | | | | **0.899** | |
| As | -0.762 | | | -0.512 | |
| **Br** | | | **0.772** | | |
| Cr | | -0.762 | | | |
| Sb | | | | | -0.862 |
| **Sc** | **0.906** | | | | |
| **Cu** | | **0.925** | | | |
| **Ni** | **0.791** | | | | |
| **Zn** | **0.951** | | | | |
| **S** | | | **0.823** | | |
| **Ag** | | | | | **0.716** |
| **Pb** | | **0.785** | | | |
| Var(%) | 33.60 | 17.66 | 14.86 | 9.17 | 8.40 |
| Cum(%) | 33.60 | 51.26 | 66.12 | 75.29 | 83.69 |

*Factor Analysis*

**Factor 1, Sc, Ni, and Zn:** This factor accounts for 33.6% of the total variance. Scandium (0.906), Ni (0.791) and Zn (0.951) have strong positive loadings. Such associations and in particularly of Ni and Zn simply reflects mineralization control.

**Factor 2, Cu, and Pb:** This factor is responsible for 17.7% of the total variance and reflects Cu-Pb mineralization showing high positive 0.925and 0.785 loading respectively

**Factor 3, Br, and S**: This factor accounts for 14.86% of the total variance. There is no known sulphide and Br association, so this factor is most likely of lithology control.

**Factor 4, Au:** This is a single element factor which account for 9.17% variance and show very high positive loading of 0.899%, it is instructive to see As, supposedly gold pathfinder element show negative loading (-0.512) in this factor, perhaps because Au in this deposit is a native type that would not form alloy with any other element, and can therefore be used as its own (Au) pathfinder.

**Factor 5, Ag:** This is another single element factor loading of Ag (0.716) that represents 8.4% variance but show high negative (-0.862) relationship with Sb. This loading is strong on its own. The explanation here is similar to that given for gold; otherwise there is no known association of Ag with Sb, such as would be expected in Ag (Cl, Br). However, the strong loading is suggestive of Ag mineralization in study area.

## IV. DISCUSSIONS

It has been observed (Roseand Web, 1974) that transitional metals in stream sediments are usually concentrated in finer size fractions. The high metal concentration observed in the fine stream sediments are generally due to increase in surface area and to surface properties of clay minerals, and/or increased concentrations of Fe-Mg oxides and hydroxides (Hale, 1994; Rose, 1974). Clay minerals and colloidal Fe-Mn oxides have large electronically charged surface areas, and in stream sediments these constituents adsorb and co-precipitate soluble trace elements (Bolucek and Kalender, 2008; Hale, 1994). Thus, hydromorphic dispersion patterns usually develop in fine fractions of stream sediments (Hale, 1994; Rose, 1974). Guguruji is in a semi-arid environment with moderate relief and a well-developed drainage system. The contribution of metals from the weathered rocks, veins, pegmatite and mineralized zones have resulted in the complex dispersion patterns in the basin. The materials from the environments might have been transported and discharged into the drainage system in form of cobbles, gravels, sand and clays. The implication is therefore that both mechanical and hydromorphic dispersion of elements are well favoured in the drainage system. Although only few mineralized pegmatites and veins were mapped within this study area, report from adjacent districts (Dada et al., 2003; Adedoyin and Adekeye, 2007; Bamigboye and Adekeye, 2011) within the same schist belt indicate lots of mineralized pegmatites and veins some of which have been worked. These reports indicate that the veins and pegmatites are of interest and economic significance because they are ore bearing, particularly gold. The weathering of these rocks and subsequent dispersion train via mechanical transportation could have contributed to mineralization in the basin as the ore related elements are expectedly deposited into the drainage system. Gold values are generally low and erratic, only few values exceed the 0.28 ppm threshold (e.g samples 13). More detailed observation of the data shows that Zn, Pb, Ni, and Cu have enhanced values and concentrated around the south western portion of the study area. There is the high possibility of sulphide complex deposit around this area. It is also instructive to note that this area falls within the amphibolite terrain. The geochemical dispersion of other elements with no apparent economic significance is controlled by lithologic and environmental factors. The analysis identifies metallic associations with positive correlation between Sc-Ni-Zn, Cu-Pb, Ni-Zn-Pb and Zn-Pb. Factor analysis also reveal existence of a four-factor model with Zn-Ni, Cu-Pb,Au and Ag group of metallic associations that are related to mineralization. Statistical analysis is suggestive of Cu-Pb mineralization because ofthe high positive correlation coefficient of the ore elements. Also, the high positive correlation of Ni with Zn (0.728) and Pb (0.514) is equally suggestive of Pb-Zn mineralization. The mutual relationship of Ni with Zn and Pb is a good geochemical signature for sulphide deposits.

## V. CONCLUSION

The application of factor analysis in this study has practically reduced the dataset into three groups, unveiling the geochemical structures within the variables (elements) that gave rise to relationships that are indicative of mineralization. The factor analysis reveals the various elemental groups that are related based on their mutual correlation coefficients. The correlation between the Ni and Sc with chalcophile elements is suggestive of the possibility of using them as pathfinder elements for sulphide complex deposits in the study area**.** The varimax rotated factor matrix yielded a five-factor model explaining 83.69% of the total variability. The five-factor analysis identified metallic associations of Sc-Ni-Zn and Cu-Pb on one hand, and single metals such as Au (0.899) and Ag (0.716) with very high positive loadings on the other. These relationships are indicative of mineralization while the Br-S association is probably related to the lithological sources. Factor analysis has proved a successful tool for the identification of factors controlling the geochemical data variability. The composition of the Guguruji stream sediments is modified by contributions largely from mineralized ore deposit(s) and less of natural weathering processes. This research thus shows high elemental concentrations and metallic associations that holds potentials for Au and base metals mineralization within the basin.

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