

RESEARCH ARTICLE

CONTROLLED METHOD OF DETERMINE GOLD MINERALIZATION POTENTIALS IN AN UNEXPLOITED AREA; A CASE STUDY OF ITAGUNMODI AND OSU, SOUTHWESTERN, NIGERIA

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ARTICLE DETAILS

Article History:

Received 02 February 2022
Accepted 04 March 2022
Available online 08 March 2022

ABSTRACT

The research was conducted to open up further unexploited areas for gold mineral exploitation in part of Ilesha schist belt using geological and geophysical approach. Itagunmodi was used as a control in order to determine the mineralization potentials of Osu as a case study. Both towns lie within Ilesha schist Belt, Southwestern Nigeria. The residual magnetic anomaly map of the study area revealed magnetic low in the two towns indicating the presence of geological structure serving as a conduit for mineralizing fluid. Airborne radiometry interpretation showed that both Itagunmodi and Osu are affected by hydrothermal alteration which is an indication of gold mineralization. Overall interpretation of aeromagnetic and airborne radiometry datasets show that hydrothermal alteration generally is associated with fault and shear zones in the study area. The isolated altered zones were subjected to further investigation by using six samples of stream sediment collected along Imo (Itagunmodi) and Olomumu (Osu) stream channels for the grain size and geochemical analyses. The results from the grain size analysis revealed that sediments in both areas are fine to medium grained, poorly sorted, fine to moderately fine skewed, which implied fluvial depositional settings, and revealed that the occurrences of gold mineralization in both areas are of secondary deposits (alluvial). The concentration of identified trace elements as related to their threshold values revealed similar contents of low to high concentrations in both areas. The results of the analyses observed in Itagunmodi are similar to that of Osu, which implies that Osu is also mineralized will gold deposit.

KEYWORDS

gold-mineralization, grain size, pathfinder elements, magnetic anomaly, Itagunmodi, Osu

1. INTRODUCTION

The rise in demand for gold and its global price increase has sparked interest in both the local and commercial mining of this noble metal. Most of the already discovered areas of these deposits are being exploited daily without any hope of being replenished due to its non-renewable nature. The Itagunmodi area has shown to be an excellent location for gold mining with visible presence of artisanal miners engaging in panning, while the Osu area which is short distance to Itagunmodi is yet to be explored. Hence, the need to open up gold mineralization potentials in Osu, by using Itagunmodi mineralised as control formed the basis of this study.

Gold is a solid naturally occurring noble metal of economic interest. It has unrivaled history by any other metal due its perceived value and enormous use that include jewelry, dentistry, electronics, coin and investment among others.

The occurrence of gold is found in trace amounts in almost all basement rocks. It is abundant in Earth's crust, and is estimated to be approximately 0.005 parts per million (Encyclopedia Britannica, 2020). Except for tellurium, selenium, and bismuth, gold mostly occurs in its native state, and remains chemically uncombined. Gold is commonly found in association with other metallic deposits like copper, lead and other

constituent elements. The possibility of finding large masses of gold-bearing rock rich enough to be called ores is commonly unusual.

Gold production in Nigeria is thought to have begun in 1913 and peaked between 1933 and 1943 (Nigeria Ministry of Solid Minerals Development, 2008). The occurrence of gold mineralization (GM) in the study areas is divided into two which are primary deposit in form of quartz vein, fracture, and fault, and secondary deposits which are alluvial and eluvial (both consolidated and unconsolidated that are formed by surface weathering and erosion of primary gold-bearing rocks) (Oyinloye, 2011). It has been reported that only 5-10% of Nigeria gold productions come from vein deposits, while the majority comes from modern alluvial derived from basement rocks (Encyclopedia Britannica, 2020). A group of researchers defined four gold fields encompassing the main producing areas in Nigeria, they are: Ilesha-Egbe, Minna Birnin-Gwari, Sokoto, and Yelwa (Woakes and Bafor, 1984). All are associated with schist belts, though gold-quartz veins can also be found in gneisses (e.g. Malele, Diko and Iperindo). The study areas fall within the Ilesha-Egbe Schist Belt in southwestern Nigeria. The rocks in Ilesha schist is of Precambrian age which are characterize by gold mineralization (GM). Artisanal miners engaging in panning focus more on alluvial deposits across the study areas.

Previous researchers in the study areas have focused more on Itagunmodi

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DOI:
10.26480/esmy.02.2022.82.92

and environ. A researcher reported the beneficiation and characterization of gold from Itagunmodi gold ore, using cyanide solution obtained from cassava (Ogundare et al., 2014). A researcher determined the work index for Iperindo lode gold deposit at Ilesha goldfield, using modified bond index (Adetula et al., 2019). A previous researcher investigated the most effective means of recovering fine gold from the ore by undertook a mineralogical study (Ajayi, 1997). Another researcher used airborne Time-domain electromagnetic data acquired over the Ilesha Schist Belt in southwestern Nigeria which were filtered, enhanced and analyzed to generate ground conductivity responses at different time gates and employed to characterize the subsurface in terms of rock distribution, structural framework as well as evaluate the gold and base metal mineralization potential of the region (Fashola, 2019). A previous researcher processed aeromagnetic data of the study area to delineate structural setting and produced gold mineralisation map of the area (Akinlalu et al., 2018). Despite all these previous work there is no research till date that isolates the gold mineralization potentials of Osu area despite fall within the same schist belt. Therefore, this current research is purported at integrating the combined methods of geophysical geological and geochemical analyses to investigate the presence of gold mineralization potentials in Osu area as manifested in the Itagunmodi area, through the mapping of geological structure, alteration zones, sieving and geochemical analysis.

Airborne datasets comprising of magnetic and radiometry were used as a reconnaissance to isolated hydrothermal alteration zones for further geochemical analysis. Aeromagnetic prospecting provides important geophysical information for geological structure through the measurement of distribution characteristics of magnetic field (Olomo et al., 2021). Aeromagnetic map enhanced with second vertical derivative and 3D Euler deconvolution increased the magnetic lineament visibility of the area. Lineaments being representation of fracture, fault, lithological contact and crustal continuity with unique patterns can be interpreted to define most favorable structural conditions that control various mineral deposits. These lineament features are clearly delineated on aeromagnetic maps and often indicate the form and position of individual folds, faults, joints, veins, lithological contacts, and other geologic features that may lead to the localization of hydrothermal mineralizing fluid. Aero spectrometer is deployed to identify areas that are under the influence of hydrothermal alteration. Among the three radioelements, potassium is considered to be the most reliable pathfinder element to isolate GM zones because of its increase in altered surrounding rocks. A group of researchers suggested that potassium is the best element to locate ore deposit. Potassium signature is always distorted by weathering (Hoover and Pierce, 1990). Weathering can affect alteration signatures because highly weathered deposits may lose their potassium K, particularly if it is hosted by K-feldspar. Transported soils may disguise or change rock signatures in often unexpected ways. In order to remove the effect of weathering, K/Th map was generated. The K/Th ratio is useful for determining where relative concentrations of potassium are high and thorium is generally considered to be immobile elements.

The mathematical method of grain-size representation data using mathematical expressions or statistical parameters like calculated mean (verbal grain size), standard deviation (verbal sorting), mode, kurtosis, and skewness was adopted in this study. The grain-size characteristics were used as valuable tools for texturally characterizing the sediment properties, rocks classification, and definition of the depositional settings in the study areas. The proportion of gold pathfinder elements in the trace elements composition of the stream sediment samples were used to determine the presence of gold mineralization in the study areas. Stream sediment geochemistry is often used as a mean of evaluating mineral resources over a large area. When hunting for gold in stream sediments, it's typically more efficient to seek for the geographical distribution of a variety of pathfinder elements like Copper (Cu), Arsenic (As), Zinc (Zn), Iron (Fe), Lead (Pb), Silver (Ag), Manganese (Mn) and others (rather than just gold. Since, pathfinder elements occur invariable in close geochemical association with the primary mineral being sought. This is the first time such research is conducted in the study areas, which showed the complementary nature of both geological and geophysical approach. This will serve as a template for similar future research in different part of the world. Moreover, owing to the erratic nature of oil price in the world, this research will enable the government and prospective investors to extend gold exploitation to the study area, consequently, increasing the revenue base of the government.

2. GEOLOGIC SETTING

The study areas are situated in Itagunmodi and Osu, both in Atakumosa West local government area of Osun state Nigeria (Figure 1). The areas are located within the Ilesha schist Belt in Southwestern Nigeria between

latitude 7°25'043" and 7°45'032" North of the Equator, and longitude 4°35'023" and 4°55'045" East of the Greenwich meridian. Quartz schist, quartzite, amphibolites, granite gneiss, amphibolites schist and migmatite gneiss complex are the major lithology unit in the study areas as described by (Oyinloye, 2011). The Ilesha schist belt forms part of the Proterozoic schist belts of Nigeria, which are developed predominantly in the Western half of the country. The Nigeria schist belts show significant similarities in terms of lithology, mineralogy, and structural features to that of the Achaean Green Stone belts. Though, the Achaean green stone belts normally contain much larger population of mafic and ultramafic bodies and assemblages of lower metamorphic grade while compared to the Nigeria schist belts (Olusegun et al., 1995; Ajayi, 1981; Rahaman, 1976). The rocks in Ilesha schist belt are divided structurally into two main segments of contrasting lithologies, which are Iwaraja and Ifewara faults. The Iwaraja faults composed of extensive Psammitic units with minor meta-pelites which are found as quartzites and quartz schists in the Eastern part. While the Ifewara faults in the Western part comprised mostly of amphibolites, amphibole schist, meta-ultramafites, and meta-pelites (Folahami, 1992; Elueze, 1986). The areas under study (Itagunmodi and Osu) are dominated by amphibolite and amphibole schist and fall within Ifewara faults in the Western divide of Ilesha schist belt. All these rocks assemblages are associated with migmatitic gneisses and cut by a variety of granitic rock bodies (Olusegun et al., 1995; Rahaman 1976). The rocks in Ilesha schist is of Precambrian age which are characterize by gold mineralization (GM). Artisanal miners engaging in panning focus more on alluvial deposits across the control study area.

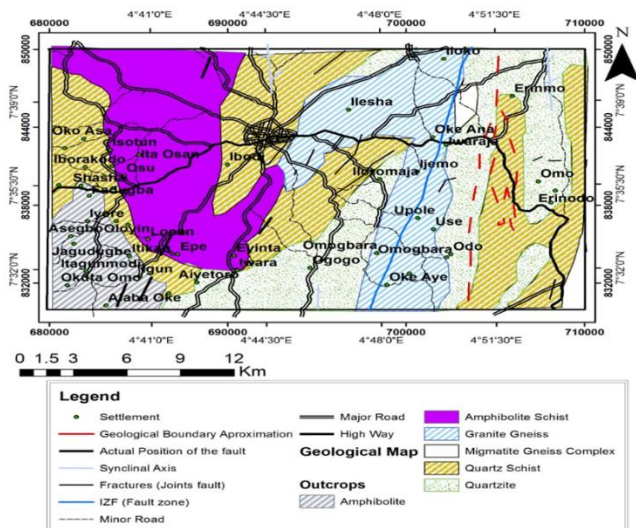


Figure 1: Geological map of the study area (modified after Elueze, 1986, Odeyemi, 1993).

3. MATERIAL AND METHODS

The aeromagnetic and aerospectrometer data were used for the geophysical investigation aimed at isolating hydrothermal alteration zones. Six (6) samples were collected along targeted alteration zones within Imo (Itagunmodi) and Olomumu (Osu) river channels. The samples were collected along active mining pits in Itagunmodi, while samples were collected along the channel of the available Stream (Olomumu) in Osu. The samples were labeled L1, L2 and L3 for Imo sediment (Itagunmodi), and L4, L5, and L6, for Olomumu stream sediment (Osu). The coordinates and elevation of the locations were taken using the Global Positioning System. After collection, the samples were labeled in the sample bags to avoid mix-up. The collected samples were used for geological (grain size), and geochemical (trace elements composition) analyses. The collected samples and data were analyzed to determine the presence of gold mineralization in Olomumu (Osu) stream sediment through the integration of the analyzed results, by using Imo (Itagunmodi) stream sediment response as control. Below are the employed methods as discussed:

3.1 Geophysics (aeromagnetic and aerospectrometer)

The excel format of aeromagnetic data, was provided by Nigerian Geological Survey Agency (NGSA). The acquisition of the data was made possible by 3x Scintrex CS3 Cesium Vapour magnetometer mounted on 7 Cessna Caravan fixed-wing aircrafts. Data acquisition and magnetic counter was aided by Flux-Adjusting Surface Data Assimilation System (FASDAS). Fugro Airborne Surveys was contracted in 2009 for data

acquisition. The contracted company has subjected the acquired magnetic data to standard processing procedures which includes diurnal correction, de-culturing, magnetic compensation, de-spiking, directional filtering, micro-leveling, geomagnetic correction and stripped off 32,000 nT, being the International Geomagnetic Reference Field (IGRF) value over the survey area. The total magnetic intensity data (TMI) was gridded into 50 m × 50 m by adopting minimum curvature gridding method (Briggs, 1974 and Gotze, 1999). Upward continuation to a height of 200 m was applied on TMI map in order to remove cultural noise and accentuate low frequency anomalies (Olomo et al., 2021). TMI data was reduced to equator due to the nearness of the study area to the equator, consequently positioning the magnetic anomalies over the magnetic body (Gilbert and Geldano, 1985; Oyeniyi et al., 2016). Regional-residual separation was performed on the reduction to equator (RTE) by using upward continue to 2000 m with the aid of Geosoft Oasis Montaj™

Airborne radiometric data of Ilesha schist belt was acquired by Fugro Airborne surveys between 2009 using 512-channels gamma-ray spectrometers (NaI “TI” crystals) mounted on fixed-wing aircraft under the supervision of Nigerian Geological Survey Agency (NGSA). The data was processed into grids (50 m cell size).

3.1.1 Magnetic Anomaly of interest

The generated residual map help in enhancing high frequency anomaly emanated from the shallow magnetic bodies while suppressing deep magnetic bodies. In mineral exploration, the important of residual anomaly cannot be overemphasized. Other filter applied to residual map includes second vertical derivative and 3 D Euler deconvolution.

3.1.1.1 Vertical derivative

This technique accentuates short wavelength and is relatively insensitive to noise. Mostly used for delineating near surface lineaments and contacts (Giere and Sorensen, 2004). The First vertical derivative has shown to be a useful technique in the processing of magnetic data; it is a filtering technique that is equivalent to enhancing shallow sources and suppressing deeper sources (Efimov, 1978). The transform is a useful interpretation tool in the determination of shallow seated fractures and faults by making the edges of shallow seated anomalies become sharper or clearer. The mathematical expression involved is given by

$$VD = \frac{\partial T}{\partial z} \quad 1$$

Where VD is equal to the vertical derivative while $\frac{\partial T}{\partial z}$ is the magnetic field in Z direction. The first vertical derivative filter does the removal of the long wavelength properties of magnetic responses and most importantly enhances the quality of closely spaced and superposed responses (Garba, 2003).

3.1.1.2 3D Euler deconvolution

Lineament trend analysis and depth estimation is very important in magnetic interpretation. According to (Thompson, 1982; Reid et al., 1990) the 3-D standard Euler deconvolution can efficiently do justice to that. It is capable of estimating source of magnetic bodies and its depth. The 3-D standard Euler deconvolution is based on solving Euler's homogeneity equation (Equation v) (Reid et al., 1990):

$$(X - X_0) \frac{\delta T}{\delta X} + (Y - Y_0) \frac{\delta T}{\delta Y} + (Z - Z_0) \frac{\delta T}{\delta Z} = \eta(\beta - T) \quad 2$$

Where

B = nominal value of the magnetic field

X_0, Y_0, Z_0 = define the position of the sources at the total magnetic intensity field T measured at (x, y, z)

η = structural index.

The geometry and depth of the magnetic field bodies can be calculated by varying the structural index; η . Structural indices of $\eta = 1$ gave good clustering solutions in the study area.

3.1.2 Hydrothermal alteration mapping

Exploring for hydrothermal alteration zones is synonymous to probing an area with geologic structures that can provide a pathway for hydrothermal mineralizing fluids (Cunha et al., 2017) Relationship between potassium enrichment and lode gold mineralizing processes has been demonstrated by (Cunha et al., 2017). In lieu of this, areas of potassium enrichment that are amplified from potassium map of the

radiometric data were used to isolate hydrothermal alteration zones.

Potassium enrichment signature is often distorted by lithology and weathering. In order to ameliorate the problem of separating real potassium enrichment associated to hydrothermal alteration from lithology and weathering factors, ratio of potassium concentration to the thorium equivalent (K/Th), were utilized in mapping hydrothermal alteration that are related to GM in the study area. Galbraith and Saunders, 1983 showed that thorium is geochemically immobile with potassium enrichment during hydrothermal alteration.

3.2 Grain Size Analysis

The sieve analysis was carried out at the Geological Laboratory of Earth Sciences Department, Adekunle Ajasin University, Akungba Akoko, Ondo State, Nigeria. The sieving analysis was achieved by sieve shaker using a set of nine sieves agitating for about 5min. Samples that were slightly consolidated were effectively disaggregated by squeezing them between fingers and paper sheets. Approximately 100gram split of the sample was used in the grain size analysis. The sieve sizes used for this operation are: 1.00m, 850um, 600 um, 425um, 300um, 212um, 180um, 150um, and 90um respectively. The fraction left in each sieve and the pan after sieving were weighed and used for statistical calculations. The percentage of the aggregates was estimated. The corrected weight of each fraction was used to calculate individual percentage (Tables 1-6). Each cumulative percentage was obtained as a percentage of the cumulative of the cumulative corrected weight to the total corrected weight. This was followed by a plot of grain size (x-axis) versus cumulative percent (y-axis), called cumulative curve (Figures 3-5). The cumulative curve was later used to determine the phi size for each of the following phi values: phi at 5% (ϕ_5), phi at 16% (ϕ_{16}), phi at 25% (ϕ_{25}), phi at 50% (ϕ_{50}), 75%, 84% and 95% (where the % refers to the cumulative percent). The grain size of the 16th, 25th, 50th, 75th, 84th and 95th percentiles were obtained from each cumulative curve drawn. These were used to calculate statistical parameters for the Graphic Mean (M), Standard Deviation (SD), and Graphic Skewness (SK) based on Folk and Ward (1957) as follows:

1. Graphic Mean: the average size category

$$M = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3} \quad 3$$

2. Graphic Standard Deviation; a measure of sorting or variation in sizes.

$$SD = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_{5}}{6.6} \quad 4$$

3. Graphic Skewness; reflection of depositional process

$$SK = \phi_{95} - \phi_5 \quad 5$$

3.3 X - Ray Fluorescence Analytical Procedure (Trace elements composition)

The samples were firstly pulverized (grind to fine powder) using target pulverizing machine (planetary micro mill pulverisette). The ground samples were made to pass 150 micro mesh sieves. This was to ensure homogeneity of the samples. 5g of the pulverized sample was weighed into a beaker of 1g of binding aid (Starch soluble). The mixture was thoroughly mixed to ensure homogeneity, which was pressed under high pressure (6 tones) to produce pellets, which were labeled and packaged for analysis. The x-ray fluorescence analysis was carried out at the National Agency for Science and Engineering Infrastructure (NASANI) Akure, Ondo State, Nigeria. The pelletized samples were initialized (calibrated) using pure silver standard. Followed this was the selection of the working curve according to the samples. The samples were then tested and output into excel. The selected filters used for the trace elements were Ag/Al thin. The resulted trace element were presented in excel (Tables 10-15; figures 8-13), and used to calculate threshold/crustal abundance values for the needed pathfinder elements in the study areas. The threshold value (Tables 16 & 17), is the standard value to which the value of individual element in the study areas is compared, and the value above it is considered anomalous.

4. RESULTS AND DISCUSSION

4.1 Airborne Geophysical Interpretation

4.1.1 Airborne Magnetic Interpretation

Figure 1 is residual magnetic anomaly map of the study area with the values ranges between -413 and 242 reflecting inhomogeneity nature and

various geological complexities in the study area. The area is divided into zone A and Zone B. zone A is located at Itagunmodi with visible mining pit and artisanal miners currently engaging in panning and the zone dominates the extreme south-western part of the study area. The zone is characterized by magnetic low signifying geologic structure and it is observe on amphibolite rock. While zone B is located at Osu with no mining activities. The zone is also characterized by magnetic low and found to be associated with amphibolite schist. The two zones show similarity signature with low magnetic value. Low magnetic anomalous areas were considered to account for the hydrothermal alteration which is also controlled by faults, fractures and shear zones responsible for localization of gold deposits in the study areas.

4.1.2 Vertical Derivative

Vertical derivative (Figure 2) accentuates the image by showing major structural and lithological details which were not obvious in residual anomaly map. It enhances shallow anomalies while deemphasizing regional trends. There is an increase in visibility of lineament and fault trends in NE-SW direction representing tectonic history associated with the study areas. The structural trends of zone A and B are clearly defined.

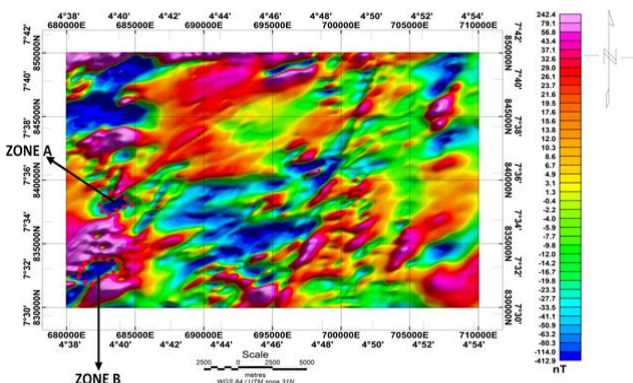


Figure 1: Residual anomaly map of the study area

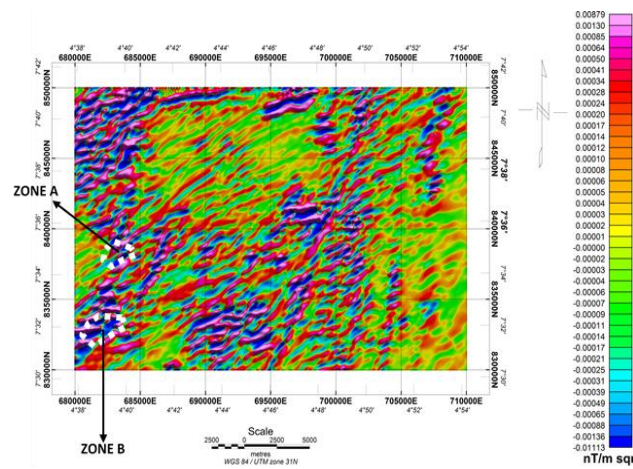


Figure 2: Derivative map of the study area

4.1.3 3D Euler deconvolution

The accurate clustering for Euler solutions in Figure 3 was achieved with SI = 1.0, which is the representation of thin dyke/fault. It shows an excellent correlation with local geology of the study areas and vertical derivative (Figure 2). The depth ranges from 300 m- 500 m.

4.1.4 Hydrothermal Alteration Mapping

Potassium alteration is one of the most important useful guide elements for gold mineralization zones because of its increase in altered rock surrounding the deposits. Figure 4 is a potassium map of the study area. Zones A and B located at Itagunmodi and Osu respectively displays high potassium indicating high level of alteration. Figure 5 revealed K/Th ratio map of the study area. Generally, K/Th enhances hydrothermal alteration haloes that are closely associated with orogenic gold mineralization (Saunders et al., 1987). Anomalously high K/Th (0.0988–6.0809) which is the signature accentuation of potassium enrichment haloes that are related to the orogenic gold mineralization indicates fractured and hydrothermally altered areas within the study areas. Integrated

aeromagnetic and airborne radiometry interpretations showed that hydrothermal alteration generally accompanies and is controlled by tectonic deformation within the study areas. Itagunmodi is used as a control to determine the level of mineralization in Osu and since both displays signature similarities in term of geology structure and hydrothermal alteration imply that Osu is highly mineralized.

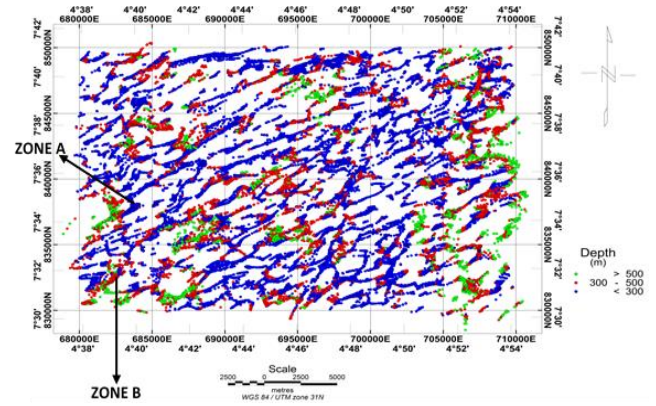


Figure 3: 3D Euler Deconvolution (SI=1)

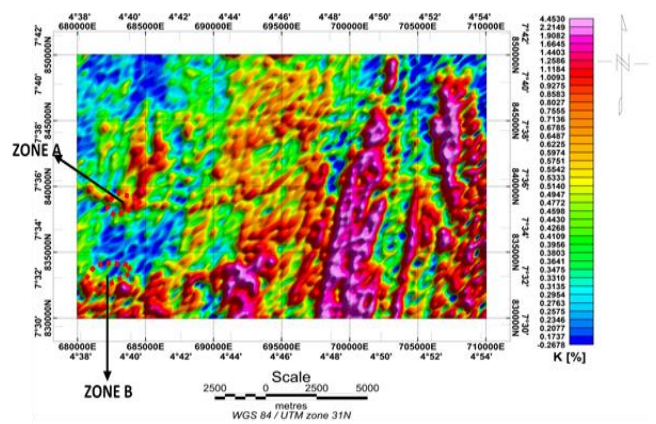


Figure 4: Potassium enrichment map of the study area.

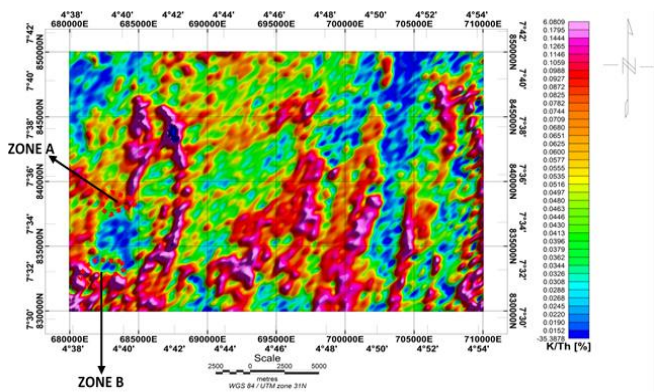


Figure 5: K/Th ratio map of the study area

4.2 Grain Size Analysis

The results for the grain size analyses for locations 1 to 6 are presented in Tables 1 to 6, and the graphical representations in figure 6 to 11. Tables 7, 8, and 9 represented the skewness, sorting (standard deviation) and the graphic mean of the grain size analyses.

The graphic mean, standard deviation, and skewness were the statistical procedures adopted for the sieve analysis technique to determine the sediment grain size, sorting, and the process of deposition in the study areas. The results from the grain size analysis (Table 9) revealed that both areas have a mean grain size of sediment ranges between 0.2mm and 0.50mm, which indicated fine to medium grained sediment sizes in accordance with the work of a previous researcher (Krumbein, 1934). The standard deviation values for both areas fall within 1.13φ and 1.49φ (Table 8), which suggested poorly, sorted sediment in both areas. Standard deviation is one of the most important parameters in grain sizes analysis, since it gives an indication of the effectiveness of the depositional

Table 2: Grain Size Analysis Result for Sample location 2 (L2) Imo

Sieve Size (mm)	Phi=-log ₂ d	Sample Weight Retained (g)	Percentage (%) Weight Retained (g)	Cumulative Weight Percent Retained
0.85	0.23	43	16.7	41.54
0.60	0.74	25	9.7	26.4
0.425	1.23	30	11.6	38
0.30	1.74	48	18.6	56.6
0.212	2.24	44	17.1	73.7
0.150	2.74	21	8.1	81.8
0.075	3.74	21	8.1	89.9
0.063	3.99	17	6.6	96.5
Total		249		
Initial Weight		257		

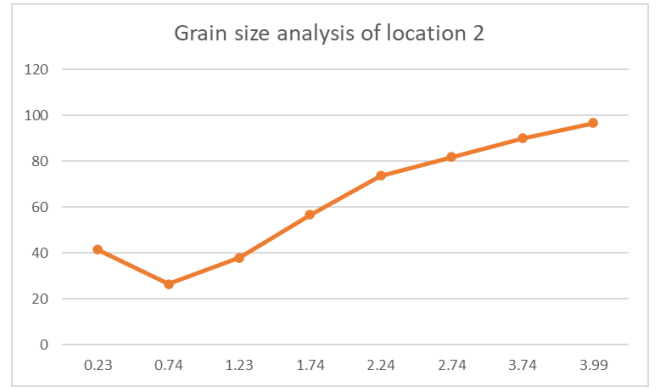


Figure 7: Graphical representation of Grain Size Analysis Result for Sample L2

medium by separating grains of different sizes. The Skewness is a measure of the symmetry of the distribution of the sediments, and a reflection of the depositional process. The skewness values for the study areas range between 0.13 and 0.63 (Table 7), and is interpreted as fine to moderately fine skewed. The average skewness value for the samples is 0.30, which falls in fine skewed range. The skewness of the sediments is mainly positive. This indicated fluvial depositional environments for the sediment of both streams, and this is confirmed by the works of several researchers (Tucker, 1981; Visher, 1969). The grain size analysis of Imo was used as control for the determination of the grain size analysis of Olomumu in order to characterize the types of sediment associated with gold mineralization in the study areas. Hence; the results revealed that the occurrences of gold mineralization in both areas are of secondary deposits (alluvial).

Table 1: Grain Size Analysis Result for Sample location 1 (L1) Imo

Sieve Size (mm)	Phi=-log ₂ d	Sample Weight Retained (g)	Percentage (%) Weight Retained (g)	Cumulative Weight Percent Retained
0.85	0.23	67	20.9	20.9
0.60	0.74	25	7.81	28.7
0.425	1.23	27	8.43	37.13
0.30	1.74	45	14	51.1
0.212	2.24	48	15	66.1
0.15	2.74	42	13.1	79.2
0.075	3.74	41	12.8	92
0.063	3.99	25	7.8	99.8
Total		320		
Initial Weight		320		

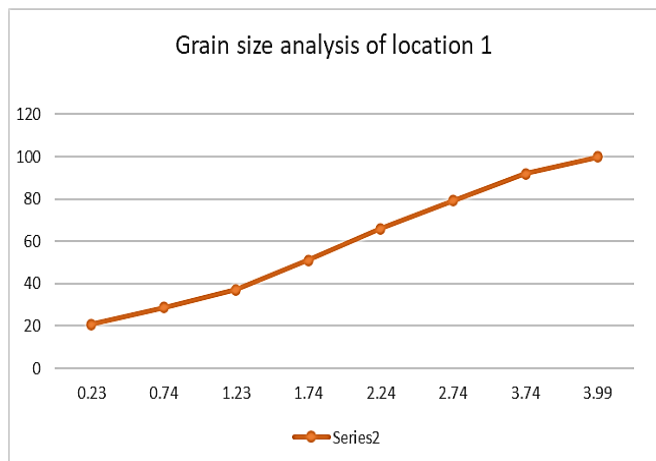


Figure 6: Graphical representation of Grain Size Analysis Result for Sample L1

Table 3: Grain Size Analysis Result for Sample location 3 (L3) Imo

Sieve Size (mm)	Phi=-log ₂ d	Sample Weight Retained (g)	Percentage (%) Weight Retained (g)	Cumulative Weight Percent Retained
0.85	0.23	94	26.5	26.5
0.60	0.74	43	12.14	38.6
0.425	1.23	42	11.8	50.4
0.30	1.74	54	15.25	65.7
0.212	2.24	43	12.14	78
0.15	2.74	22	6.21	84
0.075	3.74	29	8.2	92.2
0.063	3.99	17	4.8	97
Total		344		
Initial Weight		354		

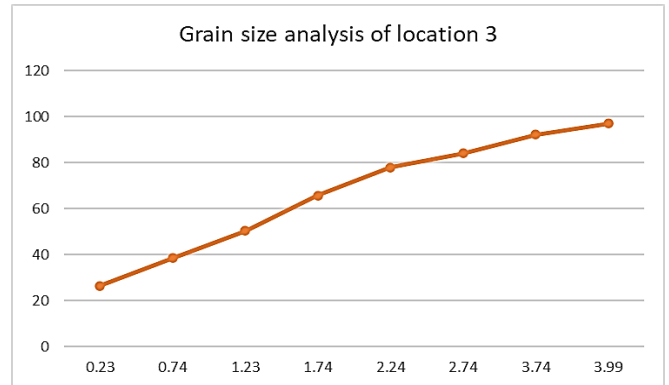


Figure 8: Graphical representation of Grain Size Analysis Result for Sample L3

Table 4: Grain Size Analysis Result for Sample location 4 (L4) Olomumu

Sieve Size (mm)	Phi=-log ₂ d	Sample Weight Retained (g)	Percentage (%) Weight Retained (g)	Cumulative Weight Percentage Retained
0.85	0.23	119	48.1	48.1
0.60	0.74	16	6.4	54.5
0.425	1.23	12	4.8	59.3
0.30	1.74	22	8.9	68.2
0.212	2.24	30	12.1	80.3
0.150	2.74	14	5.6	85.9
0.075	3.74	16	6.4	92.4
PAN	3.99	8	3.2	95.6
Total		237		
Initial Weight		247		

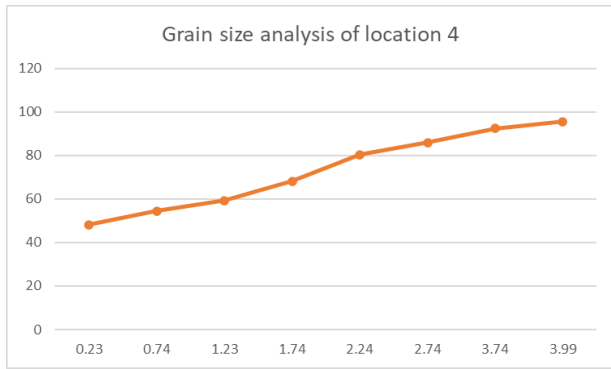


Figure 9: Graphical representation of Grain Size Analysis Result for Sample L4

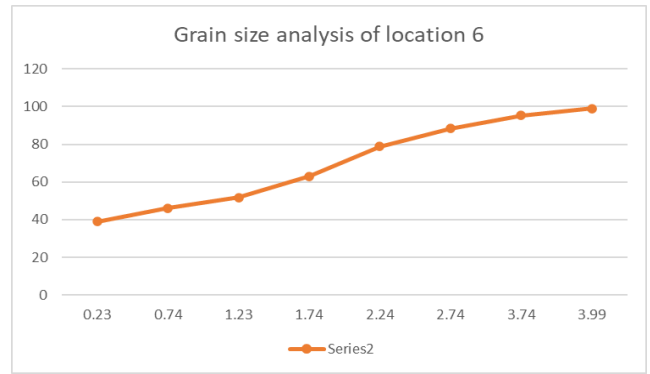


Figure 11: Graphical representation of Grain Size Analysis Result for Sample

Table 5: Grain Size Analysis Result for Sample location 5 (L5) Olomumu

Sieve Size (mm)	Phi=log ₂ d	Sample Weight Retained (g)	Percentage (%) Weight Retained (g)	Cumulative Weight Percent Retained
0.85	0.23	129	47.6	47.6
0.60	0.74	16	5.9	53.5
0.425	1.23	10	3.7	57.2
0.30	1.74	19	7	64.2
0.212	2.24	32	11.8	76
0.15	2.74	35	12.9	88.9
0.075	3.74	23	8.5	97.4
0.063	3.99	5	1.8	99.2
Total		269		
Initial Weight		271		

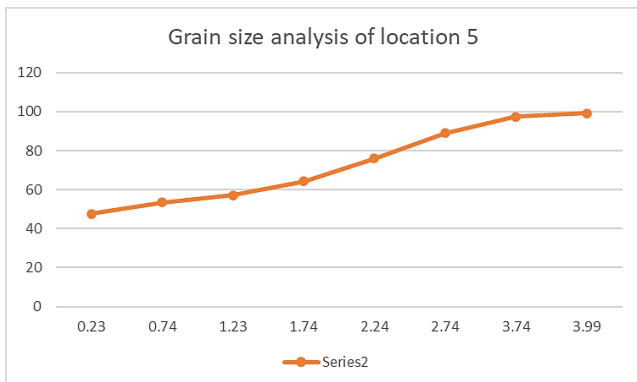


Figure 10: Graphical representation of Grain Size Analysis Result for Sample L5

Table 6: Grain Size Analysis Result for Sample location 6 (L6) Olomumu

Sieve Size (mm)	Phi=-log ₂ d	Sample Weight Retained (g)	Percentage (%) Weight Retained (g)	Cumulative Weight Percent Retained
0.85	0.23	125	39	39
0.60	0.74	23	7.2	46.2
0.425	1.23	18	5.6	51.8
0.30	1.74	36	11.25	63
0.212	2.24	51	15.9	78.9
0.15	2.74	31	9.6	88.5
0.075	3.74	22	6.8	95.3
0.063	3.99	12	3.75	99.1
Total		318		
Initial Weight		320		

Table 7: Skewness of grain size analysis of Imo and Olomumu stream sediments

SKEWNESS	SKEWNESS DESCRIPTION	
SAMPLE ID	RESULTS	INTERPRETATION
LOCATION1 IMOO	0.15	Fine skewed
LOCATION 2 IMOO	0.13	Fine skewed
LOCATION 3 IMOO	0.3	Strongly fine skewed
LOCATION 4 OLOMUMU	0.63	moderately skewed
LOCATION 5 OLOMUMU	0.61	moderately skewed
LOCATION 6 OLOMUMU	0.3	moderately skewed

Table 8: Standard deviation (sorting) of grain size analysis of Imo and Olomumu stream sediments

SORTING	STANDARD DEVIATION SORTING DESCRIPTION	
SAMPLE ID	RESULTS	INTERPRETATION
LOCATION1 IMOO	1.27	Poorly sorted
LOCATION 2 IMOO	1.23	Poorly sorted
LOCATION 3 IMOO	1.24	Poorly sorted
LOCATION 4 OLOMUMU	1.49	Poorly sorted
LOCATION 5 OLOMUMU	1.14	Poorly sorted
LOCATION 6 OLOMUMU	1.13	Poorly sorted

Table 9: Graphic mean of grain size analysis of Imo and Olomumu stream sediments

SAMPLE LOCATION	GRAPHIC MEAN	
	RESULT (mm)	INTERPRETATION
LOCATION1 IMOO	0.46	Medium grain
LOCATION 2 IMOO	0.20	Fine grain
LOCATION 3 IMOO	0.36	Medium grain
LOCATION 4 OLOMUMU	0.21	Fine grain
LOCATION 5 OLOMUMU	0.42	Medium grain
LOCATION 6 OLOMUMU	0.50	Medium grain

4.3 Geochemical Analysis

Five (5) trace elements were identified as pathfinder elements for gold mineralization in the study areas (Tables 10-15; figures 8-13). The identified trace elements were subjected to some simple statistical calculations from which the threshold values were obtained for the study areas (Tables 16 & 17). Threshold, according to a researcher is the upper limit of normal background values in which background itself is the normal range concentration for an element or elements in an area (Levinson, 1974). The determination of threshold value in exploration geochemistry is important, because it is the value above which the concentration of any element is considered anomalous. The concentration of the identified trace elements as related to their threshold values in the study areas are discussed below.

Table 10: The abundance of trace elements in location 1

S\N	ELEMENTS	PPM
1	Pb	41
2	Zn	761
3	Mn	456
4	Ag	0
5	Au	0
6	As	0
7	Cu	325

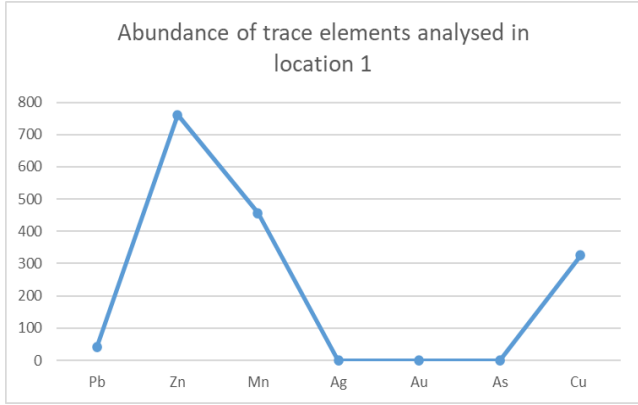


Figure 12: Abundance of trace elements analyzed in location 1

Table 11: The abundance of trace elements in location 2

S\N	ELEMENTS	PPM
1	Pb	0
2	Zn	794
3	Mn	1339
4	Ag	21
5	Au	0
6	As	0
7	Cu	424

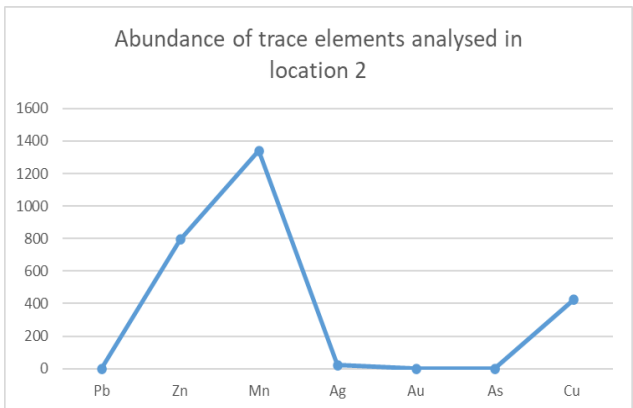


Figure 13: Abundance of trace elements analyzed in location 2

Table 12: The abundance of trace elements in location 3

S\N	ELEMENTS	PPM
1	Pb	18
2	Zn	650
3	Mn	835
4	Ag	1
5	Au	0
6	As	0
7	Cu	322

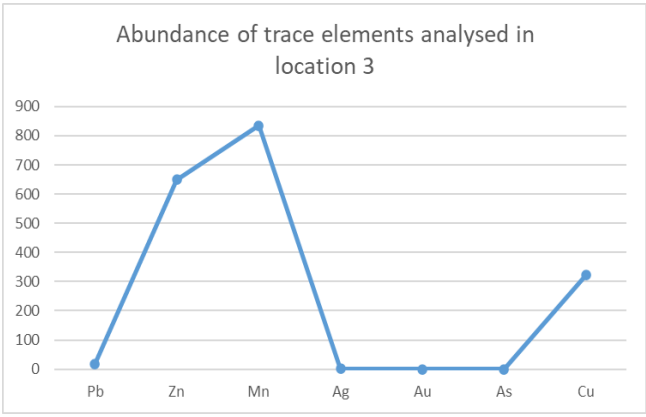


Figure 14: Abundance of trace elements analyzed in location 3

Table 13: The abundance of trace elements in location 4

S\N	ELEMENTS	PPM
1	Pb	9
2	Zn	805
3	Mn	211
4	Ag	0
5	Au	0
6	As	0
7	Cu	334

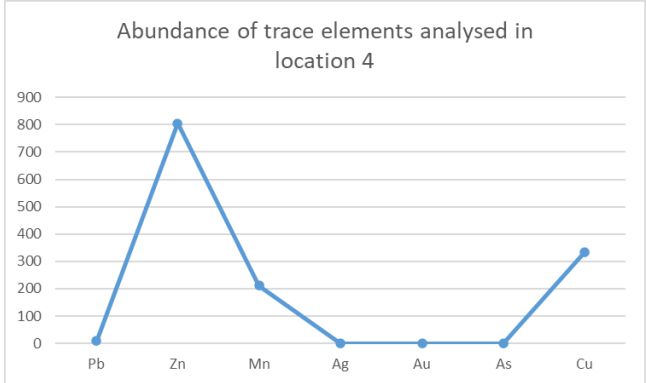


Figure 15: Abundance of trace elements analyzed in location 4

Table 14: The abundance of trace elements in location 5

S\N	ELEMENTS	PPM
1	Pb	52
2	Zn	862
3	Mn	96
4	Ag	0
5	Au	0
6	As	0
7	Cu	396

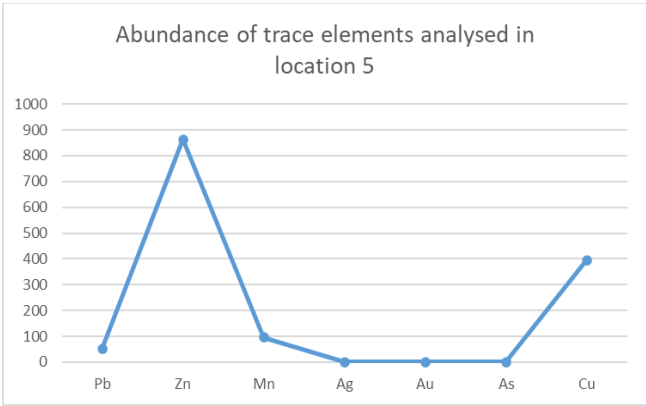
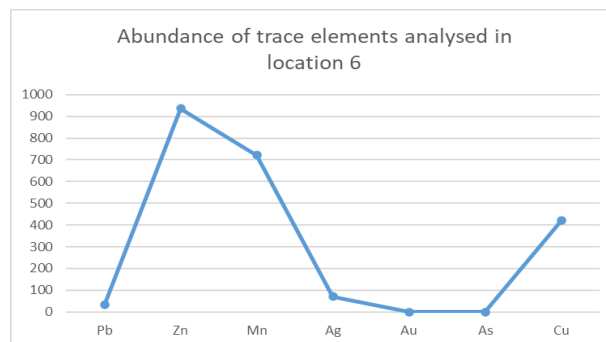


Figure 16: Abundance of trace elements analyzed in location 5

Table 15: The abundance of trace elements in location 6

S\N	ELEMENTS	PPM
1	Pb	33
2	Zn	936
3	Mn	721
4	Ag	71
5	Au	0
6	As	0
7	Cu	421

**Figure 17:** Abundance of trace elements analyzed in location 6**Table 16:** Threshold and crustal abundance for elements analyzed in Imo (Itagunmodi)

ELEMENTS ppm	L1	L2	L3	MEAN X	STANDARD DEVIATION	THRESHOLD X+2SD
Pb	41	0	18	19.6	20.55	60.7
Zn	761	794	650	735	75.43	885.86
Mn	456	1339	835	876.6	442.97	1760
Ag	0	21	1	7.3	11.84	30.9
As	0	0	0	0	0	0
Au	0	0	0	0	0	0
Cu	325	424	322	357	58.04	473

Table 17: Threshold and crustal abundance for elements analyzed in Olomumu (Osu)

ELEMENTS ppm	L4	L5	L6	MEAN X	STANDARD DEVIATION	THRESHOLD X+2SD
Pb	9	52	33	31.3	31.33	93.96
Zn	805	862	936	867.6	65.68	998.96
Mn	211	96	721	342.6	332.65	1007.9
Ag	0	71	0	23.6	40.99	105.5
As	0	0	0	0	0	0
Au	0	0	0	0	0	0
Cu	334	396	421	383	44.79	472.48

4.3.1 Lead (Pb)

Lead was detected in locations 1 and 3 in Imo, Itagunmodi (Tables 10, 11 & 12), with content values range between 18ppm and 41ppm, while location 2 has 0ppm. The mean value is 19.6ppm, while the threshold value is 60.7ppm. Comparing these values with the threshold value, it is interpreted that the lead content in Imo is from low to medium concentration. In Olomumu, Osu, lead was detected in all the three locations 4, 5 and 6 (Tables 13, 14 & 15). The content value ranges from 9ppm to 52ppm, with a mean value of 31.3ppm, and a threshold value of 93.96ppm. This shows that the content of Lead in Olomumu is from low to medium concentration. Hence; by comparing the lead content in Imo and Olomumu, it is interpreted that both locations have low to medium concentration of Lead.

4.3.2 Zinc (Zn)

Zinc was detected in all the 3 locations in Imo, Itagunmodi (Tables 10, 11 & 12), with content ranges from 650ppm to 794ppm. It has a mean value of 735ppm and a threshold value of 885.86ppm. Given these values the concentration of Zinc in Imo is interpreted to be high. In Olomumu, Osu, Zinc was also detected in all the three locations (Tables 13, 14 & 15), with content ranges from 805ppm to 936ppm. The mean value is 867.6ppm, while the threshold value is 998.96ppm. This shows that the content of Zinc in the area is of high concentration. Comparing the results from Imo and Olomumu, it is interpreted that both areas have high concentration of Zinc.

4.3.3 Manganese (Mn)

Manganese was detected in all the 3 locations in Imo, Itagunmodi (Tables 10, 11 & 12), with content ranges from 456ppm to 1339ppm. It has a mean value of 876.6ppm and a threshold value of 1760ppm. Given these values the concentration of Manganese in Imo is interpreted to be from

medium to high. In Olomumu, Osu, Manganese was also detected in all the three locations (Tables 13, 14 & 15), with content ranges from 96ppm to 721ppm. The mean value is 342.6ppm, while the threshold value is 1007.9ppm. It is interpreted that the content of Manganese in this area is of low to high concentration. Comparing the results from Imo and Olomumu, it is interpreted that both areas have high concentration of Manganese.

4.3.4 Silver (Ag)

Silver was detected in locations 2 and 3 in Imo, Itagunmodi (Tables 10, 11 & 12), while location 1 has 0ppm. The silver content in this area ranges from 1ppm to 21ppm, with a mean value of 7.3ppm, and a threshold value of 30.9ppm. Given these values the concentration of Silver in this area is interpreted to be from low to anomalous. Silver was also detected in only location 5 out of the three locations in Olomumu, Osu (Tables 13, 14 & 15), with content value of 71ppm. The mean value is 23.6ppm, and the threshold value is 105.5ppm. This shows that the content of Silver in this area is of high concentration. Comparing the results from Imo and Olomumu it is interpreted that both locations have low to anomalous concentration of Silver.

4.3.5 Copper (Cu)

Copper was detected in all the 3 locations in Imo, Itagunmodi (Tables 10, 11 & 12), with content ranges from 322ppm to 424ppm. It has a mean value of 357ppm and a threshold value of 473ppm. Given these values the content of Copper in this area is interpreted to be from medium to high concentration. Copper was also detected in all the 3 locations in Olomumu, Osu (Tables 13, 14 & 15). Its concentration ranges from 334ppm to 421ppm, with a mean value of 383ppm, and a threshold value of 472.48ppm. This shows that the content of Copper in this area is of medium to high concentration. Comparing the results from Imo and Olomumu, it is interpreted that both areas have medium to high

concentration of copper. The trace elements composition response of Imo (Itangunmodi), where gold mineralization has been detected was used as a control to determine the presence of gold mineralization in Olomumu (Osu). The results from the geochemical analysis of sediment from both areas revealed similar concentration of elements. Hence; it is interpreted that Olomumu (Osu) is gold mineralized.

5. CONCLUSION

The gold mineralization potential of Osu has been investigated by using the mineralization potential of Itangunmodi as control. The aeromagnetic survey delineated the structural architecture of the study areas. In order to enhance the structural visibility in the study areas, enhancement techniques such as vertical derivatives and 3D euler deconvolution were applied. The vertical derivative enhances the shallow geological structures and improving its visibility. It aligns the geological features in Northeast Southwest directions indicating tectonic episodes associated with pan African orogeny. While the 3D euler deconvolution located the position of structural features and estimated the depth to the structural features. Airborne radiometry showed the hydrothermally altered zones in the study areas. The airborne magnetic and radiometry data analyses revealed that both areas have signature similarity in term of geologic structure and hydrothermal alteration. It was observed that fracture and fault provide a conduit for hydrothermal mineralizing fluid in the study area, and show that Osu is highly mineralized with gold deposit. The calculated statistical parameters of Graphic Mean (M), Standard Deviation (SD), and Graphic Skewness (SK) were used for the grain size analysis. The result of the grain size analysis showed that the sediment in both areas range from fine to medium grained, poorly sorted, finely skewed to moderately fine skewed, which indicated fluvial depositional environments for the areas, and suggested that the occurrence of gold mineralization in the areas are secondary deposits (alluvial). The analyzed trace elements composition in both areas showed similar varied concentration of elements from low to high, with the exception of Silver that was anomalous in Itangunmodi. Hence; the geochemical analysis revealed that Osu is gold mineralized by using Itangunmodi mineralized zone as control. This research has further opened up unexploited area (Osu) for promising gold mineralization potentials. Samples collections were targeted at stream channels in both Itangunmodi and Osu. However, further research can still be conducted by carrying out more samples collection devoid of stream channel in Osu for geochemical analyses to ascertain the level of gold mineralisation in the area.

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