Spatial Distribution Of Gold And Associated Base Metals In Rock Units Of Ogute Area, Edo State, Nigeria

Adiotomre, E. E.

Abstract: The solid mineral industry in Nigeria has not seen any major investment since Nigeria became a major player in the production and exportation of hydrocarbon products. In recent years, the Federal Government of Nigeria has made reasonable efforts to revive the solid mineral industry through the World Bank assisted Sustainable Management of Mineral Resources Project. Regardless, the exploration for gold, a widespread mineral resource in the country continues to suffer from lack of funds when the global demand for gold as a store of value continues to surge. In this study, samples of outcrops of Precambrian basement rocks in Ogute area were analyzed for their Au, Ag, Cu, Zn and Pb contents using an Atomic Absorption Spectrophotometer. Statistical data and spatial geochemical concentration contour maps developed with Surfer software illustrates that the mineralization of Au, Ag and Pb probably occurs in the porphyritic-biotite-granite. There is also potential for Zn mineralization to occur in the granodiorite. The microgranite is un-mineralized with the analyzed elements, as a result of lateral depletion or element mobilization facilitated by thermal conductivity associated with the emplacement of quartz veins. The association of Ag with Au in the bulk fraction suggest that the Au-mineralization is probably epithermal Au-Ag vein deposits.

Index Terms— Key words - Concentration contour map, Geochemical anomaly, Gold, Primary pattern, Surfer.

---

1 INTRODUCTION

The search for concealed mineral deposits is perform sampling a geochemical medium or media that can lead to the discovery of such deposits [1]. Some important geochemical sample media that have been used successfully in the recent past include soil, stream sediment, and termitaria or termite mound [2, 3, 4, 5, 6]. 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 rock samples and the pattern of distribution of outcrops within an area [1]. However there are previous studies where the patterns of abnormal concentrations of chemical elements in rock samples have led to the successful discovery of concealed mineral deposits [e.g. 7; 8]. The study area (Ogute and its environs) lies between latitudes 7o14'N and 7o18'N and longitudes 6^{o}14'E and 6^{o}19'E. The area lies within the Igarra basement area which is part of the south-western Basement Complex of Nigeria (Fig. 1). An extensive discussion of the geology of the Igarra basement area is documented by [9]. The rock units mapped in the study area includes porphyritic-biotite-granite, microgranite and granodiorite. The porphyritic-biotite-granite occurs across the largest part of the study area, and the microgranite and granodiorite occur within the central part of the study area (Fig. 2). In the Ogute area, crystalline basement outcrops are ubiquitous and easy access is provided by excellent networks of roads and footpaths. As a result, the area is suitable for geochemical reconnaissance surveys for concealed mineral deposits. Nevertheless lithogeochemical data on the rocks of the study area is scanty or non-existence. The present study, therefore, is focused on establishing the distribution of element concentrations in rock units of the Ogute area and also to delineate zones of anomalous metal concentrations in the rocks.

2 MATERIALS AND METHODS

The first stage of the study consists of geologic field mapping that entails the collection of rock chips from outcrops of the different rocks that occurs in the study area. Atomic Absorption Spectrophotometer was used to analyse samples of the rocks for their Au, Ag, Pb, Zn and Cu content after hot digestion with aqua regia. The chemical data is processed with Microsoft Excel and Surfer software to generate univariate statistics and grid files for the elements analyzed. The gridded data in Surfer are used to produce geochemical contoured maps to illustrate the spatial distribution of element concentration in the rock units and to discriminate zones of anomalies from background areas.

3 RESULTS AND DISCUSSION

The results of the chemical analysis illustrate that the average content of the Au in the rock samples is maximum (35.6ppm) for the porphyritic-biotite-granite and minimum (11.4ppm) for the microgranite. An intermediate average Au content of 20.7ppm characterized the granodiorite (Table 1; Fig. 3). It is also evident from Table 1 and Figure 3 that the average content of Ag in the rock samples is maximum (8.5ppm) for the porphyritic-biotite-granite and a minimum (5.7ppm) for the microgranite. Similar to Au, intermediate Ag content of 6.2ppm characterized the granodiorite. A different trend in element content however occurs with Cu, Zn and Pb (Table 1; Fig. 3). Average Cu content is maximum (8.3) for the microgranite and a minimum (5.3ppm) for the granodiorite. Rock samples of porphyritic-biotite-granite have intermediate average content (7.4ppm) of Cu. Average content of Zn is highest (7.3ppm) for samples of granodiorite and minimum (4.1ppm) for microgranite rock samples, while intermediate Zn content (6.2ppm) occur with samples of porphyritic-biotite-granite. Rock samples of granodiorite have with maximum (15.3ppm) average Pb content whereas samples of porphyritic-biotite-granite shows a minimum average Pb content of 9.5ppm. However, an intermediate average Pb content (10ppm) is associated with samples of microgranite.

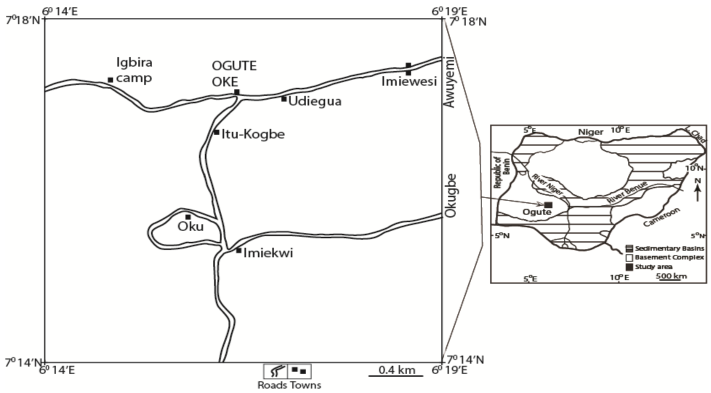

Fig. 1. Geologic map of Nigeria showing the location of the study area; adapted from [10].

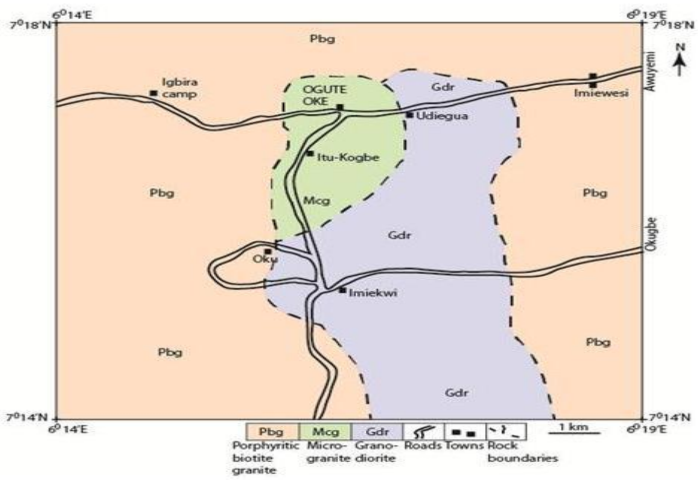

Fig. 2. Simplified geologic of Ogute and its environs showing the distribution of rock units.

Table 1. Average element content in rock units of Ogute area (in ppm)

Rock Units	No of Samples	Au	Ag	Cu	Zn	Pb
Microgranite	12.0	11.4	5.7	8.3	4.1	10.0
Granodiorite	12.0	20.7	6.2	5.3	7.3	15.3
Porphyritic-biotite-granite	15.0	35.6	8.5	7.4	6.2	9.5

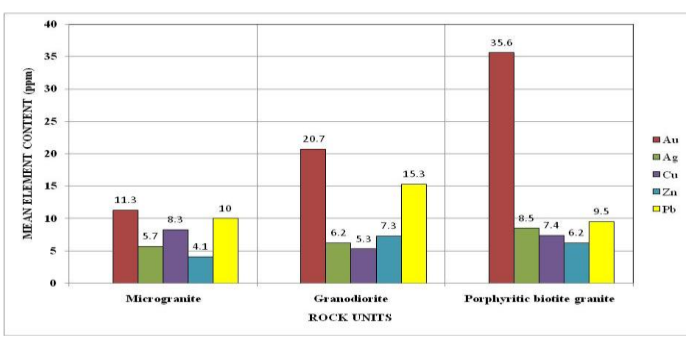

Fig. 3. Mean element content in rock units

Furthermore, the result of chemical analysis illustrates that the concentration of Au is higher in samples of the porphyritic-biotite-granite than samples of granodiorite and microgranite in the Ogute area (Fig. 4). Similarly, the median content (38.5ppm) of Au is higher in the porphyritic-biotite-granite than in samples of granodiorite and microgranite that are characterized with median values of 16.5ppm and 11.7ppm respectively (Fig. 4). The observed median of Au content suggests that 50% of samples of porphyritic-biotite-granite have 38.5ppm or higher Au content, whereas 50% of samples of microgranite and granodiorite have Au content that equals or greater than 16.5ppm and 11.7ppm respectively. This statistical information indicates that the porphyritic-biotite-granite is a possible source of gold mineralization in the Ogute area. On the basis of statistical information above, an additional possible source of gold that could also be a target for further exploration surveys is the granodiorite (Fig. 4). In a previous study, the statistical median has been employed to indicate the presence of high Au content in samples of ultramafic (serpentinite), and also to identify the source of gold mineralization in the Hajr gold mine, Saudi Arabia [11]. Figures 5-9 are geochemical concentration contoured maps that illustrate the spatial distribution of element concentrations in the study area. The geochemical concentration contoured map of Au discriminates a positive anomaly that occur to the east and a negative anomaly that is located to the south of the area (Fig. 5). The positive anomaly is characterized by inwardly increasing spherical-elliptical concentration contours, and the negative anomaly shows inwardly decreasing concentration contours that are also elliptical in configuration. The positive anomaly developed within the area where the porphyritic-biotite-granite occurs in the north-west, whereas, the negative anomaly occurred within the porphyritic-biotite-granite in the south and developed into the southern area of granodiorite (Fig. 5). The presence of the negative anomaly in association with positive anomalies in the porphyritic-biotite-granite and granodiorite suggest some form of lateral dispersion of element (s) during ore-forming processes [e.g. 12, 6]. Furthermore, the overlap of the negative anomaly across the boundary with the granodiorite may indicate that some mobilization and dispersion occurred through the granodiorite that resulted in the depletion of Au content. According to [11], element mobilization through host rocks may occur when thermal conductivity caused by quartz veins and aplite-dyke intrusions developed in the rock. Although, in the study area, no aplite-dyke intrusions are observed, it is probable that the quartz veins that occur in the granodiorite have favoured thermal conductivity of gold to mobilize through the rock during ore-forming process. These deductions corroborate information from statistical interpretation and suggest the porphyritic-biotite-granite as a main source of gold mineralization in the study area.

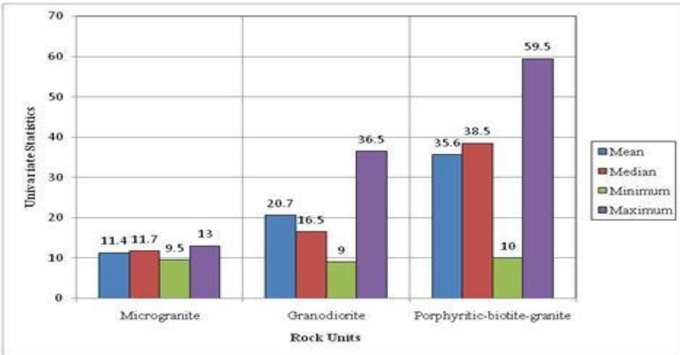

Fig. 4. Univariate statistics of Au in rock units of Ogute area. Note that the mean and median content of Au is higher in the Porphyritic-biotite-granite than in other rock units.

The geochemical concentration contoured map of Ag is similar in pattern to that of Au in the sense that a positive anomaly and a negative anomaly also developed in the north-west and south of the study area respectively. The positive anomaly is spherical-elliptical while the negative is spherical in configuration (Fig. 6). Furthermore, the positive anomaly occurs in the porphyritic-biotite-granite while the negative anomaly developed in the boundary between the porphyritic-biotite-granite and the granodiorite, although it is more developed into the former rock unit. An additional negative anomaly occurs in the northern part of the study area that is spherical-elliptical in configuration, although it is not as developed as the one that developed in the south. As mentioned earlier, for Au, the presence of a negative anomaly with positive anomaly also indicates lateral dispersion or Ag mobilization through the granodiorite as element concentrates in the porphyritic-biotite-granite during ore-forming process [e.g. 12, 11, 6]. According to [12], negative anomalies may develop due to loss of ore elements. In line with this assertion, the negative anomaly in the northern part may have developed from insignificant loss of ore elements during the lateral dispersion process which results in the development of an insignificant geochemical response. The anomalies in the geochemical contour map illustrate that the porphyritic-biotite-granite is a possible source of Ag-base metal mineralization. The similarity in the Ag primary anomalous patterns and trend with the primary patterns and trends observed for Au anomalies suggest the association of Ag with Au in the bulk fraction which indicate that the deposit is probably epithermal gold-silver vein type mineralization [e.g. 13]. The geochemical concentration map for Cu shows a negative anomaly that developed in the microgranite and also extends across its boundary with the granodiorite (Fig. 7). The negative anomaly is characterized by an elliptical configuration that trends approximately north-south. The occurrence of a negative anomaly in a geochemical system with no positive anomaly close by has been attributed to the effect of "lithogenesis" [12]. The contoured concentration map for Zn illustrates a negative anomaly that occurs dominantly in the microgranite and also developed across the boundary with the porphyritic-biotite-granite (Fig. 8). The pattern of the anomaly is spherical-elliptical and trends approximately N-S. In addition, a positive anomaly that is of a similar trend occurs in the granodiorite at about 1km from the microgranite (Fig. 8). The proximity of these anomalies may suggest a local concentration of Zn in the granodiorite as it is laterally dispersed through the microgranite during ore-forming process [e.g. 12]. In the geochemical concentration contoured maps for Pb, a positive anomaly occurs in the porphyritic-biotite-granite in the northern part of the study area and is characterized by a primary pattern that is spherical-elliptical, and trends in a north-south direction (Fig. 9). Furthermore, a negative anomalous concentration of lead occurs in the microgranite at about 500m from the positive anomaly in the porphyritic-biotite-granite. The configuration of the anomaly is spherical-elliptical and extends across the boundary between the microgranite and the porphyritic-biotite-granite. The proximity of the negative anomaly to the positive anomaly with which it is similar in trend suggests an occurrence of local concentration of Pb in the microgranite [e.g. 12]. A more significant positive anomaly of Pb occurs in the porphyritic-biotite-granite to the south of the study area, and it is characterized by an elliptical pattern that trends NW-SE.

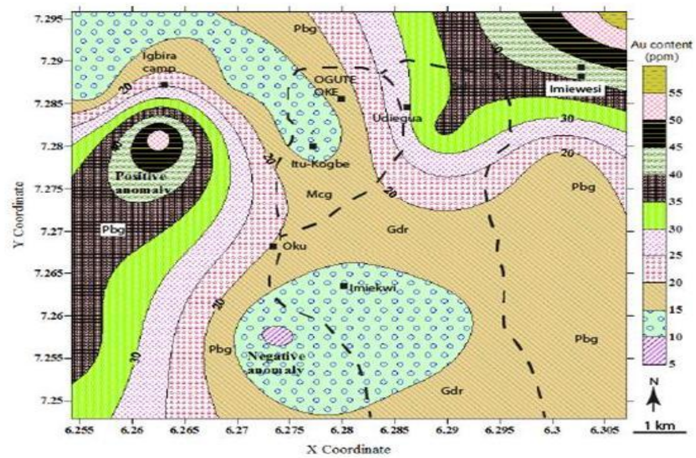

Fig. 5. Geochemical contoured map showing the spatial distribution of Au in rock units (contours in ppm) Pbg = porphyritic biotite-granite, Gdr= granodiorite, Mcg = microgranite. Dashed lines are rock boundaries.

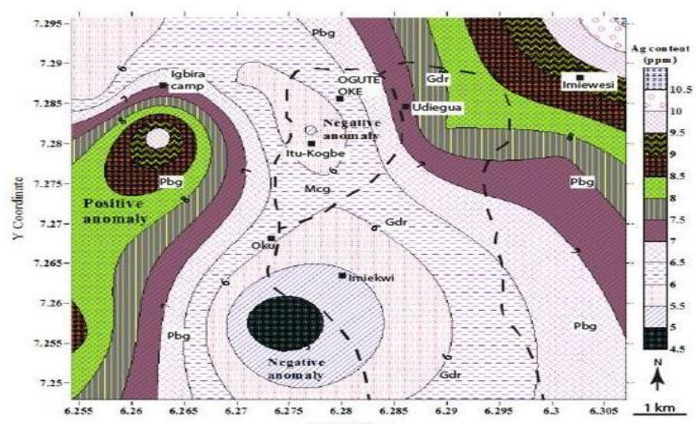

Fig. 6. Geochemical contoured map showing the spatial distribution of Ag in rock units (contours in ppm). Pbg = porphyritic-biotite-granite, Gdr= granodiorite, Mcg = microgranite. Dashed lines are rock boundaries.

4 CONCLUSION

Results of the study suggest that the porphyritic-biotite-granite is a probable primary source of Au in the area with 50% of the samples containing greater than or equals to 38.5ppm of Au.

In the spatially rendered geochemical map contoured for Au, positive anomaly occurs in the porphyritic-biotite-granite which corroborates the deduction from statistical analysis. The presence of negative anomaly occurring with the positive anomaly of Au in the porphyritic-biotite-granite is evidence that lateral dispersion of Au occurred during ore-forming process. It is evident from statistical data that the porphyritic-biotite-granite has a higher mean content of Ag (8.5ppm) than that of granodiorite (6.2ppm) and microgranite (5.7ppm). In the geochemical map contoured for Ag, positive and negative anomalies jointly occur in the porphyritic-biotite-granite. As a result, the porphyritic-biotite-granite is a probable source of Ag mineralization in the Ogute area. Furthermore, the similarity in the pattern and trends of primary anomalies of Ag and Au suggest that Ag occur with Au in the bulk fraction of the analyzed samples and also indicate that the mineralization in the porphyritic-biotite-granite is probably Au-Ag-base metal epithermal vein deposits.

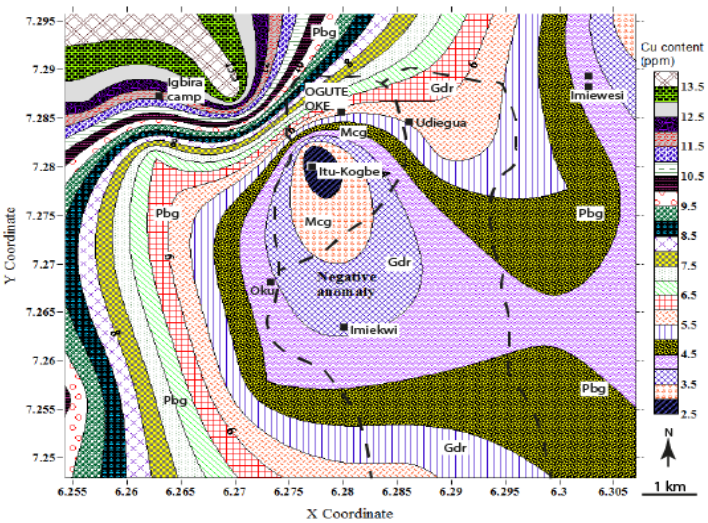

Fig. 7. Geochemical contoured map showing the spatial distribution of Cu in rock units (contours in ppm). Pbg = porphyritic biotite-granite, Gdr= granodiorite, Mcg = microgranite. Dashed lines are rock boundaries.

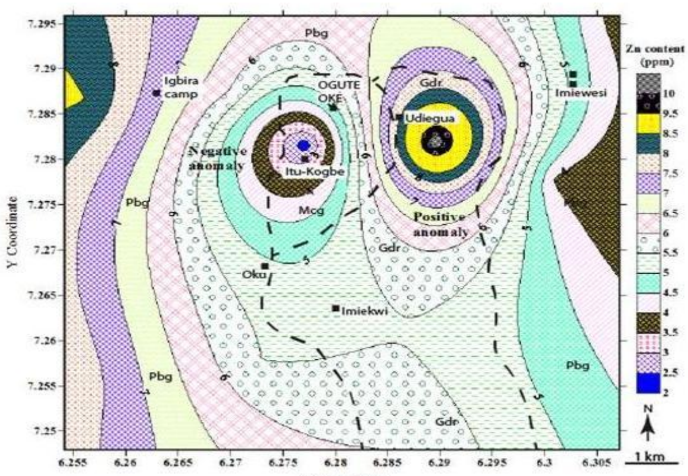

Fig. 8. Geochemical contoured map showing the spatial distribution of Zn in rock units (contours in ppm). Pbg = porphyritic biotite-granite, Gdr = granodiorite, Mcg = microgranite. Dashed lines are approximate rock boundaries.

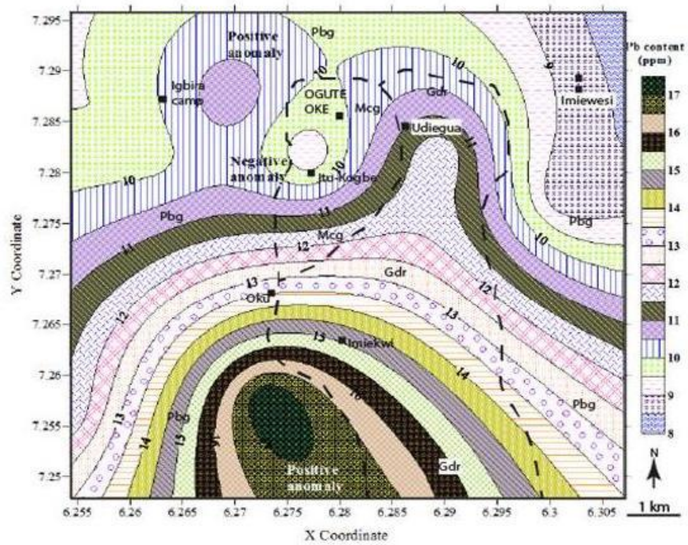

Fig. 9. Geochemical contoured map showing the spatial distribution of Pb in rock units (contours in ppm). Pbg = porphyritic biotite-granite, Gdr= granodiorite, Mcg = microgranite. Dashed lines are rock boundaries.

The occurrence of a negative anomaly of Cu in the microgranite and the absence of a Cu positive anomaly in the studied rocks suggests that Cu mineralization does not occur in rocks of the Ogute area. The geochemical concentration map contoured for Zn illustrates a positive anomaly in the granodiorite and a negative anomaly in the microgranite. These anomalies show similarity in trend and dimension which may indicate that Zn concentration may have occurred in the granodiorite as a consequence of lateral dispersion or mobilization of Zn through the microgranite. Element mobilization of this type would occur when thermal conductivity result due to quartz veins or aplite-dyke intrusions in country rocks. These findings suggest that the granodiorite is a possible source of Zn mineralization in the Ogute area. In the geochemical concentration maps contoured for Pb, positive anomalies occur in the porphyritic-biotite-granite and negative anomaly occurs in the microgranite. These observations suggest that porphyritic-biotite-granite is a possible source of Pb mineralization, and that lateral dispersion of Pb occurred during ore-forming process. The microgranite is un-mineralized with the analyzed elements; as a result of lateral depletion or mobilization that result from thermal conductivity related to the occurrence of quartz veins in the country rock.

5 ACKNOWLEDGMENT

The author appreciates the management of the Delta State University for logistic support.

REFERENCES

[1]. J.S. Webb and M. Thompson, "Analytical requirements in exploration geochemistry," *Pure and Applied Chemistry*, vol. 49, pp. 1507-1518, 1997.

[2]. E. Arhin and P.M. Nude, "Use of termitaria in surficial geochemical surveys: evidence for >125-μm size fractions as the appropriate media for gold exploration in northern Ghana," *Geochemistry: Exploration, Environment, Analysis,* vol. 10, pp. 401-406, 2010.

[3]. O.S.I. Bamigboye, and J.I.D. Adekeye, “Stream sediment survey of Eruku and its environs, Central Nigeria: Implications for Exploration,” *International Journal of Research and Reviews in Applied Sciences*, vol. 7, no. 2, pp. 160-172, 2011.

[4]. P.K. Mukherjee, K.K. Purohit, N.K. Saini, P.P. Khanna, M.S. Rathi and A.E. Grosz, “ Stream sediment geochemical survey of the Ganga River headwaters in the Garhwal Himalaya,” *Geochemistry*, vol. 41, 83-95, 2007.

[5]. M.O. Adepoju and J.A. Adekoya, “Reconnaissance geochemical study of a part of Igarra schist belt, southwestern Nigeria,” *Ife Journal of Science*, vol. 13, no. 1, 75-92, 2011.

[6]. E.E. Adiotomre, “Enhancing Stream Sediment Geochemical Anomalies Using Spatial Imaging: Case Study from Dagbala and Its Environs,” *IOSR Journal of Applied Geology and Geophysics*, vol. 2, no. 2, pp. 85-96, 2014.

[7]. G.J.S. Govett, “Bedrock geochemistry in mineral exploration,” *Proc. Expl. ’87 Conf., Ontario Geological Survey Special Publication, 3,* pp. 273-299, 1989.

[8]. Y. Li, H. Cheng, X. Yu and W. Xu, “Geochemical exploration for concealed nickel-copper deposits,” *Journal of Geochemical Exploration*, vol. 55, pp. 309-320, 1995.

[9]. I.B. Odeyemi, “Preliminary report on the field relationships of Basement complex rocks around Igarra, Mid-Western State, Nigeria,” *Geology of Nigeria*, C.A, Kogbe, ed., Nigeria: University of Ife, 1976.

[10]. C.A. Kogbe, *Geology of Nigeria*. Lagos: Elizabethan Publishing Company, 1976.

[11]. M.M. Hariri and M.H. Makkawi, “Gold mineralization distributions within rock units at the Hajr gold mine, southwest Saudi Arabia,” *The Arabian Journal for Science and Engineering*, vol. 29, no. 2A, pp. 111-121, 2004.

[12]. C. Shi and C. Wang, Regional geochemical secondary negative anomalies and their significance,” *Journal of Geochemical Exploration*, vol. 55, pp. 11-23, 1995.

[13]. R.Y. Takahashi, R.Y. Shingo, A. Imai, K. Watanabe, A. Harijoko, I.W. Warmada, A. Idrus, L.D. Setijadji, P. Phoumephone, A. Scherstén and L. Page, “Epithermal gold mineralization in the Trenggalek District, east Java, Indonesia,” *Resource Geology*, vol. 64, no. 2, pp. 149-166, 2014.