

Geochemical Assessment for Gold in Sediments of Gora River in Minna Area, North-central Nigeria

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Abstract Investigation was carried out on sediments of River Gora to geochemically assess for gold and its origin. The study area is situated in Minna in the North-Central geo-political zone of Nigeria. The area is constrained within latitude 9° 33'N and 9° 35'N and longitude 6° 34'E and 6° 35'E. Major and trace elements were analyzed using X-Ray Fluorescence spectrometry method. To decipher the factors responsible for the elemental association with gold, factor analysis, principal component analysis and cluster analysis were performed. The result revealed two main clusters of variables classified into three groups, namely: cluster 1, cluster 2(a) and cluster 2(b). Cluster 1 is made up of Ba and Sr, while cluster 2(a) consists of Rb, Cu, Zn, Cr, Ba and cluster 2(b) contains As, Mn, Mo, Fe, Au, Sb, Ni, Pb. The principal component analysis solution revealed four components, namely: component 1 (Sb, Ba, As, Zn, Cu, Ni, Cr, Fe), component 2 (Ba, As, Pb, Zn, Cu, Cr, Fe), component 3 (Sb, As, Zn, Sr, Ni, Cr, Fe) and component 4 (Au, Sb, Ba, As, Pb, Cu, Mo, Cr). The elemental associations suggested sulphide-gold mineralization within the surrounding schist and granitoids as possible source rocks.

Keywords Geochemical exploration, placer gold, Gora river, Minna, Nigeria

1. Introduction

The study area is situated in Minna in the North-Central geo-political zone of Nigeria. The area is constrained within latitude 9° 33'N and 9° 35'N and longitude 6° 34'E and 6° 35'E (Fig. 1). Accessibility to the sampling locations is via Chanchaga-Tegina road, minor roads, footpaths and the river

channel. The study area is covered by “Guinea woodland savannah” vegetation. This vegetation comprises typical combinations of tall grasses, shrub and scattered trees with denser tree cover along drainage channels. Cotton and sugar plantations are found in the study area. The vegetation cover helps to prevent wind-scoring of unconsolidated soils during the wet season, but not during the dry season [1].

The main aim of the study was to investigate sediments from River Gora for placer gold and its origin. To achieve the goal, objectives involving fieldwork, laboratory analysis, data interpretation and statistical methods were used to reduce the data to useful forms for meaningful interpretation and drawing of inferences.

Twenty-four samples were collected from various locations in Gora river bed with the main aim of carrying out geochemical exploration for gold and assessment of the origin of gold mineralization in the study area. To achieve the project aim, objectives involving field and laboratory techniques were engaged. The samples were wet sieved in the field and placed in kraft envelopes to dry gradually at the base camp and later transported to the laboratory for further treatment. Each sample was oven dried, sieved and 10 g of 63 µm fractions were taken for further treatment and analyzed for major and trace elements using X-Ray Fluorescence spectrometry method.

The dominant lithologic unit in River Gora area is schist. The area has undulating topography comprising high hills and valleys with covered vegetation. The highest elevation within the area is about 240 meters above mean sea level. The area is drained principally by River Gora. The drainage pattern of the area is dendritic. Most of the streams that drain the area are seasonal. Several quartz veins cross-cut the schist rocks in the area.

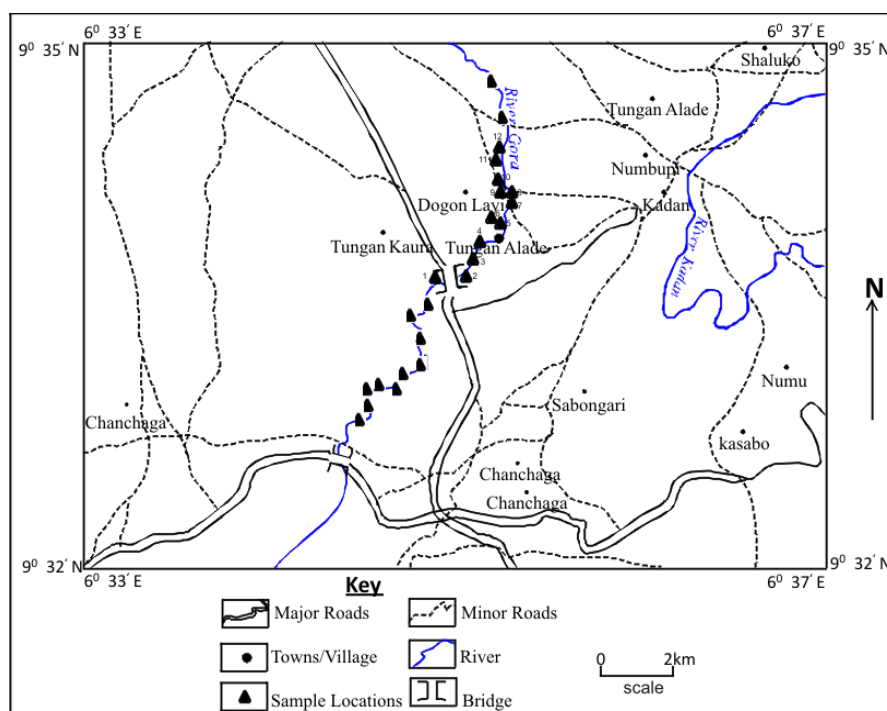


Figure 1. Road Map of Study Area showing Sampling

2. Materials and Methods

In the field, the following materials were used, namely: location map, plastic samplers, plastic panning bowls, set of sieves, global positioning system (GPS), digital camera, kraft envelops, nylon bags, plastic hand gloves, field notebook and rubber boots. In the laboratory, the materials used are weighing balance (model: ScoutPro SPU601 S/N-7123270179), brush, set of sieves, sieves shaker (STSJ-4 digital high frequency sieves shaker, S/N-100064) and cardboard.

The fieldwork involved the collection of Gora river sediments and the recording of the geographical coordinates and elevations of the sediments sampling points using GPS. Twenty-four stream sediments taken at depths of 30-50 cm with the aid of plastic sampler were wet sieved and packed into labeled brown kraft envelops, left to sun dry and transported to field base camp for onward transmission to the laboratory. Panning was also done to confirm the presence of gold in the selected sampling location.

Sample preparation via dry sieving was carried out in the Department of Geology Laboratory of the Delta State University, Abraka, South-southern Nigeria. 10 g from 63 μm fractions of each sample were taken to the National Geochemical Laboratory of the Nigerian Geological Survey Agency in Kaduna, North-western Nigeria for X-Ray Fluorescence analysis

The stream sediment samples were crushed to less than 63 microns with the aid of a Tema vibrating mill before sieving to 60 μm . Beads for major element analysis expressed in oxide weight percent were prepared by first drying the pulverized samples in an oven at 110 degree Celsius for 24 hours to remove moisture content. 5 grams of the dry sample

was weighed in the silica crucible and then ignited in the furnace at 1,000 degree Celsius for 2 to 3 hours for the calcination of impurities in the sample powder. Thereafter, samples were removed from furnace and allowed to cool to room temperature in desiccators. Each ignited sample powder was weighed again to determine the weight of calcinated impurities which were H_2O^- , H_2O^+ and CO_2 . 1 gram of stored ignited sample powder and exactly 5 times of flux (x-ray flux-type) 66%:34% (66% lithium tetraborate: 34% lithium metaborate) was added to lower the vitrification temperature. The weighed mixture was properly mixed in a Platinum dish and ignited in the pre-set furnace (Eggon-2 Automatic Fuse Bead Maker) at 1,500 degree Celsius for 10 minutes to form glass bead. Each glass bead was labeled and slotted into the computerized XRF (Epsilon-5 Panalytical model) for major oxide analysis measured in weight percentages. Trace elemental analysis was carried out using compressed powder pellets. These pellets were prepared by weighing 3 grams of oven-dried samples and 3 grams flux (cellulose-powder) added as a binder and dispersive agent and shaken in small plastic containers for 12 minutes. The well mixed mixture was then compressed by applying pressure of 1,500 kgm^{-2} using electronic compressor. The pellets were placed in the computer programmed XRF and the conditions for trace elemental analysis were set to give result in part per million (ppm).

3. Results and Discussion

3.1. Results

The summary of the descriptive statistics of the result of

the XRF analysis is given in Table 1, while the cluster analysis dendrogram is displayed in Fig. 2.

3.2 Discussion

The results show concentrations of trace elements and major elements (Fe and Mn) in the River Gora sediments.

Zr, Ba and V are considerably high in comparison to other trace elements in the samples. Zr ranges from 21-640 ppm with an average of 285 ppm probably due to the complete weathering of the source bedrocks in the Minna area [6]. Ba has average concentration of 131.17 ppm. V has average concentration of 112.33 ppm. Sr has average concentration of 181.50 ppm.

Cr, Zn, Rb, Cu, Sb and Ni have the following concentrations: Cr (10-108 ppm), Zn (8-96 ppm), Rb (28-64 ppm), Cu (21-56 ppm), Sb (9-26 ppm) and Ni (3-10 ppm) and their mean concentrations are 43.87 ppm, 39.58 ppm, 43.75 ppm, 42.42 ppm, 14.17 ppm and 12.75 ppm, respectively.

In, Co, Nb, As, Pb and Au have moderately low concentrations in comparison to the other trace elements in the samples. The concentration of In range from 2-24 ppm with average values of 6.25 ppm, while Co and Nb have average concentrations of 10.92 ppm and 11.41 ppm, respectively. On the other hand, As, Pb and Au have average concentrations of 2.5 ppm, 9.25 ppm and 6.87 ppm, respectively (Table 1).

3.2.1. Correlation Coefficient

Fe has positive correlation with, Ni, Cr and Mn but negatively correlated with Au, Rb, Sb, Pb, Mo and Sr. On the other hand, Mn is positively correlated to Rb, Zn, Sr, Ni and

Pb but negatively correlated to Au, Sb, Ba, As, Pb, Cu, Mo and Cr. The result from the correlation analysis indicated that the oxides of Fe and Mn played principal role in the concentrations of the aforementioned elements, which were adsorbed by hydrated Fe- and Mn- oxyhydroxide grains dispersed in a secondary environment [7], or by the co-precipitation processes with Fe- and Mn-oxyhydroxides. However, the negative correlation of Fe and Mn with gold (Table 2) indicated the occurrence of gold in free native form and that in turn corroborated the field observations. The high concentrations of Fe, Cr, V, Ba and Sr are indicative of probable felsic granitoids or schist source rocks in the study area.

Table 1. Summary of Descriptive Statistics of Results of Geochemical Analysis of Samples in ppm. n=24

Element	Min.	Max.	Mean	Std. Dev.
Au	2.30	11.00	6.88	2.39
Rb	28.00	64.00	43.75	12.37
Sb	9.00	26.00	14.17	4.59
Ba	91.00	216.00	131.17	32.88
Pb	2.00	48.00	9.25	13.47
Zn	8.00	96.00	39.58	30.55
Cu	21.00	56.00	42.42	10.74
Mo	0.50	21.00	4.75	6.16
Sr	12.00	319.00	181.5	86.60
Ni	3.00	30.00	12.75	9.35
Cr	10.00	108.00	43.87	32.12
Fe	5.20	14.55	9.43	2.80
Mn	0.05	0.31	0.19	0.08

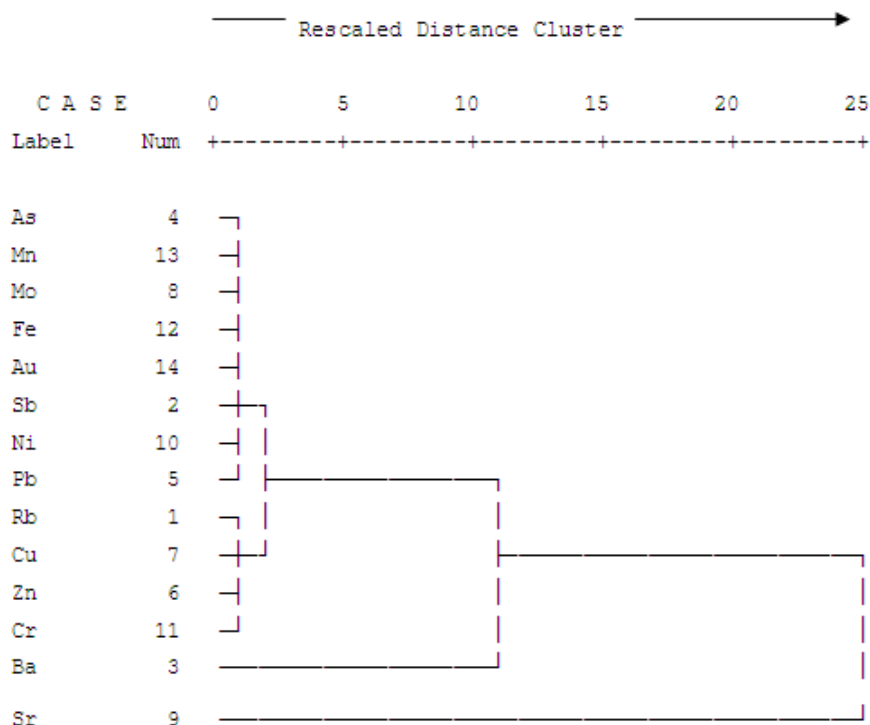


Figure 2. Cluster analysis dendrogram of trace elements in River Gora sediments using average linkage between groups

Table 2. Pearson Correlation Coefficient Matrix of River Gora Sediment Samples

	Au	Rb	Sb	Ba	As	Pb	Zn	Cu	Mo	Sr	Ni	Cr	Fe	Mn
Au	1.00													
Rb	0.096	1.00												
Sb	-0.584	-0.311	1.00											
Ba	-0.005	-0.200	-0.416	1.00										
As	-0.337	-0.286	0.119	0.701	1.00									
Pb	0.407	-0.179	-0.246	0.632	0.558	1.00								
Zn	-0.664	-0.650	0.602	-0.068	0.353	-0.262	1.00							
Cu	0.048	-0.458	0.205	0.365	0.207	0.443	-0.560	1.00						
Mo	0.725	0.087	-0.076	-0.171	-0.259	0.222	-0.494	0.248	1.00					
Sr	-0.421	0.554	0.249	-0.780	-0.477	-0.515	-0.160	-0.510	0.056	1.00				
Ni	-0.046	-0.716	0.368	-0.152	-0.179	-0.444	0.677	0.236	-0.321	-0.270	1.00			
Cr	-0.163	-0.583	0.078	0.263	0.202	0.245	0.429	0.529	-0.365	-0.434	0.461	1.00		
Fe	-0.395	-0.634	-0.011	0.288	0.205	-0.107	0.580	0.253	-0.579	-0.597	0.715	0.699	1.00	
Mn	-0.263	0.304	-0.096	-0.293	-0.251	-0.660	0.059	-0.531	-0.256	0.193	0.081	-0.368	0.226	1.00

Table 3. Stage and Clusters

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	4	13	79.608	0	0	3
2	12	14	285.359	0	0	4
3	4	8	602.265	1	0	4
4	4	12	664.442	3	2	6
5	2	10	871.000	0	0	6
6	2	4	1797.221	5	4	7
7	2	5	2685.331	6	0	11
8	1	7	4314.000	0	0	10
9	6	11	12579.160	0	0	10
10	1	6	14089.780	8	9	11
11	1	2	21312.614	10	7	12
12	1	3	167498.517	11	0	13
13	1	9	390963.109	12	0	0

3.2.2. Multivariate Analysis

The concentrations of the different groups of elements in the samples were subjected to multivariate statistical analysis using cluster analysis and principal component analysis to distinguish their various elemental associations.

3.2.2.1. Cluster Analysis

The result revealed two main clusters of variables (Table 3) classified into three groups, namely: cluster 1, cluster 2(a) and cluster 2(b). Cluster 1 is made up of Ba and Sr, while cluster 2(a) consists of Rb, Cu, Zn, Cr, Ba and cluster 2(b)

contains As, Mn, Mo, Fe, Au, Sb, Ni, Pb (Fig. 2).

Table 4. Kaiser-Meyer-Oklin (KMO) Measure of Sampling Adequacy (Communalities)

Variable	Initial	Extraction
Au	1.000	.886
Rb	1.000	.826
Sb	1.000	.929
Ba	1.000	.912
As	1.000	.907
Pb	1.000	.896
Zn	1.000	.859
Cu	1.000	.705
Mo	1.000	.774
Sr	1.000	.841
Ni	1.000	.925
Cr	1.000	.663
Fe	1.000	.969
Mn	1.000	.756

3.2.2.2. Principal Component Analysis (PCA)

The data set of the trace elements and major elements (Fe and Mn) were subjected to principal component analysis (PCA) involving three steps, namely: initial, extraction and rotation. Prior to the application of the principal component analysis, the appropriateness of the data for factor analysis was carried out. The use of the Kaiser-Meyer-Oklin (KMO) measure of sampling adequacy gave 0.705 to 0.969 (Table 4) that was interpreted to be very good to excellent because the

recommended baseline value of 0.6 was exceeded. Moreover, the Bartlett's test of sphericity yielded statistical significance that further strengthened validity of the factorability of the correlation matrix of the heavy metal concentrations in the study area. Four component factors were extracted from the principal component analysis using eigenvalues greater than 1 and they explained 33.77%, 26.35%, 13.40% and 11.11% of the variance, respectively. The cumulative per cent of the variance of the initial eigenvalues and extracted sums of squared loading was 84.63% (Table 5). Furthermore, the scree plot revealed a clear break after the fourth component and that further verified the retention of the four components for further analysis and interpretation using Varimax with Kaiser Normalization and rotated solution. The four component solution revealed the cumulative per cent of the

variance as 26.86%, 48.14%, 66.92% and 84.63% for components 1, 2, 3 and 4, respectively (Table 8). The Varimax with Kaiser Normalization and rotated solution gave cumulative per cent (84.63%) of rotation sums of squared loading for component 4 (Table 8) which was consistent with the values revealed in the unrotated Principal Component Analysis extraction loading (Table 5). The unrotated and rotated solution principal component analysis matrices are given in Tables 6 and 7. Rotated principal component analysis solution (Table 7) gave the following elemental associations given as components, namely: component 1 (Sb, Ba, As, Zn, Cu, Ni, Cr, Fe), component 2 (Ba, As, Pb, Zn, Cu, Cr, Fe), component 3 (Sb, As, Zn, Sr, Ni, Cr, Fe) and component 4 (Au, Sb, Ba, As, Pb, Cu, Mo, Cr).

Table 5. Total Variance Explained: Initial Eigenvalues

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.728	33.771	33.771	4.728	33.771	33.771
2	3.689	26.349	60.120	3.689	26.349	60.120
3	1.876	13.398	73.519	1.876	13.398	73.519
4	1.555	11.110	84.628	1.555	11.110	84.628
5	.793	5.667	90.295			
6	.654	4.669	94.964			
7	.340	2.431	97.395			
8	.170	1.213	98.608			
9	.129	.922	99.530			
10	.048	.343	99.873			
11	.018	.127	100.000			
12	.000	.000	100.000			
13	.000	.000	100.000			
14	.000	.000	100.000			

Table 6. Principal Component Analysis with UnRotated Solution

	Component			
	1	2	3	4
Au	-.493	.606	.306	-.427
Rb	-.816	-.059	-.381	.109
Sb	.299	-.474	.463	.632
Ba	.437	.685	-.502	.008
As	.507	.386	-.437	.556
Pb	.165	.903	-.034	.229
Zn	.733	-.510	.037	.245
Cu	.486	.497	.471	.013
Mo	-.491	.436	.583	-.056
Sr	-.663	-.537	.175	.287
Ni	.685	-.486	.334	-.329
Cr	.765	.136	.169	-.176
Fe	.839	-.190	-.187	-.441
Mn	-.205	-.619	-.458	-.347

Table 7. Rotated Extraction Method using Varimax with Kaiser Normalization

	Component			
	1	2	3	4
Au	-.164	-.128	-.804	.442
Rb	-.812	-.088	-.246	-.314
Sb	.059	-.282	.880	.267
Ba	.201	.908	-.215	.044
As	.015	.867	.386	.083
Pb	-.047	.710	-.229	.580
Zn	.524	.018	.743	-.175
Cu	.467	.211	-.012	.665
Mo	-.279	-.298	-.413	.661
Sr	-.621	-.618	.242	-.120
Ni	.841	-.334	.304	-.113
Cr	.752	.228	.117	.179
Fe	.891	.199	.085	-.357
Mn	-.053	-.280	-.064	-.819

Table 8. Total Variance Explained: Principal Component Analysis with Rotation Solution

Component	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.728	33.771	33.771	3.760	26.855	26.855
2	3.689	26.349	60.120	2.980	21.285	48.140
3	1.876	13.398	73.519	2.629	18.782	66.922
4	1.555	11.110	84.628	2.479	17.706	84.628

4. Conclusions and Recommendations

4.1. Conclusion

The negative correlation of Fe and Mn with gold indicated the occurrence of gold in free native form and that further corroborated with the field observation. The high concentrations of Fe, Cr, V, Ba and Sr indicated probable felsic granitoids and schist source bedrocks in the study area. As, Mo and Sb, which are exceptional pathfinder elements for gold mineralization, were detected in the analyzed samples. The cluster analysis and principal component analysis revealed Sb, Ba, As, Pb, Cu, Mo and Cr in elemental association with Au. Therefore, in processing of the gold in the area, small-scale artisanal miners should be engage in best practice to avoid possible Pb and As poisoning.

4.2. Recommendations

The following recommendations are proffered:

That detailed geochemical and geophysical surveys should be carried out to establish reserve of gold in the study area.

That microchemical and electron microscopic studies should be carried on the gold grains, specks and nuggets to ascertain the best ore dressing techniques for the gold.

That small-scale artisanal miners should be advised to engage the best practice to avoid possible Pb and As

poisoning.

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