academicJournals

Vol. 7(7), pp. 65-73, July, 2015
DOI: 10.5897/JGMR2014. 0212
Article Number: 0DF2ED854156
ISSN 2006 – 9766

http://www.academicjournals.org/JGMR

Journal of Geology and Mining Research

Full Length Research Paper

Geochemical stream reconnaissance survey of the schist belt around Igbo-Ora, Southwestern Nigeria

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Received 6 December, 2014; Accepted 6 July, 2015

Samples of stream sediments were collected in some parts of Iseyin-Oyan river schist belt, with a view to determining their elemental concentration and identifying geochemical anomalies associated with mineralization in the area. The geologic units consist of predominantly amphibolite schist with minor occurrences of coarse porphyritic biotite granite, quartzite and quartz schist. Chemical analysis was carried out on twenty stream sediment samples collected from rivers within the study area using Inductively Coupled Plasma Mass Spectroscopy (ICP - MS) technique. The samples analyzed are characterized by regional variations in the average concentration of each constituent element like Au, As, Co, Mo, Mn, Pb, Zn, Fe, Cu, Cr and Ni. Elemental concentration in each sample varies in the following range Mo (0.1 to 3.8 pm), Cu (5.9 to 63.4 ppm), Pb (16.5 to 76.1 ppm), Zn (11.0 to 55.0 ppm), Ni (1.5 to 45.5 ppm), Co (2.3 to 95.6 ppm), Mn (153.0 to 8180 ppm), Fe (0.38 to 9.11%), As (0.00 to 5.6 ppm), Au (0.5 to 5.6 ppb) and Cr (14.9 to 331 ppm). The average concentration obtained for each element is too low to indicate presence of mineralization in the study area when compared to average concentration obtained for similar elements in other schist belts with proven mineralization. The result generally revealed that the average metal content for the elements are due to lithogenic influence of the underlying bedrock. The mean metal content are however too low for mineralization to occur within the study area.

Key words: Elemental concentration, Iseyin-Oyan, mineralization, Schist belt, anomaly.

INTRODUCTION

The Nigeria schist belts referred to as Newer (Oyawoye, 1964) or Younger metasediments (McCurry, 1976) comprise of minor volcanic, basic sill and lava (amphibolites and ultramafites). The schist belts (mostly of eburnean orogeny) believed to predate the granitoids (Pan African Orogeny) (Turner, 1983) have suffered intense polyphase deformation and metamorphism under low to medium grade conditions. These schist belts have formed major litho-stratigraphic unit of the Nigerian Precambrian complex with vast economic potentials, in

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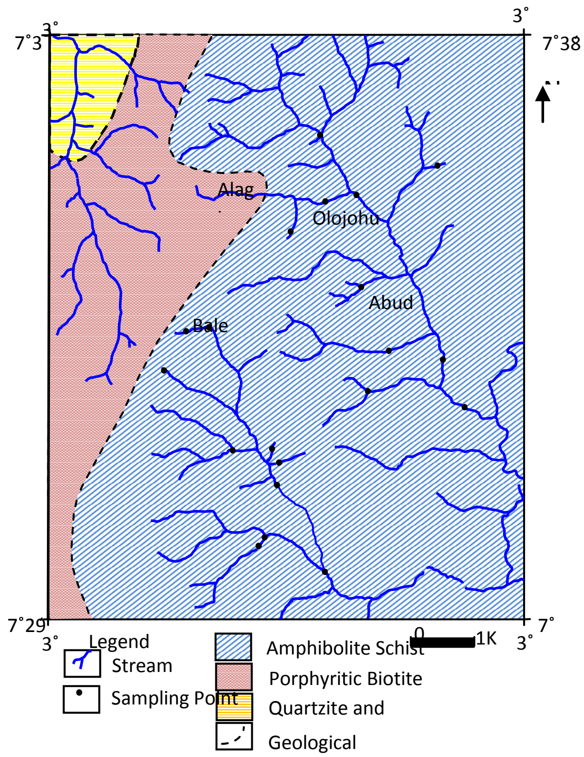

Figure 1. Geological map of the study area (Weerawarnakula, 1986).

essence, they play host to a variety of economic mineral resources. The Nigerian schist belts are exposed predominantly west of longitude 8° within a North-South trending.

The lithology of schist belts generally consists of pelitic and semipelitic schist, phyllites, quartzites, polymict meta-conglomerate, iron formation, marbles, calcsilicate rocks and subordinate igneous rocks. These rock types occur in varying proportions in different schist belts across Nigeria (Rahaman, 1976; King and De Swardt, 1949; Elueze, 1981; Odeyemi, 1988; Adekoya, 1996). Schist belts like Egbe-Isanlu, Ife-Ilesha in the south west, Minna-Birnin gwari, Yauri-Anka-Maru in the Northwest have significant gold occurrence (Garba, 2000).

The study area is located within Longitude 3° 15′ to 3° 23′ East of the Greenwich meridian and Latitude 7° 29′ to 7° 38′ North of the Equator (Figure 1). Stream sediment survey was conducted because the sediments are the most effective medium of sampling used for reconnaissance survey (Levinson, 1974; Rose et al., 1979). Stream sediment sampling helps in unraveling problems related to bedrock geochemistry and discovery of anomaly related to mineralization (Van der Oever, 2000).

This work is aimed at determining the elemental concentration of the stream sediments, identifying any geochemical anomaly associated with mineralization. It is also targeted at studying part of Iseyin-Oyan river schist belt to see whether there will be occurrence of mineralization whose geological and geochemical composition bear similarities to other schist belts in Nigeria.

GEOLOGICAL SETTING

Iseyin-Oyan river schist belt is regionally underlain by Precambrian basement rock characterized by various lithological units comprising of Mica schists, Quartzite, Quartz schist and Amphibolite schist. Crowds of granite plutons are remarkable features of the schist belt. The most abundant granite is the porphyritic potassic granite (Kayode, 1976), potassic syenite is also associated with these granite plutons (Oyawoye, 1967) and (Rahaman, 1976).

Amphibolite schist is the dominant rock occurring within the study area. Other rock types identified are coarse porphyritic biotite granite, quartzite and quartz schists. The meta-sediments are confined to the North western part of the study area (Figure 1). Due to reconnaissance nature of this work, various geological units were studied while samples of stream sediments were collected for analysis. Stream sediment samples collected in an uninhabited area roughly reflects the bedrock lithology

Table 1. Statistical Summary of the Geochemical data for the study area (n = 20).

Elements	Range	Arithmetic mean	Geometric mean	Standard deviation	Median	Mode
Mo (ppm)	0.1– 3.8	1.16	0.8	0.93	1.05	0.20
Cu (ppm)	5.9 – 63.4	27.1	23.0	15.12	24.2	24.20
Pb (ppm)	16.5 – 76.1	33.5	30.6	15.44	31.15	16.5
Zn (ppm)	11.0 – 55.0	27.0	25.1	11.13	25.5	16.5
Ni (ppm)	1.5 – 45.5	13.9	10.2	11.08	13.3	14.5
Co (ppm)	2.3 – 95.6	27.6	20.54	20.5	38.8	2.30
Mn (ppm)	1530 – 8180	15.05	984	1771.17	1117	477
Fe (%)	0.38 – 9.11	2.8	1.99	1.92	2.4	2.4
As (ppm)	0.00 – 5.6	1.0	1.12	1.5	0.65	0.00
Au (ppb)	0.5 – 5.6	1.5	1.18	1.4	1.0	0.9
Cr (ppm)	14.9 – 331	72.2	53	70.9	60	14.9

upstream from the sampling site with anthropogenic influences being low or absent (Halamic et al., 2001).

Quartzite, Quartz schist, porphyritic biotite granite and Amphibolite schist contributed sediments into the streams where the samples were collected from (Figure 1). Stream sediment samples collected from various second order rivers, stream channels are products of eroded bedrocks underlying the drainage basin around the study area. They also represent the geochemistry of materials from the upstream drainage basin.

The topography of the study area is undulating and rugged. Series of highlands, lowlands, massive rock exposure with steep and gentle slopes drain into the valleys, gullies and basins within the study area. During rainy season, the valleys accumulate weathered materials and minerals which are transported by water and deposited as sediments in the basin. The sediments are detrital, fragmented and eroded residues from different rock bodies occurring within and outside the catchment area. Few streams with networks of branching tributaries draining southwardly are common. The drainage pattern is dendritic in nature (Figure 1).

METHODOLOGY

Twenty samples of stream sediment were collected mostly at a depth of about 20 cm near the middle of the stream using plastic scoop sediments free of organic materials were collected. Sediments that were composed of coarse grained materials were avoided, fine grained portions were carefully collected to ensure that meaningful amount of materials would be contained in the samples. Wet samples of stream sediment were packed in black polythene bags, after which they were air-dried to avoid contamination from bacterial activities of the oxygen-poor environment in the polythene bag. Samples were then sieved using -80 mesh size fraction (0.177 mm). 0.5 g of each samples were digested using 6ml of HCl and 2 ml of HNO_3 in 5 ml of water.

The resulting solution was boiled at 95°C for one hour. The solution was filtered off while the filtrate was thereafter diluted with 10 ml of water. The digested samples were then analyzed for their trace metal content using Inductively Coupled Plasma Mass Spectroscopy (ICP- MS) technique at ACME Laboratory in Canada. The data obtained were interpreted using statistical techniques like correlation coefficient analysis, factor analysis, scatter plots and frequency distribution plots. These techniques provided insights into the underlying geological and geochemical processes that are significant in controlling the stream sediment geochemistry.

RESULTS AND DISCUSSION

Statistical summary of geochemical data (Table 1) shows the mean metal contents of each element like Mo(0.8 ppm), Cu(23.0 ppm), Pb(30.6 ppm), Zn(25.1ppm), Ni(10.2 ppm), Co(20.54 ppm), Mn(984ppm),Fe(1.99%),As(1.12 ppm), Au(1.18 ppb) and Cr(53.0 ppm) that are present in stream sediments collected in the study area. Highest values were recorded for elements such as Mo, Cu, Ni, As and Cr at Abudu river (Figure 1). Maximum values were as well recorded for elements like Pb, Co, Fe, Au, and Mn while peak value was recorded for Zn at the river tributary near Olojohun River (Figure 1).

Amphibolite schist that is mostly mafic in composition strongly affects content of elements like Ni, Cr, Co and Cu in sediments even if this rock type cropped out in small area. Pb is mostly derived from felsic rocks like quartzite, quartz schist and porphyritic biotite granite. However, at various points along the stream course, enrichment of metal content was noted, this is as a result of inputs from tributaries adjoining the main stream channels. There is no evidence of mining or industrial activities within the vicinity of the study area hence the only controlling factor contributing to the distribution of elemental concentration is the surface geology.

Amphibolite schist being the dominant rock type of the study area contributes the highest amount of elemental abundance into the stream sediments (Figure 1). It could be inferred that the lithology through which sediments are collected is simple thus sediments are homogeneous in nature and composition from the point where erosion

Table 2. Mean metal contents obtained from different areas with similar lithology.

Area	Mean metal content in ppm										
	Mo	Cu	Pb	Zn	Ni	Co	Mn	Fe	As	Au	Cr
Katanga metasediments of Copperbelt area (Webb et al., 1963)	*	42	20	*	38	20	610	*	*	*	100
Ife-Ilesha Schist belt (Elueze and Olade, 1985)	*	69	33	95	71	43	1186	16	*	*	196
Ife-Ilesha Schist belt (Ajayi, 1995)	*	35	33	58	29	22	400	26	*	*	120
Crustal abundance (Levinson, 1974)	1.5	55	22	70	75	25	950	3.54	11.8	0.004	100
Ultramafic abundance (Levinson, 1974)	0.3	10	12.5	50	2000	100	1300	*	1.0	0.005	2000
This study (2004)	0.8	23	30.6	25.1	10.2	20.54	984	1.99	1.12	0.0012	53

* values not available, Fe is in wt%, Au is in parts per billion (ppb).

occurs to the points the materials are deposited. Lithological diversity is disadvantageous as the sediments are progressively mixed. The resultant heterogeneous mixture generated stream sediments whose geochemical composition is charged with “noise” which renders interpreting the provenance of source materials difficult (Halamic et al., 2001). The mean metal content of the geochemical result obtained from the study area was compared with those obtained from different areas of almost similar lithology (Table 2). It could be observed that the mean metal content is relatively low and implies that the area is unmineralised with respect to the elements.

The metal contents could be due to input from the lithological composition of the bedrock underlain by amphibolite schist within the study area. The study area bears lithological semblance with mineralized drainage basin at NE Chalkidiki particularly the area around Kokkinolakkas which is predominantly underlain by amphibolites (Kelepertzis et al., 2012). The range and mean values of metal concentration in the mineralized basin are higher in elements such as Pb (1165-3439 ppm), Zn (1368-4538 ppm), As (964-2714 ppm) and Mn (6811 up to >10000 ppm). The result of the analysis as presented in Table 3 indicates that elements such as Mo, Cu, Pb, Zn, Ni, Co, Fe, Mn, Au and Cr are present in the study area. Most of the stream sediment samples were obtained from portions which were underlain by amphibolite schist (Figure 1).

Sediment contribution from adjoining lithology such as porphyritic biotite granite and quartzite are low. High amount of Fe in the stream sediment is due to the presence of mafic minerals. The amount of stream sediment within the catchment is controlled by the drainage system which is dendritic in nature. Sediments are acquired, gathered and distributed along the river channel. High amount of metal content was generally observed in rivers Olojohun, Abudu and Bale due to amphibolite schist underlain the drainage system.

Frequency distribution plots

Frequency of sample occurrence was plotted against concentration of each element (Figure 2). Elements considered show same trend and pattern that is, they are all asymmetrical and positively skewed. Mean metal contents obtained in this study are generally lower than that obtained from other areas with proven mineralization, values of standard deviation likewise are very low in the study area compared to other areas. Generally, it could be observed from the plots that all the elements are asymmetrical and positively skewed. The implication of this trend on mineralization is that the metal contents are too low for any mineralization to have occurred in the area. The concentration of elements present is only due to lithological composition of the bedrock.

Correlation coefficient (R)

Association of some elements may lead directly to an interpretation of the type of deposit likely to be present in the area. Mutual correlation between these elements helps in clearly identifying the variations present in the geochemical landscape.

Correlation matrix is generated by correlating multi element data. It contains the correlation between all possible pairs of elements under consideration. The coefficient of correlation tends

Table 3. Result of Geochemical Analysis of selected elements in stream sediments of the study area.

Sample	Fe %	Mo ppm	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	Mn ppm	As ppm	Cr ppm	Au ppb
1	5.04	2.6	49.1	76.1	49.0	33.5	95.6	3796	1.3	137.5	5.6
2	2.52	1.2	25.4	39.2	26.0	14.8	33.7	8180	-	64.3	2.2
3	2.22	0.8	24.2	31.0	26.0	17.2	34.1	1593	-	67.3	4.7
4	0.38	0.1	5.9	22.4	16.0	1.5	2.3	153	-	14.9	-
5	1.77	0.3	13.2	19.9	16.0	4.5	13	583	-	26.4	1.5
6	3.51	1.3	19.5	24.6	32.0	8.9	19.5	724	0.9	45	0.6
7	2.21	0.8	14.3	27.2	22.0	6.0	20.9	1032	-	36.9	1.0
8	0.83	0.2	7.3	18.6	11.0	2.0	5.5	336	-	18.6	0.5
9	3.1	1.6	23.7	35.5	30.0	13.5	30.3	1392	0.8	72.4	-
10	0.87	0.2	21.1	16.5	21.0	4.8	9.2	477	-	16.1	1.0
11	0.98	0.2	10.6	18.9	20.0	4.5	9.6	477	-	20.2	1.2
12	3.83	2.2	25.9	51.6	18.0	9.2	35.1	1933	2.1	65.1	0.6
13	4.0	1.3	53.1	46.6	55.0	13.5	39.5	1709	0.5	58.1	2.0
14	2.4	1.1	24.2	32.7	25.0	13.1	31.2	1070	-	75.3	0.9
15	4.23	1.8	30.5	37.4	17.0	14.4	22.3	919	9	155.9	0.7
16	1.95	0.5	36.6	31.3	41.0	28.2	32.0	1307	-	57.6	0.9
17	1.91	3.8	63..4	57.0	32.0	45.5	40.9	1825	5.6	331	1.2
18	2.05	0.7	22.8	21.9	29.0	17.4	27.2	1254	-	48.5	0.9
19	2.92	1.0	34.8	42.7	31.0	18.1	43.5	1164	-	61.8	1.1
20	2.4	1.4	36.4	18.4	23.0	7.9	6.2	183	1.6	70.2	1.0

towards + 1 or -1.

The generated matrix obtained for correlating elements in the study area is shown in Table 4. An element association tending towards +1 shows positive and strong correlation while association tending towards -1 indicates strong but negative correlation. However as the values tend away from +1 or -1 the correlation becomes weak. All the elemental association considered are positively correlated with Ni-Cu being the most strongly correlated while Au-As, the least strongly correlated. It is implied that the same geochemical conditions influence their concentration as they all exhibit dominant positive correlation. It also points to the fact that all the elements have a common lithogenic source (Table 5).

Factor analysis

Factor analysis was employed to establish principal element association related to various bed rock types which contribute to the concentration of stream sediments; this factor helps to discriminate between concentration of streams sediments that are related to mineralization and those that are unrelated to mineralization. R-mode factor analysis was selected as the appropriate model based on the recognition of metal association considered meaningful in terms of geological or surface processes. The factor matrix for elements in stream sediments is as shown in Table 6. Factors extracted in the matrix are four and they are as shown below. Factor variables with values >0.5 were considered to be significant.

Factor 1- Mo-Cu-Pb-Ni-Fe-As-Cr
Factor 2- Pb-Co-Mn-Au
Factor 3- Cu-Zn
Factor 4- Ni

Factor 1 (Mo, Cu, Pb, Ni, Fe, As, Cr): This factor accounts for 64.4% of the data variability. The distribution of the factor scores is associated with amphibolite schists which generally have higher quantity of As, Fe, Cr, Mo and low quantity of Cu, Pb and Ni. These elements with higher quantities are those that have dominant influence on the concentration obtained from the bedrock. The presence of these elements is due to lithological composition rather than mineralization.

Factor 2 (Pb, Co, Mn, Au): Factor 2 accounts for 21.6% of the total data variability. The element associations do not suggest any mineralization. The metal content is as a result of lithological influence of the predominant rock occurrence in the study area.

Factor 3 (Cu, Zn): This factor accounts for 6.7% of the total data variance. This element association is simply a base metal association. Zn has higher influence than Cu in this factor, thereby suggesting the dominating effect

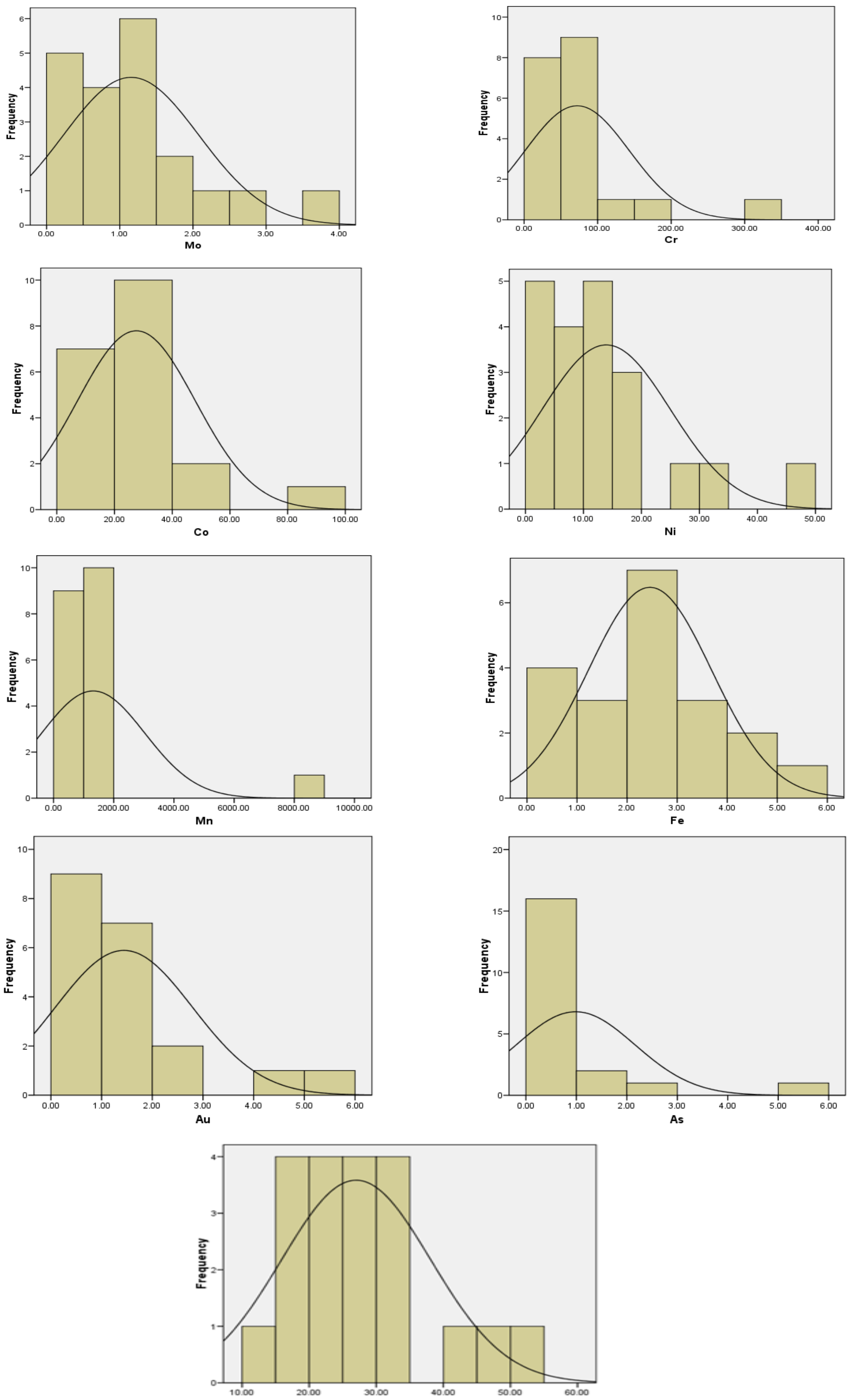

Figure 2. Frequency distribution plot of elements in the study area.

Table 4. Correlation matrix of elements in the study area (n=20).

Elements	Mo	Cu	Pb	Zn	Ni	Co	Mn	Fe	As	Au	Cr
Mo	1.000										
Cu	0.**776**	1.000									
Pb	0.**805**	0.**741**	1.000								
Zn	0.379	0.**741**	0.**603**	1.000							
Ni	0.**743**	0.**831**	0.**730**	0.**608**	1.000						
Co	0.**621**	0.**665**	0.**910**	0.**716**	0.**727**	1.000					
Mn	0.314	0.273	0.498	0.293	0.344	0.059	1.000				
Fe	0.**956**	0.**827**	0.**761**	0.450	0.**800**	0.**586**	0.250	1.000			
As	0.**899**	0.**635**	0.491	-0.004	0.**622**	0.201	0.296	0.**887**	1.000		
Au	0.225	0.311	0.**529**	0.463	0.388	0.**710**	0.426	0.178	0.059	1.000	
Cr	0.**886**	0.**756**	0.**640**	0.268	0.**830**	0.460	0.197	0.**928**	0.**875**	0.152	1.000

Table 5. Elements association selected for correlation in the study area.

Pb –Zn	0.603
Au-As	0.059
Ni-Co	0.727
Fe-Mn	0.250
Cu-Zn	0.741
Ni-Cu	0.831
Cu-Mo	0.776

Table 6. R-Mode factor matrix of elements in stream of the study area (n=20).

Elements	Factor 1	Factor 2	Factor 3	Factor 4	Communality
Mo	0.**914**	0.388	0.027	-0.011	0.987
Cu	0.**664**	0.280	0.**634**	0.144	0.946
Pb	0.**500**	0.**817**	0.206	0.0302	0.979
Zn	-0.029	0.442	0.**878**	0.0912	0.977
Ni	0.**592**	0.378	0.312	0.**634**	0.992
Co	0.185	0.**922**	0.265	0.185	0.990
Mn	0.260	0.**920**	0.218	0.112	0.974
Fe	0.**918**	0.274	0.190	0.104	0.974
As	0.**974**	0.0237	-0.0032	0.0316	0.951
Au	0.0261	0.**833**	0.269	0.0243	0.999
Cr	0.**914**	0.137	0.040	0.0340	0.974
Eigen value	7.087	2.372	0.731	0.318	
% variance	64.4	21.57	6.65	2.89	

of Zn bearing sulphide on the bedrock.

Factor 4(Ni): Factor 4 accounts for 2.89% of the data variance of the siderophilic elements. This factor does not have any influence on mineralization. Its presence is only due to lithological composition of the bedrock which is mafic and/or ultramafic in nature.

Scatter diagram

Scatter diagram is employed to analyze the relationship between two trace elements. The plots of randomly selected element association generally revealed positive correlation among elements considered. Figure 3 showed

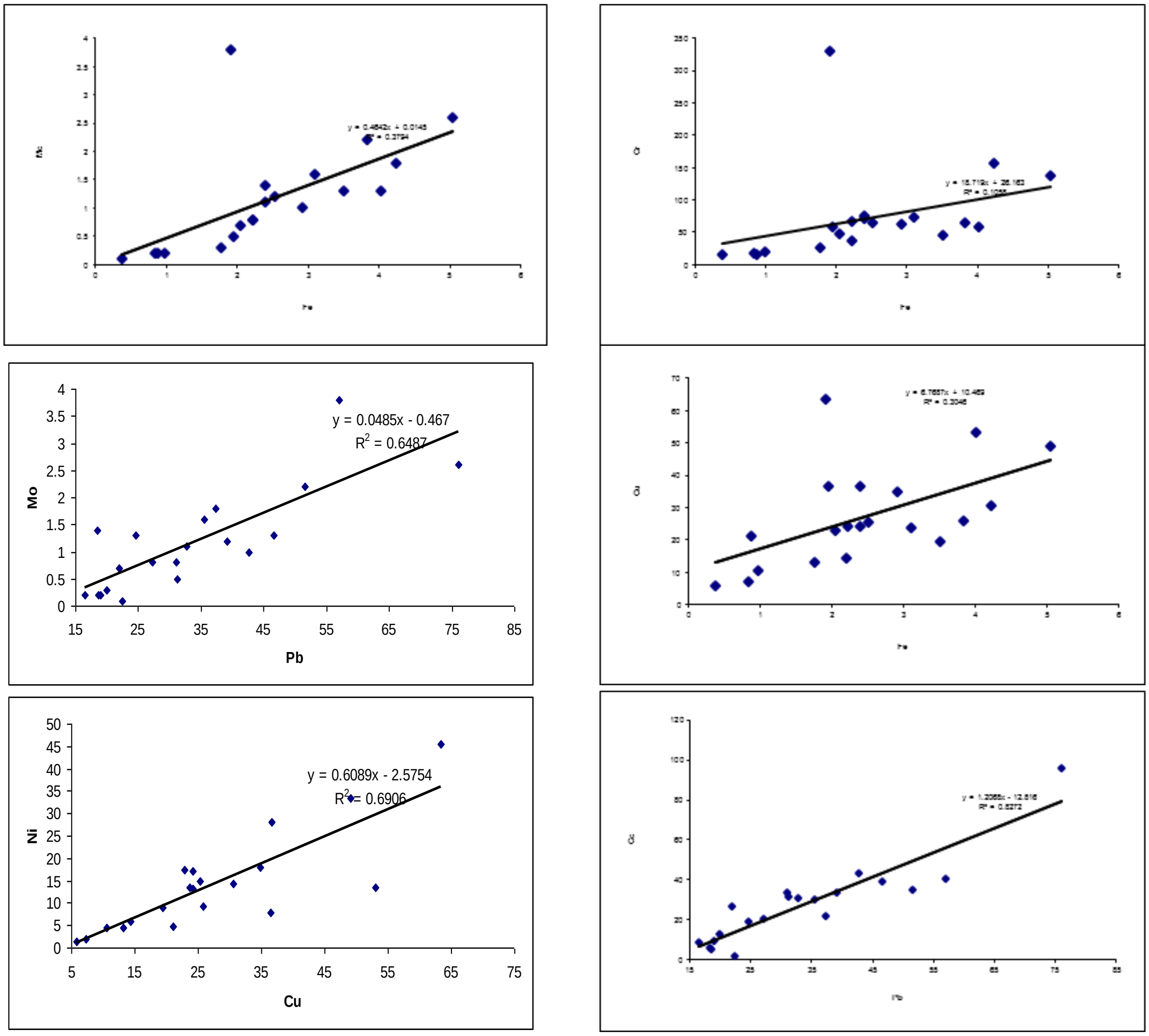

Figure 3. Scatter plots of selected elements in the study area.

a graphical representation of elemental association of Cu-Pb, Ni-Cu, Cu-Fe, Mo-Pb, Cr-Fe and Mn-Fe. Element association of Cu-Pb displays strong positive correlation while Cu-Fe is not correlated. Associations of Mn-Fe, Cr-Fe, Mo-Pb and Ni-Cu exhibit weak positive correlation.

Conclusion

This study has been able to show that geology plays a vital role in the nature and composition of stream sediment samples. Information on the regional variation in the average metal content of elements like Mo, Cu, Zn, Pb, Ni, Cr, Mn, Fe, As, Au and Co in the study area is also provided by this investigation. Mean metal content obtained is too low for mineralization to occur.

Application of various statistical techniques has also been able to show that the concentration of the elements is not indicative of mineralization. It is however, observed that the average metal content obtained for these elements are due to lithological composition of the underlying bedrock.

Conflict of Interest

The authors have not declared any conflict of interest.

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