GEOCHEMICAL STUDY OF GOLD ENRICHMENT IN STREAM SEDIMENTS IN BUTU PAIKO, NORTH-WESTERN NIGERIA

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Abstract: *Stream sediments are widely employed in reconnaissance exploration for gold especially in areas where outcrops are scarce and the overburden thick. Geochemical study of gold enrichment in 15 stream sediments samples in Butu, North Western- Nigeria were carried out. The result of the field geological mapping revealed four lithologic units namely: granite-gneiss, schist, granite and pegmatite, which occurred as intrusion into the older lithology. Trace elements analysis in the stream sediments revealed that, Arsenic (As), Colbalt (Co), Copper (Cu), Nickel (Ni), Lead (Pb), Strontium (Sr) and Zinc (Zn) are depleted and while Gold is considerable enriched in the stream sediments. Thus, Stream sediments geochemistry has been shown to be a suitable exploration technique for gold within the Butu area.*

Keywords: Geochemistry, Stream Sediments, Gold, Enrichment, Butu

1. Introduction

Stream sediments are widely employed in reconnaissance exploration for gold especially in areas where outcrops are scarce and the overburden thick (Mumbfu *et al.*, 2014).
Stream sediment geochemistry and heavy mineral surveys are routinely used in the early stages of gold (Au) exploration. However, it is well known that results from such surveys are often extremely erratic and difficult to reproduce or confirm. Such problems are typical of geochemical patterns for elements that are principally transported in stream sediments as the constituents of rare grains of heavy minerals (Flecther and Muda, 2005). The mobility and redistribution of elements in the secondary environment has been widely used as a tool for exploration especially in areas where weathering is intense and outcrops are rare (Flechter and Muda, 2003).

Stream sediments plays an important role in geochemical exploration for possible sources of gold enrichment and its associated elements especially in areas where rock exposures are rare and primary mineralization is indefinable.

Geochemical data signatures from stream sediments can differentiate rock types. The Butu area is located between Longitudes 006° 30′ 30″E and 006° 33′ 30″E and Latitudes 009° 23′ 30″N and 009° 26′ 00″N, part of North-western portion of the Nigerian Basement Complex as shown in Figure 1 and covers an area of about 25.30km^2. Artisanal mining of gold is prevalent within the study area. The women are actively involved in the mining of stream sediments and alluvial deposits while the men are actively involved in the mining of eluvial deposits.

It is part of Precambrian basement complex rocks of Nigeria, which is categorized into ancient migmatite-gneiss-quartzite complex, the schist belts and Pan African (600mya) granitic series commonly called the older granite suite. These main groups of rocks are composed of rocks of different mineralogical, chemical and textural compositions (Ajibade 1988). The most pervasive tectonic fabric of igneous reactivation of this suite is attributed to the Pan African orogenic event.

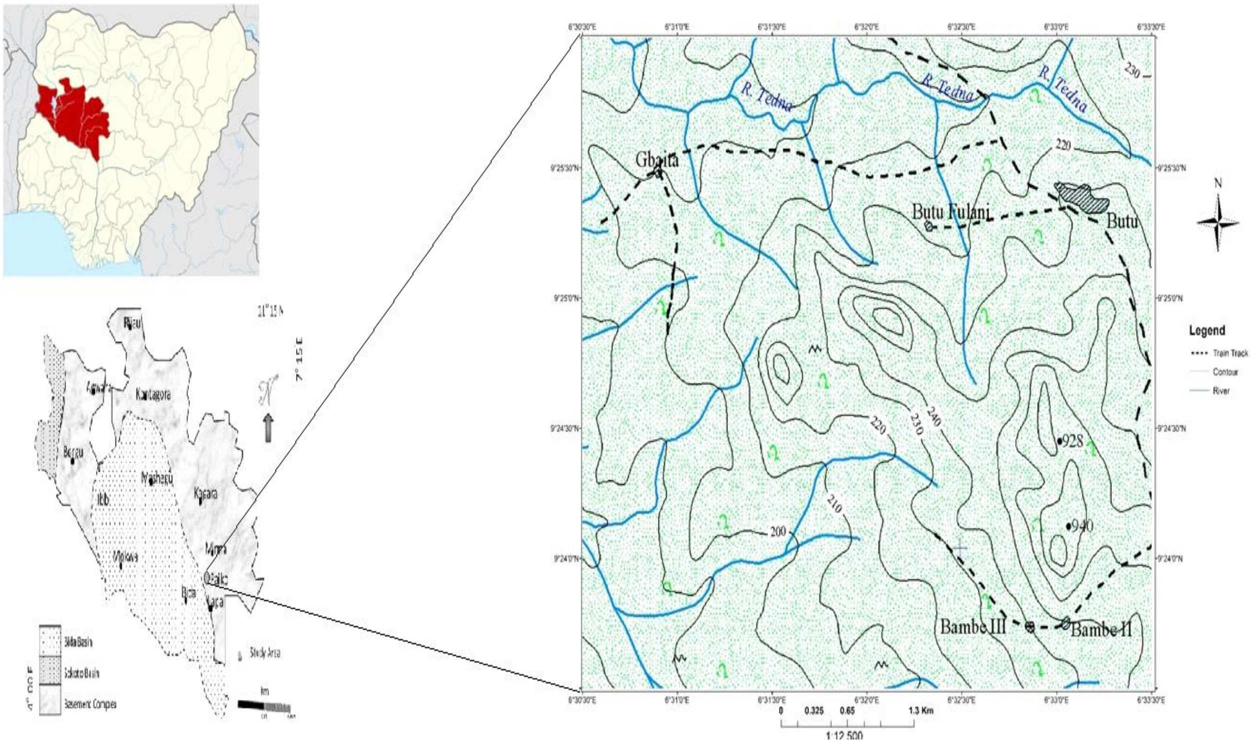

Figure 1: Location Map of the Study Area

The study area lies within the Tsohon Birnin Gwari and Kwaga gold sites are within the Kushaka schist belt of northwestern Nigeria. While the Tsohon Birnin Gwari was an active gold mine in the 1930s where over 600 ounces of gold were produced, the Kwaga site is a recent discovery by artisanal miners following the extensions of the Tsohon Birnin Gwari mine. The Tsohon Birnin Gwari gold reef system is about 7 km long, while the Kwaga reef system extends for about 3 km. Gold is mainly associated with pyrite and minor sphalerite, chalcopyrite, pyrrhotite, galena and magnetite. The gangue is predominantly quartz, but K-feldspar and graphitic matter (from wall rocks) are also constituents. Grades are very variable within the reef system and between oxide and sulphide ore zones, but generally 5-100 g/t Au are found. Recent core drilling and near-surface mine exposures have provided relatively fresh samples of the gold-quartz reefs and their altered wall rocks from which the geochemical characteristics of the Tsohon Birnin Gwari mineralization were studied.

The study area is characterized by two major seasons; A dry season which lasts for about six to seven months from November to April with very low humidity accompanied by the North-East trade winds which is usually the harmattan periods. Maximum temperature conditions between 30°C and 36°C are recorded between December and Mid-January (Elias *et. al,* 2017).

There is also the rainy season which lasts for about five to six months usually begins from April to November. This is usually characterized by a high humidity and excessive heat. The average annual rainfall is between 150 - 250mm and usually peaks between July and September. This is usually brought about by the south-East trade winds which are moisture laden. The vegetation in this area is typically that of the guinea savanah which is characterized by shrubs and very tall grasses with scattered trees of different species such as mango, cashes mahana, and sheabutter which are of economic importance. The grasses include elephant grass, goat weed, Northern gamba etc. The major agricultural activities in the areas are subsistence farming and cattle rearing by the nomadic Fulanis. Farming which is at a subsistence level include crops like yam, rice, guinea corn, millet, cowpea, and groundnuts (Elias *et. al*, 2017).

The area generally has a gentle topography with occasional hills. However, the eastern portion of the area has a rugged topography with ridges running from the north to southern portion. They stand up to 1500 ft about the surrounding country. The study area is drained mainly by River Tedina with smaller stream channels running east west of the area, the rivers are mostly seasonal. The study area is usually swampy during the rainy season and dry during the dry season (Elias *et. al*, 2017).

2. Literature Review

Gold mineralization potential has been studied by various workers in the adjacent areas of such as Minna, Paiko, Kafin-Karo and Kwakuti its extension has not been studied in the Butu area, particularly in stream sediment.

Obaje, 2015 studied geochemical assessment for gold in sediments of Gora River in Minna Area (Part of Minna Sheet 164 SW) North-central Nigeria concluded that 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.

Ogunbajo *et al.,* 2012, studied geochemical characteristics of gold mineralization in rocks of Beni/Kafin-koro Area (Part of Sheet 165, Bishini SW) concluded that the petrological and geochemical data indicate mineralization of gold with an anomaly around Beni and that economically gold and some other rare earth elements and transitional metals can be won at a profit in the project area.

This research work seeks to unravel the extent of gold mineralization potential in stream sediment Butu area and its environs.

3. Materials and Methods

3.1. Desk Study

This phase involved overlaying of the study area outline on obtainable data, purchase as well as interpretation of obtainable regional geological map of the area produced by Nigeria Geological Survey Agency (NGSA). The following were done at this stage of the research work: Review of literature on the study area was done throughout the research.

3.2 Geological Mapping

A prospect geological mapping on a scale of 1:12,500 of the study area was carried out to note the different rock types in the area and their field relationship. The mapping was carried out by traversing the whole area and description of all discernible geological features of encountered outcrops on site. A total of 15 stream sediments samples were collected within the study area.

3.3 Laboratory Analysis

Fifteen (15) stream sediments samples were selected and sent to University Central Laboratory of Umaru Musa Yar'adua University, Kastina to be analysed using XRF for the major and trace elements concentration utilizing EDX 3600B Energy Dispersive X-ray Fluorescence Spectrometer.

4. Results and Discussion

4.1 Fieldwork

The geological mapping exercise revealed four (4) major lithologic units namely: Granite Gneiss, Schist, Medium Grained Granite and Pegmatite (Figure 2).

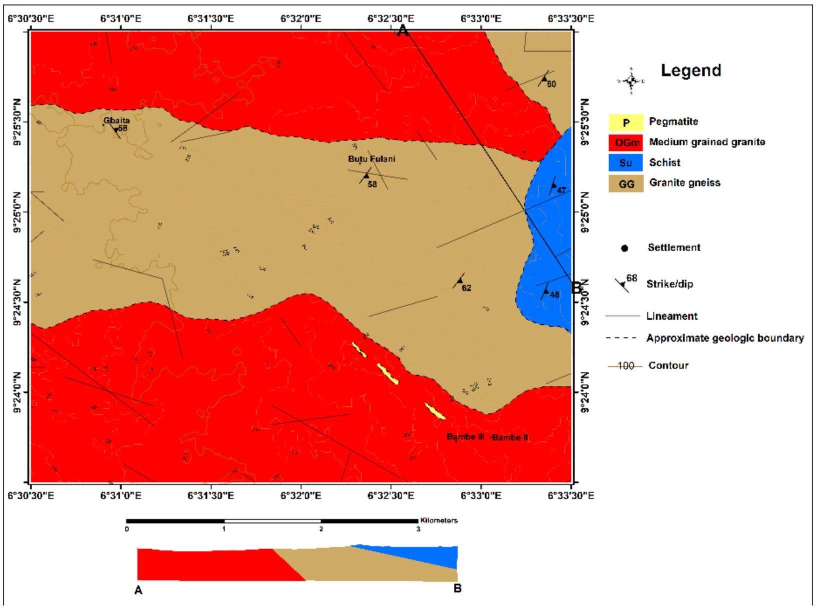

Figure 2: Geological Map of the Study Area showing the cross section different Rock types

4.1.1 Granites Gneiss

The granite gneiss occurs at the central and northwestern parts of the study area and were easily accessible. The rock is the most prominent rock type within the study area covering over fifty percent (50%) of the study area. These rocks are highly distinct in the field, outcropping as usually high, well-rounded and highly proficient outcrops.

In hand specimen, the rocks show the presence of quartz, muscovite, plagioclaise and biotite. The rocks are marked by structures such as foliations and lineations. These structures define the arrangements of the minerals held within it's matrix.

The schist occurs at the eastern part of the study area (Figure 2). A few weathered outcrops were observed.
The schist within the study area makes up about ten percent (10%) of the rock types within the study area. The schist is associated with the gold mineralization in the study area. These gold mineralization are present in the quartz veins in the area.

4.1.2 Granite

The granitic rocks within the study area belongs to the Older Granite Suite. The granites makes up over forty percent (40%) of the total tock types in the area (Figure 2). They are medium grained having a light grey colouration and marked by structures such as quartz veins and joints.
They occur as low lying flat outcrops, often exposed along the river channels. They were also observed to intrude host rocks such as quartz and schist at the eastern part of the study area.
In hand specimen the presence of minerals such as quartz, biotite, microcline, plagioclase and hornblend were observed.
The rocks are jointed with some of the joints been in filled with quartz veins. In most cases, the veins were seen to be extensive ranging from about two (2) millimeters to ten (10) centimeters as joint sets in the area where they occur. Some of the joints are cross-cutting the rocks vertically while others are horizontally, and are of different generations.

4.1.3 Schist

The schist occurs at the eastern part of the study area (Figure 2). A few weathered outcrops were observed.
The schist within the study area makes up about ten percent (10%) of the rock types within the study area. The schist is associated with the gold mineralization in the study area. These gold mineralizations are present in the quartz veins in the area.

4.1.4 Pegmatites

Pegmatites occurring as an intrusion of the granite within the study area is seen at a few meters to the North of Bambe III. The rock has lost most of it's mineral constituent due to weathering leaving behind the minerals with a higher resistance to weathering exposed. The rock trends in the Northwest - Southeast direction.

4.2 Laboratory Results

4.2.1 Trace Elements in Stream Sediments

The result of trace elements analyzes of the stream sediments and the computed mean concentrations is as shown in (Table 1 and Figure 3).

Table 1: Concentration of Trace Elements in Stream Sediments in Parts Per Million (PPM)

	Au	As	Co	Cu	Ni	Pb	Rb	Sr	Zn
STRS 1	0.39	1.40	4.50	3.00	5.00	20.00	3.60	7.50	6.00
STRS 2	0.47	2.00	6.50	12.00	8.00	10.00	7.40	13.80	14.00
STRS 3	0.26	2.00	5.50	8.50	6.00	3.00	8.00	19.50	12.00
STRS 4	0.62	3.80	7.10	14.50	9.00	5.00	3.80	35.30	20.00
STRS 5	0.60	1.00	0.50	2.50	1.00	12.00	6.80	6.90	4.00
STRS 6	0.40	-0.10	1.00	3.50	-3.00	6.00	3.00	6.00	1.00
STRS 7	0.49	2.00	11.30	5.00	5.00	49.00	8.40	6.90	7.00
STRS 8	0.75	3.20	19.30	9.00	10.00	13.00	4.40	19.10	15.00
STRS 9	0.91	4.20	13.50	14.00	7.00	9.00	4.60	7.20	16.00
STRS 10	0.62	1.00	4.90	5.50	2.00	4.00	9.60	6.70	10.00
STRS 11	0.64	1.40	5.30	1.50	-1.00	25.00	6.60	8.20	2.00
STRS 12	0.51	0.20	-0.70	0.50	-3.00	7.00	7.80	8.40	5.00
STRS 13	0.41	1.40	1.30	2.00	1.00	18.00	6.00	3.00	3.00
STRS 14	0.38	0.60	4.90	11.50	4.00	11.00	10.20	19.80	13.00
STRS 15	0.69	3.00	13.90	13.50	13.00	8.00	9.20	26.60	17.00
MEAN	**0.54**	**1.81**	**6.59**	**7.10**	**4.27**	**13.33**	**6.63**	**12.99**	**9.67**
MIN	**0.26**	**-0.10**	**-0.70**	**0.50**	**-3.00**	**3.00**	**3.00**	**3.00**	**1.00**
MAX	**0.91**	**4.20**	**19.30**	**14.50**	**13.00**	**49.00**	**10.20**	**35.30**	**20.00**

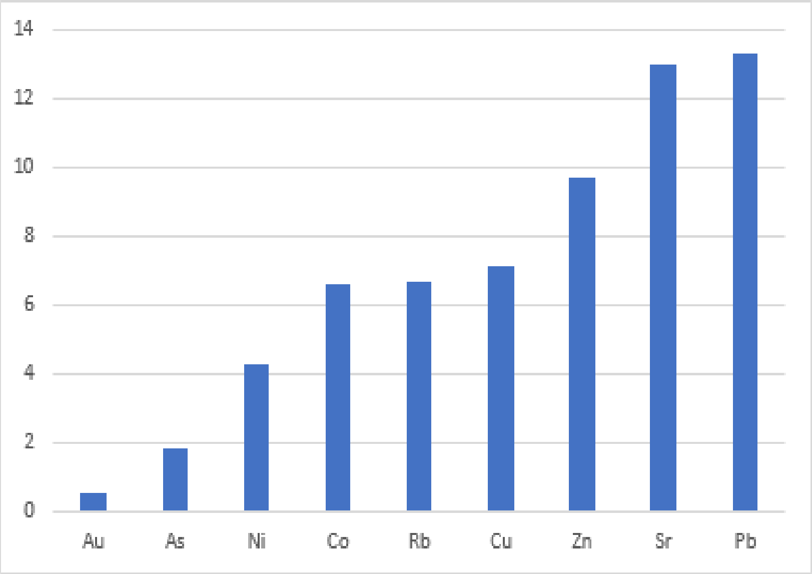

Figure 3: Mean Concentrations of Trace Elements in Stream Sediments in Parts Per Million (PPM)

The result of the analysis shows the mean concentrations of the trace elements in decreasing order as Pb > Sr > Zn > Cu > Rb > Co > Ni > As > Au.

Table 2: Correlation Matrix of (Au) with Major Oxides from the Stream Sediments

	Fe_2O_3	**SiO_2**	**Al_2O_3**	**MgO**	**P_2O_5**	**TiO_2**	**K_2O**	**CaO**	**Na_2O**	**MnO**	**Au**
Fe_2O_3	1										
SiO_2	-0.32188	1									
Al_2O_3	0.086473	-0.51229	1								
MgO	0.012794	-0.2895	0.623874	1							
P_2O_5	-0.24308	0.606029	-0.58959	-0.53729	1						
TiO_2	-0.06642	-0.67135	0.634611	0.279176	-0.65396	1					
K_2O	0.282736	-0.05388	0.2991	-0.02628	0.089271	-0.10465	1				
CaO	-0.05987	-0.59737	0.518779	0.351518	-0.29225	0.50213	-0.066	1			
Na_2O	0.112076	-0.23104	0.579931	0.310656	-0.137	0.222349	0.493743	0.598738	1		
MnO	0.046585	0.268581	-0.38646	-0.24591	0.168668	-0.42567	-0.01443	-0.00562	-0.01862	1	
Au	-0.02065	**0.288254**	**0.128294**	**0.120601**	**0.15262**	-0.1241	**0.65067**	-0.11999	**0.243908**	-0.08116	1

Statistical analyses using Pearson Correlation Coefficient were carried out to show the degree and strength of association of the other trace elements with gold (Au) so as to determine their geochemical relationships or affinities within the study area the relationships between elements may be coherent (compatibility and in-compatibility respectively).

When elements are coherent, the changes in their concentrations value are sympathetic i.e. increase in the concentration of one element results in the increase in the concentration of the other element or vice-versa ((Misech, 1969).

4.2.2 Major Oxides in Stream Sediments

The result of major oxides analyzes of the stream sediments and the computed mean concentrations is as shown in (Table 3 and Figure 4).

Table 3: Concentration of Major Oxide in Stream Sediments in Percentage (%)

	Fe_2O_3	SiO_2	Al_2O_3	MgO	P_2O_5	TiO_2	K_2O	CaO	Na_2O	MnO
STRS 1	4.84	72.88	9.18	3.4	0.16	0.43	1.37	1.15	1.01	0.30
STRS 2	4.57	71.81	9.51	2.78	0.23	0.61	1.67	1.53	1.86	0.05
STRS 3	4.48	74.40	8.512	2.25	0.27	0.24	1.62	1.01	1.39	0.07
STRS 4	4.42	70.83	9.3	2.08	0.24	0.53	1.90	1.15	1.51	0.22
STRS 5	3.93	77.02	4.93	1.15	0.35	0.12	1.59	1.07	1.23	0.50
STRS 6	4.92	74.94	5.87	2.11	0.29	0.12	1.60	1.14	1.07	0.38
STRS 7	3.95	69.46	10.28	2.18	0.21	0.69	1.51	1.65	1.27	0.27
STRS 8	4.27	76.03	7.42	1.7	0.22	0.25	1.68	0.71	1.07	0.41
STRS 9	7.92	70.85	8.76	1.84	0.22	0.37	1.81	1.06	1.59	0.31
STRS 10	4.86	71.74	10.26	2.76	0.24	0.32	1.72	1.83	2.91	0.44
STRS 11	4.81	72.95	8.37	2.71	0.21	0.39	1.85	1.11	1.95	0.41
STRS 12	4.93	73.92	11.50	2.61	0.19	0.48	1.87	1.50	2.28	0.35
STRS 13	4.75	71.23	8.09	1.78	0.18	0.56	1.57	1.43	1.93	0.21
STRS 14	4.30	75.65	9.70	2.19	0.26	0.577	1.62	1.03	1.93	0.20
STRS 15	4.63	74.37	9.94	2.56	0.27	0.21	1.92	1.00	1.94	0.156
MEAN	**4.77**	**73.21**	**8.78**	**2.27**	**0.24**	**0.39**	**1.69**	**1.23**	**1.66**	**0.29**
MIN	**3.93**	**69.46**	**4.93**	**1.15**	**0.16**	**0.12**	**1.37**	**0.71**	**1.01**	**0.05**
MAX	**7.92**	**77.02**	**11.5**	**3.4**	**0.35**	**0.69**	**1.92**	**1.83**	**2.91**	**0.5**

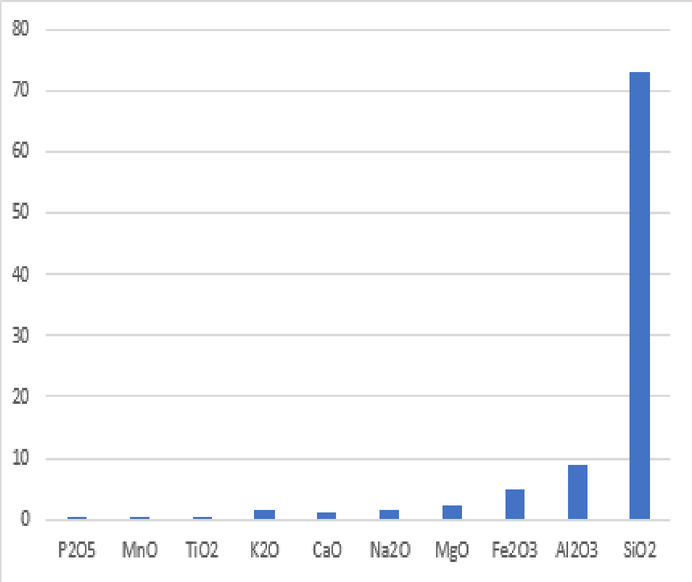

Figure 4: Mean Concentrations of Major Oxides in Stream Sediment in Percentage (%)

The result of the analysis shows the mean concentrations of the major oxides in decreasing order as SiO_2>Al_2O_3> Fe_2O_3>MgO > Na_2O >CaO>K_2O>TiO_2>MnO>P_2O_5. When elements are coherent, the changes in their concentrations value are sympathetic i.e. increase in their concentration of one element results in the increase in the concentration of the other element or vice-versa (Misech, 1969).

4.2.3 Mineral Enrichment

Five categories of enrichment factors was used for evaluating the economic potential in the study and a subsequent increase in enrichment factors values implies a better economic prospect (Sutherland, 2000) as follows:

- EF < 2 is deficiency to minimal enrichment.
- EF 2-5 is moderate enrichment
- EF 5-20 is significant enrichment
- EF 20-40 is very high enrichment
- EF > 40 is extremely high enrichment.

Table 4 shows gold and other mineralisation potentials in the stream sediments and soils respectively.

Table 4: Gold and other Mineralization Potentials in the Study Area's Stream Sediments in Parts Per Million (PPM)

Elements	Average Analysed Value	Background Concentration (ppm)	Computed Enrichment Factors (%)	Enrichment Status
Au	0.54	0.004	135	Significantly Enriched
Pb	13.33	14	0.95	Depleted
Sr	12.99	370	0.04	Depleted
Zn	9.67	70	0.14	Depleted
Cu	7.10	60	0.12	Depleted
Rb	6.63	90	0.07	Depleted
Co	6.59	25	0.26	Depleted
Ni	4.27	84	0.05	Depleted

As	1.81	1.8	1.01	Depleted

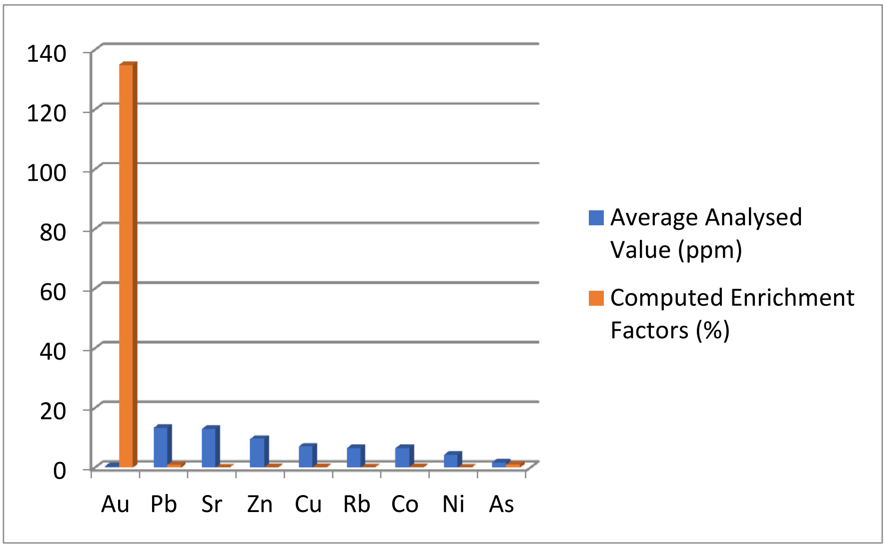

Figure 5: Gold and other Mineralization Potentials in the Study Area's Stream Sediments in Parts Per

5. Conclusion

Geologic mapping revealed four lithologic units namely. Granites, granites gneiss, schist and pegmatite. The rocks of the study area to be fine to medium grained.

The laboratory analysis revealed that, Trace elements Arsenic (As), Cobalt (Co), Copper (Cu), Nickel (Ni), Lead (Pb), Strontium (Sr) and Zinc (Zn) are depleted and hence considered not mineralized within the study area.

However, Gold is considerably enriched in the stream sediments with the result of the analyses showing that gold has a computed enrichment factor of 135 from the stream sediments within the Butu study area. Thus, Stream sediments geochemistry has been shown to be a suitable exploration technique for gold within the Butu area.

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