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Geochemical Investigation for Gold Potential in Soil and Stream Sediment of Wadji and Its Environs Part of Wamba Sheet 210nw, North-Central, Nigeria

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ABSTRACT

The geological field mapping of Wadji and its environs part of Wamba sheet 210NW located between latitude $N08^{\circ}50'00''$ - $08^{\circ}55'00''N$ and longitude $E08^{\circ}30'00''$ - $08^{\circ}35'00''$ was carried out to delineate geology and geochemistry of stream sediments of the area. This investigation was carried out in order to identify the rock units with their mineralogical contents and to determine the concentration and distribution of major and trace elements in stream sediments with a view to establish the potential mineralization of Gold in the study area. On the basis of textural and mineralogical features four (4) different rock types were identified; Banded gneiss, schist, Biotite granite and fine-grained granite. Mapping also revealed the presence of joints, quartz veins, pegmatite veins, folds, foliation and exfoliation as the structural elements which mostly trend in the NE-SW, NW-SE directions. These structures attest to poly-deformational episode in a brittle-ductile environment. The correlation coefficient and factor analysis further more revealed that strong positive correlation of greater than 0.5 loading exist among Zn vs As, As vs Au, Sr vs Pb, Y vs Zr and Au vs Pb among others. These possibly suggest originating from similar source.

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Introduction

The study area Wadji is part of Wamba sheet 210 NW Nasarawa state, North central Nigeria. It falls within the Basement Complex rocks of Nigeria. This area which is part of the Basement Complex of North Central Nigeria forms part of the Pan African Mobile belt which lies between the West African Craton and the Trans Saharan Craton south of the active margin of the Tuareg Shield. The area was mapped systematically on a scale of 1:12,500 and covers an area extent of approximately 10 km².

The Basement Complex of North Central Nigeria which is Precambrian in age is made up of the Migmatite-Gneiss. Several mineral exploration researches in the past had been carried out by different authors on the Basement Complex of Nigeria using different methods to understand the geology of the area and their mineral potentials (Olade et al., 1979; Garba, 1985; Yahaya and Tanko, 2020; Tanko and Ridwan, 2021). But it appears that most of these works were carried out on a regional scale; this implies that some features within the area have not been captured in detail. This research work is aimed at carrying out a detailed geological and geochemical investigation to establish gold mineralization potential and other economic resources of the study area.

Complex, the Schist Belts and the Older Granites is known to host several mineral deposits of primary origin. These mineral deposits over the years had been reworked through various surficial geologic processes such as weathering to form the surrounding soil and stream sediments that accumulate different kinds of mineral deposits regarded as secondary in origin.

Stream sediments remain the dominant sampling media in regional geochemical exploration. The distribution of metals in sediments depend on the sorption capacity of these elements in various systems which represent a composite sample of detrital material derived from the drainage basin (Rose, 1979).

Location, Extent and Accessibility

The area studied is part of Wamba (Sheet 210) in North Central Nigeria). It lies between latitude 08°50'00"N – 08°55'00"N and longitude 08°30'00"E – 08°35'00" (Fig 1.1). It has an area extent of approximately 10km². It is accessible by the old Jos-Akwanga Road and also innumerable minor roads and footpaths. The areas studied include part of Lakpa, Nbaba, Dange, Kweku, Kurizie, Wadji, Dechu areas. A minor road trending North North East connects Oge, Oboja, Dechu, Kurizie, Wadji. Other villages are connected by footpaths.

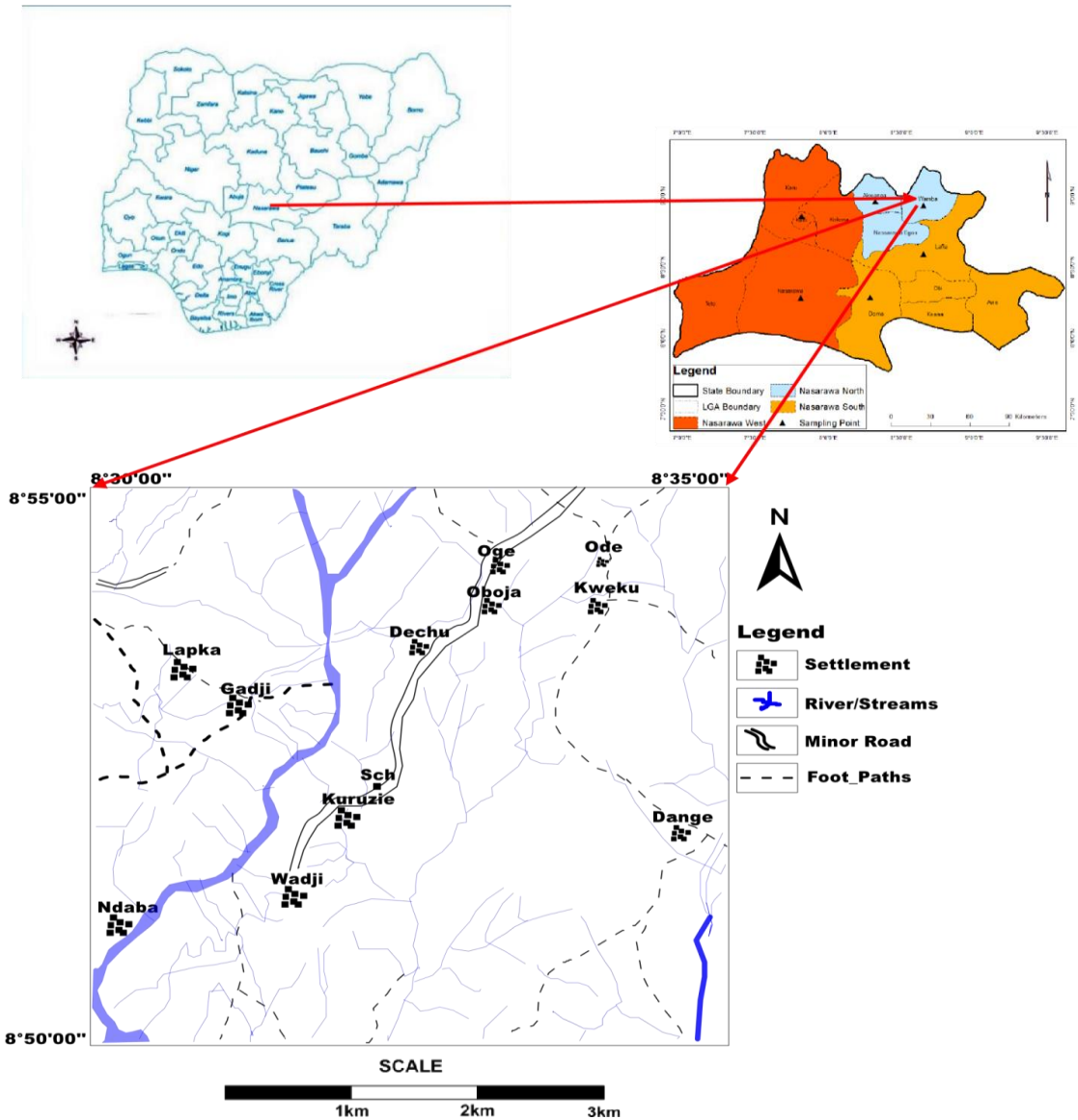


Figure 1.1: Map Showing Location, extent and Accessibility

Figure 1.1 above shows the extract of the study area from the map of Nigeria. Wamba sheet 210NW was extracted

from the map of Nasarawa State, from which the map of the study area was extracted.

Summary of the Geology of Nigeria

Geologically, Nigeria is located within the mobile belt of Africa between the West African Craton and the Congo Craton (Oyawoye, 1964) (Figure 2.2). Nigeria is situated in the West African sub-region and lies between Longitude 30 and 140E and latitude 40 and 140N. The Nigerian geology comprises of three main petrological components; the Basement Complex, the Younger Granite and the Sedimentary Basins. The Basement Complex is intruded by Younger Granites and is unconformably overlain by the Cretaceous and Tertiary sediments. The Basement Complex which is Precambrian

in age is made up of the Migmatite-Gneiss Complex, the Schist Belts and the Older Granites. The Younger Granite comprises the Jurassic magmatic ring complexes centered on Jos and other part of north central Nigeria. The Sedimentary Basins contains sediments of Cretaceous to Tertiary ages and comprises the Niger Delta Basin, Anambra Basin, Benue Trough, Borno Basin, Sokoto Basin, MidNiger Basin and the Dahomey Basin. For the purpose of this research project, only the Basement Complex is discussed in detail. The Nigerian Basement complex rocks are subdivided into:

1. The Migmatite-Gneiss Complexes;
2. The Schist Belt (The Metasedimentary and Meta-Volcanic Rocks)
3. The older Granites;
- The Younger Granite Intruded the Basement

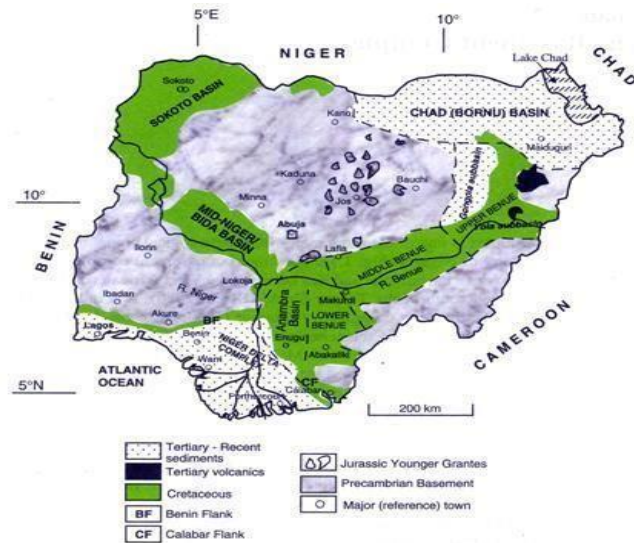


Figure 2.1: Outline map of the geology of Nigeria

3. Method and Materials

3.1 Desk Study

A preliminary search through records, maps and other literature relevant to the geology of the study area was conducted. The map of the region was acquired and thoroughly studied to be able to obtain an indication of the local geology and other significant geological characters of the ambience.

appearances, orientation, geological structures were studied and noted in the field notebook.

During the field work, representative rock samples were collected from all available rock exposures, while stream sediment samples were also collected along the stream at intervals of 200m in the area studied. In the field, each outcrop was observed and described based on its mode of occurrence, macroscopic characteristics, structural elements and field relation with adjacent outcrops. Hand specimens were described based on the following macroscopic features: color, texture, mineralogy and are

3.3 Equipment used

Global Positioning System (GPS), Field Note Book, Silver Compass Clinometers, Sample Bag, topographic/Base Map, Hammer, Camera, Hand lens, Measuring Tape and Ruler, masking tape and marker.

3.2 Field Mapping

The field study is the most important method of all. Every necessary detail in the field was studied to determine the geology of the area as well as various structural elements present and their deformational episode. Different places suitable for the geological study were selected and their location was determined by the map and the observation related to such structures such as physical

carefully labeled. Points plotted on the base map at the appropriate locations where the samples were collected with the use of a Global Positioning System (GPS) and the geographic coordinates of the base map. Careful observation of lithological boundaries was made by observing changes in rock exposures, nature of soil, vegetation and topography. A compass clinometer was used to measure strike and dip values and directions of outcrops using the contact method.

3.4 Sample Collection

This involves collection of rock samples from outcrops on the field which will be taken for further analysis in the laboratory.

A total of 28 samples were collected in a sample bag and well labeled. The coordinates and elevation of sampling location were recorded with the Global Positioning System (G.P.S) and noted in the field notebook. The

3.5 Geochemical Analysis

Geochemical investigation is a necessary tool in applied geochemistry. It is broadly divided into two; Geochemical prospecting and environmental geochemistry. Geochemical prospecting is the application of geochemistry to mineral exploration therefore it is the use of geochemical principles and data in the search for economic mineral deposits for example ores, petroleum and natural gas. While environmental geochemistry is the application of geochemical principles to survey and

3.6.1 Stream sediment geochemical survey method

This method is also known as drainage survey. Soluble products of weathering get incorporated into the sediment either by adsorption, absorption or precipitation when there are changes in the environment. Drainage sediments includes stream sediments, seepage sediments and active stream as well as flood or lake sediments. These samples are usually collected systematically along streams or river channels at an interval of 300 meters then a composite was done. In areas with no flowing streams, samples can be collected from Old River or abandoned river beds. Most stream sediments were collected along the major stream channel (River Buku).

3.6.2 Sample Preparation

After collection of samples from the field, the samples were subjected to treatment in laboratory and field to get them ready for analysis. The preparation is designed to avoid or check contamination of samples, most especially the removal of water. The samples were grounded, crushed or turned to pellet (chopping into pellets or fragments) for analysis.

3.6.3 Sample analysis

The samples were analysed using the X-ray fluorescence spectrometry. This involves the activation of X-ray beam to displace electron in the inner shell of an element, electron in the outer shell would fall into the vacancy left

observed samples were described and identified in order to identify their textural characteristics. Stream sediments were taken along the river for geochemical analysis.

Laboratory Work

In the laboratory, petrographic and geochemical analyses were carried out on selected representative rock and stream sediment samples.

monitor the distribution of elements, especially heavy metals in the environment, whose concentration levels (if anomalous) leads to contamination and poisoning that could affect the plants, animals and humans in that environment. The investigations were carried out systematically by the analysis of bedrocks, soil, surface and groundwater systems, stream sediments, vegetation and atmospheric gas for elements of economic interest, or elements commonly associated with ore bodies or elements.

by displaced electron causing emission of fluorescent x-rays of a wavelength characteristic of the activated element is emitted and the emission intensity is proportional to the element's concentration. The normal laboratory X-ray fluorescence unit uses an x-ray tube as the source of exciting radiation. Appropriate excitation of specimen can produce an electromagnetic radiation and the X-ray spectrum produced can provide the means of identifying an element by measuring its characteristic emission wavelength and determining its concentration by measuring the emission intensity.

4. Results and Interpretation

4.1 Geology of the study area

Based on field observations and further petrographic studies carried out, four (4) lithological units which include; banded gneiss, schist, biotite granite and fine-grained granite are identified. The schist and banded gneiss predominate the study area and are intruded by the granites. The study area is characterized by low-lying outcrops and some altitudinous thus, the topography is undulating.

The banded gneiss covers the north eastern to the southern parts of the area, with about 35% area coverage. The northern to the western parts of the area is dominated by schist covering about 40% of the area.

The Biotite granite is located in the eastern portion of the map and constitutes about 15%. The fine-grained granite

is located at the north western part of the map and occupies about 10% of the mapped area.

The major rock forming minerals such as quartz, biotite, muscovite, plagioclase, feldspars and microcline are the basic minerals observed in the field and as hand

specimen. Structural features observed on the field include joints/fractures, faults, veins and folds. The joints and the veins show predominant orientations in the NE-SW and SW-NE directions.

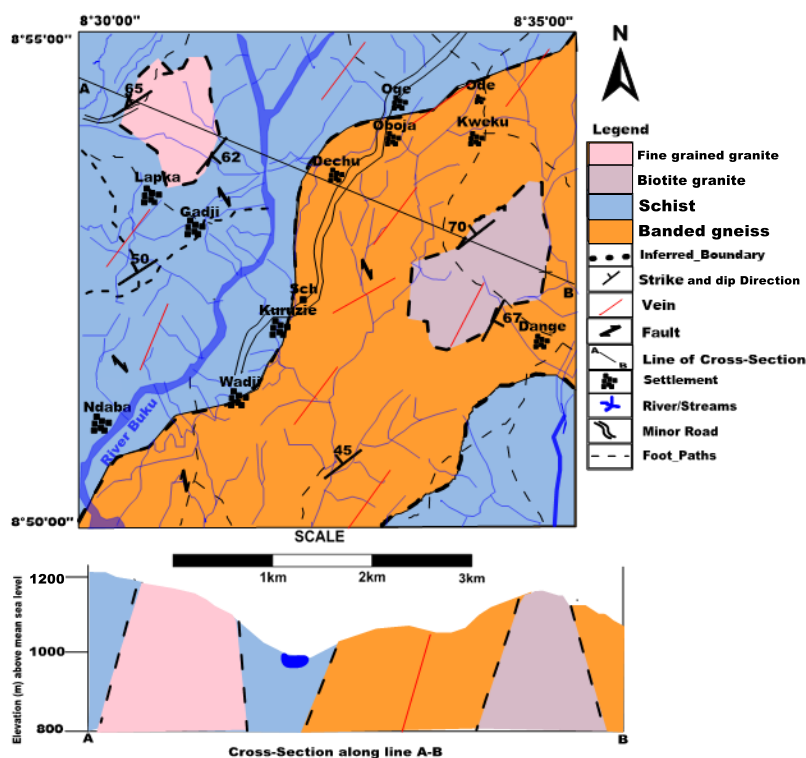


Figure 4.1: Geological map and cross-sectional area of wadji and its surroundings

The joints and fractures in the area are both closed and opened. The orientation of the joints and fracture are dominant in the NE-SW direction. These occur in virtually all the rock types and they exhibit ductility under high temperature and pressure conditions, deep burial and tectonic stresses. As shown in plate

2 below the rock has undergone ductile deformation and metamorphism.



Plate 4.11: Field photograph of (a) Joint (b) Fracture ($N8^{\circ}51'15''$, $E8^{\circ}31'30''$)



Plate 4.2: Field photograph of an open fold in the study area (N8°51'32", E8°32'15")

Quartz veins are the major vein occurrence in the study area. The quartz veins composed completely of quartz crystals. All the veins in the area are younger than the host rock. The rosette diagram of the quartz veins also indicates an orientation trending in a NE-SW direction.

Veins are prime importance of mineral deposits, because they are the source of mineralization either in or proximal to the veins. Examples include gold lodes, chalcopyrites as well as skarn mineralization. Plate 4.3 shows a vein in the study area.



Plate 4.3: Field photograph of vein in the study area (N 8°54'15", E8°30'40")

5 Geochemistry

A total of five (5) stream sediment samples were collected and analyzed for oxides and trace elements concentrations.

Table 5.1: Major elements (oxides) concentration (wt%)

S/N	Oxides	SS1	SS2	SS3	SS4	SS5
1	SiO2	60.4	66.3	57.0	60.2	70.8
2.	Na2O	1.97	2.53	2.74	2.30	2.30
3.	MgO	1.52	1.33	1.56	2.43	0.653
4.	Al2O3	16.3	16.0	15.8	18.4	13.5
5.	K2O	3.87	4.88	3.12	3.42	4.37
6.	CaO	2.21	1.55	2.35	2.31	0.925
7.	TiO2	4.59	1.35	6.59	3.00	1.98
8.	MnO	0.238	0.108	0.277	0.135	0.131

9.	Fe ₂ O ₃	7.20	5.34	8.71	7.14	4.78
10.	P ₂ O ₅	-	0.199	-	0.0799	0.0928
	L.O.I	1.702	0.413	1.853	0.5851	0.4682
	TOTAL	100	100	100	100	100

Table 5.2: Trace elements concentration in (ppm)

SN	ELEMENTS	SS1(ppm)	SS2(ppm)	SS3(ppm)	SS4(ppm)	SS5(ppm)
1	Cu	131	99	104	126	134
2	Zn	144	90	148	124	100
3	As	15	4	9	7	6
4	Sr	133	140	140	139	82
5	Y	71	22	107	40	28
6	Zr	4670	822	5140	2090	1810
7	Ag	6	5	7	6	8
8	Au	11	9	8	8.8	7
9	Pb	12	9	10	16	4

Table 5.3: Statistical description of major elements (wt %)

Sample Name	Range	Mean	Standard Deviation	Crustal Abundance
SiO ₂	57.0-70.8	62.94	24.46	27.71
Na ₂ O	1.97-2.74	2.368	8.782	23.00
MgO	0. 653-2.43	1.4986	0.323	2.33
Al ₂ O ₃	13.5-18.4	12.8	12.718	8.20
K ₂ O	3.12-4.88	3.932	0.403	2.10
CaO	0.925-2.35	1.869	0.307	4.10
TiO ₂	1.35-6.59	3.502	3.584	0.56
MnO	0.108-0.238	0.1778	0.00182	0.095
Fe ₂ O ₃	4.78-8.71	6.634	1.997	4.10
P ₂ O ₃	0.0799-0.199	1.029	0.493	2.6

Table 5.4: Statistical description of trace elements

Sample Name	Range	Mean (ppm)	Std. Deviation	Crustal abundance (ppm) Rose et al(1979)
Cu	99-134	118.8	208.56	50
Zn	9-148	121.2	399.12	75
As	4-15	8.2	14.16	1.5
Sr	82-140	126.8	508.56	370
Y	22-107	53.6	998.64	35
Zr	822-5140	2906.4	2862516	165
Ag	5-8	6.4	1.044	0.07
Au	7-11	8.76	1.131	0.004
Pb	4-16	10.2	76.8	13

Results from the geochemical analysis reveal varying concentrations of trace elements in the area. They include; Zinc, Copper, Arsenic, Zircon, Lead, Silver etc. Geochemical maps and bar charts have been used to show the concentration and distribution of some elements in the analyzed samples of the study area. Also

Lead (Pb)

Lead concentration ranges from 4ppm to 16.00ppm with the mean of 10.20ppm, and crustal abundance of 13.00ppm (Table 5.4). The Result reveals the concentration of Lead in all the samples. The

the relationship amongst various element concentrations were used to determine the gold's associated metals which may serve as indicators to gold deposits. However, only elements with relatively high concentrations, good relationship and prospect have been selected for discussion.

concentration of Sample 1 (12.00ppm), Sample 2 (9.00ppm), Sample 3 (10.00ppm), Sample 4 (16.00ppm). Sample 5 (4.00ppm). Figure 5.2 shows its concentration against its crustal abundance. From the geochemical map (Figure 5.1), the concentration of Pb shows relative trend of increase upstream.

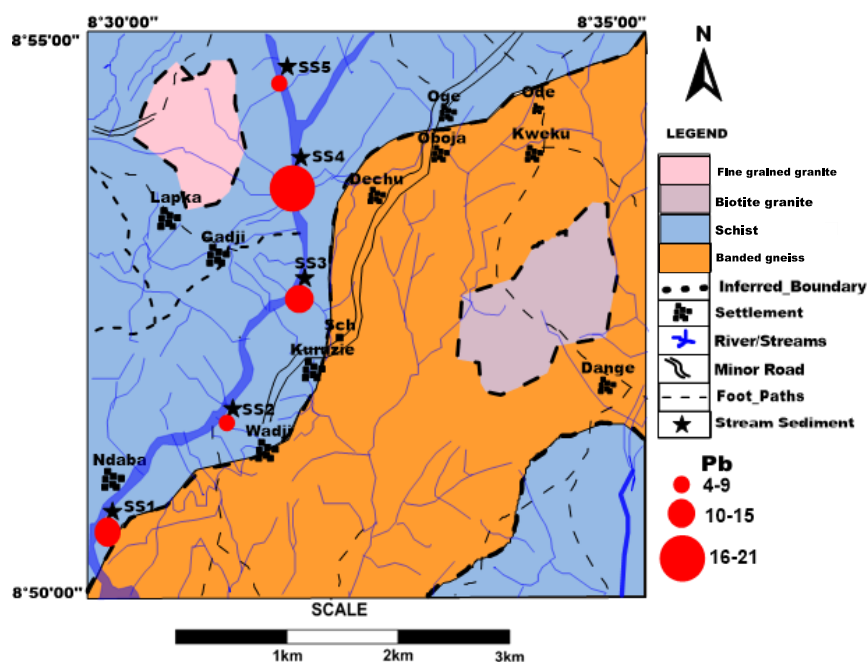


Figure 5.1: Geochemical map of Lead (Pb) in the study area

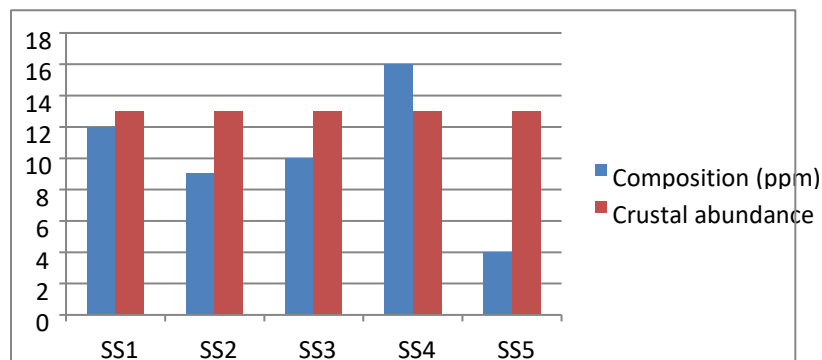


Figure 5.2: Barchart of Pb concentration and its crustal abundance in the study area

Zinc (Zn)

Zinc Concentration ranges from 90ppm to 148ppm with mean of 121.2ppm (Table 5.4). The result reveals the concentration of copper in all the samples

From the barchart (Figure 5.4), the concentration of Zinc in all samples is higher than its crustal abundance. While

in the geochemical map (Figure 5.3), the concentration is high towards the downstream section and considerable moderate up stream. This anomalous concentration may be due to intrusions into the surrounding banded gneiss and schist. VD

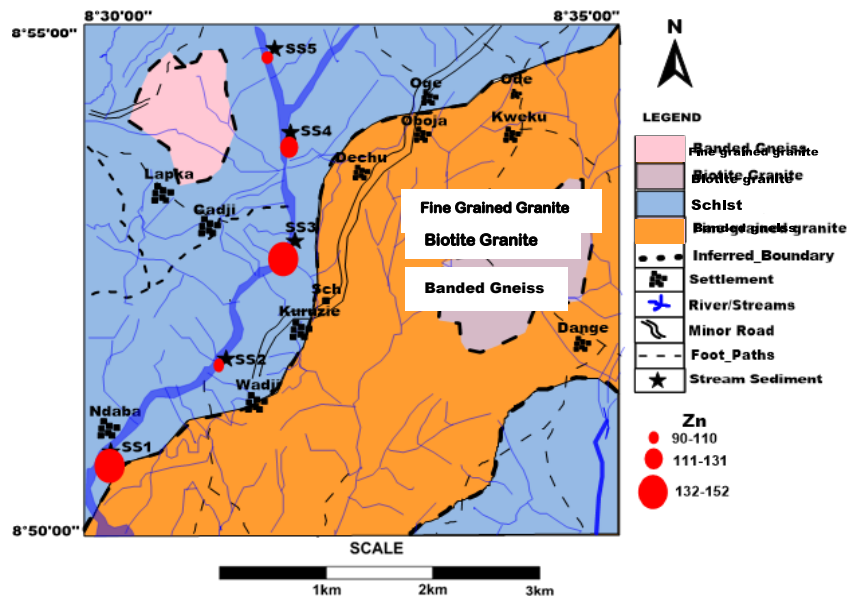


Figure 5.3: Geological map for the concentration of Zinc (Zn) in the study area

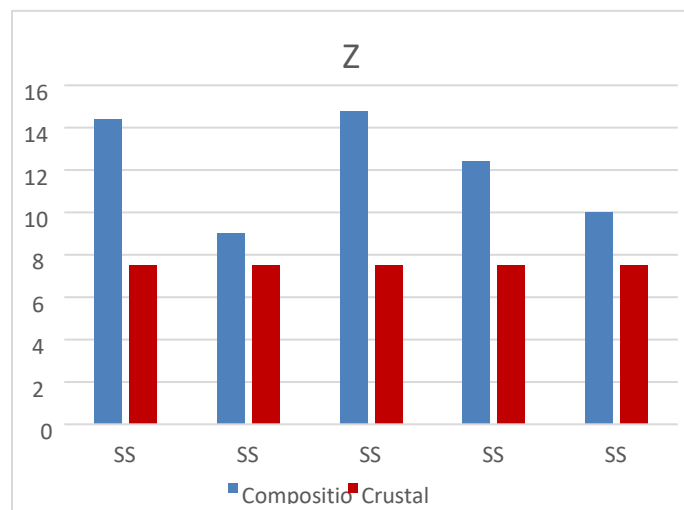


Figure 5.4: Barchart of Zinc (Zn) concentration in the study area

Arsenic (As)

Arsenic concentration ranges from 11.00ppm to 7.00ppm with mean value of 8. The concentration of arsenic in all samples which include: Sample 1(15ppm), sample 2(4ppm), sample 3(9ppm), sample 4(7ppm), sample 5(6ppm). Sample location 1 has the highest concentration

(15ppm). When compared with the crustal abundance of 1.5ppm, the concentration of As in the study area is high (Figure 5.6). From the geochemical map (Figure 5.5), it is observed to be considerably higher in the south western part of the study area at location close to banded gneiss.

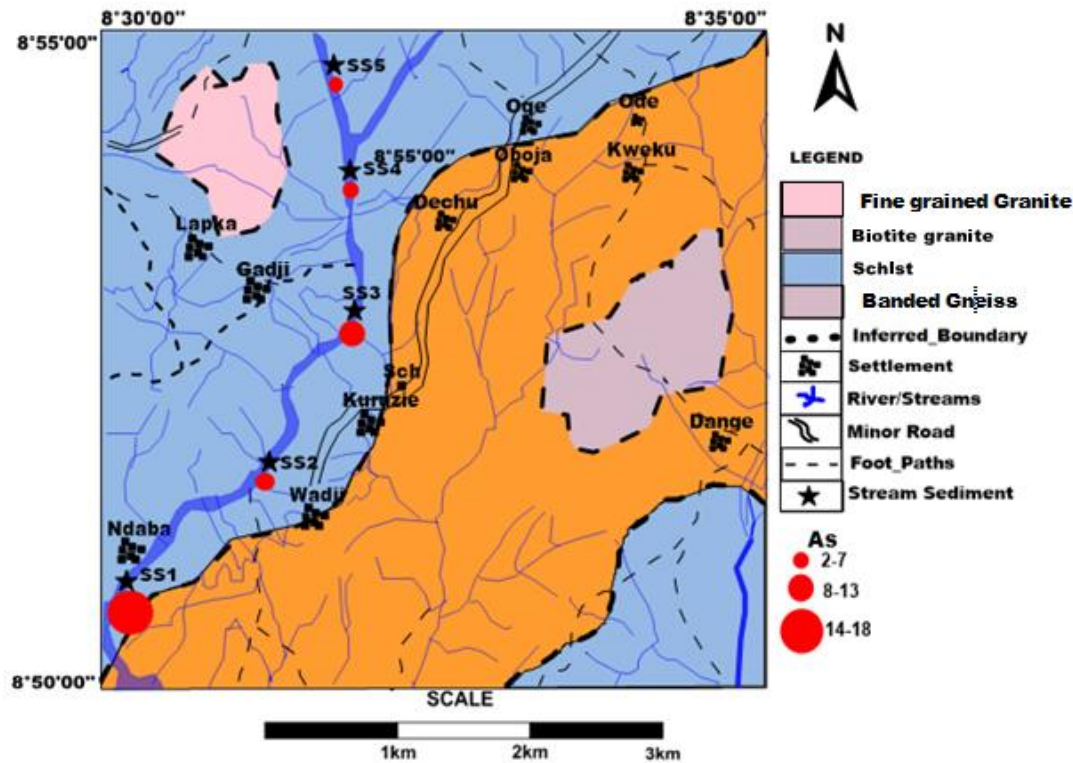


Figure 5.5: Geochemical map for the concentration of Arsenic (As) in the study area

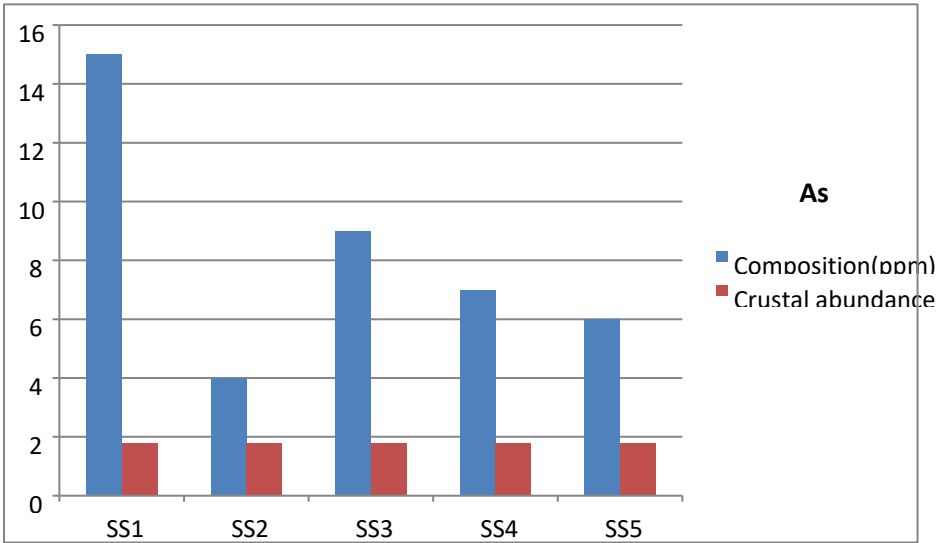


Figure 5.6: Barchart of Arsenic (As) concentration in the study area.

Gold (Au)

Gold concentration ranges from 11.00ppm to 7.00ppm with mean of 8.76ppm (Table 5.4). Gold is observed to be considerably higher in stream sediment on the SW part of the study area. Generally Gold concentration in the study area is higher than the crustal abundance. Figure 5.7 presents the geochemical map of gold (Au) concentration in river Buku. The result shows that sample 1 has the

highest concentration and the high value may be attributed to change in lithology probably as a result of a gold bearing underlain rock bed. This indicates that the primary source of gold mineralization in the area may be from schist up stream. As opined by the studies conducted by Garba (2003) in other parts of Schist belt in Nigeria e.g. Maru schist belt.

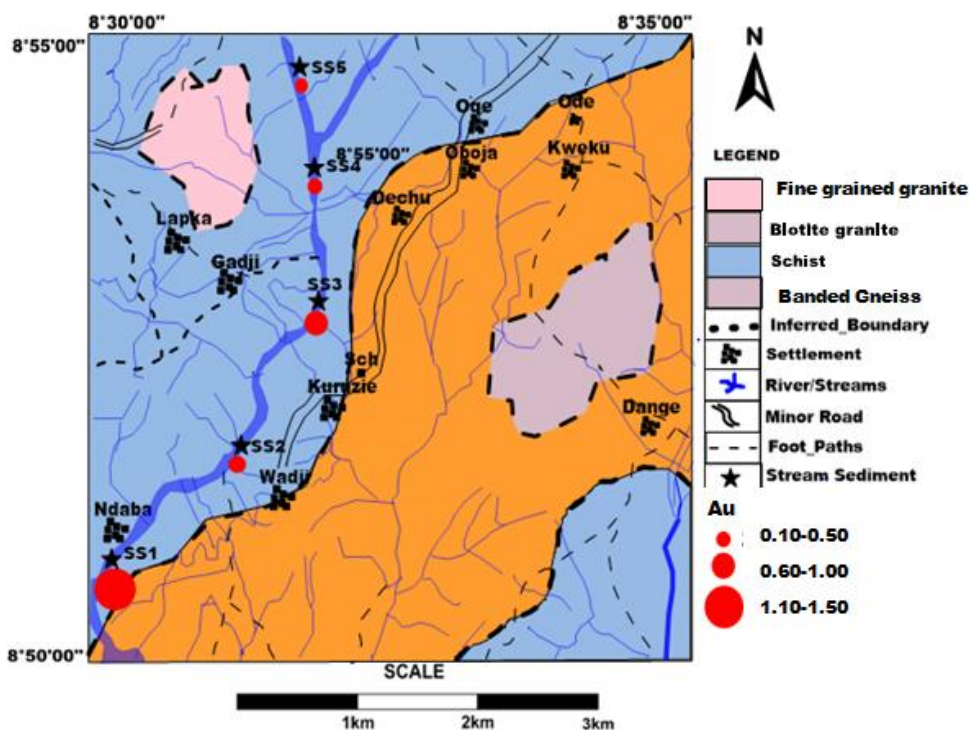


Figure 5.7: Geochemical map of gold (Au) concentration in River Buku

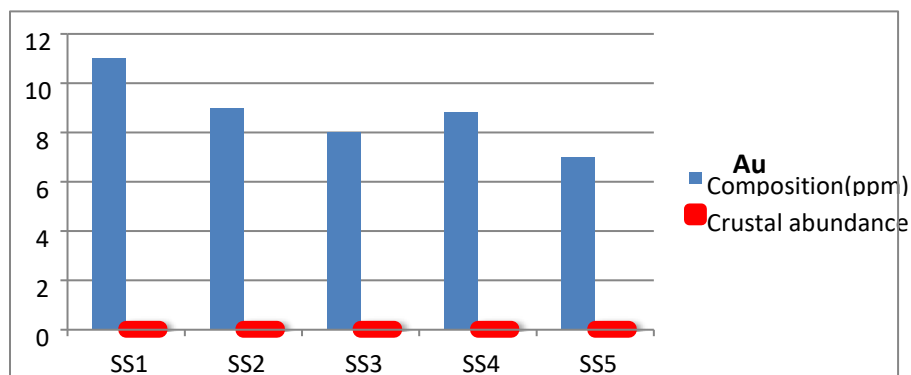


Figure 5.8: Bar chart of gold (Au) concentration and its crustal abundance in the study area

5.1 Correlation Coefficients (Inter-Elemental Relationship)

Pearson Correlation was computed for all pairs of elements and is a useful tool for multivariate analysis (example Agterberg, 1974). Certain elements are found in association with another element or group of elements (Goldschmidt, 1954) so that different type of bedrock or mineralization can be characterized by elemental associations. The correlation coefficient measures the

strength of a scale of -1(perfect inverse relation) through 0(no relation) to +1(perfect sympathetic relation).

The correlation coefficient and factor analysis in Table 5.5 and Table 5.6 carried out between the elemental concentration revealed that strong positive correlation of greater than 0.5 loading exist among Zn vs As, Zn vs Y, Zn vs Zr, As vs Y, As vs Zr, As vs Au, Sr vs Au, Sr vs Pb, Y vs Zr and Au vs Pb. These therefore possibly suggest they originate from similar source.

Table 5.5: The Correlation Coefficient of trace element in the study area

Elements	Copper	Zinc	Arsenic	Strontium	Yttrium	Zircon	Silver	Gold	Lead
Copper	1								
Zinc	0.118	1							
Arsenic	0.413	0.807	1						
Strontium	-0.598	0.410	0.191	1					
Yttrium	-0.193	0.909	0.616	0.386	1				
Zircon	0.059	0.952	0.814	0.273	0.954	1			
Silver	0.481	0.132	0.031	-0.779	0.210	0.246	1		
Gold	0.077	0.397	0.701	0.579	0.169	0.326	-0.670	1	
Lead	-0.013	0.488	0.323	0.772	0.223	0.220	-0.570	0.580	1

5.2 Factor Analysis

Factor analysis uncovers inter-correlations within datasets and allows for mutually correlated associations to be grouped. This method was employed to exposed elements that behave similarly in a geochemical environment and could serve as a pointer to associations in the mineralization (Chork and Salminen *et al.* 1993).

The trace elements values were analyzed on R-mode factor analysis to ascertain the dominant elemental factors (associates) in the rock and stream sediments as shown in Table 5.6. The factor loadings and percentage of variance explained by the three factors extracted (values in bold represent loadings with absolute values >0.5). The factor analyses values were generated using the SPSS package.

The factor analysis in Table 5.6 revealed five groups (Five factors) of inter-related elements, but only three (3) major groups were considered due to their high level of inter-relationship.

These three major groups are:

(i)Factor 1: Zn, Zr, As, Y, Au, Pb and Sr.

(ii)Factor 2: Ag and Cu.

(iii)Factor 3: Au and Cu.

Factor one

The first factor accounted for about 47.732% of the total variance. The first factor presents high positive loadings between Zn,Zr, As, Y,Au,Pb and Srall with a positive loading of greater than 0.50.Therefore this suggests positive relationshipco-existing among the base metals and so they may probably be from the same source.

Factor two

The second factor was characterized by high positive loadings of Ag and Cu as a radioactive element with a percentage variance of 30.138%.The positive correlation shows they may possibly come from the same source.

Factor three

The third groups of elements are Au and Cu has a total variance of 15.826% with a strong positive correlation and signifies the possibility of the elements being from the same source too.

Table 5.6: R-mode factor analysis of stream sediments prospect of the area

Elements	Factor 1	Factor 2	Factor 3
Zinc	0.918	0.350	-0.104
Zircon	0.847	0.480	-0.209
Arsenic	0.825	0.356	0.371
Yttrium	0.796	0.373	-0.476
Gold	0.694	-0.388	0.510
Lead	0.651	-0.486	0.227
Silver	-0.259	0.941	-0.140
Strontium	0.668	-0.697	-0.241
Copper	-0.041	0.579	0.785
Eigen Value	4.296	2.712	1.424
% of Variance	47.732	30.138	15.826
Cumulative %	47.732	77.870	93.696

Summary

Geological studies of the area around Wadji part of Wamba Sheet 210NW revealed varying lithologies with varying textural, mineralogical, and structural characteristics. The study area is a typical example of the Precambrian Basement Complex of Nigeria. Four (4) different rock types were identified; banded gneiss, schist, biotite granite and fine-grained granite. The rocks in the area are distinguished based on textural, mineralogical and colour differences. Most of the schist are seen along the river channels which occur as low-lying outcrop, and the granite is on the NW part of the area. Mapping revealed the presence of joints, quartz veins, pegmatite veins, folds, foliation and exfoliation as the structural elements and this structures mostly trend in the NE-SW, NW-SE directions. These structures attest to poly-deformational episode in a brittle-ductile environment.

The correlation coefficient and factor analysis in Table 5 and Table 6 carried out between the elemental concentration revealed that strong positive correlation of greater than 0.5 loading existing among Zn vs As, Zn vs Y, Zn vs Zr, As vs Y, As vs Zr, As vs Au, Sr vs Au, Sr vs Pb, Y vs Zr and Au vs Pb. Therefore, these may possibly suggest that they originated from similar source.

Conclusion

In conclusion, the mapped area is dominated by banded gneiss, schist, biotite granite and fine-grained granite

respectively. Also, most of the structural features observed (such as joints & veins) trend mainly in NE-SW and NW-SE directions and vary between rock units.

From the geochemical maps of gold concentration and bar charts comparing gold and its crustal abundance the concentration of gold (Au) and other associated elements such as Pb, Zn and As in all the sampled locations are relatively high in the study area. This therefore indicates that the study area has high prospect for gold mineralization. Also the associated elements such as Pb, Zn, As found in the area could serve as indicators for gold investigation in the study area and any other similar terrain.

Furthermore, the correlation coefficient and factor analysis showing strong positive correlation among the various elements in the area suggest originating from similar source.

Recommendations

It is highly recommended that more detailed geophysical and geochemical surveys be carried out in these locations for mineralization of gold in order to evaluate the possible mineralization zones and potential mineable areas within then study area; as this will help in determining the quality and quantity (tonnage) of mineralization in the study area.

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