Bima Journal of Science and Technology, Vol. 7 (2) June, 2023 ISSN: 2536-6041

DOI: 10.56892/bima.v7i2.431

STREAM SEDIMENT RECONNAISSANCE SURVEY OF NGABAHI AREA, SOUTH OF MUBI, NORTH EASTERN NIGERIA: IMPLICATIONS FOR MINERAL EXPLORATION

HAFIZULLAH ABBA AHMED and IBRAHIM GARBA

[1]Department of Geology, Modibbo Adama University, Yola-Nigeria
[2]Department of Geology, Ahmadu Bello University, Zaria-Nigeria

Corresponding Author: hifzullahahme@yahoo.com

ABSTRACT

The occurrence of ilmenite fragments around Ngabahi in southern Mubi, prompted this work. The aim of this study is to delineate potential areas of ilmenite and other economic mineralization in the area. Mubi is located in northeastern Nigeria within the Hawal Massif of Eastern Nigeria Terrain (ENT). The geology of the area consists predominantly of Pan African granite with rhyolitic and basaltic extrusions. Forty-seven (47) stream sediment samples were collected and analysed for 49 elements using ICP and INAA analytical techniques. The results show that ten (10) trace elements, namely Pb, Ba, Be, Mn, Rb, Y, Hf, Th, U, Ta in addition to Fe, have concentrations above the Average Universal Crustal Abundance (AUCA), and were subjected to statistical treatment. Median values of U, Th, Ta, Hf, Mn, Rb, Ba and Mn are well above the AUCA. Pearson correlation coefficients show that significant correlation exists among Fe-Mn and U-Th-Ta-Mn-Y-Hf. Though, no significant concentration of ilmenite has been observed, the dispersion train however, indicates anomalous concentrations of U, Th, Ta, Mn, Ba, Rb, Hf and Y, suggesting that the area is favourable for mineralization of lithophile (granitoid) affinity. Findings of the survey result in the delineation of some prospective targets for mineral deposits. Targets for this mineralization include the Sabongari region and the areas with anomalous metallic values, particularly Hf, Y and Rb, revealed by the stream sediments geochemical survey. All these, coupled with the favourable geology, make the study area of great potential value for economic mineralization.

Keywords: Stream sediments, Mineral exploration, Hawal Massif, Northeastern Nigeria.

INTRODUCTION

Mubi area is part of Hawal Massif, which together with Adamawa Massif and Mandara Mountain forms the north-eastern Nigerian Basement Complex. The Nigerian Basement Complex is broadly divided into two provinces (Figure 1): The western province which is characterized by well-developed N-S trending, largely low-grade schist, and the eastern province which is made up of mainly migmatite-gneisses. The Basement Complex in the NW, SW and SE have been fairly studied by many workers such as Mc Curry (1976), Rahaman (1976, 1988) among others. In the northeast, Bauchi area received the attention of Dada et al (1993, 1995); but Mubi area remains one of the least studied among the Basement Complex outcrops of the country (Ahmed, 2011). Hence, the aim of this work is to study the geology and delineate potential areas of economic mineralization within the study area. This study was motivated when fragments of ilmenite were found scattered within the study area.

Location and Accessibility

The study area (about 100Km^2), is found approximately 8km south of Mubi, Mubi South Local Government Area of Adamawa

DOI: 10.56892/bima.v7i2.431

State and about 30Km north of Nigeria-Cameroonian border. It is located between latitudes 10^0 09'N

and 10^0 15'N and longitudes 13^0 15'E and 13^0 21'E, and covers the following villages among others: Ngabahi, Sabongari, Jamtari, Wandure, Farkusa Muda, Kabur, Manigi, Gedkwara, Gude and Malinda. The roads linking these villages are fairly accessible (Figure 2).

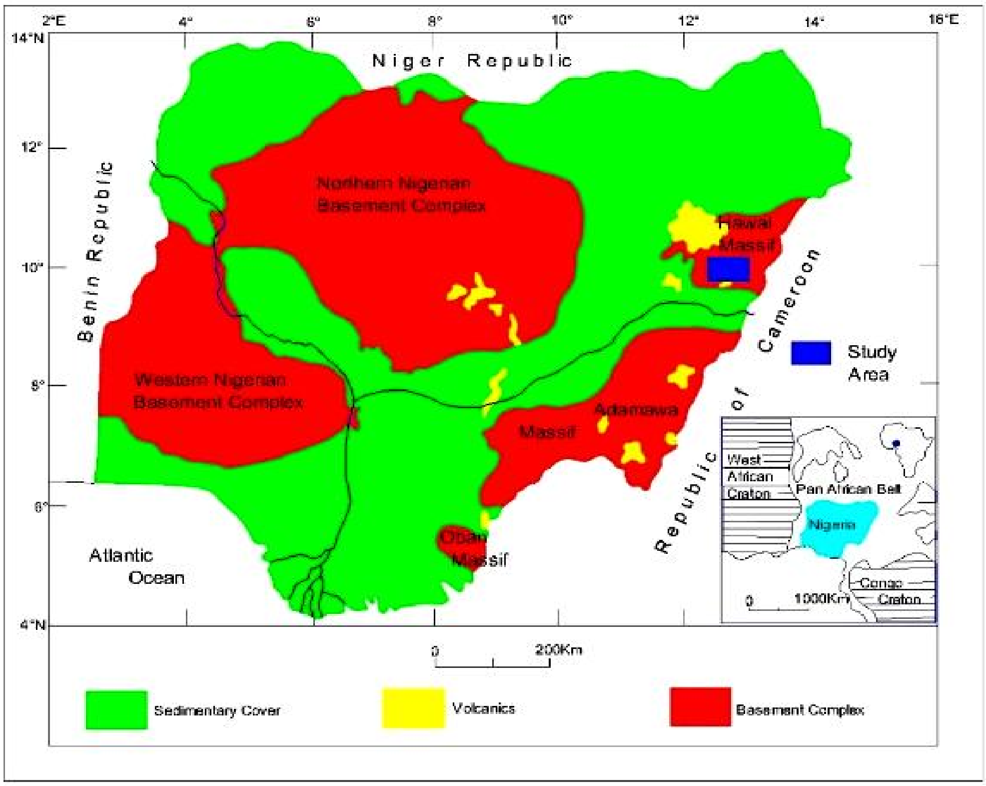

Figure 1: Regional Geology of the Study Area

Regional Geological Setting

About half of the surface area of Nigeria is covered by Precambrian crystalline rocks in the pre-drift mobile belt defined by Kennedy (1964), east of the west-African and Sao-Luis Cratons and west of Congo and Sao-Francisco Cratons. The entire belt, including the study area lies in the reactivated region, which was affected by the 600Ma Pan-African Orogeny that resulted from plate collision between the passive continental margin of West African Craton and the active Pharusian continental plate to the east (Burke and Dewey, 1972; Black et al, 1979; Caby et al, 1981).

Recent studies, particularly by Dada and Rahaman (1995) and Dada (2006, 2008) adopted a multidisciplinary approach in the study of the evolution of the Basement rocks, and grouped them into three units: the Archean migmatitic gneisses, the Proterozoic (schist) rocks and the Pan-African granitoids. This multidisciplinary approach (post structural, geochronological, geochemical and geophysical) argues for a complex pre-drift, all pervasive Proterozoic evolution culminating in the Pan-African-Braziliano event of 600Ma (Dada, 2006). The Pan-African- Braziliano event gave rise to heterogeneous deformations of older rocks

DOI: 10.56892/bima.v7i2.431

and intrusion of larger volume of granitoids, typical of the Himalayan type, thickened crust resulting from continent-continent collision. The Pan-African event was followed by Mesozoic magmatism, which invaded the Precambrian-Paleozoic basement rocks episodically from north to the south extending from the Republic of Niger (Ahmed et al, 2021).

Local Geology

The main lithologic units mapped in the area of study include: Granites, rhyolite and basalt (Figure 2). Most of the granites are porphyritic and occupy more than 90% of the total area of study. The granites are highly weathered and fractured. the granites contain more feldspars in the eastern half, than in the western part particularly the NW region around Lamorde. Phenocryst sizes range from 5mm -2cm.

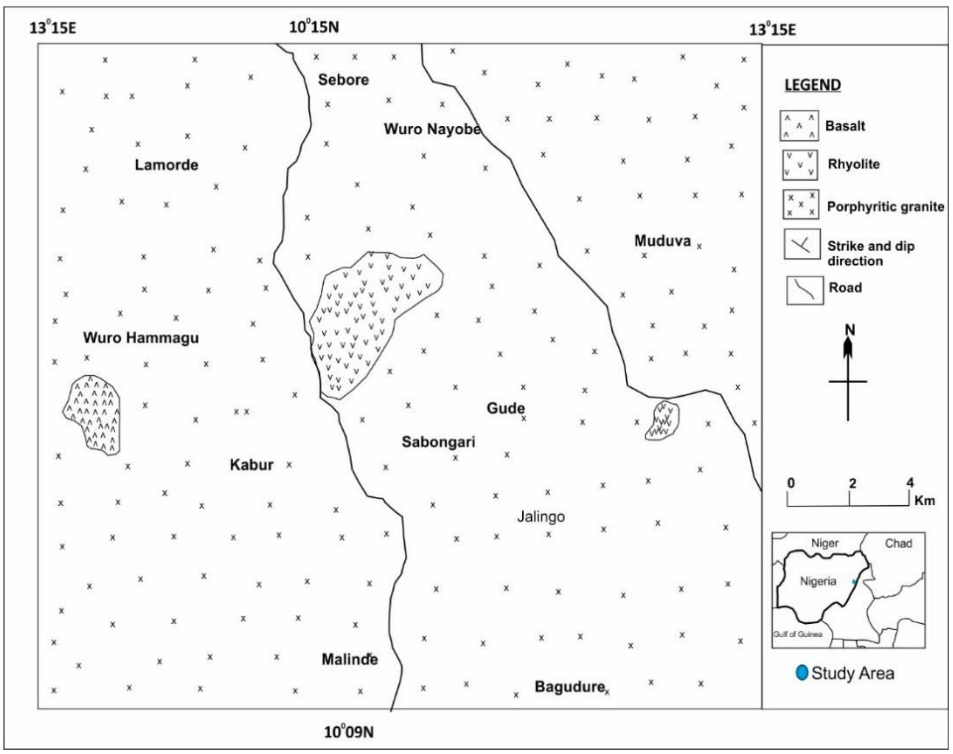

Figure 2: Geologic map of the study area

In some places particularly the southern portion, localized rhyolites occur intermitted with the granites and cannot be mapped as separate units. Generally, outcrops are less exposed in the northeastern part of the study area due to thick alluvial cover. Mappable units of rhyolite occur around Ngabahi and Wandure in the central region and around Moduva in the eastern part (Figure 2). In hand specimen, the rhyolite is greyish to reddish brown. It is highly weathered and fractured.

Basalt occurs in the southwestern part of the study area. It is dark coloured and occurs in small mappable units extruding through the porphyritic granites. The basalt is also highly fractured and weathered.

The general structural features observed in the study area are fractures and veins. Joints are

DOI: 10.56892/bima.v7i2.431

also common particularly in the rhyolites having an irregular trend. No major fault displacement has been observed from the fieldwork. The fractures, veins and joints generally indicate dominant N-S, E-W, NNW-SSE and NE-SW trend.

MATERIALS AND METHODS

Sampling and analytical techniques

Field work was carried out for 1week. During the field exercise, samples collected were mainly stream sediments and some few rocks samples. The stream sediments were collected along confluence points of tributaries and at intervals along the streams; this is to give a better representation of the sediments. To obtain representative samples that were not contaminated; holes were dug at locations to the bedrock, and at least 1Kg of stream sediments were collected at 47 different locations within the study area (Figure 3). A hand trowel was used in collecting the samples and was cleaned regularly to minimize contamination. The samples were packed in polythene bags and appropriately labelled. Most samples collected were wet. They were sun-dried right from the field and at home. Dried samples were sieved using 0.05mm (32 meshes). Each sieved sample was well packaged in a polythene bag and properly labelled, weighed and sent to Activation Laboratories Ltd., 1336 Sandhill Drive, Ancaster, Ontario Canada L9G 4V5, for pulverization and subsequent analysis. The preparation was done to produce the INAA portion and total digestion for ICP. The techniques employed for the determination of the elements in stream sediments were by INAA and ICP.

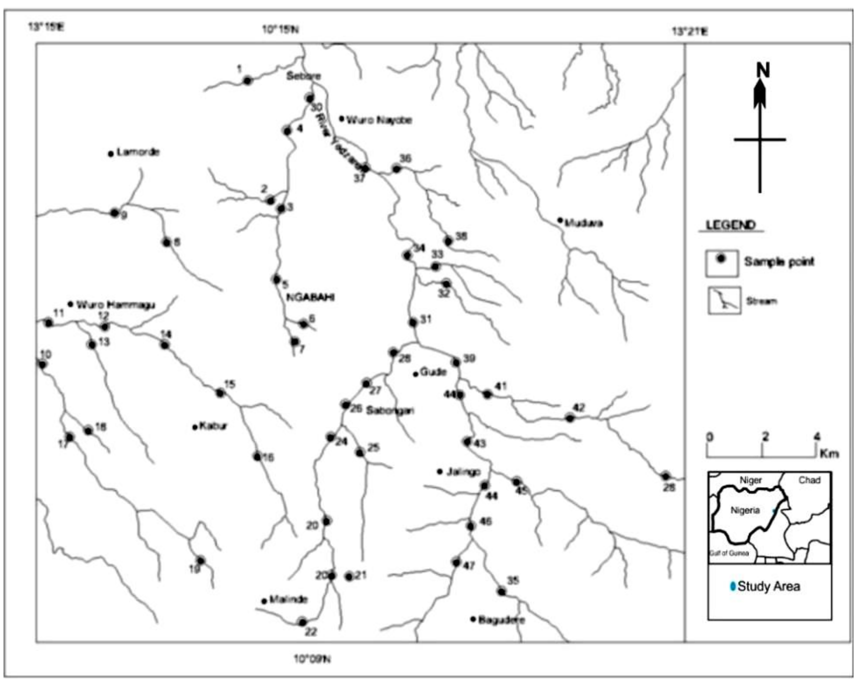

Figure 3: Study Area Showing Streams and ample Locations

The INAA portion was determined based on the method described by Hoffman (1992): a 30g aliquot was encapsulated in a polythene vial and irradiated with flux wires and an internal standard (1 for 11samples) at a thermal neutron flux of $7x10^2$ $nCm^{-2}S^{-1}$. After a 7-day decay to allow Na-24 to decay, the samples were counted on a high purity Ge-detector with resolution of better than 1.7KeV for the 1332Kev Co-60 photo peak. Using the

DOI: 10.56892/bima.v7i2.431

flux wires, the decay-corrected activities were compared to a calibration developed from multiple certified international reference materials. The standard present was only a check on accuracy, and was not used for calibration purposes. About 10-30% of the samples were rechecked by re-measurement.

For the ICP portion, a 0.25g aliquot of sample was digested in $HCLO_4$-HNO_3-HCL-HF at 26°C to fuming and was diluted with dilute HCl. This leach was partial for magnetite, chromites, barite, spinels, zircon and massive sulphides. The solutions are read on a Varian vista or Varian 735ES ICP. Reported quality control QC included a blank analysis frequency of 2%, 1 for every 20 samples or less. A sample replicate frequency of 7%, 1 for every 15 samples, 6% or more were analysed additionally, there was an internal method quality control QC with a frequency of 20. For the ICP analysis, reagent blanks, with and without the lithium borate flux were analysed as well as the method reagent blank. Interference correction verification standards were analysed. Calibration was performed using multiple USGS and CANMET certified materials. Two of the standards were used during the analysis for every group of 10 samples. The sample solution was also spiked with internal standards and is further diluted and introduced into a Perkin Elmer SCIETEX ELAN 600 ICP/MS using appropriate sample introduction methodology. Calibration was performed using USGS and CANMET certified reference materials (Ahmed, 2011).

RESULTS

The data obtained from the geochemical analysis (Table 1) were subjected to simple statistical and geochemical treatment and interpretation. SPSS version 15.0 computer software has been useful in the statistical analysis.

Table 1: Results of Geochemical analysis from 47 stream sediment samples

Analyte symbol Sample No.	Pb (ppm)	Ba (ppm)	Be (ppm)	Mn (ppm)	Rb (ppm)	Y (ppm)	Hf (ppm)	Th (ppm)	U (ppm)	Ta (ppm)	Fe (wt.%)
1	30	980	2	304	142	11	3	22.7	2.4	0.5	1.11
2	29	1140	2	233	151	9	2	9.8	2.5	1.7	0.95
3	30	1250	2	183	153	10	2	30.5	2.5	1.2	0.96
4	28	890	1	283	159	14	4	59.1	4.9	2.1	1.06
5	22	1250	2	668	102	19	5	20.6	3.5	2	4.73
6	35	990	1	280	176	13	4	60.5	3.8	3.3	1.1
7	40	970	2	503	196	19	7	142	8.5	3.1	1.44
8	29	1140	2	1250	112	18	7	16.7	5.1	5.9	3.34
9	29	940	2	343	151	8	4	10.9	1.2	0	1.3
10	30	740	1	252	168	7	3	19	2.7	1.2	0.89
11	40	800	2	590	191	24	8	99.9	7	4.1	1.23
12	33	970	1	257	203	11	3	43.1	3.2	1.4	0.91
13	36	830	2	280	179	22	5	89.2	6	0	1.07
14	38	850	2	361	210	14	5	60.5	5.1	2.4	1.25
15	44	860	2	375	301	17	7	103	6.8	2.4	1.33
16	39	1000	2	385	256	15	4	132	9.8	2.6	1.27
17	27	890	2	421	129	13	7	12.1	2.2	2.7	2.96
18	38	870	2	519	182	28	6	112	7.7	2.6	1.34
19	44	700	2	495	229	35	4	163	8.7	0	1.43

Bima Journal of Science and Technology, Vol. 7 (2) June, 2023 ISSN: 2536-6041

DOI: 10.56892/bima.v7i2.431

20	38	730	2	644	305	18	5	128	9.4	3.3	1.5
21	44	1070	1	404	288	15	5	341	19.4	2.3	1.57
22	34	740	1	346	242	14	4	75.1	5.6	2.3	1.15
23	35	860	1	96	280	4	2	9.6	1.2	1.2	0.72
24	44	1140	2	434	318	18	6	85.7	7.1	3.5	1.64
25	33	1140	2	711	215	21	8	409	28.2	3.7	3.29
26	17	1040	2	818	160	26	7	34.6	3.8	2	5.83
27	39	830	1	1670	198	54	6	524	28.2	8.4	2.58
28	27	900	2	487	150	27	28	47.5	6.8	6.2	1.62
29	37	1020	1	651	241	16	4	148	8.6	4.9	1.46
30	32	890	2	280	196	11	6	12.2	1.7	1.7	1.38
31	21	770	1	145	173	9	4	29.4	3.1	1.3	1.02
32	28	720	0	218	124	5	4	8.8	2.4	1.4	1.12
33	29	820	1	276	132	7	5	11.3	1.8	1.2	1.2
34	28	860	1	152	160	8	4	17.5	1.4	0	0.79
35	29	740	2	196	179	4	4	15.2	2.4	2	1.31
36	32	880	5	262	124	9	7	9.5	1.8	0	1.21
37	29	900	2	158	190	12	7	15.5	1.4	2.2	0.92
38	34	790	1	623	128	25	44	75.4	2.4	3.4	2.27
39	26	850	2	135	174	11	6	8.9	1.8	2.2	0.89
40	26	780	2	229	164	14	5	41	2.8	1.9	1.33
41	28	890	2	208	168	14	10	12.5	10	2.8	0.98
42	30	900	2	711	150	33	40	90.8	1.6	9.8	1.92
43	28	980	2	246	165	16	20	35.7	5	0	1.59
44	28	900	2	761	135	20	14	124	1.8	6	4.64
45	25	980	2	252	173	18	14	29.1	5.5	4.7	1.73
46	27	980	2	121	165	5	5	6.6	3.8	0	1.01
47	37	1130	1	205	225	7	5	17.8	10.5	0	1.2

Statistical Analysis

Table 1 shows some statistical data of importance obtained for the trace elements analysed in the 47 stream sediment samples. Only 10 trace elements plus Iron (Fe) were considered since most of the elements analysed have concentrations below the Average Universal Crustal Abundance (AUCA), or even below detection limits. These statistical data were used to estimate basic parameters such as background, threshold and different populations. Pearson correlation analysis was done on the set of data to study interelement relationships. The analysis was done using SPSS software. The results (Table 2) show correlation matrices between the 11 elements considered to have values above the Average Universal Crustal Abundance (AUCA). Table 3 shows the correlation of trace elements and REEs.

The results are expressed for each pair of elements as Pearson correlation coefficients (p) and the level of significance, (0.05). According to Adams et al (2001). Samples showing R>0.7 are considered to be strongly correlated, whereas R>0.5-0.7 shows moderate correlation at a significant level (p) of 0.05.

Table 2: Correlation of Trace Elements above the AUCA

	Pb	Ba	Be	Mn	Rb	Y	Hf	Th	U	Ta	Fe
Pb	1										
Ba	-0.073	1									
Be	-0.036	0.152	1								
Mn	0.164	0.129	0.008	1							
Rb	.722(**)	-0.042	-0.139	-0.039	1						
Y	0.282	-0.063	0.065	.788(**)	0.06	1					
Hf	-0.099	-0.093	0.064	0.228	-0.252	.405(**)	1				
Th	.505(**)	0.052	-0.127	.635(**)	.385(**)	.662(**)	0.022	1			
U	.456(**)	0.174	-0.107	.538(**)	.410(**)	.541(**)	-0.068	.915(**)	1		
Ta	0.085	0.047	-0.047	.702(**)	0.001	.641(**)	.511(**)	.447(**)	.333(*)	1	
Fe	-.324(*)	.338(*)	0.138	.636(**)	-0.267	.412(**)	0.202	0.224	0.169	.362(*)	1

Table 3: Correlation of Trace elements and REEs

	Ba	Be	Mn	Rb	Y	Eu	La	Yb	Lu	Sm	Ce
Pb											
Ba	1										
Be	0.152	1									
Mn	0.129	0.008	1								
Rb	-0.042	-0.139	-0.039	1							
Y	-0.063	0.065	.788(**)	0.06	1						
Eu	.378(**)	0.183	.532(**)	-0.161	.604(**)	1					
La	-0.177	-0.022	.663(**)	0.25	.879(**)	.348(*)	1				
Yb	-0.109	0.098	.370(*)	-0.131	.586(**)	.457(**)	.292(*)	1			
Lu	-0.102	0.114	0.255	-0.2	.483(**)	.415(**)	0.177	.979(**)	1		
Sm	-0.137	0.003	.712(**)	0.201	.924(**)	.458(**)	.985(**)	.376(**)	0.259	1	
Ce	-0.172	0.004	.680(**)	0.246	.894(**)	.366(*)	.997(**)	.325(*)	0.209	.987(**)	1

	Eu	La	Yb	Lu	Sm	Ce	Hf	Th	U	Fe
Eu	1									
La	.348(*)	1								
Yb	.457(**)	.292(*)	1							
Lu	.415(**)	0.177	.979(**)	1						
Sm	.458(**)	.985(**)	.376(**)	0.259	1					
Ce	.366(*)	.997(**)	.325(*)	0.209	.987(**)	1				
Hf	.454(**)	0.088	.789(**)	.808(**)	0.184	0.131	1			
Th	0.249	.654(**)	0.209	0.08	.665(**)	.675(**)	0.022	1		
U	0.232	.511(**)	0.15	0.049	.510(**)	.526(**)	-0.068	.915(**)	1	
Ta	.450(**)	.444(**)	.677(**)	.600(**)	.529(**)	.466(**)	.511(**)	.447(**)	.333(*)	
Fe	.764(**)	0.164	0.199	0.139	0.26	0.187	0.202	0.224	0.169	1

Background and threshold values of potential mineralization

Using the method of Rose et al (1979), the background b, is estimated to be the median which corresponds to 50% ordinate.

The values were rounded up (Table 4). The threshold values were calculated using X + 2S, where X= mean and S=Standard deviation.

Table 4: Calculated and Estimated threshold values for the elements

S/No	Element	Background (b)	Ave. Universal Crustal Abundance (After Beaus and Gregorian, 1977)	Mean (X)	Standard Deviation(S)	Threshold (X+2s)
1.	Pb	30ppm	9ppm	32ppm	6.0	44ppm
2.	Ba	890ppm	450ppm	921ppm	137	1,195ppm
3.	Be	2.0ppm	1.5ppm	1.8ppm	0.7	3.2ppm
4.	Mn	325ppm	90ppm	413ppm	290	993ppm
5.	Rb	173ppm	90ppm	185ppm	51	287ppm
6.	Y	14ppm	26ppm	16ppm	9.3	35ppm
7.	Hf	5ppm	2.6ppm	8ppm	8.6	25ppm
8.	Th	36ppm	7.3ppm	76ppm	104	284ppm
9.	U	3.8ppm	1.5ppm	6ppm	5.9	18ppm
10.	Ta	2.2ppm	1ppm	3ppm	2.1	7ppm
11.	Fe	1.3wt%	5.7wt%	1.6wt%	1.08	4wt%

DOI: 10.56892/bima.v7i2.431

GEOCHEMICAL DISTRIBUTION OF ELEMENTS

Manganese (Mn)

Both geochemical features and distribution patterns of Mn in the study area has shown very high levels of the element in the stream sediments. There is a strong correlation between Mn and Y (0.788), Th (0.65), U (0.538), Ta (0.702) and Fe (0.636), which are significantly indicating similar source (Table 1). Mn is also found to be correlated strongly with the REEs in the study area with the exception of Yb and Lu. These include correlation with Nd (0.641), Eu (0.532), La (0.663), Tb (0.569) and Sm (0.712).

Iron (Fe):

Fe distribution in the study area is not significant having only one sample (No.26) around Sabongari above the AUCA with 5.83w%. Fe is found only to be correlated with Mn (0.636) among the 11 elements considered (Table 2). However, Fe was also strongly correlated to some trace elements Sc (0.921), Zn (0.875), Ni (0.851), Co (0.801), Cr (0.589) and Eu (0.764), which have values above detection limit, but below AUCA.

Beryllium (Be):

Beryllium is normally distributed throughout the study area in concentrations slightly above the AUCA. Be is not correlated with any of the trace and REE, but only with Na in the study area, indicating a distinct source, probably anthropogenic.

Barium (Ba):

Ba is fairly normally distributed in the study area with a single population. Ba does not correlate with any element in Table 1; rather, it correlates significantly with Zn, Co, Sr and Eu and at lower significance with Fe. Ba occurs in high concentrations in all samples, with values above the average crustal abundance. Two sample points 3 and 5 have anomalous concentrations of 1250ppm each, (above the threshold values), hence, are targets for follow-up.

Hafnium (Hf):

Distribution of Hf in the stream sediments have concentrations of anomalous values exceeding the threshold in samples 28(28ppm), 38(44ppm) and 42(40ppm). These high values are unidirectional, indicating a common source emanating from the eastern part of the study area (Figure 2). Hf correlates with trace elements Ta (0.511) and Y (0.405) and with REEs Yb (0.789) and Lu (0.808).

Lead (Pb):

Lead is fairly normally distributed throughout the study area. Pb is strongly correlated with Rb (0.722), U (0.456), and Th (0.505) (Table 2), indicating a common source. Distributions of Pb in anomalous concentrations of 44ppm occur uniformly in samples 15, 19, 21 and 24, (around Kabur and Sabongari (Figure 2)), in the southern part of the study area. This is a target area worthy of follow up since surrounding points are as well above average crustal abundance. Pb also correlates very significantly with REEs such as Nd (0.547), La (0.514) and Ce (0.525).

Rubidium (Rb):

Rb is fairly distributed normally in the study area. It correlates significantly with Pb (0.722) and less significantly with U (0.410) and Th (0.385). All values are above the AUCA, with anomalous concentrations in samples 15(301ppm), 20(305ppm), 21(288ppm), 23(280ppm) and 24(318ppm). These concentrations are unlikely to occur by chance clustered in one region, hence may be a target area and the need for follow up, particularly for lithophile elements mineralization.

Tantalum (Ta):

DOI: 10.56892/bima.v7i2.431

Tantalum distribution in the study area is positively skewed. It is positively correlated with Mn (0.702), Y (0.641), Hf (0.511) and Th (0.477). Ta is also significantly correlated with all the REEs analysed in the study area. Presence of biotite in the study area as indicated by field observations and in thin sections is an interesting indicator of niobium tantalite, so also the presence of ilmenite, zircon and sphene (Beus and Gregorian, 1977).

Thorium (Th):

Except for sample 46, all other samples have concentrations above the AUCA. This may be attributed to the high-level mobility of Th. It is significantly correlated with U, Y, Mn and Pb, and at lower significance, it is correlated with Ta (0.447) and Rb (0.38). It also correlates significantly with the REEs (Table 3). Apart from the strong correlation that exists between Th and U, it is interesting to note that high concentration of these elements cluster together near Gude and Gedkwara - which is not far from the observed quartz veins and decreases downstream. High values reach up to 524ppm Th and 28.8ppm U, indicating potentials for mineralization. Zircon is a common accessory mineral in acid magmatic rocks like granitoids and has very partitioning coefficients for REEs, U and Th (Finch and Hanchar, 2003). The distribution of U and Th may be partly controlled by the abundance of zircon in granitoids and partly by secondary mineralization. Interestingly, Th is relatively immobile as compared to U, hence, secondary dispersion or mineralization may not be located far upstream. Also, the positive correlation that exists between Rb and these elements (Th and U) is a clear indication of Radioelement mineralization. Th is also significantly correlated with the REEs in the study area, particularly Nd (0.663), La (0.654), Tb (0.555), Sm (0.665) and Ce (0.675).

Uranium (U):

Uranium is normally distributed in the stream sediments of the study area, with concentrations mostly above the AUCA. Three samples have values above the threshold values. These are samples 21, 25 and 27 around Sabongari with (19.4ppm), (28.2ppm) and (28.2) respectively. U correlates very significantly with Th (0.915), Mn (0.538), Y (0.541) and Rb (0.410) indicating their common source and close association. U also correlates with the REEs Nd (0.531), La (0.511), Sm (0.510) and Ce (0.526).

Yttrium (Y):

Y occurs in anomalous concentrations in three samples of the study area, (19, 27 and 42). They correlate significantly with Th, U, Ta and Hf. Y is a lithophile metallic element that forms several minerals including Xenotime and Yttriate, but is also present as an accessory element in biotite, feldspars, pyroxene, garnet and apatite.

In stream sediments, Yttrium may be mobilized through dissolution of ferromagnesian silicates, notably clinopyroxene, but subsequent dispersal is typically restricted by sorption to hydrous iron oxides and clay minerals. Like Th, Y also displays low mobility in all environmental conditions. With the significant correlation existing between Y and Th and the nature of their mobility, it is a strong indication that they have similar source and can be located not very far eastward of the study area. They are also associated with Ta, U and Hf.

DISCUSSION

The geochemical characteristics of the elements studied have been useful in the interpretation of this geochemical survey. Statistical and geochemical interpretations of the trace elements composition of the stream

DOI: 10.56892/bima.v7i2.431

sediments have pointed out to the dispersion train for high concentrations of U, Th, Ta Mn, Ba, Rb, Hf and Y, suggesting that the area is favourable for economic mineralization of lithophile (granitoid) affinity. Median values of radioelements in the context of Average Universal Crustal Averages, (AUCA), are higher. The deficiency of Pb, Cu and Zn in stream sediments of the study area may be suggestive that the elements mineralization potential is not related to hydrothermal deposits, rather controlled by induced mineralization fluids derived from radiogenic granite sources. The high concentration of the REEs may probably have its genesis to the presence of secondary uranium and thorium anomalous concentration in the study area that are expectedly rich in REEs. This conforms to the positive correlation of U and Th to almost all the REEs analysed indicating similar sources. U and Th are concentrated in the central part of the study area around Sabongari. High concentrations of tantalum are also observed in the study area, with anomalous values occurring in samples 27 and 42. These conform to tantalum mineralization worked in quartz veins at Mujera village- about 2km east of study area. Also, the quartz veins around Sabongari may be linked to that of Mujera and is probably the potential source of Ta anomaly in the study area. Rubidium concentration decreases downstream from the granitic rocks which is a known source of its enrichment. Rb is usually enriched in the late stage differentiates and residual fluids of granitic magmas. Therefore, any positive correlation of high Rb with any metal can indicate potential for mineralization.

Manganese and Barium are anomalous around Sabongari. Ba however, is not found to correlate with any of the trace elements considered; rather it correlates negatively with Pb, but significantly with zinc and cobalt. Hafnium anomaly occurs in the SE part of the study area. Hf mineralization may be detected upstream. Yttrium anomaly also occurs in three sample points of the study area (Samples 19, 27 and 42). Its distribution in the study area can be related to that of Th, U, Ta and Hf.

CONCLUSION

In conclusion, the survey has ended up in the delineation of some prospective targets for mineral deposits. Targets for this mineralization include the Sabongari region (Figure 2) and the areas with anomalous metallic values, particularly Hf, Y and Rb, revealed by the stream sediments geochemical survey sample points (Figure 2). All these, coupled with the favourable geology, make the area of great potential value for economic mineralization. If these targets are further assessed, they might meet the full objectives of this survey.

Recommendation

The vast east of the present study area remains unexplored as was not covered by the present work. Perhaps similar or even more favourable geological and geochemical features continued eastward as indicated by the eastward increase in concentration of Hf and Ta, which conform to known Tantalite mineralization worked out by artisanal miners in quartz veins about 2km east of study area. Therefore, a detailed survey is desirable to cover the area, since stream sediments do not capture the expected anomalous concentrations of ilmenite, (Fe TiO_2) that motivated this work. Hence, detailed investigations involving soil and rock geochemistry is recommended to be carried out in the vicinity of the ilmenite occurrence.

REFERENCES

Adams, S., Titus, R., Pietersen, K., Trendoux, G And Harris, G. (2001).

DOI: 10.56892/bima.v7i2.431

Hydrogeochemical Characteristics of aquifers near Sutherlan in the Western Karoo, South Africa. Journal of Hydrogeology, 241, pp91-103.

Ahmed, H.A. (2011). Stream Sediment Survey of Ngabahi Area, South of Mubi, North Eastern Nigeria. An unpublished M.Sc. thesis, Federal University of Technology, Yola, 108p

Ahmed, H.A., Wang, LX., Ma, CQ. Abdallsamed, M.I.M., Girei, M.B., Zhu, Y.X., Vincent, V.I., Kamaunji, D.V., Cao, L. (2021). Contrasting Neoproterozoic and Mesozoic granitoids in Zaranda complex (Nigeria): insights into the distinct origins, tectonic settings and mineralization potential. Int J Earth Sci (Geol Rundsch) 110, 1389–1413. https://doi.org/10.1007/s00531-021-02021-z

Black, R., Cabby, R., Moussine, P., Ponchkline, A., Bayer, R., Bertrands, J.M; Boullier, M.M; Fobrej. And Resquer, A. (1979). Evidence for Late Precambrian Plate Tectonics in West Africa. Nature, 278, 5701, pp223-227.

BEUS, A. A. AND GREGORIAN, S.V. (1977). Geochemical Exploration Methods for Mineral Deposits. University of Chicago Printing Dept., Chicago, Illinois. 287p.

BURKE, K.C AND DEWEY, J.F. (1972). Orogeny in Africa: In African Geology, Dessaugie, T.F.J and Whiteman, A.J.(Editors), Ibadan, Ibadan University press, pp 583-608.

CABY, R., BERTRAND, J.M.I. AND BLACK, R. (1981). Pan African Ocean Closure and Continental Collision in the Hoggar-Iforas, Segment, and Central: in: Precambrian plate Tectonics, Kroner, A. (Ed), Elsevier, Newyork pp 401-423.

DADA, S.S; TUBOSON, I.A; LANCELOT, J.R and LAR, A.U. (1993). Late Archean U-Pb age for the Reactivated basement of northeastern Nigeria, journal of African Earth Sciences, 16, pp. 405-412.

DADA, S.S. AND RAHAMAN, M.A. (1995). Late Archean/Early Proterozoic Crustal Initiative And Growth in Nigeria. African Geosciences Review, 2, 2 pp 219-225.

DADA, S.S; BRIQUE, L; HARMS, U; LANCELOT, T.R. and MATHEIS, G. (1995). Charnockitic and Monzonitic Pan African Series from North-Central Nigeria: Trace Elements and Nd, Sr, Pb Isotope Constraints under their Petrogenesis. Chemical Geology, 124, pp 223-252.

DADA, S.S. (2006). Proterozoic Evolution of Nigeria in: The Basement Complex of Nigeria and its Mineral Resources. A Tribute to Prof. M. A. O. Rahaman. O. Oshin (Ed). pp 29-44.

DADA, S.S. (2008). Proterozoic Evolution of The Nigeria Boborema Province in: Pre-Cenozoic Correlations across the South Atlantic Region. Geological Society of London Special Publication, 294 pp 121-136.

FINCH, R.J. AND HANCHAR, J.K. (2003). Structure and Chemistry of Zircon and Zircon group Minerals. Reviews in Mineralogy, 53, (Hanchar, J.M and Hoskin, P.W.O., (ed.), 1-25.

HOFFMAN, E.L. (1992). Instrumental Neutral Activation in Geoanalysis. Journal of Geochemical Exploration. 44, pp 297-319.

KENNEDY W.Q. (1964). The structural differentiation of Africa in the Pan African Tectonic Episode. 8th Annual Report, Research Trust, African Geology, Leeds. pp 48-50.

Mc CURRY, P. (1976). Geology of the Precambrian to Lower Paleozoic Rocks of Northern Nigeria- A Review in Kogbe, C.A (Ed) Geology of Nigeria, Elizabethan Publishing Company, Lagos. pp 15-39.

ROSE, A.W; HAWKES, H.E. AND WEBB, J.S. (1979). Geochemistry in Mineral Exploration (2nd Edt.). Academic Press, London. 657p.