Stream Sediment Geochemical Survey around Mildo and Its Environs, Madagali, Northeastern Nigeria

H. A. Ahmed[a], M. Halilu[a], M.B. Saleh[a] and A. Hassan[a]

[a]Department of Geology, Modibbo Adama University of Technology, PMB 2076, Yola Adamawa State, Nigeria.

**Corresponding author: hifzullahahmed@yahoo.com +8613164690700*

Abstract

In an attempt to explore the mineral potentials of Mildo area, geology and stream sediments geochemical survey around Mildo and its environs, Madagali area, Northeastern Nigeria was carried out. The area is part of Mandara Mountains. The Mandara Mountains together with the adjacent Hawal and Adamawa Massif form the northeastern basement complex. Stream sediments were collected at the confluence points of two or more streams mostly at a depth of 20 – 30cm. The stream sediment samples were analyzed for trace and major elemental concentration using XRF analytical method. The result of the geochemical analysis was thereafter subjected to statistical analysis. Elements of high concentrations were identified and they include Ba, Ti, Fe, Zn, Cu, Hg, Cd, Co, Zr, Sr and Ag. Locations SSP4 and SSP13 have concentrations of these elements in high values. We speculate that high concentration of Ag can be associated with mineralization of gold and other Platinum Group Metals in the area. Although, most elements studied have high concentrations, but they fall short of threshold values to be considered as anomalous to constitute an economic deposit. However, we recommend further surveys in the vicinity of areas with highest concentrations for possible location of economic deposits upstream.

Keywords: Mildo, Madagali, Stream Sediments, Hawal Massif, Northeastern Nigeria

1. Introduction

The study area lies between the coordinate of latitude $10^0 47'$ N and $10^0 51'$N and longitude $13^0 33'$ E and $13^0 36'$ E (Fig.1.2). The area is part of Mandara Mountains which together with the adjacent Hawal and Adamawa Massifs form the northeastern basement complex. The Nigerian basement Complex is broadly divided into two provinces, the western province which is characterized by Well-developed N-S trending largely low-grade schist and the eastern province which is made up mainly of migmatite-gneisses complex (MGC), intruded by large volumes of Pan-African granitoids (Older granites). In the eastern province (to which the study area belongs), the basement complex outcrops in three main areas; the Bauchi area, which is the continuation of the North-Western-Hawal massif in the extreme northeast and Adamawa massif south of the Benue Trough. The outcrops in the NW, SW and SE have been fairly studied by many workers such as McCurry (1976), Rahaman (1976, 1988), Elueze (1982), Ajibade (1988), Ajibade & fitches (1988) and Ekwueme (1991, 2003) among others. In the northeast, the Bauchi and Adamawa areas received the attention of few workers such as Dada et al. (1993, 1995), Haruna et al, 2008, Bassey et al, (2006, 2012) and Ahmed et al, (2017b) among others. However, Madagali area remains the least studied among the basement complex of the country.

The use of stream sediment geochemistry in prospecting for ore deposits has been successfully employed in many parts of the world (Ahmed et al, 2015). However, with many significant metallogenic belts in Nigeria, the use of stream sediment geochemical survey for exploration of mineral deposits is not common.

The northeastern Nigeria (including this study area) is one of the least studied areas using stream sediment geochemical survey and has only received the attention of few workers such as Haruna et al (2008) and Caleb, (2010) and Ahmed et al, (2015). This paper describes a reconnaissance stream sediment geochemical survey around Mildo area and environs in Madagali, Northeastern Nigeria. The aim of this investigation is to establish the importance of stream sediment geochemistry as an important tool in delineating areas of potential mineralization.

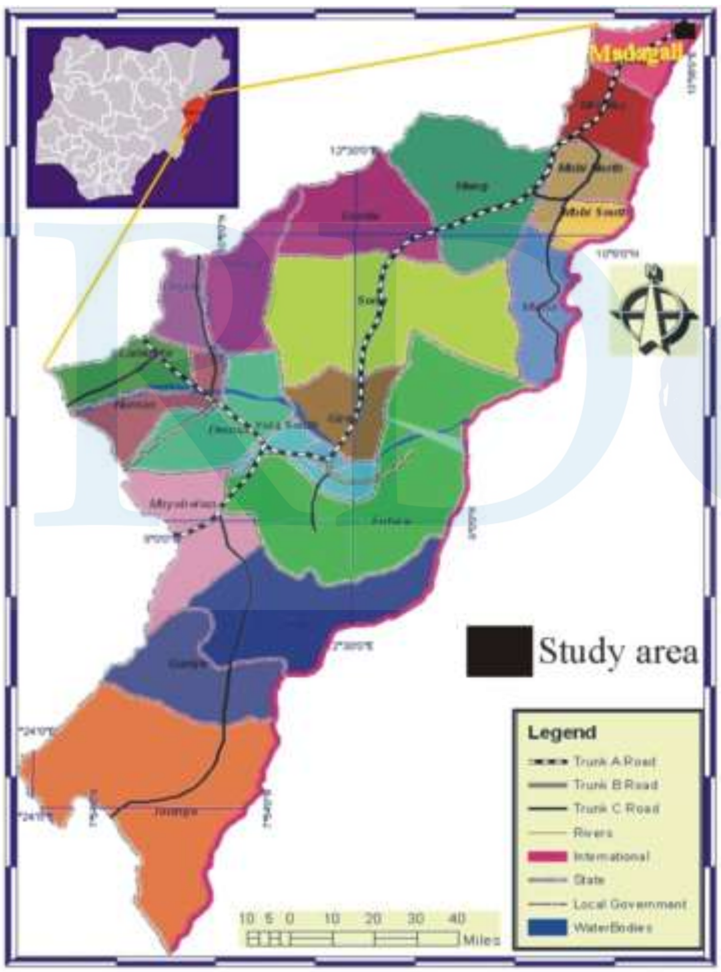

Fig. 1 Map of Nigeria and Adamawa state showing the study area. (From Adebayo, 1999).

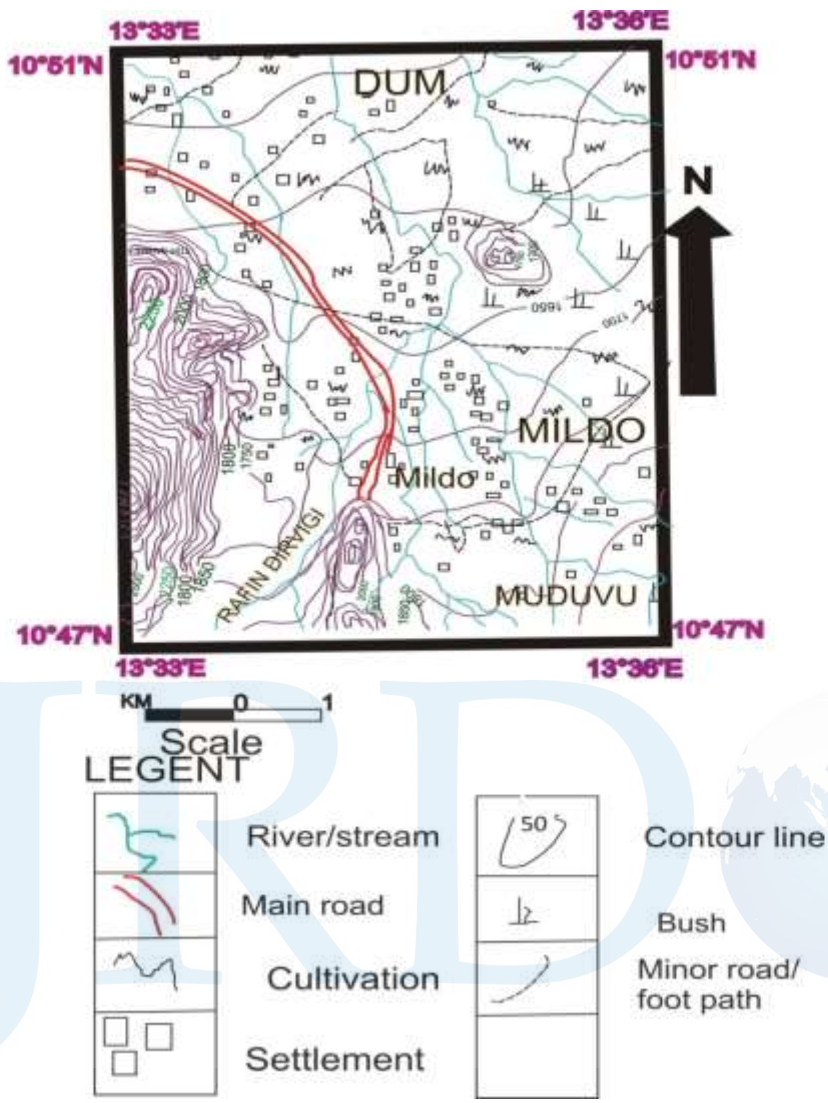

Figure 2 Topographic Map of the Study Area (Source: Madagali NW Sheet 136, Federal Survey, 1969)

1.1 Relief and Drainage

The Madagali hills form prominent parallel and elongated topographic highs in the study area. The hills stand about 180m above the general surroundings which in turn about 420 meters above sea level. The hills are dominant of granitic rocks while the flood plains are underlain dominantly by metamorphic rocks. The topography is generally undulating and dominated by rugged Mandara hills which extend to Pulka in the north to Gulak in the south and further down to Hong. Drainage is poorly developed in the area and is characterized by few seasonal streams with dendtritic pattern which generally flows northward into Lake Chad.

2. Regional Geology of the Area

Between the 1970s and 1980s, the Precambrian geology was significantly documented with the contributions of McCurry (1976), Rahaman (1976, 1988), and Ajibade (1988). The early studies were mainly based on the field relations and petrography and aimed at correlating and classifying the rocks into petrological and to some extent of geochronological units. However, recent study particularly by Dada and Rahaman (1995), Dada (2006, 2008) adopted a multi displinary approach in the study of the evolution of the basement rocks and grouped them into three units; the Archean magmatic gneiss, the Proterozoic (schist) rocks and the pan African granitoids. Metamorphic episodes in the Nigerian basement rocks are heterogeneous as indicated by the variation in the metamorphic imprints on the older rock units and to a lesser extent in the granitoids.

The MGC have mineral association of sillimanites and kyanites reflecting staurolites–almandine sub–faces of the amphibolites facies indicating high metamorphic grade. Rahaman et al (1991) pointed out that Pan–African magmatism was the main heat source for the metamorphism and that it took place in the interval between 450Ma and 630Ma while deformation was migratory from west to eastwards in consonance with a prograde metamorphic gradient until granulites –facies conditions were locally attained in Ikare area (Rahaman and Ocan, 1978).

2.1 Local Geology of the area

The geology and structures of Hawal Massif including the study area have extensively been studied by Bassey, (2006, 2012) and Bassey and Barka (2016). Bassey and Barka (2016) categorized Madagali Hills and environs into Migmatite-Gneiss-Schist Complex, Granites and Pegmatites.

2.1.1 Migmatite-Gneiss-Schist Complex

These are the oldest rock group and form the host to the granitic rocks and best exposed at Takaskara hill to the northeast of Madagali Hills (Bassey and Barka, 2016). The rocks in this area consist of slightly migmatized to unmigmatized gneisses and schist. The gneisses consist of banded type. Cleavage attitudes on the gneiss and schist is between N020°, 58°W and N195°, 60°W. The rocks are commonly sheared and jointed along E-W direction (Bassey and Barka, 2016).

2.1.2 Granites and Pegmatites

(Bassey and Barka, 2016) reported that the granites in Madagali have intruded the migmatite gneiss-schist rocks and occur as undeformed (fine, medium, coarse grained and pegmatitic varieties) and as deformed types. The Hills at Madagali town are granitic comprising of coarse grained, pinkish weakly foliated biotite granite. The rock changes texturally to medium grain on the western sector of the hill and; southward at Bebel the rock is fine grained and largely tectonised. They further reported occurrence of granites at Chikale, Gwoza-Madagali Road and Limankara areas. Pegmatite dikes occur at Madagali town and near Namtari Jambutu in few places. Bassey and Barka (2016) remarked that the emplacement of the pegmatite dykes seems to mark the last phase of intrusion in the area.

Bassey (2012) observed an aeromagnetic mapping over the Hawal basement and revealed several lineaments of NE-SW, NW-SE and N-S trends of regional significance which correlated with boundaries or trends of major tectonic features such as the north central crystalline shield, Middle Niger basin, Benue Trough, Chad basin and equatorial Atlantic fracture.

Islam and Baba (1990) reported the occurrence of manganese ore hosted by pegmatite in Gwoza area, near the study area.

2.2 Significance of Stream Sediment Geochemical Surveys

The use of stream sediment geochemical survey in prospecting for ore deposits has been successfully employed in many part of the World. In recent years, various stream sediment geochemical surveys have been conducted in Nigeria (Garba, 1987; Haruna et al, 2008; Adepoju & Adekoya, 2008; Caleb, 2010, Ahmed et al, 2015).

Geochemical patterns in steam sediment are affected by a combination of factors including sampling density, size of the sample, grain size, fraction, chemical digestion, analytical methods, chemical and physical process (Rose et al, 1979, Ottesan and Theobald, 1994). Haruna et al, (2008) stated that River system and their numerous tributaries make stream sediment Geochemistry, the most convenient tool for mineral prospecting in poorly outcropped or in accessible region of the World.

3. Materials and Methods

Various materials were employed for the different aspects of this research work, including sample bags used in storing rocks and stream sediment samples before transporting to the laboratory. Samples were carefully labeled with permanent markers to avoid mix up. Other materials included compass clinometers, global positioning system (GPS). During the fieldwork, geologic mapping of the basement rocks and systematic sampling of the stream sediments along stream channels were carried out. Thirteen stream sediment samples were obtained and rock samples to determine the geology of the area and used in the interpretation of the stream sediment results. Wet samples were sun dried for about 24 hours. Large grains (pebbles) were handpicked from the samples. Samples were sieved to obtain finer grain sizes for laboratory analysis. The sieves were regularly cleaned and dried after sieving sample. This is to avoid the contamination of each sample, with another. Each sieved sample was well packaged in a polythene bag and properly labeled, weighted and sent to the department of Geology, Kano state University of Science and Technology, Wudil for geochemical analysis.

3.1 Analytical Techniques

The 13 stream sediment and rock samples were subjected to laboratory analysis including chemical analyses and petrographic studies. The technique employed in determination of element in the stream sediment samples was by x-ray fluorescence spectrometry (XRF). The samples were analyzed, for the following elements; K, Ca, Ti, Cr, Mn, Fe, Co, Ni, Zn, Rb, Cu, Sr, Zr, Ag, Cd, Ba, Hg, Pb, Mo (Table 1).

3.2 Statistical Analysis

Result of the geochemical analysis was subjected to statistical analysis by SPSS 16.0 to determine parameters such as frequency distribution, standard deviation, range, minimum and maximum values, background, threshold value, which are all very useful in the interpretation of the geochemical data..

4. Results and Discussion

Table 1 Major Element Distribution in the Stream Sediments

Elements		K	Ca	Ti	Fe
Unit	Locality	ppm	ppm	ppm	ppm
Station					
SSP1	Ndilme near Dirvigi	27700	6426	1165	5330
SSP2	Ndilme near Dirvigi	35100	5823	1338	6304
SSP3	Rafindirvigi	27300	5579	2808	5884
SSP4	Mildo	34200	9712	1705	220.5
SSP5	Mildo	36500	5870	1090	8194
SSP6	Muduvu	34600	6169	1307	9892
SSP7	Jimango hill	30500	7332	2007	259.3
SSP8	Jimango	36800	2292	1189	6022
SSP9	Nyibango	32400	6629	2100	136.9
SSP10	Mildo	36100	5447	1615	9135
SSP11	Mildo	17600	6137	1641	112.3
SSP12	Dum	36000	3334	1566	78
SSP13	Dum	29300	6730	2527	202.7

Table 2 Descriptive Statistics of Major Elements

Descriptive Statistics							
	Range	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
K	19200	17600	36800	31853.85	5436.545	-1.62061	3.007392
Ca	7420	2292	9712	5960	1781.334	-0.19826	1.974391
Ti	1718	1090	2808	1696.769	532.2384	0.93202	0.12356
Fe	9814	78	9892	3982.362	3889.104	0.192593	-1.77336

Table 3 Trace Element Distribution in the Stream Sediments

Elements	Cr	Mn	Co	Ni	Cu	Zn	Rb	Sr	Zr	Ag	Cd	Ba	Hg	Pb	Mo
Unit Symbol	ppm	ppm	ppm	ppm	Ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Station															
SSP1	23	95	81	64	-	21	98	508	106	28	27	583	10	26	-
SSP2	-	114	-	97	-	23	117	492	586	40	28	601	15	81	-
SSP3	27	133	138	-	-	25	101	473	335	21	-	587	-	28	9
SSP4	45	229	527	60	82	39	110	539	725	48	33	696	14	34	-
SSP5	29	114	188	90	46	34	107	488	540	36	34	704	-	31	-
SSP6	33	104	227	105	42	52	114	440	283	38	35	578	10	31	-
SSP7	32	163	268	67	31	41	105	490	485	32	36	599	-	29	-
SSP8	28	618	92	95	32	36	123	195	269	40	32	561	-	27	-
SSP9	32	205	199	97	61	34	119	398	275	28	35	548	-	28	-
SSP10	37	195	124	71	39	30	118	343	429	46	46	570	-	30	-
SSP11	56	117	240	-	61	56	82	474	806	31	39	549	-	26	16
SSP12	56	371	171	90	-	37	143	320	392	32	-	584	-	33	-
SSP13	36	222	321	55	106	60	113	364	3221	45	23	616	14	32	-

Table 4 Descriptive Statistics of the Trace elements

	Range	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
Cr	33	23	56	36.16667	10.81105	1.049062	0.124565
Mn	523	95	618	206.1538	145.0941	2.230016	5.408757
Co	446	81	527	214.6667	121.4955	1.600092	3.418896
Ni	50	55	105	81	17.7426	-0.20298	-1.76577
Cu	75	31	106	55.55556	25.02554	1.142335	0.724385
Zn	39	21	60	37.53846	12.23121	0.570783	-0.46292
Rb	61	82	143	111.5385	14.40264	0.12236	1.879739
Sr	344	195	539	424.9231	96.86628	-1.19043	1.173991
Zr	3115	106	3221	650.1538	796.5793	3.236587	11.08764
Ag	27	21	48	35.76923	8.01201	-0.10064	-0.68002
Cd	23	23	46	33.45455	6.186496	0.305623	0.882453
Ba	156	548	704	598.1538	49.30322	1.474151	1.492109
Hg	5	10	15	12.6	2.408319	-0.4725	-3.08561
Pb	55	26	81	33.53846	14.48916	3.408071	11.98081
Mo	7	9	16	12.5	4.949747	.	.

The results of both field and geochemical investigations of this work are presented in Tables 1-4. Table.1 shows the localities and distribution of major elements in the stream sediments, table 2 presents the statistical analysis of major elements occurring in the stream sediments and table 3 and 4 shows trace elements and their statistical parameters respectively. The statistical analysis of the data revealed that the average skewness of the totality of the trace elements analyzed is 0.9, while the average kurtosis is 2.3. Major elements distribution in the stream is relatively high

(Table 1), with K being highest with mean value of 31853.85 ppm (3.18wt %). This could be as a result of contribution from the k- feldspar bearing rocks and clay around the streams.

A careful look at the result of the analysis of trace elements (Table.3) revealed that their values range from extremely high to low and even undetected in some locations. Concentration of Zr and Ba is considerably higher when compared to other elements. However, concentration of high values does not qualify an element to be anomalous, because some elements naturally occur in minute quantities, hence having lower background values (Table 5). Zr distribution ranges from 106-3221ppm with highest concentration occurring at location SSP13 and Ba ranges from 548-704ppm with its peak concentration at SSP5. Both Zr and Ba have concentrations above the universal crustal abundance. In their studies of about 1,600 stream sediments samples in Nigeria, Key et al (2012) concluded that wet season characterized by tropical storms and a dry season with very strong unidirectional winds has caused the very high concentration of heavy minerals, including zircon in Nigeria's stream sediments. This remarks perhaps rules out possibility of zircon mineralization, even if the values in this study were anomalous and exceed the threshold values (Fig. 5). Cr has very high concentrations ranging from 23-56ppm and an average of 36ppm, with highest concentration at SSP11. Ni, Cu, Sr, Pb, Ag and Mo have high concentrations above the universal crustal abundance, with Ni (55-105ppm), Cu (31-106ppm), Sr (195-539), Pb (26-81ppm), Ag (21-48ppm) and Mo (9-16). It is interesting to note that highest concentrations of Zr, Cu and Zn occur at location SSP13, while highest concentration of Co, Sr and Ag occur in SSP4. A follow up survey to these sites might be promising. Most of these elements have their concentrations well above the average universal crustal abundance for elements. Although, having passed this mineral reconnaissance stage, they fall short of threshold values to be considered as anomalous (Table 5).

Table 5 Average Crustal Abundance (Background) of Some Trace Elements (From Emsley, John (2001) and Ahmed et al, (2017a)

Elements	Average crustal abundance (PPM)	Mean	Std. Deviation	Threshold
K	26000	31854	54365	42300.37
Ca	36,300ppm	5967.69	1784.677	9397.0158
Ti	5600ppm	1696.77	532.238	2719.4854
Cr	10ppm	35.33	9.442	53.4134
Mn	1000ppm	210.92	142.922	485.5534
Fe	50,000ppm	3905.2785	3881.0115	11455.337
Co	20ppm	210.50	123.962	447.8682
Ni	80ppm	81.00	17.743	91.2013
Zn	75ppm	37.54	12.231	44.0569
Rb	300ppm	111.54	14.403	119.2142
Sr	370ppm	424.92	96.866	476.5469
Zr	190ppm	650.15	796.579	1074.6818
Ag	0.070ppm	35.77	8.012	40.0391
Cd	0.11ppm	33.45	6.186	37.0115
Ba	500ppm	598.15	49.303	624.4294
Hg	0.05ppm	12.60	2.408	14.5267
Pb	14ppm	29.69	2.594	31.0749
Mo	1.5ppm	12.50	4.950	22.4
Cu	100ppm	55.56	25.026	71.2851

Hawkes and Webb (1964) noted that the mean plus twice standard deviation can be used to establish the threshold in determining economic deposits.

5. Conclusion

Considering the geochemical analysis of the stream sediments, field studies and petrographic analyses as well as their interpretations, it can be concluded that the stream sediments of Mildo area and environs originate from rocks that are highly rich in ferromagnesian minerals, given that the local geology of the area includes lithologies such as Pegmatite, schist, Granite, and migmatite-gneiss. Therefore, it can be deduced that the geochemistry of the stream sediments originated from their surrounding rocks. Locations SSP4 and SSP13 indicated highest concentrations of elements including Cu, Co, Zr, Zn, Sr and Ag. These locations might have anomalous concentrations of some of these elements upstream. Moreover, the concentration of Ag is unusually high, and hence, might be an indicator for occurrence of Gold mineralization and other Platinum Group Metals (PGM), within the migmatite-gneiss-schist complex of Madagali Hills.

Recommendations

Considering the high concentrations of Cu, Zn, Co, Zr, Sr and Ag, a more comprehensive stream sediments survey is recommended in the areas around SSP4 and SSP13. Additional study is needed to search for more anomalous areas and possibly link these areas to the environments of deposition or source. The concentration of Cadmium and Mercury is very high in the stream sediments, which will probably affect the quality of the stream water. We therefore recommend hydrogeochemical studies of the stream and groundwater in the area for safe domestic and agricultural use.

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