Stream Sediment Survey of an Area around Madagali, Northeastern Nigeria

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Abstract: Geochemical (Stream Sediment) survey around Madagali was carried out in order to delineate areas of potential mineralization. The geology of the study area is predominantly Pan-African granites (750Ma-450Ma). 13 stream sediments samples were collected and analyzed for 19 elements using x-ray fluorescence (XRF). Results of 9 trace elements namely Ba, Zr, Co, Ag , Hg, Cd, Pb, Mo and Ni have concentrations well above the average Universal Crustal Abundance (AUCA), and were subjected to statistical treatment. Pearson correlation coefficients show that significant correlation exists among Cu, Cr, Zn, Co and between Rb, Ni and Mn. Geochemical maps of these elements are plotted. The dispersion train indicates anomalous concentration of Ba, Co, Ag ,Hg, Cd, Pb, Mo and Ni suggesting that the area is favourable for mineralization.
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Keywords: Stream sediment survey, Geochemical map, Madagali and Mineralization

1.0 Introduction

The use of stream sediment geochemistry in prospecting for ore deposits has been successfully employed in many parts of the world. However, with many significant metallogenic belts in Nigeria, the pace for their exploration and exploitation is negligible. Stream sediment geochemical methods for prospecting of ore deposits are not being properly applied in Nigeria. The Basement Complex in the NW, SW and SE has been fairly studied by many workers such as
Garba, 1987. Adepoju and Adekoya, 2008, Haruna et al, 2008, Roger et al, 2012 among others. The northeast (including this study area) Nigeria is the least studied and has only received the attention of few workers such as Haruna et al (2008) and Ahmed, (2012).

This paper describes a reconnaissance stream sediment geochemical survey around Madagali. The aim of this investigation is to establish the importance of stream sediment geochemistry as an important tool in delineating areas of potential mineralization in northeastern Nigeria.

1.1 Location and Accessibility

The study area is situated in the northeastern part of Nigeria between laitude $10^0 51^1$N and $10^0 58^1$N and longitude $13^0 36^1$E and $13^0 42^1$E. The area is fairly accessible especially in dry season. A federal road from Maiduguri to Yola passes through the western side of the main mountain range. Few secondary roads cross the hills into the Cameroon (Fig 1). Other parts of the hill are mainly accessible through footpaths.

1.2 Climate and Vegetation

Two main seasons (rain and dry) characterize the climate of the area. The rainy season covers from May to September with peak in August. Maximum precipitation is about 700mm annually. The rain fall mainly as short shower in the form of thunder storm, which hardly last for more than three hours. The effective precipitation is appreciably reduced by high rate of evaporation. The dry season is longer, usually lasting seven months (October to April). The temperature variations are extreme (both annual and diurnal). Coolest nights are experienced in December and January when temperature less than 10^0c are sometimes recorded.

1.3 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.

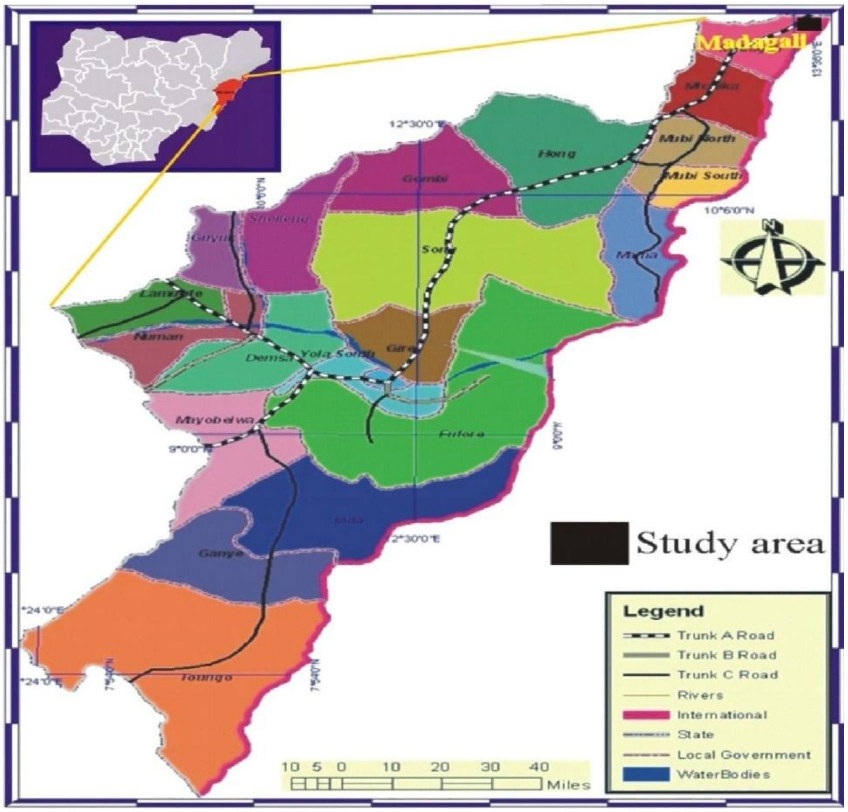


Fig. 1. Location Map of the Study Area

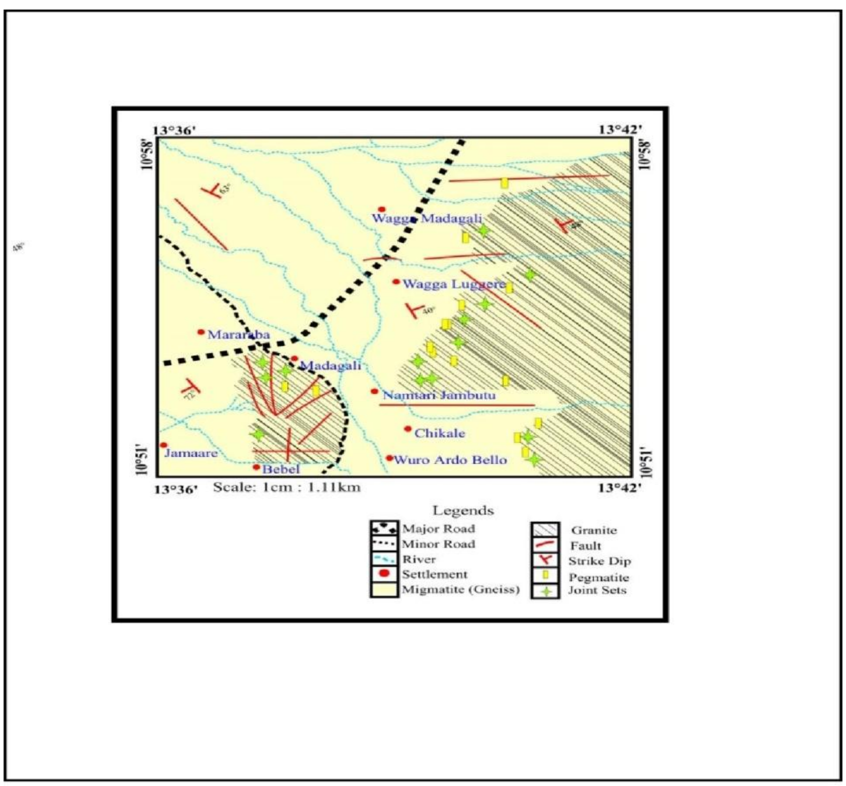


Fig. 2. Geologic Map of the Study Area

2.0 Geological setting

The area is part of Mandara Mountains which together with the adjacent Hawal and Adamawa Massifs form the northeastern basement complex of Nigeria. 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 Pan-African granitoids.

The study area is underlain mainly by granite and pegmatite with minor quartzite. Outcrops are restricted to the eastern part of the study area, as the western side is characterized by pond and flood plains. Granites are most dominant rock in the study area. They grade from fine to medium to coarse and even porphyritic grains. All the granites are similar in mineralogical composition but vary in texture under visual observation. The rocks of the study area are grouped into granite, pegmatite and migmatite and they are described in that order.

Under the microscope, the granite is characterized by large grain quartz which shows pleochroism under plain polarized light during the stage rotation. Plagioclase was also identified which shows multiple twinning and zoning under cross polarized due to alteration. Quartz, feldspar and biotite constitute the dominant minerals in hand specimen. Under microscope, the feldspar is made up of microcline. Quartz is the most abundant mineral as observed under microscope. Microcline grains are characterized by twinning while the biotite grain show interference colour and extinction under cross polarized light.

Quartz shows an irregular, subhedral body which occupies the space of plagioclase. Microcline and plagioclase possesses randomly oriented euhedral crystals. Muscovite interpenetrates the quartz and feldspars, the cleavage is perfect and it maintains a brownish to pinkish blue coloration.

The granite of the study area is characterized by numerous faultzones which generally strike approximately NE and jointing is more pronounced in granite than any other rock type in the study area. In most cases they are vertical to slightly dipping and strike roughly NE-SW and NW-SE.

Bassey (2006) deduced the dominant N-S, NNESSW and NW-SE structural trend in the NE Nigeria and the northern Cameroon from field studies. Generally, the basement complex rocks of the northeastern Nigeria are the least studied and as consequence very little discoveries of economic mineral deposit are made. Most of the mineral exploited are industrial which include feldspars, quartz, clays and some gem minerals. Islam and Baba (1990) reported the occurrence of manganese ore hosted by pegmatite in Gwoza area, some few kilometers away from the study area. Baba et al (1991) also reported the occurrence of sulphide as dissemination within the older granite of Mandara Mountains.

The element concentration within the area will vary upon the geologic processes, tectonic events and original composition of weathered, eroded and deposited materials. Therefore it is not unusual to find certain portion in the study area with high concentration of element of economic importance.

One of the most important applications of such database would be in indicating areas where there are potentials of trace element enrichment and distribution and hence detailed exploration for mineral deposits exploration to be targeted, through the stream sediments, rock types, structures and field relation.

Through stream geochemical survey of the study area, it is expected that the mineral resources potential will be delineated. Result will also be useful in environmental studies, especially the adverse effect of toxic element on the environment and human health.

3.0 Sampling and Analytical Methods

During the survey, samples collected were mainly stream sediments along confluence points of tributaries and at intervals along the stream; this is to give a better representation of the sediments. At least 1Kg of stream sediments were collected at thirteen (13) different locations of the tributaries and the main stream channels, along the entire network of the study area.

Most samples collected, were wet samples and few dried once. The 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 the other. Each sieved sample was well packaged in a polythene bag and properly labeled, weighted and sent to the department of Geology, Kano University for Science and Technology, Wudil for geochemical analysis.

The technique employed in determination of element in samples was by x-ray fluorescence spectrometry (XRF).

Thirteen (13) stream sediments 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. The analysis was done at Kano State University, Wudil. Samples were prepared by milling to less than 40μm, and then 500mg per sample. The samples were mixed with 2.5g lithium metaborate and 12.5mg lithium bromide and fused at 1200^0c for 10 minutes. For samples with loss on ignition (LOL), they were determined by heating to 1030^0 c for 10 minutes. For samples with a LOL greater than 20%, 1.25g lithium metaborate and 1.2g lithium tetraborate were used. The samples were mixed well and transferred to 25 ml calibration flask, then diluted to 25 ml with 4% boric acid to dissolve CaF_2 precipitate and remove HF acid. Pipet an aliquot of 5µl quartz carrier and dry it under infrared lamp or vacuum.

3.1 Exploration History

There has been limited published work in Nigeria on exploration geochemistry, especially in Northeastern part of the country. No stream sediments study in this area has been published so far to the best of our knowledge.

4.0 Results

The result obtained from geochemical analysis is shown in table 1 and was subjected to statistical analysis. SPSS was used for the statistical analysis and excel was used for designation of geochemical map.

Table 2 shows the statistical data of trace elements within the study area indicating their mean, standard deviation and threshold values. Pearson correlation analysis was also done on the set of data to study inter element relationships. The results are expressed for each pair of elements as Pearson correlation coefficient and level of significance of 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 significant level of 0.05. The mean, standard deviation coefficient of variation and threshold values were computed, using appropriate formulas. Concentrations of trace elements in the study area were compared to Average Crustal Abundance (Table 3) to be able to pinpoint areas of potential mineralization.

Table 1. Geochemical result of samples from the study area.

Analyze symbol	K	Ca	Ti	Cr	Mn	Fe	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	ppm	ppm	ppm
Station																			
SSG1	2.77	6426	1165	23	95	5330	81	64	-	21	98	508	106	28	27	583	10	26	-
SSG2	3.51	5823	1338	-	114	6304	-	97	-	23	117	492	586	40	28	601	15	81	-
SSG3	2.73	5579	2808	27	133	5884	138	-	-	25	101	473	335	21	-	587	-	28	9
SSG4	3.42	9712	1705	45	229	220.5	527	60	82	39	110	539	725	48	33	696	14	34	-
SSG5	365	5870	1090	29	114	8194	188	90	46	34	107	488	540	36	34	704	-	31	-
SSG6	3.46	6169	1307	33	104	9892	227	105	42	52	114	440	283	38	35	578	10	31	-
SSG7	3.05	7332	2007	32	163	259.3	268	67	31	41	105	490	485	32	36	599	-	29	-
SSG8	3.68	2292	1189	28	618	6022	92	95	32	36	123	195	269	40	32	561	-	27	-
SSG9	3.24	6629	2100	32	205	136.9	199	97	61	34	119	398	275	28	35	548	-	28	-
SSG10	3.61	5447	1615	37	195	9135	124	71	39	30	118	343	429	46	46	570	-	30	-
SSG11	1.76	6137	1641	56	117	112.3	240	-	61	56	82	474	806	31	39	549	-	26	16
SSG12	3.60	3334	1566	56	371	78	171	90	-	37	143	320	392	32	-	584	-	33	-
SSG13	2.93	6730	2527	36	222	202.7	321	55	106	60	113	364	3221	45	23	616	14	32	-

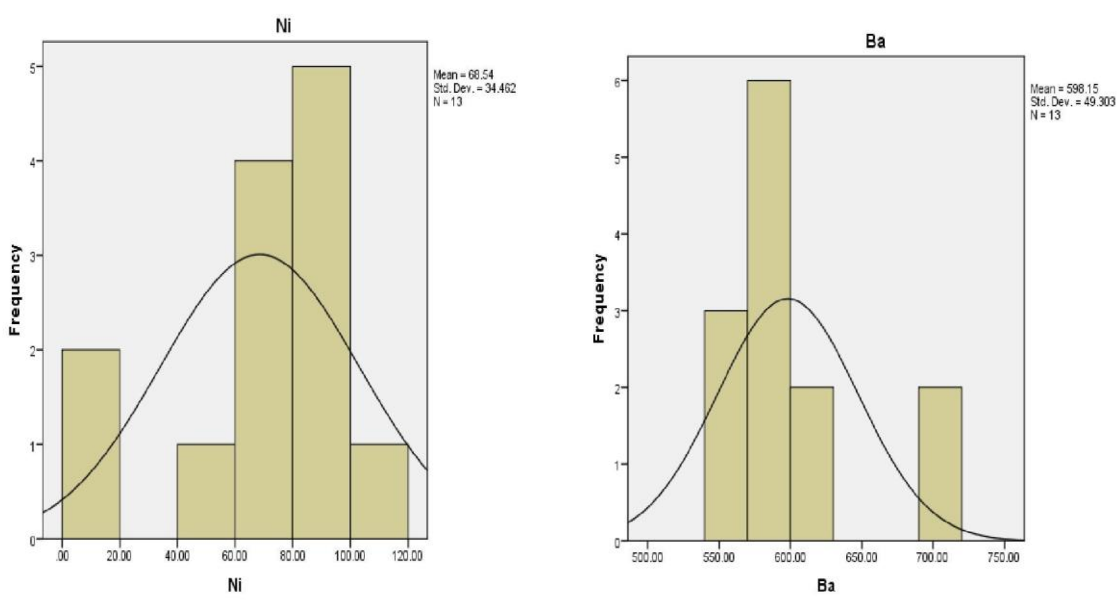
Table 2. Statistical data of trace element within the study area

						95% Confidence Interval of the Difference	
	N	Mean (BACKGROUND)	Std. Deviation	Covariance	THRESHOLD	Lower	Upper
K	13	3.1854	.54365	0.296	4.230037	2.8569	3.5139
Ca	13	5967.69	1784.677	3185070	9397.0158	4889.22	7046.16
Ti	13	1696.77	532.238	283277.7	2719.4854	1375.14	2018.40
Cr	12	35.33	9.442	89.152	53.4134	29.33	41.33
Mn	13	210.92	142.922	20426.744	485.5534	124.56	297.29
Fe	13	3905.2785	3881.0115	24.007	11455.337	1644.7728	6335.3164
Co	12	210.50	123.962	15366.455	447.8682	131.74	289.26
Ni	11	81.00	17.743	314.80	91.2013	69.08	92.92
Zn	13	37.54	12.231	149.603	44.0569	30.15	44.93
Rb	13	111.54	14.403	207.436	119.2142	102.84	120.24
Sr	13	424.92	96.866	9383.077	476.5469	366.39	483.46
Zr	13	650.15	796.579	634538.6	1074.6818	168.79	1131.52
Ag	13	35.77	8.012	64.192	40.0391	30.93	40.61
Cd	11	33.45	6.186	38.273	37.0115	29.30	37.61

Ba	13	598.15	49.303	2430.808	624.4294	568.36	627.95
Hg	5	12.60	2.408	5.80	14.5267	9.61	15.59
Pb	13	29.69	2.594	6.731	31.0749	28.12	31.26
Mo	2	12.50	4.950	24.50		-31.97	56.97
Cu	9	55.56	25.026	626.278	71.2851	36.32	74.79

Table 3. Comparison of trace elements within the study area and Average Universal Crustal Abundance

Elements	Average crustal abundance (ppm/%) Emsley, (2001)	Mean	Std. Deviation	Threshold
K	2.6%	3.1854	.54365	4.230037
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	
Cu	100ppm	55.56	25.026	71.2851



A B

Fig. 3. (A &B) Histograms of some Trace elemnts in the study Area (A=Nickel, B=Ba)

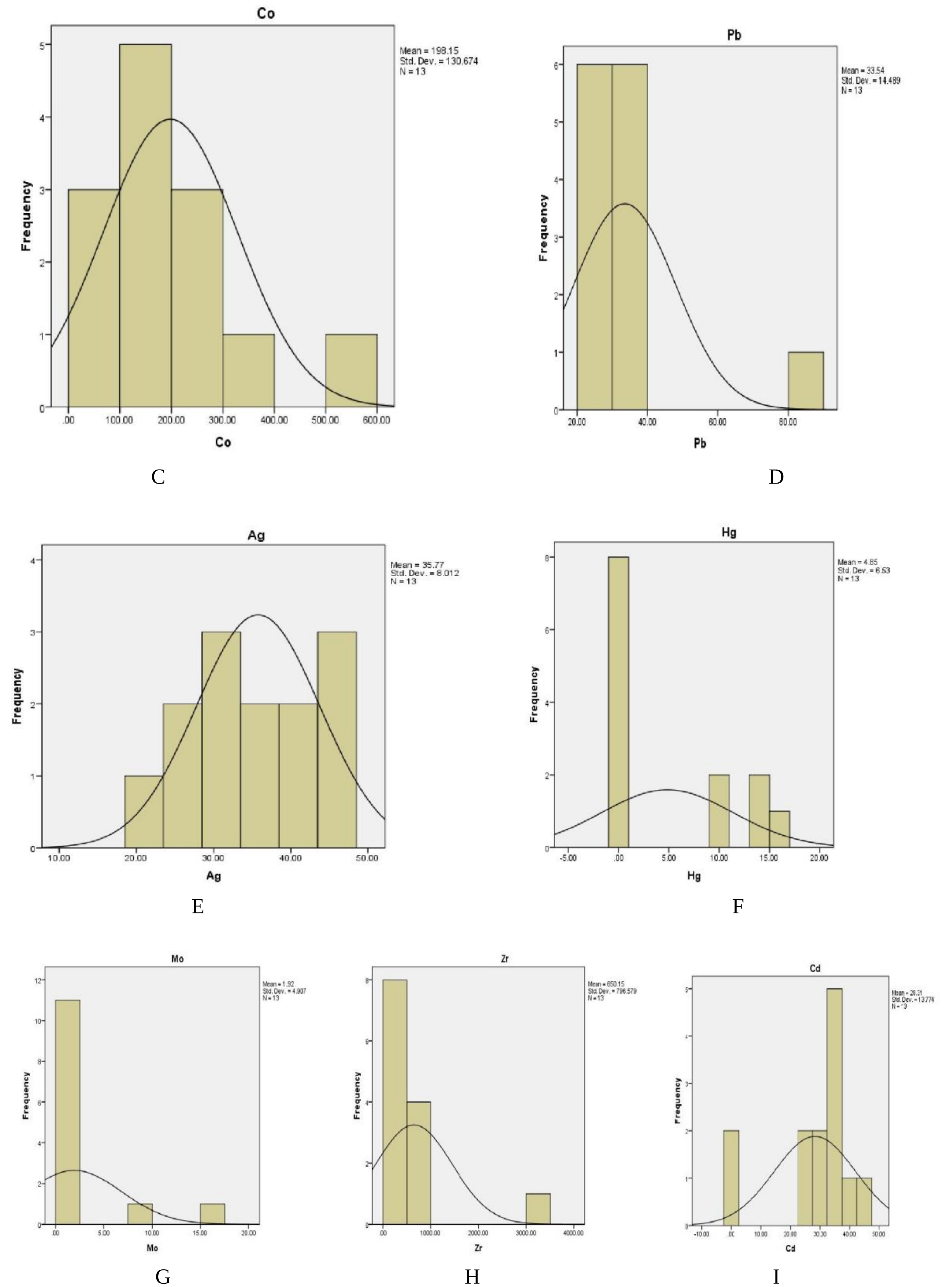


Fig. 3. Contd. (C-I) Histograms of some Trace elemnts in the study Area (C=Co, D=Pb, E=Ag, F=Hg, G=Mo, H=Zr, I=Cd.

Table 4. Correlation of trace elements in the study area

Correlations

	Ba	Zr	Co	Ag	Hg	Cd	Pb	Mo	Ni	Ca	K	Ti	Cr	Mn	Fe	Cu	Zn	Rb	Sr
Ba	1																		
Zr	.203	1																	
Co	.504	.388	1																
Ag	.393	.422	.366	1															
Hg	.339	.432	.241	.491	1														
Cd	.009	-.052	.139	.470	.038	1													
Pb	.129	.037	-.349	.259	.525	-.039	1												
Mo	-.305	-.007	.017	-.444	-.315	-.103	-.200	1											
Ni	.096	-.201	-.206	.360	.162	.231	.302	-.844**	1										
Ca	.485	.224	.692**	.191	.487	.317	.027	-.006	-.226	1									
K	.646*	-.043	-.024	.011	-.222	.124	-.051	-.122	.191	-.017	1								
Ti	-.128	.460	.299	-.265	-.069	-.412	-.189	.291	-.564*	.260	-.344	1							
Cr	-.047	.129	.572*	.025	-.362	-.066	-.640*	.359	-.326	.025	-.093	.138	1						
Mn	-.185	-.017	-.048	.239	-.262	-.149	-.179	-.244	.289	-.626*	-.188	-.128	.198	1					
Fe	.031	-.365	-.529	.115	.006	.191	.156	-.196	.288	-.299	.327	-.439	-.499	-.146	1				
Cu	.283	.681*	.744**	.538	.239	.445	-.280	.007	-.084	.488	.067	.260	.384	.016	-.374	1			
Zn	-.031	.623*	.574*	.301	.100	.209	-.308	.253	-.156	.160	-.089	.196	.572*	.042	-.368	.734**	1		
Rb	-.035	-.048	-.146	.279	-.027	-.319	.207	-.669*	.699**	-.468	-.090	-.123	.014	.585*	.021	-.173	-.151	1	
Sr	.457	-.092	.288	-.201	.360	.084	.212	.214	-.319	.788**	.193	.057	-.173	-.847**	-.065	-.019	-.134	-.616*	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

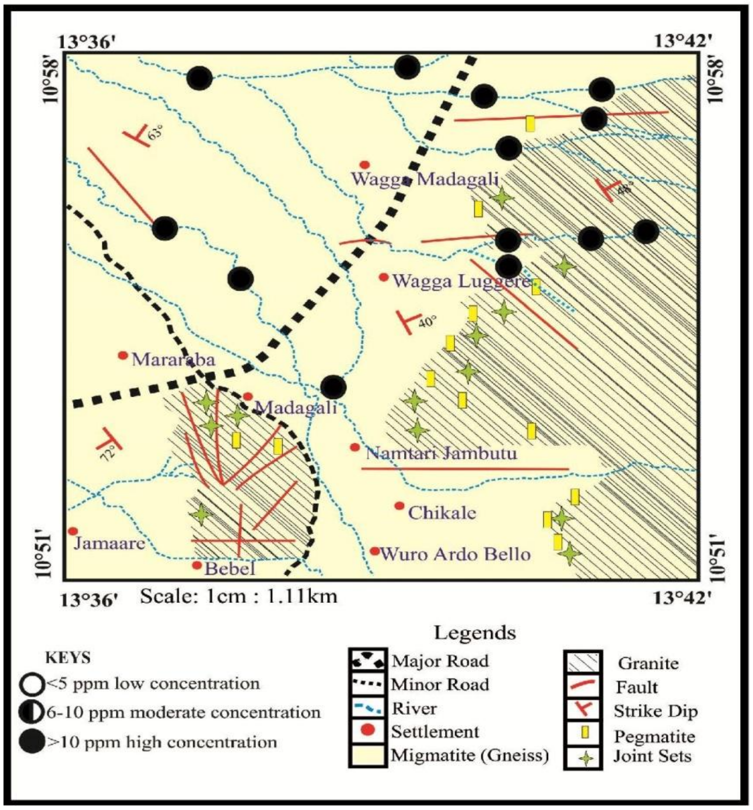


Fig. 4. Nickel concentration of stream sediments samples in the study area

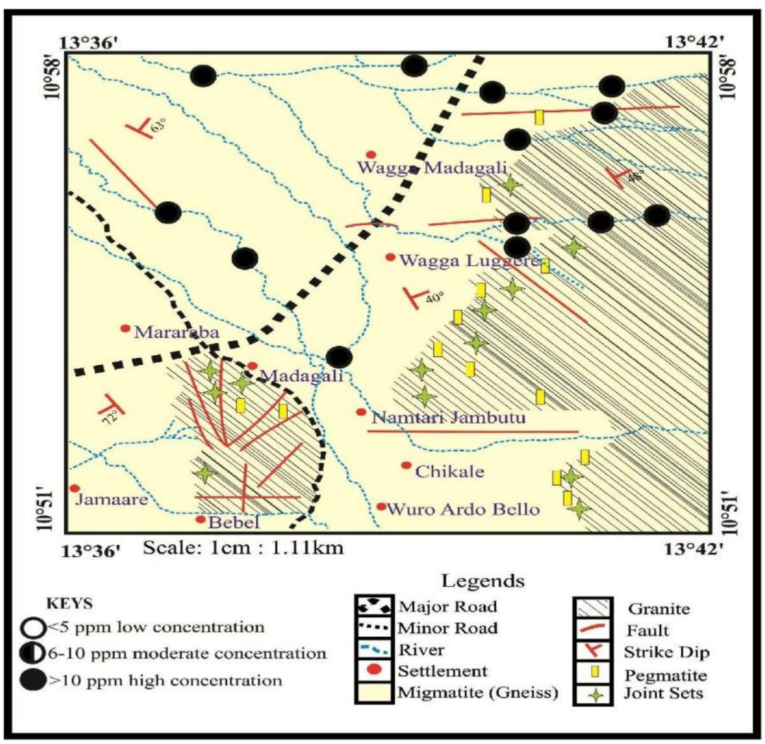


Fig. 5. Titanium concentration of stream sediments samples in the study area

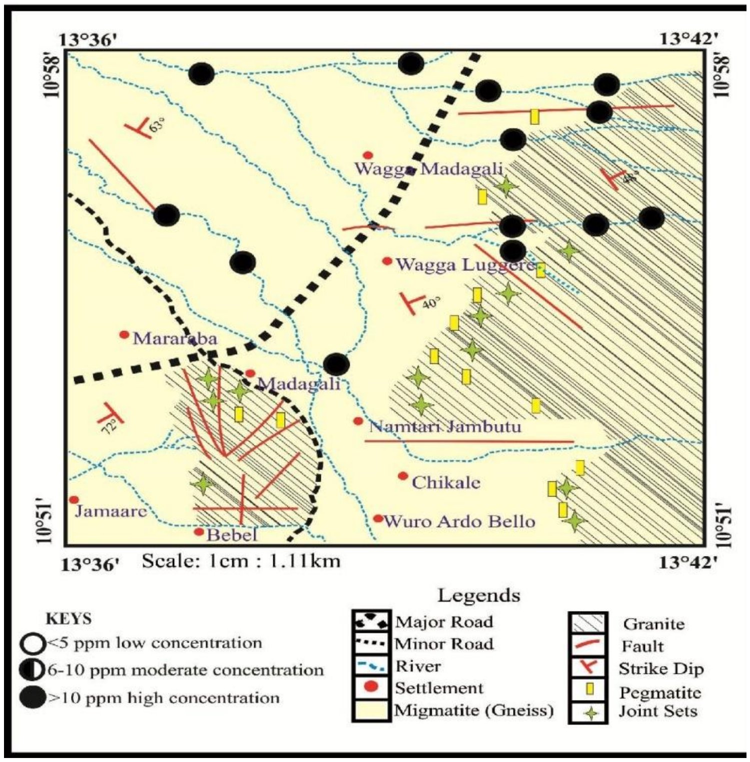


Fig. 6. Barium concentration of stream sediments samples in the study area

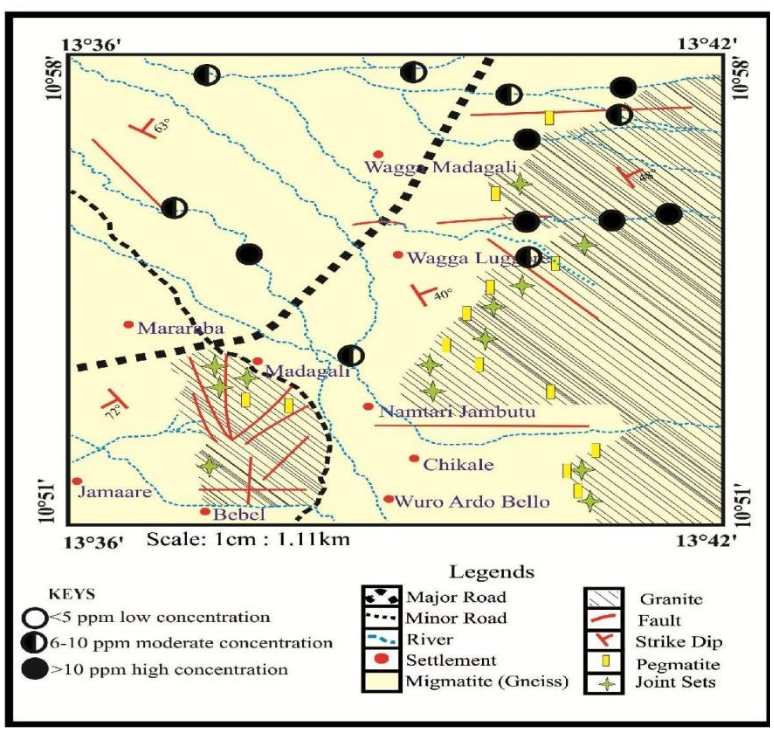


Fig. 7. Zircon concentration of stream sediments samples in the study area

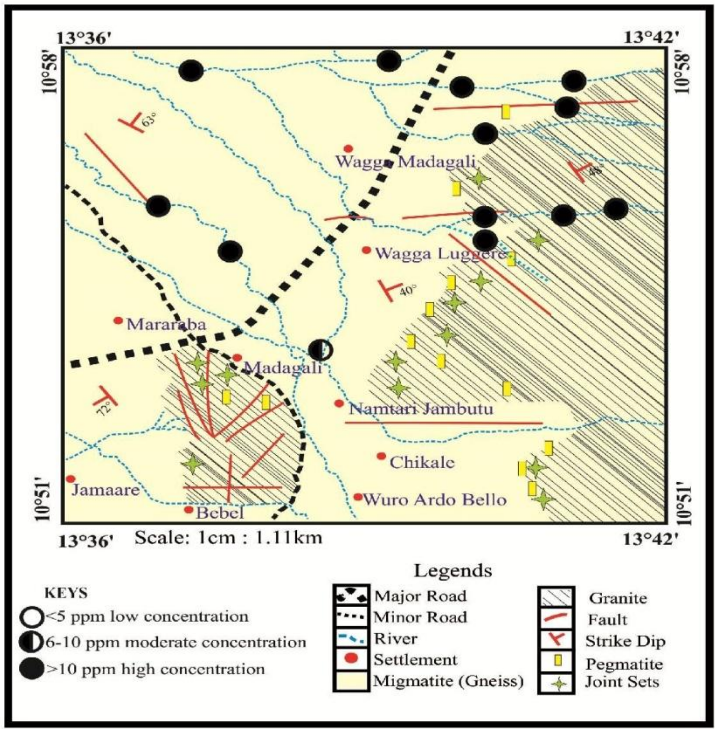


Fig. 8. Manganese concentration of stream sediments samples in the study area

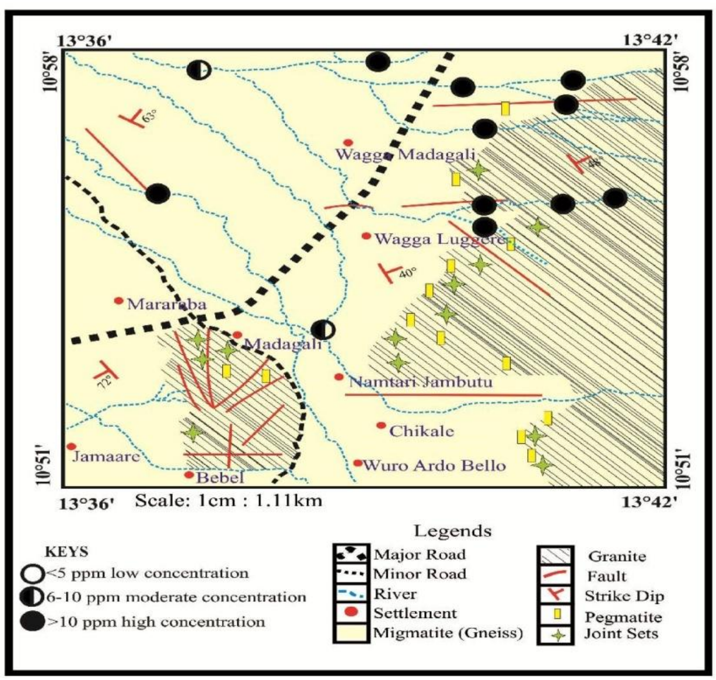


Fig. 9. Cobalt concentration of stream sediments samples in the study area

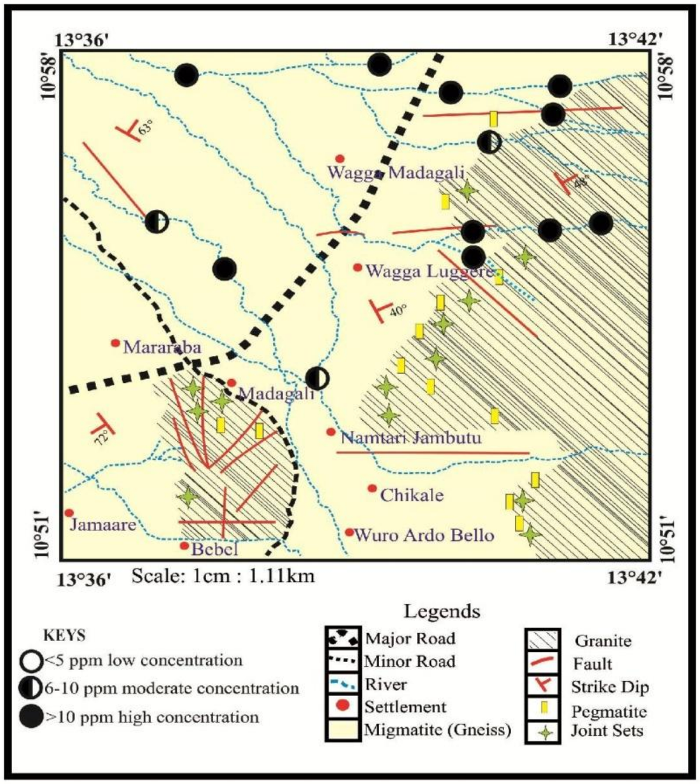


Fig. 10. Silver concentration of stream sediments samples in the study area

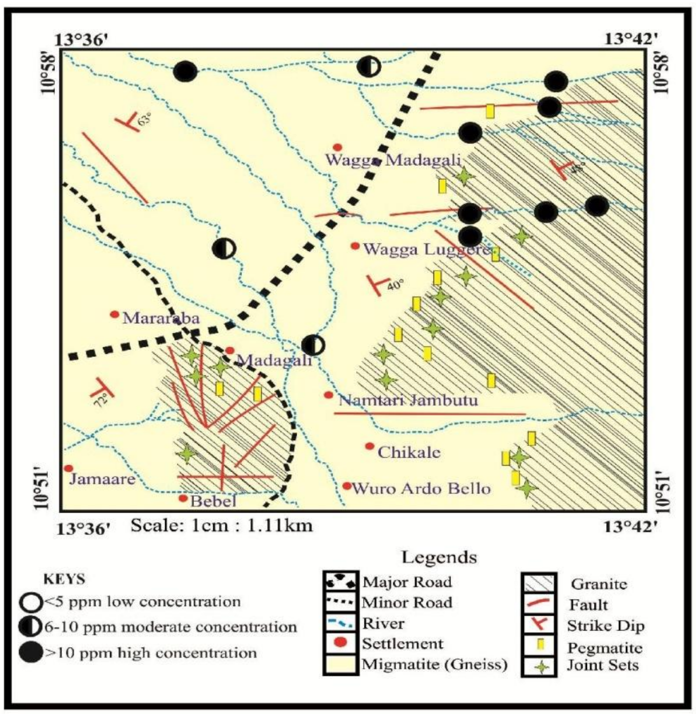


Fig. 11. Cadmium concentration of stream sediments samples in the study area

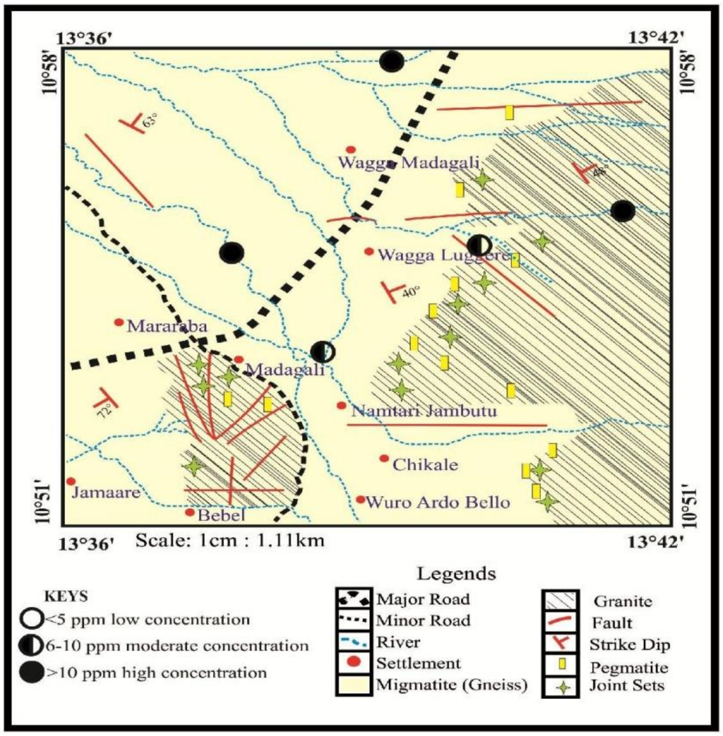


Fig. 12. Mercury concentration of stream sediments samples in the study area

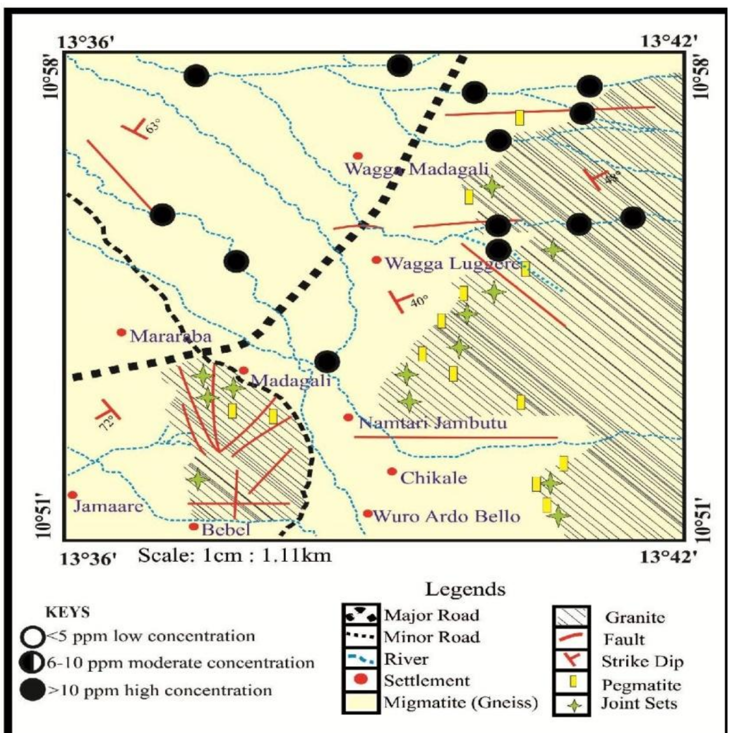


Fig. 13. Lead concentration of stream sediments samples in the study area

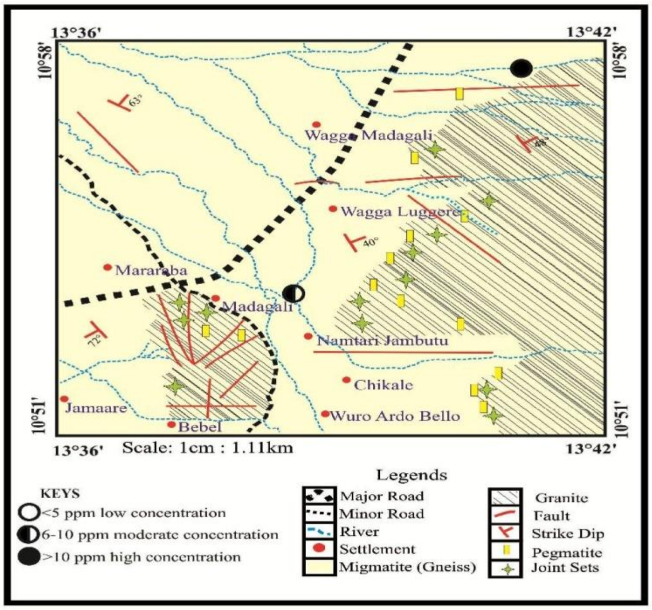


Fig. 14. Molybdenum concentration of stream sediments samples in the study area

4.1 Discussion of Result

From the above geochemical data, elements could said to be apparently anomalous with their values much higher than the background values and average universal crustal abundance as could be observed on (Tables 2 and 3).

The element includes Titanium (Ti), Manganese (Mn), Iron (Fe), Nickel (Ni), zinc (Zn), Zircon (Zr), Silver (Ag), Cadmium (Cd), Barite (Ba), Lead (Pb), Cobalt (Co) and Mercury (Hg). It could therefore be stated that, these anomalous concentration are significant and may be linked to mineralization. The anomalous concentration of these elements also suggests that they are indicator of their own mineralization. No significant correlation is observed amongst the trace elements to suggest similar source of mineralization.

The concentration of Titanium (Ti) is also high at this area compared to other anomalous values elsewhere within the study area. The highest peak of Titanium (Ti) where sample SSG 3, has 2808ppm while SSG 13 is 2527ppm, SSG 9 is 2100ppm and 2007ppm for (SSG7) but their concentration is less than the average crustal abundance in the study area.

Zinc is anomalously concentrated in sample (SSG13) where it occurs in association with significant anomalous value of Pb. This may be termed as possible Pb-Zn mineralization due to the disparity between the background value of 12.4ppm (Emsley, 2001) and the anomalous value of 34ppm of Pb in sample (SSG4). The association of Ni, Zn and Mn might be an indication of many oxide mineralizations.

Barium (Ba) is another most anomalous element within the study area mostly concentrated around Wagga Luggere (Fig. 6), Ba has a high anomaly in sample SSG4 and SSG5 with value of 704ppm and 696ppm respectively (Table 1), which is much higher than the average of crustal abundance. The enrichment of Co might be associated with Ca in the area. Pearson correlation indicates significant correlation of (0.801) between the two elements indicating similar source of mineralization.

Zircon has maximum value in (SSG11, Table 1), and by observing the geochemical map (Fig. 7), it is seen that Zr is highly concentrated at the northeastern part of the study area.

The spatial distribution of most of the anomalous elements such as Manganese, cobalt, nickel, molybdenum and zinc in the study area (Figs. 4-14) leads to the assumption that the behaviors of these element is controlled by local drainage condition. Hence, mineralization may be located upstream.

4.2 Implication for Mineral Exploration

The study area has no history of economic minerals mining and studies so far have shown appreciable mineralization potential. Calcium, Barium, Cobalt, Cadmium, Molybdenum and Titanium being the most anomalous elements in the study area could form a particularly attractive target for mineral exploration in the area.

Conclusion

The geology of the area is fairly studied consisting of fine-medium-coarse to porphyritic granite, pegmatite and migmatite gneisses. Presence of fault, fractures and joints may serve as the structural control of the anomalous concentration of trace elements in the study area. The research has ended up in the delineation of some prospective targets for mineral deposits. Target of anomalous distribution of these trace elements include; Mn, Ba, Zn, Cd, Ag, Zr, Co, Mo, and Ti which are mostly found in the northeastern portion of the study area. Therefore if these targets are further assessed, they may meet the objectives of this work.

Recommendation

Based on the above analyses of result and conclusion, it is observed that relevant and significant mineralization of Mn, Ba, Zn, Cd, Ag, Zr, Co, Mo, and Ti occurs within the study area.

It is in view of this, that we therefore recommend that detailed exploration to be carried out, particularly around the northeastern part of the study area. This is with the view to pinpoint areas of mineralization across the study area.

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