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Research paper

Geochemical investigation of stream sediments from the nlonako area; littoral, Cameroon: implications for Au, Ag, Cu, Pb and Zn mineralization potentials

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Abstract

Nlonako area belongs to Cameroon Volcanic Line. To determine the mineralization potentials of the area, stream sediment survey and geochemistry were carried out. The results show weak anomalies in Gold and Silver with threshold values of 0.001 and 0.073 respectively. Copper, Lead and Zinc have some relatively high values which are 690ppm, 182ppm and 378ppm with mean values statistically calculated to be 73.90, 46.51 and 198.58 respectively. The data analyzed using multivariate statistical methods yielded 5 factors from Principal Component Analysis (PCA). These five factors are; Factor 1 (Ce, La, Nb, Y), Factor 2 (W, Mo, Sr, As, Cd, Ni), Factor 3 (Pb, Sn, Zn, Sb), Factor 4 (Au, Ag, Cu) and Factor 5 (Cr, Co, Bi). These factors point mostly to a possible sulphide mineralization. Gold shows high correlation with Ag and Cu while Y correlates more highly and positively with Ce and La. There is a relatively high input of the light rare-earth elements which form the highest factor (34.363%) of the total PCA variance and possibly points to a granitic source rock. The existence of mafic–ultramafic igneous rocks in the study area underlies high correlations between Cr and Co and other factors gotten from PCA.

Keywords: *Anomalies; Geochemistry; Mineralization; Nlonako Area; Stream Sediments.*

1. Introduction

Sampling and analysis of stream sediments is a well-known method of mineral exploration especially at the reconnaissance and detailed scales in many areas (e.g. Ottesen & Theobald 1994). Active sediments in the channels of streams and rivers can contain high concentrations of metals derived from the weathering of mineralized rocks within the upstream catchment. When geochemical data of stream sediments are spatially displayed as well as statistically treated using appropriate procedures, they can unravel element associations that are relevant to primary exploration in a region (Atsuyuki et al, 2005).

These associations can also be useful in deciphering the source region lithology and the nature of the primary mineralization, (e.g. Levinson, 1974, Plant and Hale, 1994, Key et al., 2004). Generally, the chemical composition of stream sediments can be dependent on many factors. Some of these factors are the rock type, morphology and structural setting of the catchment, and the effect of climate. The use of stream sediments in mineral exploration in Cameroon has so far received little attention. However some examples include Embui et al, (2013), Soh et al, (2014), Mumbfu et al, (2014) and Omang et al, (2014). These works have investigated the concentrations of gold and associated elements in stream sediment in some areas of Cameroon with some giving clues on future exploration guides (e.g. Embui et al., 2013). More so, the areas have had a history of at least some legal artisanal mining and somehow explored. However, the history of exploitation in the Nlonako area and environs is not quite clear because it is not published, although some indications of such an activity exist in the area but information on exploration here is virtually absent. The available outcrops in this area consist petrographically of some volcanic and plutonic rocks.

To search for mineral potentials in Nlonako, a preliminary stream sediment survey was designed targeting some of the accessible stream beds in the area. The objective of this paper is to present and analyse preliminary baseline geochemical data which brings some information on the geochemical distribution of some elements within the heavy mineral fraction of the stream sediments of Nlonako and environs which will provide a useful guide for future exploration strategies.

2. Geological setting

The study area is located along the Cameroon Volcanic Line (CVL) which is an extensive range of volcanoes (Kamgang et al, 2008). The volcanoes of the CVL (Fig.1 B) are Tertiary to Recent in age and extend within oceanic and continental domains measuring about 1700km in length. It is made up of prominent features like the the Mounts Fako, Bamboutos, Bamenda, Oku, Manengouba, Nlonako, Koupe etc. Nlonako area (Fig. 1C) is made up of both volcanic and plutonic rocks both related to the CVL (Abolo et al, 2014). Most of the volcanic rocks are basaltic while the plutonic rocks include gabbros and granites mostly related to the Nlonako anorogenic complex. Gneisses and other rocks types are also found in the area (Fig. 2).

3. Method of study

3.1. Field methods

Heavy mineral fractions of stream sediments were collected along stream beds of the study area by panning. They were sampled mostly at depths of 30-45 cm and panned on site in order to concentrate the heavy fraction that was stored in clean polyethylene bags and transported to the laboratory. During the sampling process, simultaneous site surveys were carried out in order to provide specific information in relation to the geology of the catchment.

3.2. Laboratory methods

Laboratory works were carried out by the commercial analytical laboratory (www.alsglobal.com) Australia Laboratory Services (ALS). There, the samples were first dried at 60^0C, crushed and milled to fine powder. Five grams of each sample were then decomposed by aqua regia digestion in a graphite heating block. After cooling, the resulting solution was diluted with deionizer water, mixed and analyzed by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) followed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The analytical results were corrected for interelement spectral interferences.

4. Results

The concentrations of various elements in the stream sediment samples are presented on Table 1. For base metals; concentrations are characterized by high values and wide ranges e.g. Cu (4.28-690ppm), Pb (3.84-182ppm), Zn (53.6-373ppm) with mean concentrations of 73.902ppm, 46.508ppm and198.58ppm respectively (Fig. 3 and 4). Precious metals like Silver (Ag) values are all above detection limit with the maximum being 1.15ppm. Gold (Au) was not detected in all samples but the highest values of concentration were found in sample ARSS12 (0.102ppm). However, the ranges of concentration of precious metals are 0.0001 - 0.102ppm for gold and 0.004-1.15ppm for silver (Fig. 3) and the means of Ag and Au are 0.11 and 0.08 respectively (Table 1). Some of the transition metals include Cr, Ni and Co with concentration ranges between 39.1-311ppm, 14.15-349ppm and 16.3-81.6ppm respectively with their concentrations in all stream sediment samples above detection limit. Some Platinum Group Elements (PGE) were also found in the stream sediment samples like Palladium and platinum but Pd was found only in sample ARSS08 and ARSS13 while platinum was found in all other samples except in samples ARSS03, ARSS04, ARSS05, ARS06 and ARSS13. Values of PGEs found range from 0.06-0.001ppm and0.004-0.002ppm respectively for Pd and Pt respectively.

From Table1 Cerium (Ce) is the most abundant light REE with mean concentration values of 143.96, with maximum and minimum values in ARSS12 and ARSS09 respectively, followed by La and Y. Thorium (Th) is the most abundant Radioactive Element with mean concentration values of 74.30ppm, with maximum and minimum values in ARSS01 and ARSS09 respectively followed by Pb, Sr, U and Rb.

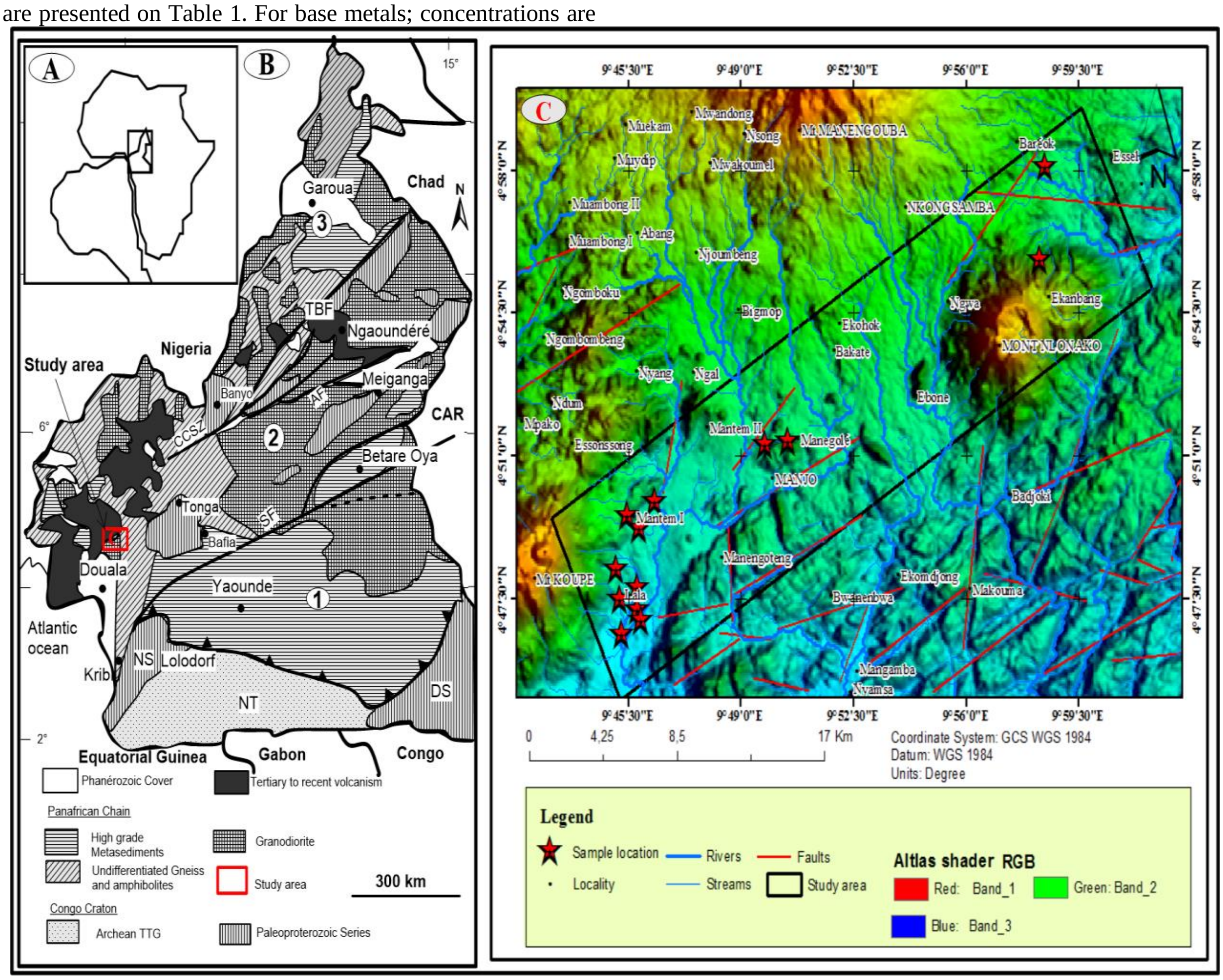


Fig. 1: Geologic Map of Cameroon (Nzenti Et Al. 2010) Showing the Location of Nlonako Area and the Main Lithotectonic Domains: (1) Southern Domain; (2) Central Domain; (3) Northern Domain; CCSZ: Central Cameroon Shear Zone; SF: Sanaga Fault; TBF: Tibati-Banyo Fault; NT:Ntem Complex; DS: Dja Series; NS: Nyong Series; AF: Adamawa Fault (C) Numeric Model of the Area of Study.

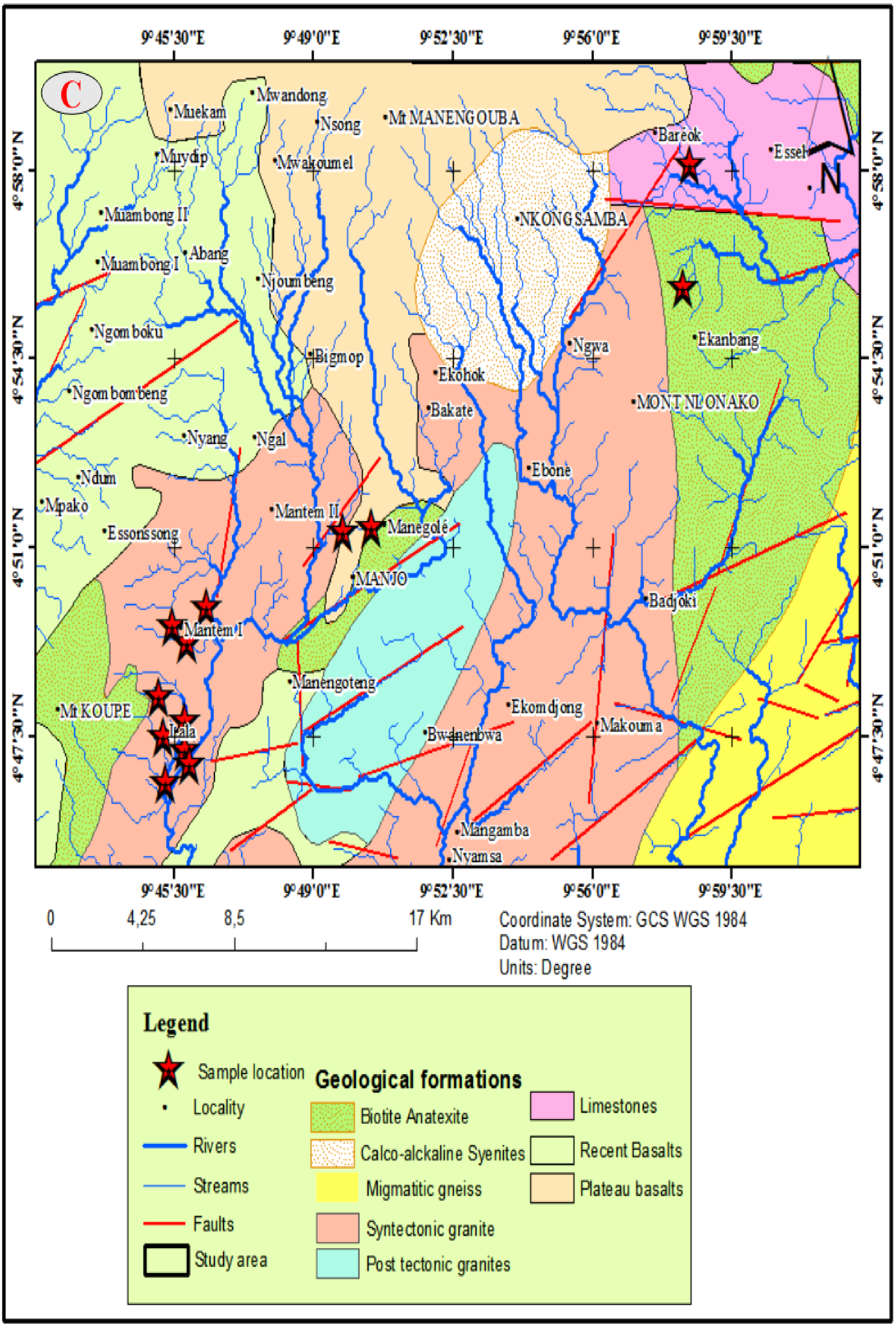


Fig. 2: Geologic Map of the Studied Area (Modified from Gazel Et Al., 1954).

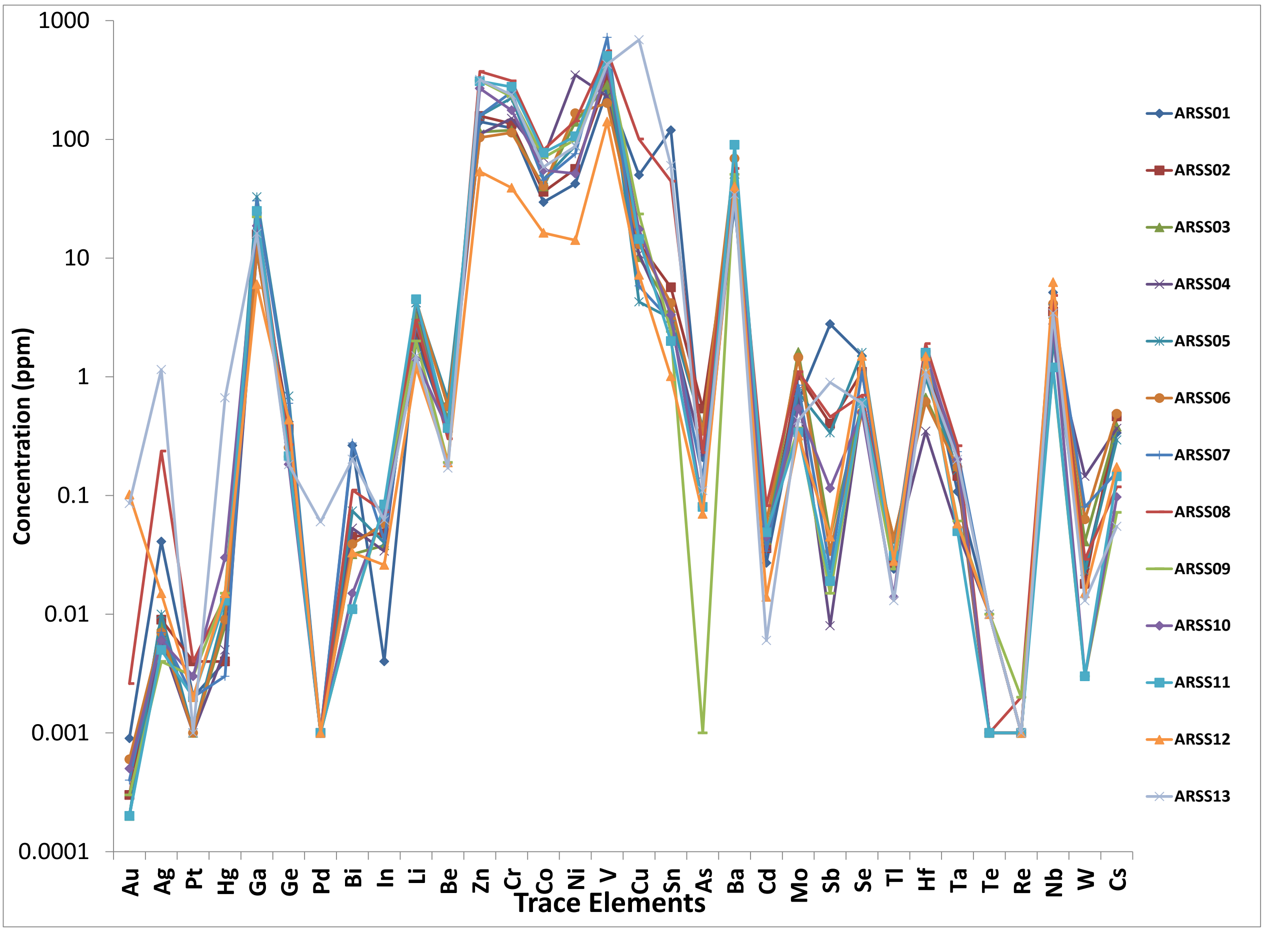


Fig. 3: Plots of Some Trace Elements' Concentrations Gotten from the Heavy Mineral Fractions.

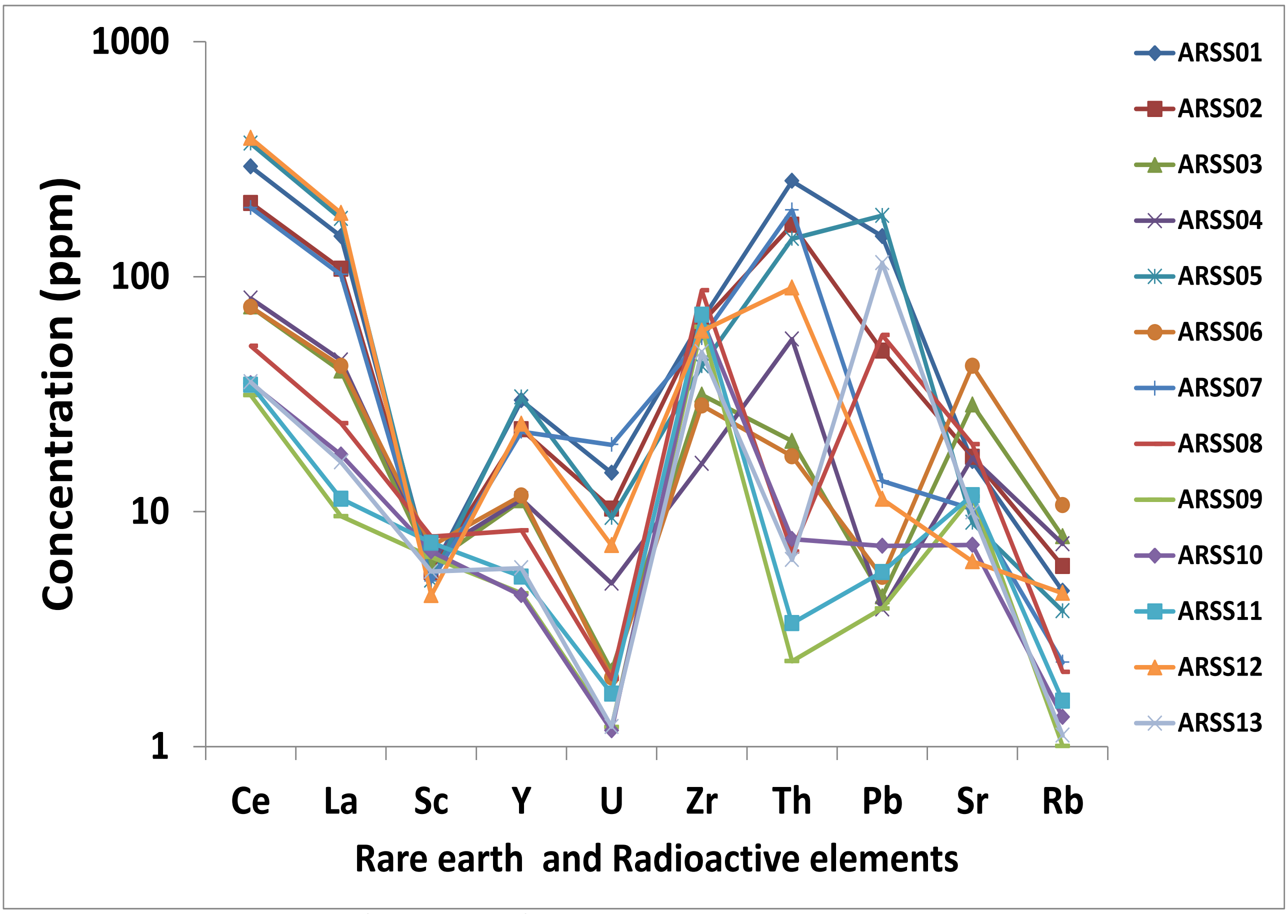


Fig. 4: Plots of Concentrations of Rees and Radioactive Elements in Stream Sediments (Ppm).

Table 1: Full Element Geochemical Data from Stream Sediments Sampling in Nlonako Area

Sample	ARSS01	ARSS02	ARSS03	ARSS04	ARSS05	ARSS06	ARSS07	ARSS08	ARSS09	ARSS10	ARSS11	ARSS12	ARSS13	MEAN (M)	MEDIAN	MAX	MIN	STDEV(S)	2S*M®
Au	0,0009	0,0003	0	0	0	0,0006	0,0004	0,0026	0,0003	0,0005	0,0002	0,102	0,0858	0,0149	0,0005	0,102	0	0,0352	0,0010
Ag	0,041	0,009	0,008	0,006	0,01	0,007	0,007	0,237	0,004	0,006	0,005	0,015	1,15	0,1158	0,0085	1,15	0,004	0,3171	0,0734
Al	0,82	1,02	1,05	0,82	0,94	1,29	0,71	1,49	1,32	1,06	1,83	0,33	0,95	1,0485	1,0342	1,83	0,33	0,3759	0,7882
As	0,21	0,54	0,37	0,22	0,37	0,35	0,14	0,23	<0.01	0,08	0,08	0,07	0,11	0,2308	0,2200	0,54	0,07	0,1487	0,0687
Ba	31,6	35,7	51	28,7	28,9	69,1	28,6	56,9	50,7	34,5	89,9	40,1	34,2	44,6077	37,9000	89,9	28,6	18,5196	1652,2377
Be	0,36	0,37	0,43	0,38	0,64	0,56	0,4	0,3	0,19	0,36	0,37	0,19	0,17	0,3631	0,3665	0,64	0,17	0,1363	0,0990
Bi	0,264	0,045	0,032	0,053	0,074	0,039	0,277	0,111	0,011	0,015	0,011	0,033	0,202	0,0898	0,0490	0,277	0,011	0,0954	0,0171
Cd	0,027	0,036	0,042	0,038	0,045	0,059	0,034	0,082	0,05	0,045	0,049	0,014	0,006	0,0405	0,0413	0,082	0,006	0,0192	0,0016
Ce	294	206	74,5	80,8	369	74,3	196,5	50,7	31,3	35,1	34,7	389	35,6	143,9615	77,6500	389	31,3	132,4120	38124,4703
Co	29,6	36,1	40	69,7	46,1	40,3	45,4	81,6	70,2	55	77,2	16,3	58,5	51,2308	48,6654	81,6	16,3	19,5525	2003,3802
Cr	124,5	135,5	119,5	150	223	114	251	311	229	176	277	39,1	237	183,5846	179,7923	311	39,1	77,8827	28596,1188
Cs	0,336	0,463	0,38	0,367	0,293	0,489	0,158	0,118	0,072	0,097	0,145	0,174	0,055	0,2421	0,2080	0,489	0,055	0,1520	0,0736
Cu	50	13,25	10,15	10,85	4,28	13,1	5,82	100,5	23,5	17,5	14,45	7,23	690	73,8946	13,8500	690	4,28	186,9613	27630,8739
Ga	12,15	15,85	13,4	11,45	32,8	11,55	30,4	24	22,2	18,7	24,9	6,02	16,15	18,4285	17,2892	32,8	6,02	7,9771	294,0108
Ge	0,418	0,367	0,275	0,301	0,687	0,254	0,598	0,268	0,212	0,183	0,214	0,435	0,182	0,3380	0,2880	0,687	0,182	0,1589	0,1074
Hf	1,635	1,545	0,669	0,348	0,982	0,616	1,385	1,9	1,405	1,61	1,595	1,485	1,09	1,2512	1,3950	1,9	0,348	0,4703	1,1769
Hg	0,004	0,004	0,008	0,005	0,011	0,009	<0.004	0,014	0,015	0,03	0,013	0,015	0,665	0,0661	0,0130	0,665	0,004	0,1887	0,0249
La	148,5	108	39,7	44,1	176,5	41,7	102	23,8	9,56	17,45	11,35	186,5	16,25	71,1854	42,9000	186,5	9,56	65,0603	9262,6834
Li	2,1	2,5	3,3	4,2	4,2	4,4	2,8	3	2	1,4	4,5	1,2	1,5	2,8538	2,8269	4,5	1,2	1,1921	6,8040
Mo	0,62	1,03	1,62	0,77	0,74	1,45	0,85	1,1	0,37	0,54	0,34	0,32	0,43	0,7831	0,7550	1,62	0,32	0,4188	0,6559
Nb	5,13	3,54	3,39	1,905	2,07	4,11	4,04	4,84	1,16	2,78	1,2	6,27	3,43	3,3742	3,4100	6,27	1,16	1,5404	10,3955
Ni	42,3	56,4	140,5	349	88,4	166	75,7	143	99,6	51,5	106	14,15	87,5	109,2346	94,0000	349	14,15	83,9682	18344,4587
Pb	148,5	48,4	4,35	3,84	182	5,27	13,5	56,4	3,87	7,14	5,53	11,3	114,5	46,5077	12,4000	182	3,84	62,0211	5768,9156
Pd	<0.001	<0.001	<0.001	0,001	<0.001	<0.001	<0.001	0,001	<0.001	<0.001	<0.001	<0.001	0,06	0,0207	0,0108	0,06	0,001	0,0341	0,0014
Pt	0,002	0,004	<0.002	<0.002	<0.002	<0.002	0,002	0,004	0,003	0,003	0,002	0,002	<0.002	0,0028	0,0028	0,004	0,002	0,0009	0,0000
Rb	4,59	5,86	7,83	7,28	3,77	10,65	2,28	2,08	1,005	1,335	1,565	4,5	1,115	4,1431	3,9565	10,65	1,005	3,0340	25,1404
Re	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,002	0,002	0,001	0,001	0,001	0,001	0,0012	0,0010	0,002	0,001	0,0004	0,0000
Sb	2,78	0,403	0,045	0,008	0,337	0,034	0,024	0,46	0,015	0,115	0,019	0,045	0,898	0,3987	0,0800	2,78	0,008	0,7624	0,6080
Sc	5,52	5,53	6	6,55	5,1	7,14	5,05	7,83	6,41	6,76	7,37	4,4	5,56	6,0938	6,0469	7,83	4,4	1,0156	12,3774
Se	1,5	1,1	0,6	0,6	1,6	0,5	1,1	0,7	0,6	0,5	0,6	1,5	0,6	0,8846	0,6500	1,6	0,5	0,4180	0,7396
Sn	119,5	5,67	3,79	2,7	3,11	4,17	2,96	44,4	2,41	3,32	2	1,01	60,1	19,6262	3,5550	119,5	1,01	35,3172	1386,2827
Sr	16,35	17,1	28,5	16,95	8,98	41,7	10,25	19,35	11,6	7,21	11,75	6,14	9,95	15,8331	13,7915	41,7	6,14	9,8348	311,4313
Ta	0,108	0,146	0,176	0,05	0,163	0,173	0,234	0,262	0,061	0,202	0,05	0,058	0,201	0,1449	0,1545	0,262	0,05	0,0731	0,0212
Te	0,01	<0.01	<0.01	0,01	<0.01	<0.01	0,01	<0.01	0,01	<0.01	<0.01	0,01	0,01	0,0100	0,0100	0,01	0,01	0,0000	0,0000
Th	255	166,5	19,95	54,2	145	17,2	192	6,76	2,31	7,63	3,35	89,8	6,24	74,3031	37,0750	255	2,31	86,9477	12920,9660
Ti	1,98	1,955	1,005	0,75	1,28	0,892	1,415	3,65	3,03	3,11	3,11	2,21	2,82	2,0928	2,0364	3,65	0,75	0,9787	4,0967
Tl	0,024	0,027	0,043	0,032	0,031	0,044	0,027	0,031	0,024	0,014	0,031	0,028	0,013	0,0284	0,0282	0,044	0,013	0,0090	0,0005
U	14,6	10,3	2,1	4,95	9,41	1,965	19,25	1,94	1,21	1,17	1,68	7,18	1,215	5,9208	3,5250	19,25	1,17	5,9010	69,8768
V	260	331	288	230	486	202	723	556	474	408	503	141	430	387,0769	397,5385	723	141	164,0703	127015,69
W	0,024	0,018	0,041	0,145	0,023	0,063	0,08	0,029	0,003	0,003	0,003	0,015	0,013	0,0354	0,0235	0,145	0,003	0,0403	0,0029
Y	29,7	22,4	11,15	11,3	30,7	11,7	21,9	8,32	4,49	4,4	5,29	23,6	5,75	14,6692	11,5000	30,7	4,4	9,6789	283,9648
Zr	65,3	63,7	31,4	16	41,6	28,3	54,8	87,5	61,1	66,2	68,8	58,7	47,8	53,1692	56,7500	87,5	16	19,5438	2078,2590
In	<0.005	0,048	0,038	0,034	0,04	0,058	0,042	0,073	0,081	0,075	0,084	0,026	0,062	0,0551	0,0551	0,084	0,026	0,0198	0,0022
Zn	141	157,5	115,5	110,5	158	103,5	159	373	313	269	309	53,6	319	198,5846	158,5000	373	53,6	103,3211	41035,9491

® is the threshole =2standard deviation * mean

N.B: The values below detection limit are considered as half of the values of detection limit

The highest concentration of Cu (690ppm) was found in ARSS13 sampled around locality 12 which yields the highest gold concentration. The same location (locality 13) which is made up of granitic and gabbroic rocks yields the highest concentration of Cr (389ppm) and the values of Pb, Co, Zn, Ni are amongst the highest values in the whole study area. The highest Zn concentration (373ppm) amongst all samples is found in ARSS10 and the lowest concentration of Zn (53.6ppm) was found in ARSS12. La and Ce have concentration ranges of 9.56-186ppm and 31.3-389ppm respectively. For the presentation and interpretation of the data to be enhanced, graduated point symbol maps for some elements that make up the factors 3 and 4 were generated (Fig. 5). These plots show that most of the gold greater than 0.0009ppm occurs to the North eastern part of the study area as well as one sample in the south western part (Fig. 5). Cu and Pb (Fig. 5) concentrations above 52ppm are found both in the south western and north eastern parts of the study area while concentrations of Zn greater than 250ppm are found both in the north eastern and south eastern parts of the region (Fig. 5). Some high values of Zn (>250ppm) and Au (0.0009ppm) are found in the same sample found to the north eastern part of the study area. More so, it can be observed that some of the very high concentrations of Au, Ag, Cu, Pb and Zn are found in the same samples except for a sample around the central area which is not very high in Zn concentration compared relatively.

5. Discussion and interpretation

Threshold values from which background and anomalous concentrations can be gotten are given by 2standard deviation × mean (2S*M, Table 1). However, from the data in this work it is evident that only two elements Au and Ag show very weak anomalies compared to geological standards. The threshold value of 0.001 for discriminating background from anomaly is lower than one Au concentration (0.102ppm in ARSS12) in the stream sediments of the studied area suggesting a weak Au anomaly.

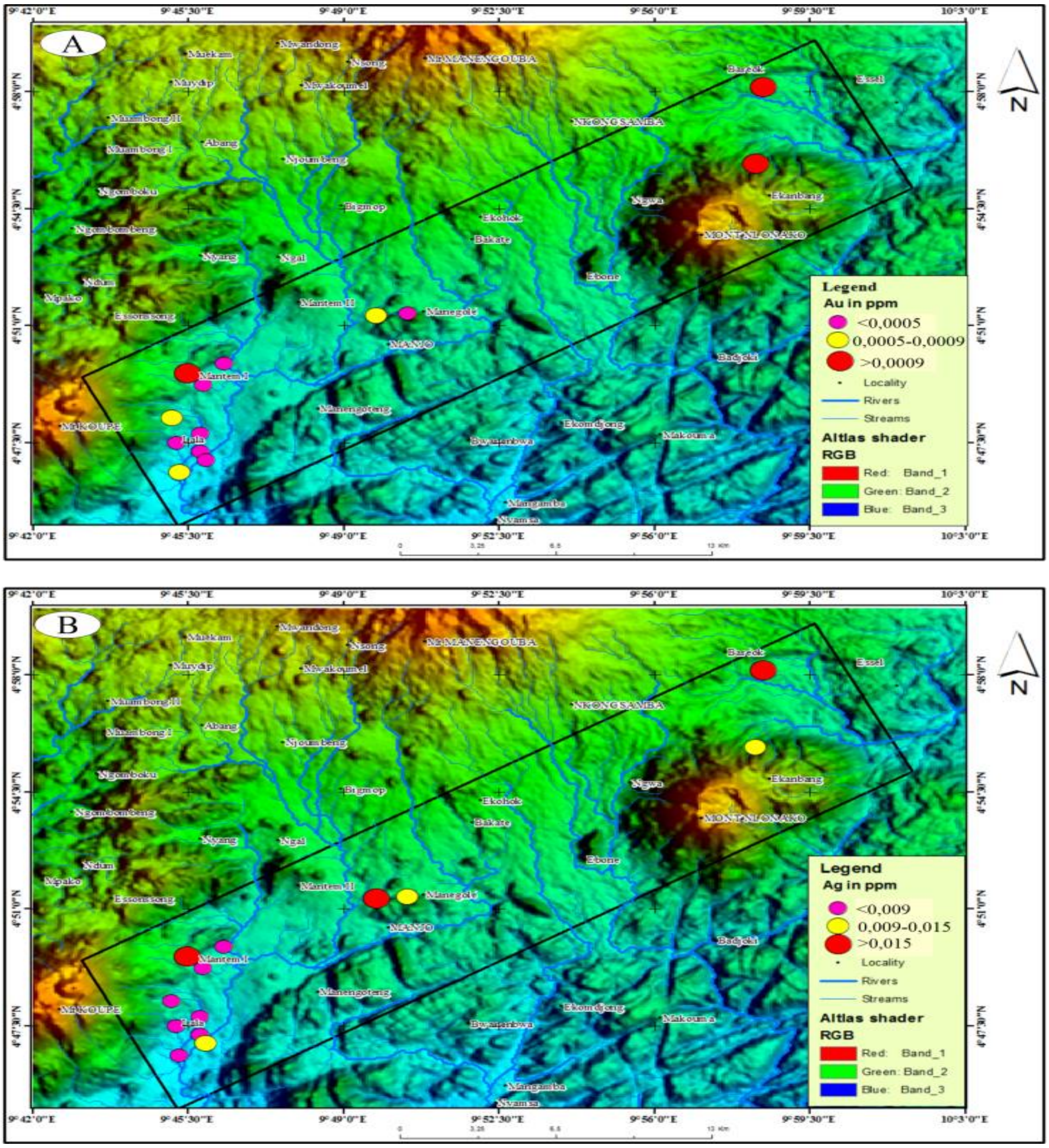
It is also shown that the threshold value of 0.07343 for discriminating background from anomaly is lower than the Ag value in one sample (1.15ppm in ARSS13). Worth mentioning is the fact that the average concentration of Cu (73.902) is very far lower than certain Cu concentrations (690ppm in ARSS13 and 100.5 in ARSS08) in the stream sediments of the studied area. This occurs in Essel village in the North eastern part of the study area. Furthermore there was comparison of the values gotten in this work with stream sediments geochemical data from where world stream sediment geochemical baselines for certain elements including Cu, Pb, Zn As and Cd are gotten (Callender, 2004) and have equally been used to establish geochemical anomalies elsewhere gotten from both lognormalised and raw geochemical data (e.g. Carpenter 1971, Adiotomre 2014, Yilmaz, 2007, Cocker, 1996, Stanislav, 2008). Most of these anomalies are accounted for in stream sediments from streams draining over areas of indicated mines and known mineralization at points in various areas clearly described in their literature. As such, a value of Cu (50.1ppm) below average in this study is a high anomaly elsewhere, where threshold was calculated by 2×standard deviation+mean (6.22ppm as anomaly for Adiotomre, 2014). Also, the average value of Zn (198ppm) for Zn is lower than the maximum Zn content of the analyzed stream sediments. This value is found in sample ARSS8 and compared to world baseline values of Oyarzun et al (2006) relatively, it is a very strong anomaly (e.g. in Adiotomre, 2014). This is the same case with some Pb concentration which (maximum is 144ppm) is higher than the average of 46.51ppm.

Worth mentioning equally is the fact that the concentration of Cu, Zn and Pb in these studied stream sediments are far higher than those studied elsewhere in Cameroon e.g. in Gouap Nkollo (Soh et al 2014), the maximum concentrations of Cu, Zn and Pb respectively in their studied stream sediments are 29ppm,210ppm and 43ppm. Also we have maximum concentrations of Cu, Zn and Pb in studied stream sediments (Embui et al 2013) of 88ppm, 99ppm and 44ppm in Waimba Lidi respectively. These two areas mentioned have relatively extremely high concentrations of gold in their studied stream sediments while on this scale, gold values in this work in Nlonako might be indicating that the mineralization can be of some other sulphide probably that of copper.

Other wide deviations from means exist which are in Ce (389ppm), V (723ppm), U (19.25ppm), Th (255ppm), which are higher than their averages which respectively are; 143.96ppm, 387.08ppm, 5.9208ppm and 74.303ppm (table 1b). The maximum concentration of Cerium is far lower than in Gouap Nkollo (1307ppm, Soh et al 2014) but higher than those in the studied stream sediments of Vaimba Lidi (163ppm, Embui et al 2013). This could be as a result of variations of the various elemental concentrations in the weathered parent rocks within their various catchments. The Pearson's correlation matrix computed for some elements (Table 2) reveals some inter element relationships. From table 3, it can be seen that Au has the highest correlation coefficient (r) of 0.566 with Cu and 0.561 with Ag. The strongest positive correlations occur between, La-Ce, Ag-Cu, La-Y, Zn-Cr, Sr-Mo. Other element pairs with positive r values include As-Sr, As-Mo, Bi-Sb, Cd-Co, Ce-Y, Co-Zn, Co-Cr, W-Ni, Pb-Y, Pb-Sb, Pb-Sn, Sn-Sb. Many elements have equally very low positive r values. These are for example Ni-Co, Pb-Cu, and Zn-Cu amongst others. To further investigate these element associations, the data were reduced by being subjected to principal component analysis (PCA), (Grunsky, 2002, 2010,) using the five factor model by rotation using quartimax method with Kaiser Normalization. Five factors or components were generated accounting for 90.975% (Table 3) of the total variance with each representing a cluster of interrelated elements within the data set. These five factors are Factor 1 (Ce, La, Nb, Y) from a REE lithology, Factor 2 (W, Mo, Sr, As, Cd, Ni) which is from sulphide – ultramafic inputs , Factor 3 (Pb, Sn, Zn, Sb) and factor 4 (Au, Ag,Cu), related probably to a sulpide mineralization and Factor 5 (Cr, Co, Bi) indicating an ultramafic lithology.

Factor 1 accounts for 36.477% of the total variance which is made up of four of the Light Rare Earth Elements; Ce, La, Nb, Y which mostly point to a felsic rock origin especially intrusive granites. More so, the strong correlation between La and Ce (Table 2) might be linked to accessory minerals phases e.g, flocerite $(Ce,La)F_3$, loperite $(Na,Ce,La)TiO_3$ and Xenotime (Y,Ce) PO_4 amongst other LREE mineral phases.

This correlates well with the fact that there are good outcrops of granites within the catchments. Factor 3 and 4 could equally point to granitic rocks with possible sulfide mineralization of Zn, Pb, Cu, in association with Au. Also factor 5 which has Co and Cr which correlate highly together with factor 2 having Nickel might point to the presence of mafic to ultramafic rock associations in the area. Mafic rock types have been sampled to the South west of the study area. It should be known that factors 2, 3, 4 and 5 account for 22.587%, 17.057%, 8.643%, and 6.213% respectively of the total variance.



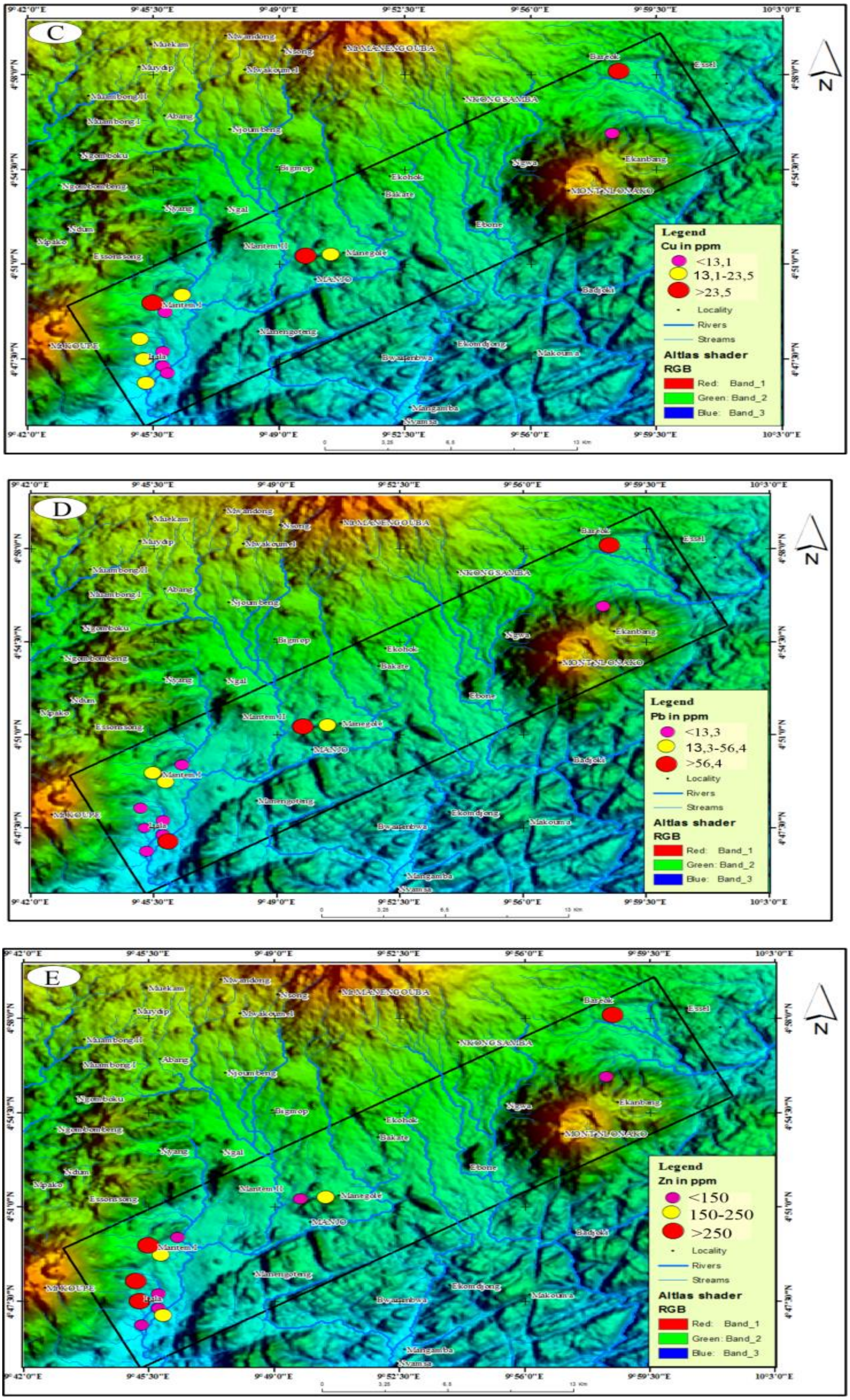


Fig. 5: Graduated Symbol Plots for (A) Au, (B) Ag, (C) Cu, (D) Pb and (E) Zn Scores (Ppm) Superimposed on the Drainage Map+ Numeric Model of the Nlonako Area.

Table 2: Pearsons Correlation Matrix

	Au	Ag	As	Ba	Bi	Cd	Ce	Co	Cr	Cu	La	Ni	Pb	Sn	Sr	Zn	Sb	Nb	Mo	W	Y
Au	1																				
Ag	**0.566**	1																			
As	-0.3	-0.19	1																		
Ba	-0.26	-0.14	-0.11	1																	
Bi	0.049	0.383	-0.08	-0.45	1																
Cd	-0.7	-0.42	0.191	**0.502**	-0.35	1															
Ce	0.376	-0.27	0.232	-0.47	0.245	-0.39	1														
Co	-0.37	0.189	-0.32	0.383	-0.18	**0.547**	-0.73	1													
Cr	-0.36	0.293	-0.26	0.241	0.212	0.442	-0.45	**0.812**	1												
Cu	**0.561**	**0.996**	-0.21	-0.15	0.385	-0.46	-0.27	0.167	0.263	1											
La	0.341	-0.28	0.273	-0.49	0.27	-0.4	**0.997**	-0.76	-0.47	-0.28	1										
Ni	-0.41	-0.06	0.147	0.077	-0.21	0.313	-0.43	0.493	0.076	-0.08	-0.41	1									
Pb	0.178	0.355	0.252	-0.41	0.491	-0.23	**0.5**	-0.18	0.147	0.355	0.492	-0.28	1								
Sn	0.053	0.411	-0.06	-0.21	**0.682**	-0.22	0.128	-0.11	0.041	0.422	0.138	-0.21	**0.618**	1							
Sr	-0.37	-0.16	**0.54**	0.412	-0.15	0.433	-0.3	-0.08	-0.26	-0.16	-0.26	0.412	-0.23	-0.02	1						
Zn	-0.21	0.442	-0.41	0.325	0.003	0.363	-0.62	**0.792**	**0.835**	0.424	-0.65	-0.09	0.05	0.166	-0.28	1					
Sb	-0.02	0.229	0.051	-0.29	**0.639**	-0.28	0.304	-0.27	-0.1	0.253	0.318	-0.29	**0.676**	**0.957**	-0.05	-0.01	1				
Nb	0.435	0.084	0.112	-0.22	0.41	-0.22	0.48	-0.64	-0.45	0.056	**0.501**	-0.38	0.118	0.41	0.132	-0.37	0.373	1			
Mo	-0.45	-0.21	**0.739**	0.118	-0.06	0.445	-0.15	-0.15	-0.18	-0.24	-0.11	0.33	-0.15	-0.13	**0.836**	-0.32	-0.14	0.194	1		
W	-0.22	-0.18	0.2	-0.26	0.165	0.049	-0.06	0.079	-0.14	-0.19	-0.02	**0.812**	-0.24	-0.17	0.33	-0.46	-0.19	-0.03	0.364	1	
Y	0.091	-0.3	0.429	-0.5	0.408	-0.31	**0.938**	-0.71	-0.38	-0.3	**0.954**	-0.33	**0.574**	0.241	-0.13	-0.64	0.431	0.444	0.046	0.079	1

Table 3: Rotated Component Matrix

	Component				
	1	2	3	4	5
Au	0,395	-0,322	-0,12	0,785	-0,127
Ag	-0,266	-0,071	0,317	0,898	0,096
As	0,275	0,734	0,148	-0,108	-0,074
Ba	-0,504	0,308	-0,295	-0,191	-0,398
Bi	0,201	-0,036	0,611	0,167	0,727
Cd	-0,56	0,478	-0,139	-0,545	-0,005
Ce	0,944	-0,143	0,112	-0,112	0,056
Co	-0,976	-0,064	-0,005	-0,069	0,036
Cr	-0,866	-0,111	0,105	-0,043	0,394
Cu	-0,251	-0,095	0,331	0,896	0,072
La	0,953	-0,097	0,127	-0,119	0,084
Ni	-0,659	0,69	-0,128	0,026	0,085
Pb	0,145	0,009	0,938	0,308	0,032
Sn	0,101	0,018	0,964	0,128	0,037
Sr	-0,037	0,961	-0,013	-0,066	-0,091
Zn	-0,922	-0,225	0,176	0,09	-0,014
Sb	0,261	-0,011	0,951	-0,021	-0,04
Nb	0,734	0,235	0,2	0,175	0,208
Mo	0,032	0,93	-0,032	-0,147	0,243
W	0,242	0,551	-0,145	-0,069	0,755
Y	.870	.067	.309	-.228	.217

Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
7,66	36,477	36,477	7,66	36,477	36,477	7,216	34,363	34,363
4,743	22,585	59,062	4,743	22,585	59,062	3,707	17,653	52,016
3,582	17,057	76,119	3,582	17,057	76,119	3,686	17,55	69,566
1,815	8,643	84,762	1,815	8,643	84,762	2,867	13,65	83,216
1,305	6,213	90,975	1,305	6,213	90,975	1,629	7,759	90,975

Extraction Method: Principal Component Analysis.
Rotation Method: Quartimax with Kaiser normalisation.

From the mineralization point of view, it can be either an anthropogenic pollution or because of the influence of geological setting. However, from field observation of mineralization, careful sampling and the fact that neither intensive agricultural activites are taking place nor industrial pollution, there is very high probability of geological setting influence on the input of the various elements into stream sediments resulting to the various elements distributions in the study area.

6. Conclusions

1) The element anomalies found in this study are the results of geological influence and not as a result of pollution.
2) The element associations defined by multivariate statistics between Au, Cu and Ag suggests that the sulphides of Ag and Cu depositions and gold mineralization are contemporaneous, thus rocks with these sulphides are the most prospective during litho geochemical surveys in the region.
3) Since there are visible sulphide mineralizations in the field hosted by granites and factor 1 of PCA points to that effect, it can be thought that most of the indications of the sulfide mineralization can be sought in the granites in this region. More so since the gold is found in the factor with Cu we might think that searching for this sulphide mineralization might possibly lead to finding anomalous gold mineralization. This equally does not preclude the idea of the search for the presence of mafic –ultramafic rocks which can as well host such mineralization.
4) It can be suggested that input of the various elements results from weathering of mineralized rocks from within the catchment of the study area evident from field observations of such mineralization. The study equally points to the fact that there is a good mineralization potential for plutonic rocks of the Nlonako area and environs.
5) Heavy mineral geochemistry has been shown to be a suitable starting point for exploration for gold, silver, copper, zinc and lead amongst other elements within the Nlonako area and environs as points have been identified for their high concentrations within the study area.

All these point to the fact that there is a good mineralization potential within the Nlonako area and environs needing further research on.

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