RECONNAISSANCE GEOCHEMICAL STUDY OF A PART OF IGARRA SCHIST BELT, SOUTHWESTERN NIGERIA

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ABSTRACT

Geochemical exploration of Orle district within the Igarra schist belt in southwestern Nigeria was carried out using reconnaissance stream-sediment survey. A total of 56 samples were collected and chemically analysed for 22 trace elements including Au, Ag, As, Pb, Zn, Cu, Co, Mo, Hg, Sb, Tl, Sc, Cr, Ni, La, W, V, U, Th, Sr and Ga. The analytical results were subjected to univariate statistical analysis in order to determine statistical parameters such as means, standard deviation, etc. that allow the calculation of thresholds for individual elements. Geochemical distribution and anomalous-concentration maps were plotted for the elements, so as to have an insight into their distribution patterns. The geochemical distribution maps of the elements reveal that Cu, Pb, Zn, Co, Sc, Ni, Cr, Au, Sr, Hg and Tl show similar distribution patterns, and their anomalous-concentration maps also reveal that they have some common sites of anomalous concentrations; also, U, Th, La and W show similarity in their geochemical distribution and have some anomalous concentration sites in common, which may indicate close associations among the elements in each of these two groups in the study area. Comparison of the anomalous values derived for the different elements with their mean contents in geological materials suggests that the anomalous values for Co, Mo, Cr, Ni, Bi, Sr, Sb, V and Ga reflect underlying lithologies; while those for Au, Hg, U, Cu, Pb, Zn, Th and La indicate possible mineralization in the study area. Precious-metal (Au-Hg), base-metal (Cu-Pb-Zn etc) and U-Th-La mineralization potentials are high in the study area. The occurrence of pathfinder elements such as As and W; and of rock units, such as amphibolites and pegmatites, within the schist belt that could serve as hosts for mineralization of these elements, provides a strong basis for this assertion.

Keywords: Reconnaissance, Stream Sediment, Geochemical Distribution, Anomalous Concentration, Igarra Schist Belt

INTRODUCTION

There have been age-long speculations that Igarra schist belt contains metallic mineralization especially gold, which was reportedly mined during the colonial era at Dagbala, northeast of Igarra (Adekoya, 1999). The lithostratigraphic similarity of the Igarra schist belt with other schist belts that host precious and other metals both in Nigeria and elsewhere in the world (Olobaniyi and Annor, 1997) further raises prospecting interest in the Igarra belt of low-grade metasediments. In spite of the foregoing, there has been no systematic exploration of the belt to locate the alleged mineral deposits. It is for this reason that the Mineral Exploration Postgraduate Section of the Department of Applied Geology, The Federal University of Technology, Akure (FUTA) initiated a systematic geochemical prospecting of the Igarra Schist Belt for metallic mineralization.

The present study is part of the first stage of the systematic prospecting programme, which is a regional geochemical study of the drainage systems of the Igarra Schist Belt. This stage is aimed at outlining broad areas of high mineralization potential for a follow up action (Bradshaw et al., 1972). In this particular study, a stream sediment survey of River Orle and its tributaries (Fig. 1) was undertaken on a regional scale. The Orle River drains in part a large portion of the Igarra belt and its catchment is thus a suitable regional exploration target.

GEOLOGICAL SETTING

Igarra area, which encompasses the study area, lies within the southwestern Nigerian basement which itself is a part of the Nigerian Basement Complex. The Nigerian Basement Complex is also a part of the Pan African mobile belt that lies between the West African craton to
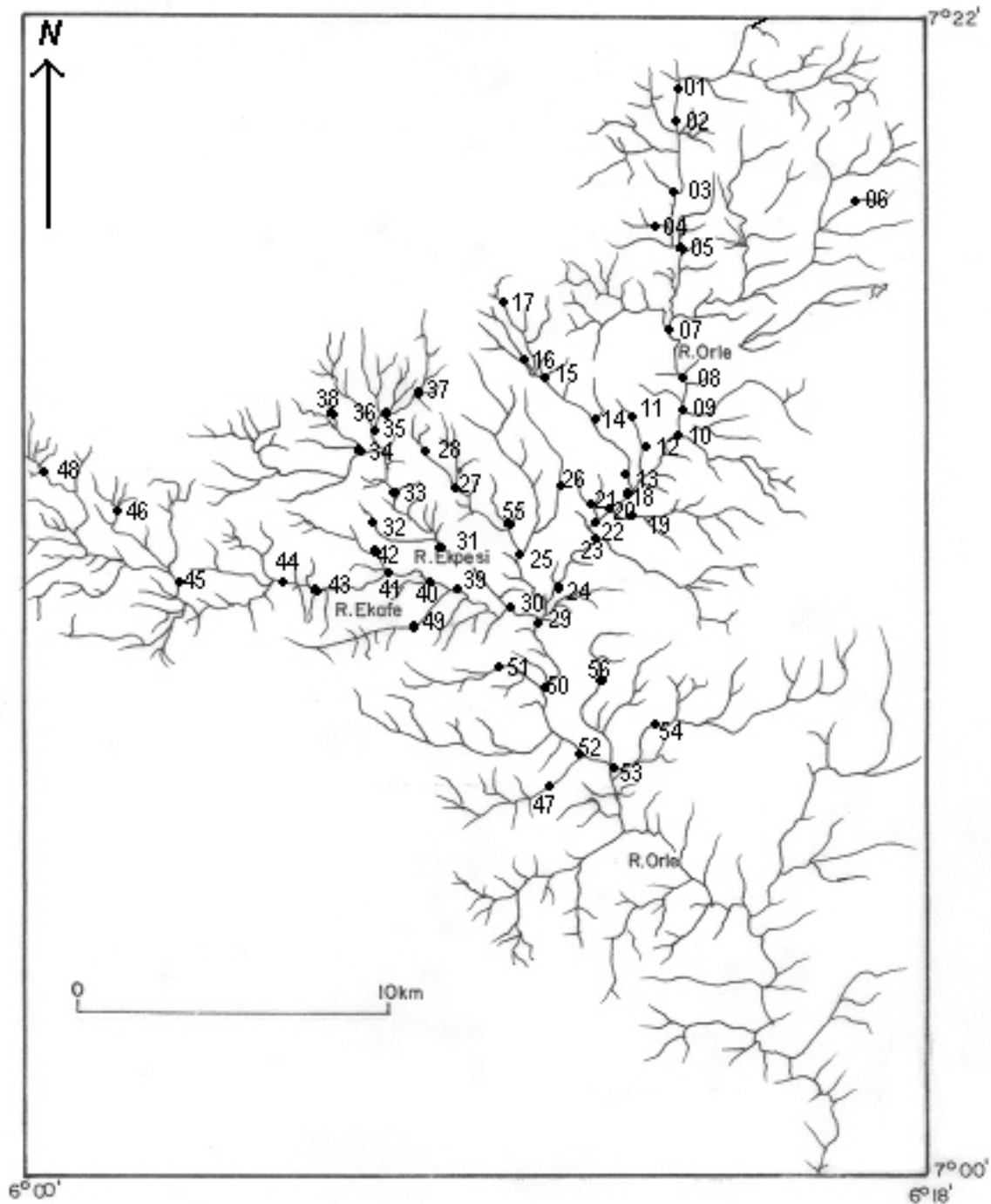
Fig. 1. Orle Drainage System Showing the Positions of the 56 Stream Sediment Samples.

the east and the Congo craton to the southwest within the African continent. The Basement Complex in Igarra area consists of the following four major rock groups (Odeyemi, 1988 and Adekoya, 2003):

(i) Migmatites, biotite and biotite-hornblende gneisses;

(ii) Low to medium grade metasediments consisting of schists, calc-silicate gneisses, marbles, polymict metaconglomerates and quartzite;

(iii) Syn- to late-tectonic porphyritic, biotite and biotite-hornblende granodiorites and

adamellites, charnockites and gabbros; and

(iv) Minor felsic and mafic intrusives comprising pegmatite, aplite, dolerite, lamprophyre and syenite dykes.

The study area is underlain in most parts by the metasediments, referred to as the Igarra Schist Belt, which presumably overlies an older gneiss-migmatite basement, possibly of Liberian age (Odeyemi, 1988). The metasedimentary succession in Igarra area consists predominantly of pelitic to semi-pelitic rocks of low to medium grade metamorphism. Major rock types exposed in the area include (i) semi-pelitic phyllites; (ii)

quartz-biotite schist; (iii) mica schist; (iv) calc-silicate gneiss and marble; and (v) metaconglomerate; all of which have been deformed in at least two episodes (Odeyemi, 1976). These supracrustal rocks and the underlying basement were subsequently intruded by Pan African granites such as the Igarra batholiths and other minor intrusives including pegmatite, aplite, dolerite, lamprophyre and syenite. Small bands of green amphibolitic rocks have been observed to be interbanded with some

of the aforementioned main rock units that constitute the schist belt. Showings of sulphides are reportedly found in the pelitic to semi-pelitic rocks.

MATERIALS AND METHODS

This study involved reconnaissance-scaled stream sediment sampling, geochemical analysis of the stream sediment samples as well as processing and interpretation of the geochemical data derived from the analysis (Ajayi, 1981a, 1995;

Fig. 2. Geological Map of the Study Area. (Modified after Odeyemi, 1988)

Bammeke, 1992). The stream sediments of the Orle drainage system were sampled at intervals of 4-5 km along the stream channels using the 1:100,000 topographic sheet no. 266 (Auchi) as a base map. However, selection of sample sites was influenced by the accessibility and geometry or configuration of the river channels. A global positioning system (GPS) receiver was employed for accurate sample site location on the map. Altogether, fifty-six samples were collected (Fig. 1) and processed subsequently for chemical analysis. Each sample was taken from about 20 cm depth in the streambed. Standard field observations (the stream dimension, the volume of water, flow rate, flow direction, nature of stream bed, and human activities around the sampling points) were recorded to assist a meaningful and reasonable data interpretation.

The samples were air-dried at room temperature after which they were disaggregated and sieved employing 177- sieve with nylon screens. The sieved fractions were pulverized to < 75 . Half of a gram (0.5 g) of each of the pulverized samples were digested with 6 ml of 2-2-2 ml mixture of $HCl-HNO_3-H_2O$ at 95°C for one hour. After filtration, the leached solutions were diluted with ultra pure water to 10ml. The resulting solutions were subjected to elemental analysis using an Inductively-Coupled Plasma Atomic Emission Spectrophotometer (ICP-AES) at Petroc Laboratories, Canada.

Subsequently, the analytical results of twenty-two trace elements namely, Au, Ag, As, Pb, Zn, Cu, Co, Mo, Hg, Sb, Tl, Sc, Cr, Ni, La, W, V, U, Th, Bi, Sr and Ga, were selected for qualitative treatment and quantitative statistical analysis. Quantitative statistical treatment of geochemical data as a useful and a necessary technique in geochemical interpretation is widely accepted and practised (Nichol et al., 1969; Woodsworth, 1971; Closs and Nichol, 1975; Rossiter, 1976; Chapman, 1978; Ajayi, 1981a). The quantitative analysis, in this paper, consisted essentially of univariate statistical treatment of both raw and log-transformed data, which involved the plotting of frequency histograms and curves, and cumulative frequency probability graphs necessary to reasonably establish the thresholds leading to the isolation of the anomalous concentrations of the elements in the study area. The qualitative interpretation here entailed the production of both distribution and anomalous-concentration maps for the various elements.

RESULTS

The distribution maps of the elements (Fig. 3) were drawn using the raw geochemical data and the stream sediment sample location map of the study area (i.e. Fig. 1). A study of these maps provides a useful insight to the distribution patterns of the trace elements in the study area.

The elemental concentration values and their log-transformed version for 20 of the 22 trace elements, Ag and Sb not considered because of their detection respectively in only one and seven samples, were analysed statistically by plotting the frequency distribution histograms and curves (Figs. 4 and 5) as well as the cumulative frequency graphs using the probability-log paper (Figs. 6 and 7). This univariate statistical analysis is employed here essentially for the determination of threshold, which is crucial for the isolation of anomalies, which are values above the threshold. Basic statistical parameters including the mean, geometric mean, deviation coefficients and threshold were determined graphically from the frequency distribution curves of the both raw and log-transformed data and the cumulative frequency probability plots (Tables 1A, 1B and 1C). Statistically the threshold is background plus two times the coefficient of deviation in lognormal distribution (Lepeltier, 1969), which applies to the case of the Orle stream sediment data (Adepoju and Adekoya, 2008).

The cumulative probability curves revealed single population for some elements such as Cu, Pb, Zn, Co, Mo, Cr, Ni, and Sc; and double populations for other elements as As, Au, Bi, Hg, La, Mo, Sr, Th, Tl, U, V and W in the Orle stream sediments. For the single population elements the threshold values from both graphs are similar (Table 1B and 1C). In the case of the two-population elements the threshold values of the Population 1 (with lower concentrations) obtained from the cumulative probability plot are taken as threshold for these elements (Table 1C). Table 2 summarises the thresholds and the anomalous sites for elements whose concentrations are above the selected threshold values.

Anomalous sites of the elements in Table 2 have been plotted on the various sample location maps to generate the anomaly maps (Fig. 8). Also, the mean values obtained for the different elements in this area were compared with their Levinson's (1974) average abundances in selected
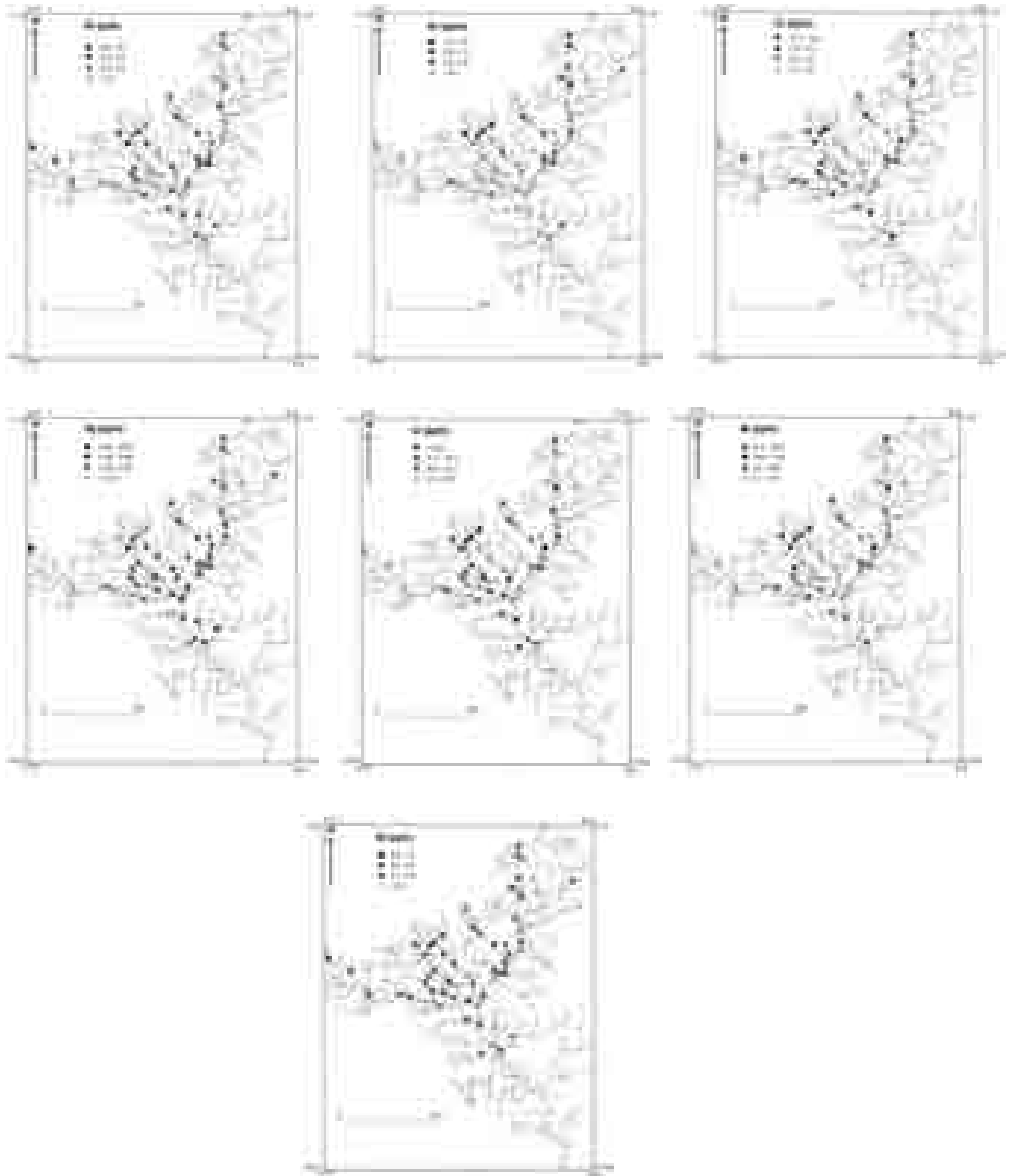
Fig. 3. Distribution Map of Some Elements (Au, As, Co, Hg, Cr, Ni and Bi) in Stream Sediments of the Orle Drainage System.

rock types, soils and the earth's crust (Table 3).

DISCUSSION

Antimony was detected in only seven samples, hence, its distribution in this area is generally low with a peak value at site MTP54 (0.9 ppm). A high content of Sb in stream sediments is a positive indication of a sulphide deposit in the immediate vicinity (Polikavpochkin et al., 1958). The presence of Sb, albeit at low contents in only few samples, might reflect only a restricted occurrence of sulphide deposits in the study area.

Arsenic was detected in only 21 samples; it was present in amount less than the instrument's lower detection limit of 0.5 ppm in the remaining 35 samples. In the twenty-one samples where it
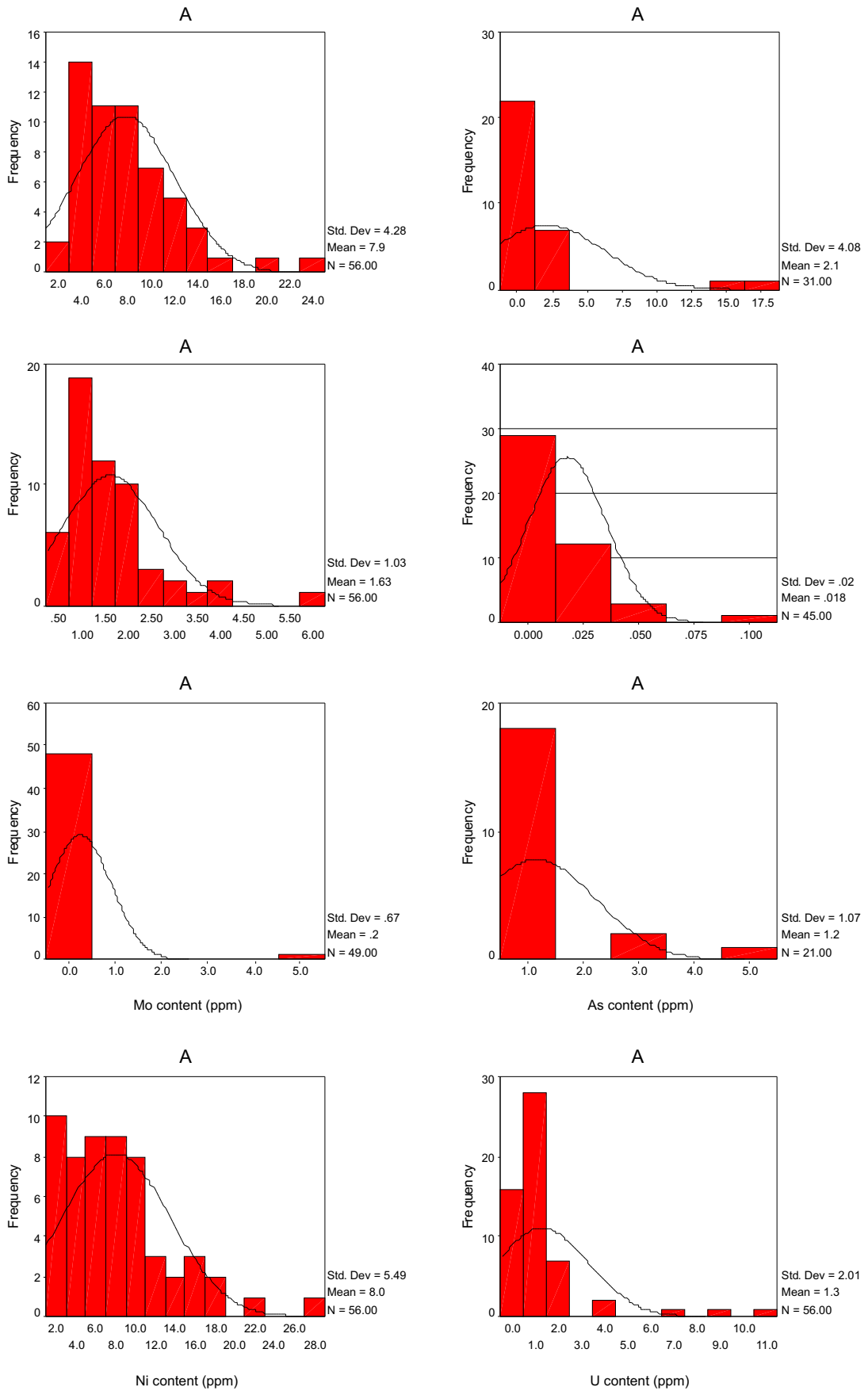
Fig. 4. Frequency Distribution of Original Data on Some Elements in Stream Sediments from the Orle Drainage System.

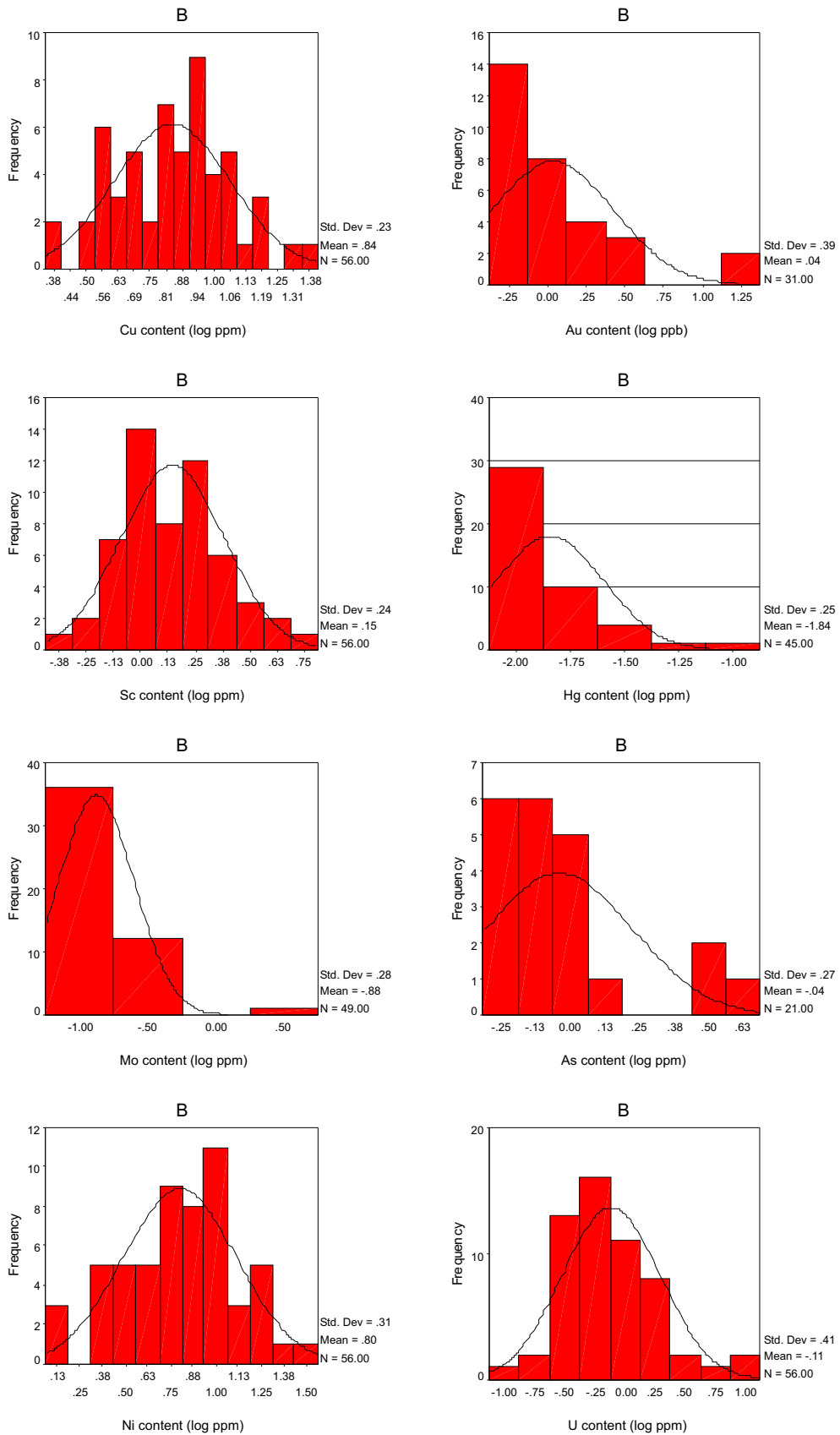**Fig. 5.** Frequency Distribution of Logarithmically Transformed Data on Some Elements in Stream Sediments from the Orle Drainage System.
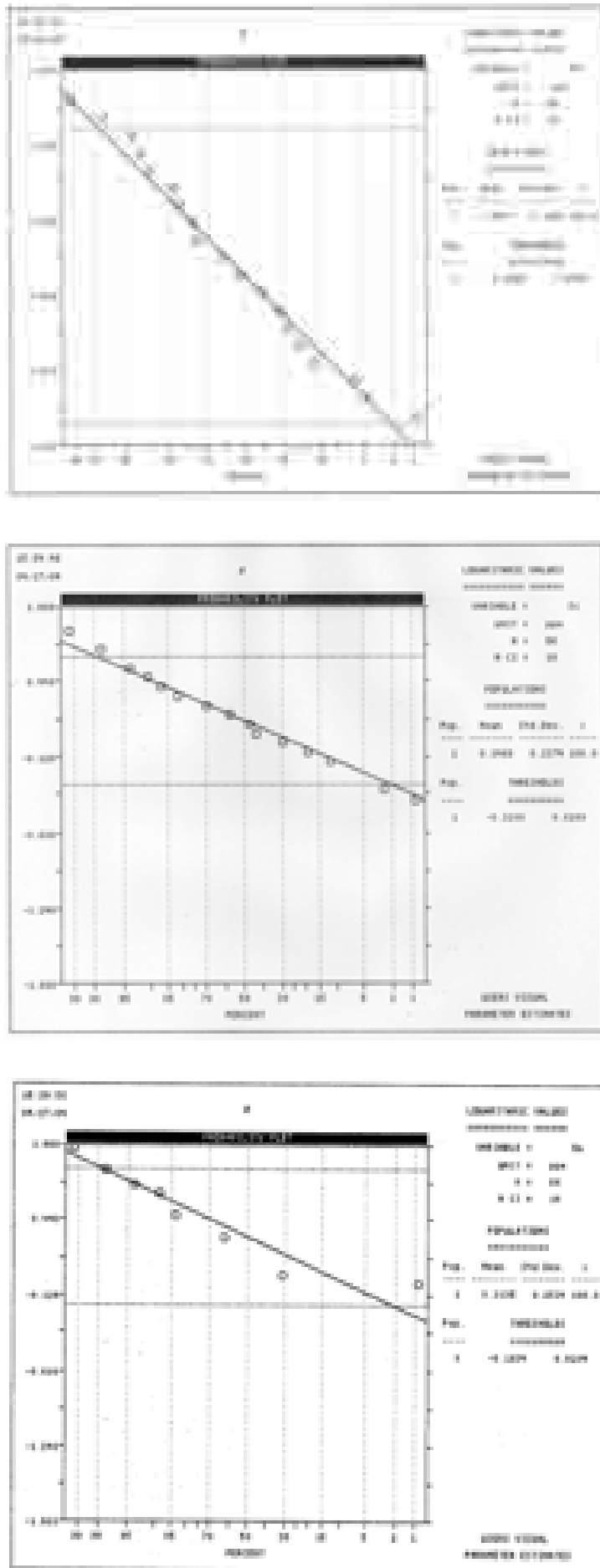
Fig. 6. Cumulative Probability Plots of Some Single-population Elements in Stream Sediments from the Orle Drainage System.
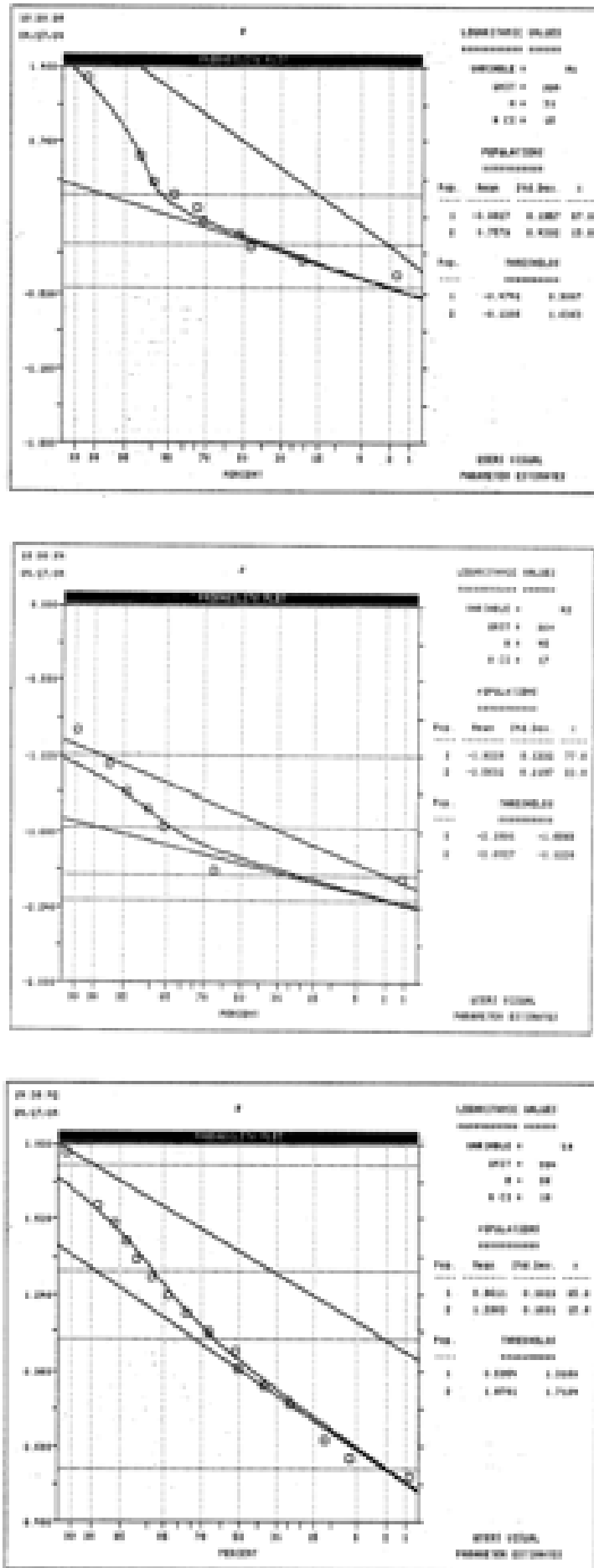
Fig. 7. Cumulative Probability Plots of Some Multiple-population Elements in Stream Sediments from the Orle Drainage System.

Table 1A. Summary of Raw Data Statistics of Trace Elements in Stream Sediments from the
Orle Drainage System.

Element	Unit	Minimum conc.	Maximum conc.	No of samples within the range	Arithmetic mean (X)	Standard deviation (S)	Threshold (X + 2S)	Coefficient of variation
Cu	ppm	2.30	24.30	56	7.8679	4.2799	16.46	54
Pb	ppm	2.00	162.30	56	7.7482	21.1671	9.78	50
Zn	ppm	5.00	57.00	56	17.3571	10.0461	37.50	58
Ag	ppm	0.10	0.10	1				
Au	ppb	0.5	18.10	31	2.1000	4.0842	10.26	194
Hg	ppm	0.01	0.06	45	0.18	0.2	0.58	111
Co	ppm	1.20	14.40	56	4.6286	2.8670	10.34	62
Mo	ppm	0.10	4.80	49	0.2286	.6699	1.54	134
As	ppm	0.50	4.80	21	1.1524	1.0703	3.34	89
Sb	ppm	0.10	0.90	7				
Sc	ppm	0.40	6.10	56	1.6339	1.0324	3.69	63
Ni	ppm	1.20	28.50	56	8.0196	5.4857	18.98	69
Cr	ppm	4.60	109.50	56	25.3482	5.4857	61.82	72
La	ppm	4.00	55.00	56	12.2143	8.5168	29.24	70
W	ppm	0.10	0.70	27	.1593	.1394	0.44	88
U	ppm	0.10	11.00	56	1.3268	2.0145	5.32	155
Th	ppm	1.00	119.50	56	10.7036	18.6577	48.02	174
Bi	ppm	.10	1.30	27	.1596	.1884	0.54	119
Sr	ppm	2.00	80.00	56	11.2679	13.9850	39.28	124
Ga	ppm	1.00	9.00	56	2.4464	1.5831	5.56	66
Tl	ppm	0.1	0.40	41	0.13	0.06	0.25	46
V	ppm	5.00	59.00	56	20.7143	11.8946	44.48	57

Table 1B. Summary of Log-transformed Data Statistics of Trace Elements in Stream Sediments
from the Orle Drainage System.

Element	Unit	Minimum conc.	Maximum conc.	No of samples within the range	Geometric Mean (X/)	Std. Deviation (S/)	Threshold antilog (X/ + 2S/)	Coefficient of variation
Cu	ppm	0.36	1.39	56	0.8381	0.2268	19.95	27
Pb	ppm	0.30	2.21	56	0.6456	0.2864	11.25	31
Zn	ppm	0.70	1.76	56	1.1783	0.2304	43.65	19
Ag	ppm	-1.00	-1.00	1				
Au	ppb	-0.30	1.26	31	0.0379	0.3931	6.61	975
Hg	ppm	-0.200	-0.96	45	-1.85	0.2500	0.04	14
Co	ppm	0.08	1.16	56	0.5905	0.2582	12.88	44
Mo	ppm	-1.00	0.68	49	-0.8786	0.2791	0.48	32
As	ppm	-0.30	0.68	21	-0.0397	0.2651	3.16	675
Sb	ppm	-1.00	-0.05	7				
Sc	ppm	-0.40	0.79	56	0.1460	0.2374	4.26	160
Ni	ppm	0.08	1.45	56	0.8030	0.3130	26.30	39
Cr	ppm	0.66	2.04	56	1.3113	0.2891	77.62	22
La	ppm	0.60	1.74	56	1.0156	0.2388	31.62	24
W	ppm	-1.00	-0.15	27	-0.8805	0.2327	0.38	26
U	ppm	-1.00	1.04	56	-0.1122	0.4063	5.13	373
Th	ppm	00	2.08	56	0.7352	0.4510	43.65	61
Bi	ppm	-1.00	0.11	47	-0.8952	0.2325	0.36	26
Sr	ppm	0.30	1.90	56	0.8890	0.3365	37.15	38
Ga	ppm	00	0.95	56	0.3135	0.2534	6.46	81
Tl	ppm	-1.00	-0.40	41	0-.9149	0.1596	0.26	18
V	ppm	0.70	1.77	56	1.2489	0.2484	56.23	20

Table 1C. Graphically Determined Statistical Parameters for Trace Elements in Stream Sediments from the Orle Drainage System.

Element	Population	Mean	Standard deviation	Threshold	Sample percentage in population
Cu	1	6.88	7.526	19.58	100
Pb	1	4.4	4.19	11.05	100
Zn	1	15	16.1	43.56	100
Au	1	0.8	0.77	2.036	87
	2	5.7	13.661	43.285	13
Hg	1	0.012	0.007	0.022	77
	2	0.027	0.029	0.075	23
Co	1	3.89	4.518	12.79	100
Mo	1	0.115	0.065	0.201	85
	2	0.287	0.57	1.655	15
As	1	0.732	0.38	1.230	84
	2	2.638	3.213	8.355	16
Sc	1	1.400	1.608	4.177	100
Ni	1	6.354	9.971	26.851	100
Cr	1	20.481	29.33	77.555	100
La	1	9.143	70929	21.223	85
	2	25.019	18.864	52.292	15
W	1	0.112	0.006	0.190	82
	2	0.289	0.3147	0.818	18
U	1	0.673	1.109	3.025	94
	2	7.189	6.451	17.154	6
Th	1	5.484	8.173	21.767	92
	2	47.642	10.879	59.834	8
Bi	1	0.117	0.086	21.767	90
	2	0.417	0.525	59.834	10
Sr	1	6.655	7.878	20.471	93
	2	47.012	41.972	111.711	7
Ga	1	2.058	2.542	6.613	100
Tl	1	0.118	0.076	0.223	96.5
	2	0.346	0.142	0.520	3.5
V	1	5.477	1.155	6.761	6
	2	18.589	20.475	53.242	94

Table 2. Threshold Values with Number of Anomalous Values and Anomalous Sites of Metals in the Orle Drainage System.

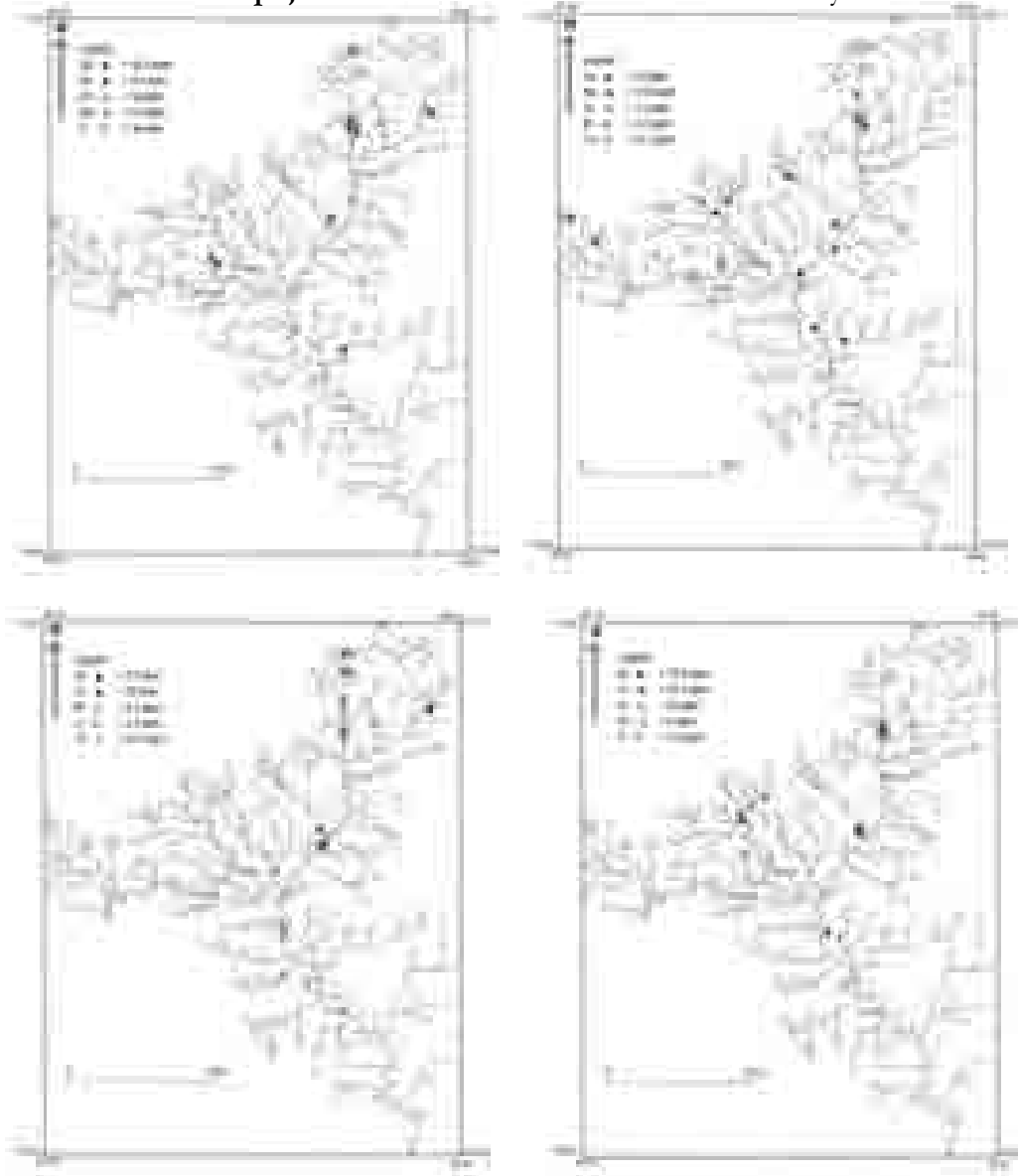| Element	Threshold	Number of anomalous values	Anomalous sites
Cu	16.5	2	05, 12
Pb	9.8	5	05, 06, 32, 42, 54
Zn	38	3	01, 05, 12
Au	2.0	5	05, 16, 19, 34, 36
Hg	0.02	5	12, 24, 48, 54, 56
Co	10.3	2	05, 42
Mo	0.2	4	01, 05, 06, 09
As	1.2	3	01, 05, 38
Sc	3.7	3	01, 05, 12
Ni	19.0	2	05, 12
Cr	61.8	2	34, 50
La	29	2	06, 18
W	0.2	3	01, 02, 18
U	3.0	5	02, 03, 06, 18, 50
Th	21.8	6	03, 06, 18, 25, 47, 50
Bi	0.2	6	01, 03, 05, 31, 42, 43
Sr	20	5	05, 35, 36, 37, 56
Ga	5	3	05, 12, 32
Tl	0.2	2	05, 12
V	44	3	01, 05, 50

Fig. 8. Orle Drainage Map Showing Sites of Anomalous Metal Concentrations.

Table 3. Average Abundance of the Twenty-two Trace Elements in the Earth Crust, Various
Rocks and Soil (all Values in Ppm, Au In Ppb) after Levinson (1974).

Element	Earth crust	Ultramafic	Basalt	Granodiorite	Granite	Soil
Cu	55	10	100	30	10	2 - 100
Pb	12.5	0.1	5	-	20	2 - 200
Zn	70	50	100	60	40	10 - 300
Ag	0.07	0.06	0.1	0.07	0.04	0.1
Au	4.0	5.0	4.0	4.0	4.0	-
Hg	0.08	-	0.08	0.08	0.08	0.03
Co	25	150	50	10	1	1 - 40
Mo	1.5	0.3	1	1	2	2
As	1.8	1	2	2	1.5	1 - 50
Sb	0.2	0.1	0.2	0.2	0.2	5
Sc	16	10	38	10	5	-
Ni	75	2000	150	20	0.5	5 - 500
Cr	100	2000	200	20	4	5 - 1000
La	30	3.3	10.5	36	25	-
W	1.5	0.5	1	2	2	-
U	2.7	0.001	0.6	3	4.8	1
Th	10	0.003	2.2	10	17	13
Bi	0.17	0.02	0.15	-	0.1	-
Sr	375	1	465	450	285	50 - 1000
Ga	15	1	12	18	18	15
Tl	0.45	0.05	0.1	0.5	0.75	0.1
V	135	50	250	100	20	20 - 500

was detected it values ranged from 0.5 to 4.8 ppm with a mean of 1.2 ppm and coefficient of variation of 89 %. The threshold value for As in this area is 1.2 ppm. Thus, there are three anomalous values in this area at sites MTP01 (4.8 ppm), MTP05 (2.9 ppm) and MTP38 (2.9 ppm). When the mean value of As in this area is compared with its average abundance in the earth's crust, the arsenic concentration in this area is low. Thus, the anomalous values recorded might not be related to As mineralization. However, they may be a pointer to the presence of sulphide and/or vein-type Au-Ag deposits in which the As occurs in trace amounts.

Bismuth is present in 47 of the 56 samples analysed. The detected values range from 0.1 to 1.3 ppm with a mean of 0.16 ppm. Above the threshold value of 0.2 ppm six anomalous values exist at sites MTP01 (0.3 ppm), MTP03 (0.5 ppm), MTP05 (0.3 ppm), MTP31 (0.3 ppm), MTP42 (1.3 ppm) and MTP43 (0.3 ppm). Its mean value of 0.16 ppm is comparable with average abundance of Bi in geological materials. This is interpreted as indicating potential occurrence of Bi minerals

associated with ores of Ag, Co, Ni and Pb in the study area.

Chromium was detected in all the samples and its contents vary from 4.6 to 109.5 ppm with a mean of 25.3 ppm and coefficient of variation of 72 %. Two anomalous values of Cr exist above a threshold value of 61.8 ppm at sites MTP35 (89.2 ppm) and MTP50 (109.58 ppm). Other relatively high values exist at sites MTP05 (51.3 ppm), MTP36 (58.6 ppm) and MTP37 (58.3 ppm). The mean content of Cr in this area as compared to the average abundance of Cr in different rocks, soils and earth crust indicates a generally low Cr distribution. This might be interpreted as revealing a restricted presence of mafic-ultramafic rock in the area.

Cobalt shows a wide distribution in the study area as it was detected in all the samples. Its concentrations in this area range from 1.2 to 14.4 ppm. At threshold value of 10.3 ppm, there are two anomalous sites at MTP05 (13.4 ppm) and MTP42 (14.4 ppm). Other relatively high values occur at sites MTP01 (8.4 ppm), MTP12 (9.1 ppm), MTP32 (8.4 ppm), MTP36 (8.7 ppm) and

MTP49 (9.9 ppm). As compared to the average abundance of Co in geologic materials, the average value of Co in the study area reflects generally lower values. This might suggest that Co-bearing minerals are not present in sufficient amount as to constitute Co deposit in the area.

Copper is detected in all the samples analysed at concentrations ranging from 2.3 to 24.3 ppm with a mean of 7.9 ppm and coefficient of variation of 54%. With the threshold value of 16.5 ppm, only two anomalous values of copper exist at sample sites MTP05 (24.3 ppm) and MTP12 (19.4 ppm) in the area. However, there are other fairly high values at sites MTP01 (15 ppm), MTP17 (14.7 ppm) and MTP32 (14.6 ppm). Compared with the average abundance of copper in ultramafic rocks, granitic rocks and soils, the concentration of copper (partially extracted) in the study area is higher. Therefore, these high and anomalous values are probably due to Cu mineralization.

Gallium is present in all the samples at concentrations ranging between I ppm and 9 ppm with a mean of 2.4 ppm and coefficient of variation of 66 %. Three anomalous values, above the threshold value of 5 ppm, occur at sites MTP05 (9 ppm); MTP12 (6 ppm) ad MTP32 (6 ppm). Other fairly high values include those at sites MTP01 (5 ppm), MTP06 (5 ppm) and MTP38 (5 ppm). Comparing the average abundance of Ga in the geologic materials and its mean value in the stream sediments of the study area one observes that Ga distribution in this area is low and therefore the anomalous values are unlikely to be related to any Ga-mineralization in the study area.

Gold was detected in thirty-one of the fifty-six samples employed for this study, it occurred below the detection limit of 0.5 ppb in other twenty-five samples. Where it was detected, it ranged in concentrations from 0.5 to 18.1 ppb with a mean of 2.1 ppb. With the threshold value of 2.0 ppb selected for gold, five anomalous values occur at sites MTP05 (2.5 ppb), MTP16 (3.5 ppb), MTP19 (18.1 ppb), MTP34 (16.2 ppb) and MTP36 (2.4 ppb) in the area. Compared with the average abundance of Au in earth materials, concentration of Au in the stream sediments of the area is generally on the high side. This might indicate possible Au mineralization in parts of the study area.

Lanthanum is present in all the samples analysed at values that range from 4 to 55 ppm with a mean of 12.2 ppm and coefficient of variation of 70 %. The selected threshold value of 29 ppm indicated two anomalous values at sites MTP06 (34 ppm) and MTP18 (55 ppm). Fairly high La contents also occur at sites MTP03 (23 ppm), MTP05 (29 ppm), MTP08 (24 ppm) and MTP13 (22 ppm). A comparison of the mean value of La in the study area and its average abundance in granite and earth crust showed that La content is generally low in the study area. This is interpreted to be due to lack of rare earth-element mineralization in the area.

Lead is detected in all the samples analyzed with contents that range from 2 to 12.4 ppm in fifty-five samples with a mean of 4.9 ppm and coefficient of variation of 50 %. However, one sample has a particularly high Pb content of 162.3 ppm, which is considered to be an outlier and interpreted as reflecting local pollution. With the selected threshold of 9.8 ppm, four anomalous values occur at sample sites MTP05 (10.6 ppm), MTP06 (12.0 ppm), MTP32 (10.9 ppm) and MTP42 (10.4 ppm). Other relatively high Pb values occur at sites MTP01 (7.8 ppm), MTP14 (7.3 ppm), MTP19 (8.3 ppm) and MTP21 (7.8 ppm). Compared with the average abundance of Pb in ultramafic rock, basalt, granite and soil, the mean Pb concentration of the stream sediments is high, which indicates that there might be lead mineralization in the study area.

Mercury was detected in 45 of the 56 samples used for this study with values ranging from 0.01 to 0.06 ppm. The selected threshold for Hg is 0.02 ppm above which there are three anomalous values at sites MTP12, MTP24 MTP48, MTP54 and MTP56 having concentrations of 0.06, 0.04, 0.03, 0.04 and 0.03 ppm respectively. Compared to its average abundance in selected earth materials, the concentration of Hg in the study area is moderate, which might be related to limited or no Hg mineralization in the area.

Molybdenum is present in detectable amounts in forty-nine samples and below the lower limit of detection of 0.1 ppm in seven samples. It ranges in concentration from 0.1 to 4.8 ppm where it is detected with a mean value of 0.2 ppm. At the selected threshold value of 0.2 ppm, four anomalous values exist at sites MTP01 (0.3 ppm), MTP05 (0.3 ppm), MTP06 (4.8 ppm) and MTP09 (0.4 ppm). A comparison of the average abundance of Mo in geological materials with its mean concentrations in the Orle stream sediments

showed that the concentration of Mo in the latter is generally low. This might just indicate possible complex sulphide mineralization, probably containing limited molybdenite, in the schists of the study area.

Nickel was detected in all the samples analysed. Its concentrations range from 1.2 to 28.5 ppm with a mean of 8.0 ppm and coefficient of variation of 69 %. The selected threshold value of 19.0 ppm indicates two anomalous values at sites MTP05 (28.5 ppm) and MTP12 (21.1 ppm). Other relatively high values occur at sites MTP32 (15.9 ppm), MTP38 (15.4 ppm) and MTP49 (17.9 ppm). A comparison of the average abundance of Ni in earth materials with its mean content in the stream sediments of this area indicates generally low contents of Ni in this area. This might suggest that ultramafic and mafic rocks are few in the study area.

Scandium concentrations range from 0.65 to 6.1 ppm with a mean of 1.6 ppm and coefficient of variation of 63 %. Three anomalous values, given the selected threshold of 3.7 ppm, were found at sites MTP01 (4.1 ppm), MTP05 (6.1 ppm) and MTP12 (4.2 ppm). Fairly high values also occur at MTP32 (3.1 ppm) and MTP39 (3.4 ppm). The mean content of Sc here in relation to its average abundance in geological materials indicates that the content of Sc in the sampled material is very low. This might reflect lack of Sc mineralization in the project area.

Strontium concentrations in the study area range from 2 to 80 ppm with a mean of 11.3 ppm. At the threshold of 20 ppm, five anomalous values exist at sites MTP05 (24 ppm), MTP35 (50 ppm), MTP36 (46 ppm), MTP37 (52 ppm) and MTP56 (80 ppm). Sr contents in the district are very low when its mean content is compared with its average abundance in geologic materials. Consequently, the anomalous values observed are not likely to be related to Sr mineralization in the area.

Thallium is present in amounts less than the lower limit of detection in 15 samples. Its values range from 0.1 to 0.4 ppm with a mean of 0.13 ppm. With a threshold value of 0.2 ppm, only two anomalous values exist at sites MTP05 (0.4 ppm) and MTP12 (0.3 ppm). As compared with the average abundance of Tl in the earth crust, the mean concentration of Tl in the samples reflects that the element has low distribution in the stream sediments of the study area. It can also be observed that its two anomalous-value sites are common to those of Cu, Zn, Ni, Sc and Ga, suggesting their possible association in suspected sulphide deposits in the area, with Tl present probably as a dispersed element in ore minerals of the other elements in this association.

Thorium is present in all the stream sediment samples analysed. Its concentrations range from 1.0 to 50.7 ppm with a mean of 10.7 ppm, excluding a value of 119.5 ppm considered to be an outlier. In the study area six anomalous values including the outlier exist above the threshold value of 21.8 ppm at sites MTP03 (50.7 ppm), MTP06 (39.2 ppm), MTP18 (47.5 ppm), MTP25 (28.7 ppm), MTP47 (40.7 ppm) and MTP50 (119 ppm). A comparison of the mean value of Th to its average abundance in granite shows that the former is somewhat lower. Nevertheless, all the six anomalous values for Th in this area are very high, and hence might be related to mineralization.

Tungsten is present in amounts less than the lower limit of detection in 29 samples. In other 27 samples where it is detected its values range from 0.1 to 0.74 ppm with a mean of 0.16 ppm and coefficient of variation of 88 %. There are only three anomalous values above its threshold of 0.2 ppm at sites MTP01 (0.5 ppm), MTP02 (0.3 ppm) and MTP18 (0.7 ppm). As compared with the average abundance of W in all the geologic materials, the mean W value is somewhat low in this area. Thus the anomalous values might not be related to W mineralization. However, it is possible for some W minerals to occur in pegmatites and for the elements to occur in trace amounts in minerals like native bismuth, quartz, pyrite, galena, sphalerite and arsenopyrite with which they are usually found (Hawkes and Webb, 1962).

Uranium distribution shows a pattern similar to that of Th in the study area. U contents range from 0.2 ppm to a peak value of 11 ppm with a mean of 1.3 ppm. With the selected threshold of 3.0 ppm, five anomalous values occur at sites MTP02 (4 ppm), MTP03 (6.9 ppm), MTP 06 (11 ppm), MTP18 (3.9 ppm) and MTP50 (8.8 ppm). The mean value obtained as compared with the average abundance of U in soil shows that the distribution of U is fairly high in the study area. This suggests that the anomalous values may be due to U mineralization in the district. It can also be observed that four anomalous-value sites are common to both U and Th, suggesting their possible occurrence in the same rock type.

Thus, granite and pegmatite dykes as well as quartz veins within the gneiss and schists of the study area could be explored for possible U and Th mineralization.

The distribution pattern of vanadium is fairly diffuse, the range being from 5 to 59 ppm with a mean of 20.7 ppm and coefficient of variation of 57 %. Three anomalous values exist for V at threshold value of 44 ppm at sites MTP01 (45 ppm), MTP05 (52 ppm) and MTP50 (59 ppm) in the study area. Other fairly high values were found at sites MTP12 (42 ppm), MTP17 (44 ppm) and MTP38 (36 ppm). Comparing the mean V concentration in the stream sediments of the area with the average abundance in the soil and earth crust, one can say that the concentration of V in the stream sediments of this area is low. Therefore, the high and anomalous values obtained might not be related to any V mineralization within the study area.

Zinc is present in all the samples analysed at concentrations that range from 5 to 57 ppm with a mean of 17.4 ppm and coefficient of variation of 58 %. The selected threshold of 38 ppm revealed three anomalous values at sites MTP01 (39 ppm), MTP05 (57 ppm) and MTP12 (42 ppm). Other sites with relatively high Zn concentrations include MTP17 (28 ppm), MTP32 (31 ppm), MTP44 (25 ppm) and MTP54 (33 ppm). However, the Zn values in the study area are low in comparison with its average abundance in different rock types and soils. Thus the anomalous values obtained for Zn might not necessarily be due to Zn mineralization in the study area.

CONCLUSION

In this area, Cu, Pb, Zn, Co, Sc, Ni, Cr, Au, Sr, Hg and Tl have similar distribution patterns. The anomalous concentration maps also revealed that these elements have some common sites of anomalous concentrations. These suggest close association between these elements. Adepoju and Adekoya (2008), using multivariate statistics that include correlation and factor analyses, have also recognized the existence of a strong association among most of these elements. However, when the mean concentrations of these elements in the stream sediments of the study area were compared to their contents in selected geologic materials, it was revealed that while the anomalous concentrations of some of them including Ni, Cr, Co were related to the presence of limited occurrences of mafic lithologies in the study area

those of others like Cu, Pb, Au were related to their possible mineralization. Therefore, in this area, the suspected gold and complex sulphide mineralizations are probably hosted by mafic lithology, such as amphibolites. It is noted that gold mineralization occurs in a similar setting in the Ilesha schist belt (Olade and Elueze, 1979; Klemm et al., 1979; Ajayi, 1981b; Bafor and Karamata, 1981; Elueze, 1981; Klemm et al., 1984; Woakes et al., 1987; Oyinloye, 1992; 1995).

Moreover, U, Th, La and W show similarity in their geochemical distribution. These elements also have some anomalous concentration sites in common, which may indicate their close association in the study area. It is therefore possible that there is occurrence of mineralized felsic lithology, most probably pegmatite, containing U, Th and La, probably with some other rare earth elements in the study area.

The occurrence of rocks like amphibolites and pegmatites that could serve as hosts for gold and U-Th-La, respectively on one hand and also the abundance of As and W which are pathfinder elements for gold and U-Th-La, respectively on the other, provide a strong basis for possible Au and U-Th-La mineralizations in the study area.

Therefore, it is recommended that a detailed geological and geochemical study be carried out in areas upstream from various sites of anomalous values of metals. This is necessary to confirm the presence or otherwise of the different suspected metallic mineralizations in the area.

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