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Full Length Research Paper

Petrography and stream sediment geochemistry of Ede and its environs south western Nigeria

[1*]Akintola AI, [2]Ikhane PR, [3]Bankole SI, [4]Adeokurolere DM

[1,2,4]Department of Earth Sciences, Olabisi Onabanjo University, Nigeria
[3]Department of Geosciences University of Lagos, Akoka Lagos, Nigeria

Abstract

Petrographic studies and geochemical analysis were carried out on the rocks and stream sediments samples around Ede in Osun, Southwestern Nigeria, the study area fall in the coordinates N 07^{0}45’ - 07^{0}48’ and E004^{0}25’-004^{0}28’. This investigation was carried out in order to identify the rock units with their mineralogical appraisal and to determine the concentration and distribution of major and trace elements in the stream sediments with a view to elucidate the mineral potentials of the study area. Five (5) rock samples were selected for thin section, which was then subjected to petrographic studies Ten (10) stream sediments were also collected for determination of all possible elements using inductively coupled plasma (ICP AES) Instrumentation technique. Geological mapping of the study area on the scale of 1:50,000 reveal three rock types which are pegmatite, banded gneiss and biotite gneiss. Petrographic studies show that Quartz, Plagioclase, Microcline, Biotite, and opaque minerals are the main mineral constituents under the transmitted light. The analytical results reveal major oxide Fe_2O_3 to range from (0.70-3.32%) with a mean value of 1.69%, Al_2O_3 ranges from (0.34-2.87%) with a mean value of 0.94% and Ca_2O ranges from (0.03-0.42%) with a mean value 0.17%. Some of the trace elements analyzed for include; Mn, Cr, V, Zn, Cu, Pb, Co, Rb, Sr, Ni, Y, Ga, Zr, As and Mo. Manganese [Mn] ranges from (225.0- 946.0ppm) with a mean value 541.0ppm, Cr ranges from (16.6-59.3ppm) with mean value of 33.2ppm and V ranges from (12.0-52.0ppm) with a mean value of (27.9ppm). This could be attributed to its underlying geology (rock types). Location 8 has the highest level of cumulative metal enrichment (1027.89%) while location 3 has the least level of cumulative metal enrichment (0.67%). It can therefore be inferred that from various geochemical parameters used, there are indications that the stream sediments from the study area, are showing low contamination factor (Cf<1). Indicating low contamination with respect to V, Cr, Mn, Co, Ni, Cu, Zn, Ga, As, Mo, Rb, Sr, Y, Zr and Pb. The degree of contamination is calculated to be 3.50˚. Manganese [Mn] contributed most to the overall degree of contamination index with a value of 65.83˚.

Keywords: Plagioclase, manganese, petrographic, quartz, pegmatites.

INTRODUCTION

The world economy at present is growing at a rate that necessitates an increasing demand for rare metals and other mineral materials; this trend is likely to continue into the future (Simmons *et al.,* 2003). The systematic mapping of Ede area was carried out with a view to elucidate the detailed geological mapping of the study area, to determine the underlying lithologic units and to in addition carry out the geochemical assessment of the area for its mineral potentials which is the rationale of this research. The method of investigation adopted includes systematic geological and geochemical mapping of the rocks and stream sediments in the study area, petrographic studies of the rock samples and; geostatistical evaluation of the bed rock and stream sediment geochemical data obtained after the geochemical analysis with the objective of providing baseline geological and geochemical information about the area, the research work involves the collection of both stream sediments and rock samples around Ede north southwestern Nigeria in other to study the rock distribution, mineralogical appraisal of the various rock types and to estimate the degree of enrichment of the

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*Corresponding Author Email: busayoakins@yahoo.com

various elements present in the streams. The geochemistry of stream sediments is related to the geology of the area and in turn could be used to infer the mineral deposits in that environment. Stream sediments are clastic materials derived as particles broken from parent rock and they serve as ultimate sinks for elements in aquatic setting. Stream sediments are employed almost exclusively for reconnaissance studies in drainage basins (Hawkes, 1976) and if samples are properly collected, the samples represent the composite of materials from the catchment areas upstream from the sampling site with potential of recognizing geochemical or mineralogical anomalies within the catchment areas for follow-up works (Hakanson, 1980; Adekeye 1999, Jacobson and Webb 1946). River sediments originate from the near surface, exposed igneous, volcanic and sedimentary rocks. Some of these are easily eroded, whereas others, especially the crystalline and metamorphic rocks are affected by streams only when altered in surface layers. Additional sources of river sediments are soil which inherited their mineral content (with some alterations) from bedrock of which in the tropics may consist completely of newly formed minerals. Most streams in south western Nigeria are derived from the basement complex which covers about half of the landmass of the entire Nigerian land scape. The Nigerian basement complex forms part of the pan –African mobile belt and lies between the West African and Congo cratons and south of the Touareg Shield. In stream sediments, a whole range of known minerals can be found such as the heavy minerals which are the most important group. Heavy minerals are known to occur in igneous, metamorphic and sedimentary rocks. These minerals are economically viable if they occur in sufficiently large concentrations and in deposits of sufficiently large size. Geochemical mapping of stream sediments give a clearer picture that allows mineral or elements to be examined in the area drained by streams. Therefore, stream sediments samples of the study area are collected from first order streams in other to represent weathered rocks in the drainage system. The study area lies between latitude N7° 45’00” and N7° 48’00” and longitude E 4° 25’00” and E 4° 28’00” of Iwo sheet 242 N.E within the basement complex of south western Nigeria. The study area is easily accessible (Figure 1) by complex road network of major and minor roads as well as footpath linking one sampling point to the other on the map.

Regional Geological Setting

Rocks of the Precambrian basement complex of Nigeria underlie the project area. The Precambrian basement of African can be divided into three large cratons; these are the Kalahari craton, Congo and West African cratons, separated from each other by a number of mobile belts active in late Proterozoic times. The Nigerian basement complex lies north-east of the Congo Craton in a mobile belt affected by the Pan African Orogeny. These rocks outcrop in two large areas (viz; the south-western and north-central parts of the country) and in smaller areas in the northeastern parts and the southeastern parts notably around the Oban massif and Obudu areas (Ekwueme, 2000). Three main lithologic groups are usually distinguished in the Nigerian basement. These are (i) a gneiss migmatite complex with evidences of polycyclic metamorphism mainly of amphibolites facies grade with. Archean and Pan African ages (ii) A N-S trending schist belts of low grade subracrustal rocks with minor volcanic assemblages. They are concentrated in the western half of Nigeria although minor occurrences have been noted in the northern eastern and southern eastern parts (iii) Syn-late tectonic Pan African granite, which are collectively termed Older Granites and intrude the schist belts and the gneiss migmatite complex. They comprise mainly granites pegmatites, gabbros, charnockites, diorites and syenites. The schist belts, despite paucity of agreements in terms of their nomenclature, geographic delimitation and geodynamic setting are composed largely of metamorphosed pelitic and psammitic assemblages. Secondary lithologies such as ferrugineous rocks (Banded Iron Formation), carbonate, and metal ultramafic bodies are often used to discriminate them.

Lithological Association and Petrography

Three different lithological units were observed to underlain the study area and this includes the pegmatite, banded gneiss and biotite gneiss units. The pegmatites which occur as near vertical dykes strike mainly in the NNE-SSW direction, and intrude into the older lithology of banded gneiss. (Figure2a). The banded gneiss occurs as a massive rock consisting of alternating bands of felsic minerals notably plagioclase feldspars and quartz, and the dark bands consisting of biotite and hornblende while biotite gneiss is the oldest rock in the study area. The pegmatites of Ede north area occur as near vertical intrusions covering the study area, they are coarse grained rock with general milky white appearance. The main mineral assemblages are microcline, quartz, biotite and tourmaline (black and green) occurring as secondary associated minerals. Petrographic studies of the Ede north pegmatites show that they contain mainly plagioclase, muscovite, quartz, microcline and biotite minerals. Plagioclase exhibits characteristic albite twining and it is well distributed in all samples. Muscovite occurs as tiny elongated plates with high relief and perfect cleavage in one direction with strong birefringence. Quartz occurs as cloudy anhedral with wavy extinction and characteristic weak birefringence. Microcline often inter grown graphically, they are sometimes perthitic with

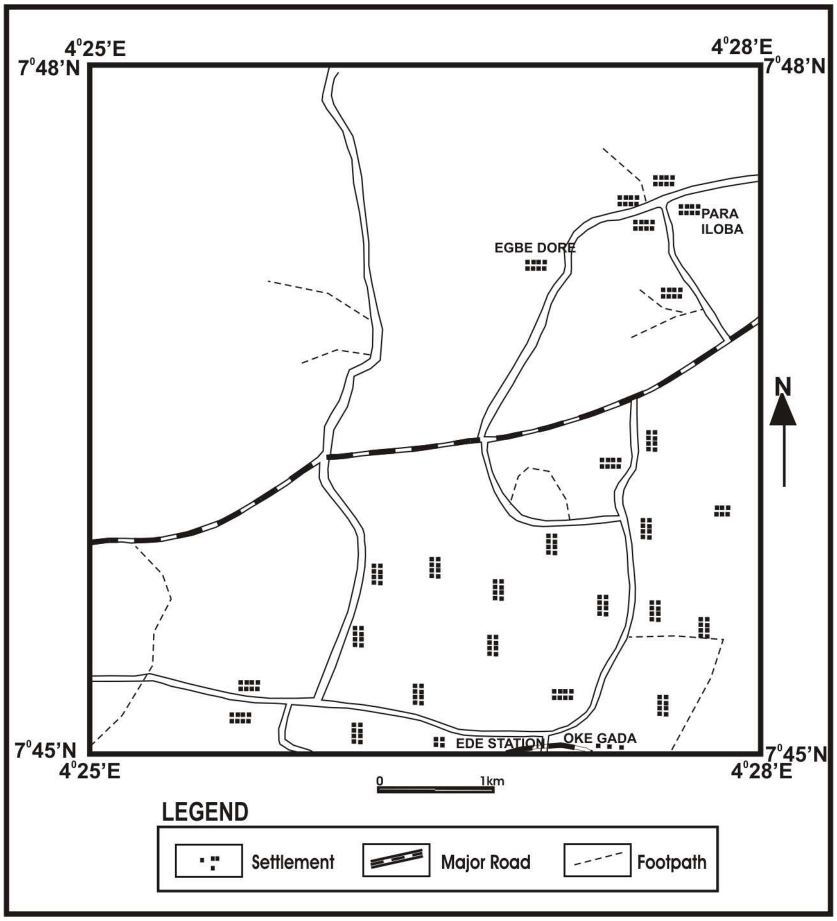

Figure 1. Location and accessibility of the study area

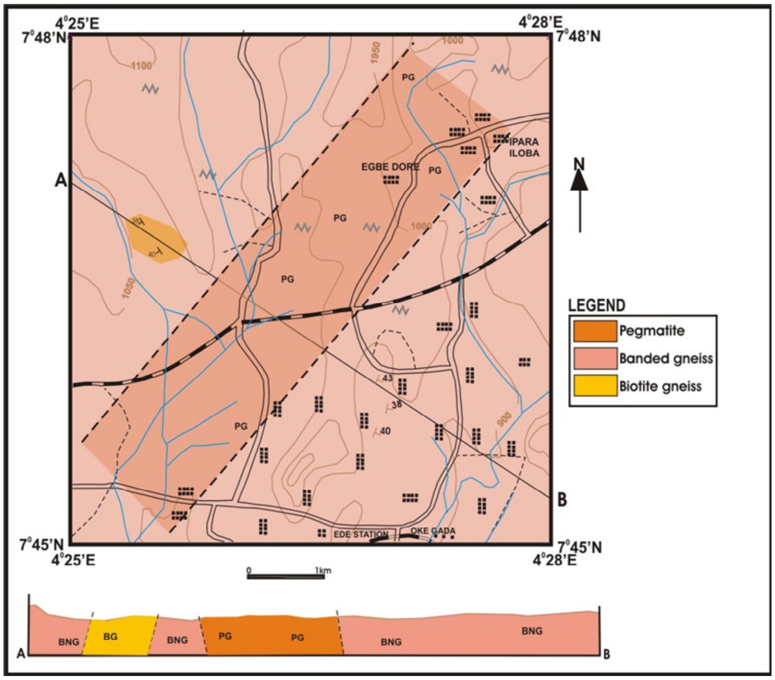

Figure 2a. Geological map and cross-section of the study area

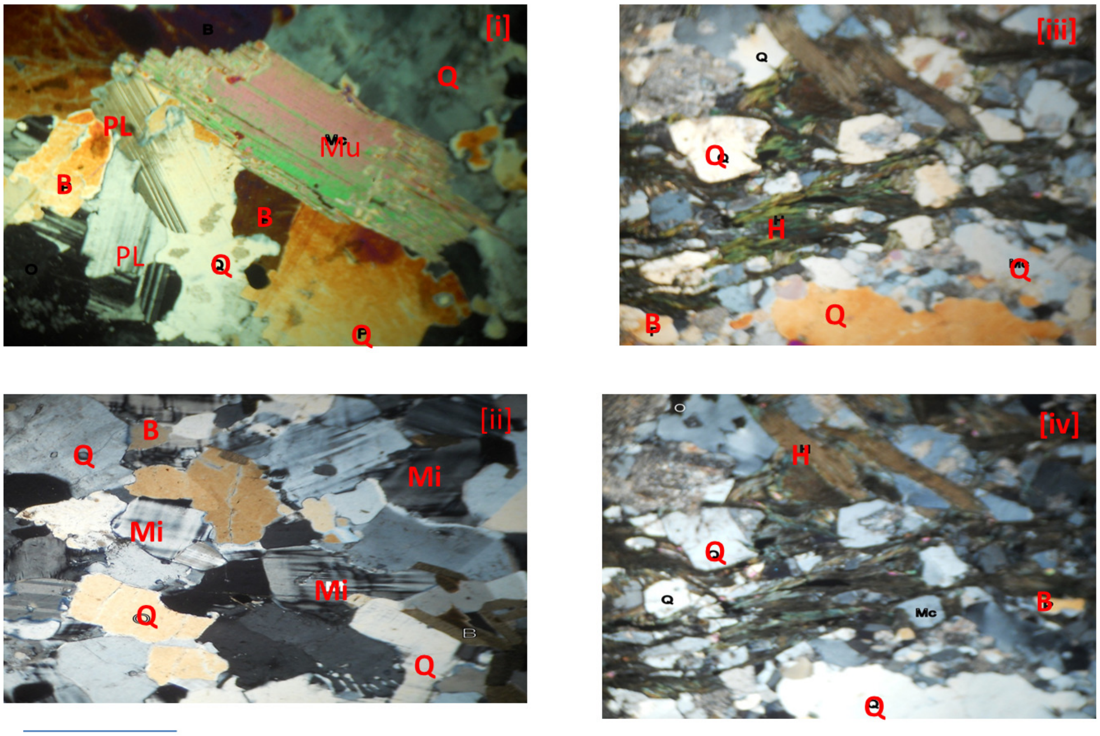

Figure 2b.{i}Photomicrograph of pegmatite in transmitted light showing Biotite (B), Plagioclase (PL), Quartz (Q), and Muscovite (Mu). {ii} Photomicrograph of pegmatite in transmitted light showing Quartz (Q), Microcline (Mi) and Biotite (B). {iii} Photomicrograph of Banded gneiss in transmitted light showing Quartz (Q), Hornblende (H) and Biotite (B). {iv}Photomicrograph of Granite gneiss in transmitted light showing Quartz (Q), Hornblende (H) and Biotite (B Bar scale = 20mm, Resolution: 150 dpi, Mag X40

albite occurring as patchy perthite. It however displays characteristic cross hatch twining. Biotites occur as fine dark brown platy grains. The banded gneiss covers most of the study area with alternation of dark (Mafic) and light (Felsic) coloured minerals with average dip of 34˚W. The percentage of dark coloured minerals is relatively low to that of felsic, the light coloured minerals are mainly quartz. Petrographic studies of the banded gneiss show Quartz as the most abundant mineral present in the banded gneiss. It has an average visual modal analysis of 29.0%. Quartz also occurs as an intrusion and veins in the outcrop. Plagioclase is the second most abundant mineral present in the banded gneiss, it usually occurs as an intrusion on the outcrop. The mineral has a pink-yellowish colour. Biotite is less abundant in the banded gneiss with dark color which usually aligns in the same direction. Hornblende shows a niddle-like appearance under the thin section and it is dark green in colour with an average visual modal analysis of 8.2%. The biotite gneiss is light grey, medium to coarse grained, the outcrop is mesocratic to melanocratic; melanocratic due to the presence of dark minerals (biotite and hornblende), light minerals includes quartz and plagioclase feldspar (Figures 2b {i-iv}). From the study of structural features and rosette diagrams plotted, the general trend of the veins and intrusions lies in the NNE-SSW direction while the joints trends in the WNW-ESE which implies that the orientation of the joints and vein of the study area trends in these directions and the tectonic forces that led to the fracturing of the outcrops were more pronounced in these directions (Figures 3a-3e; Tables 2a-2b). The intrusions and veins are younger than the host rock. The intrusions and veins in the study area are mainly quartz and pegmatitic types. The Average modal composition (%) of minerals of representative samples in Ede study area is shown in Table1

Petrochemical Features

Ten stream sediment samples were analyzed for major and trace elements using inductively-coupled plasma atomic emission spectrophotometry (ICP-AES), at ACME LABORATORY LIMITED Vancouver Canada. The geochemical analytical procedure involves addition of 5ml of Perchloric acid (HClO4), Trioxonitrate (V) HNO3 and 15ml Hydrofluoric acid (Hf) to 0.5gm of sample.

The solution was stirred properly and allowed to evaporate to dryness after it was warmed at a low

Figure 3a. Quartz intrusion at Ede study area

Figure 3b. Quartz vein at Ede study area

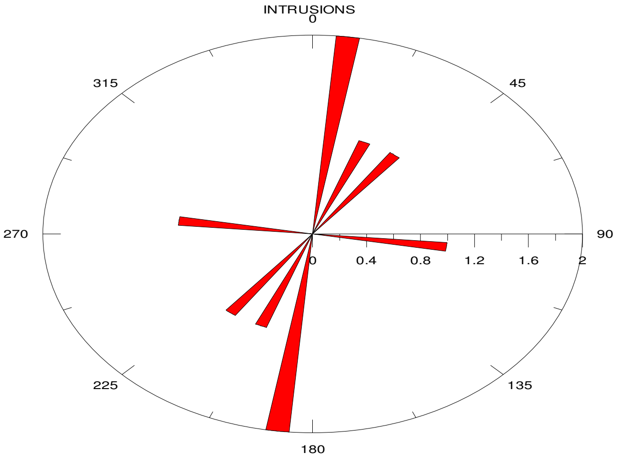

Figure 3c. Rossette diagram showing the orientation intrusion. (Trending NNE-SSW)

Figure 3d. Joint at Ede study area

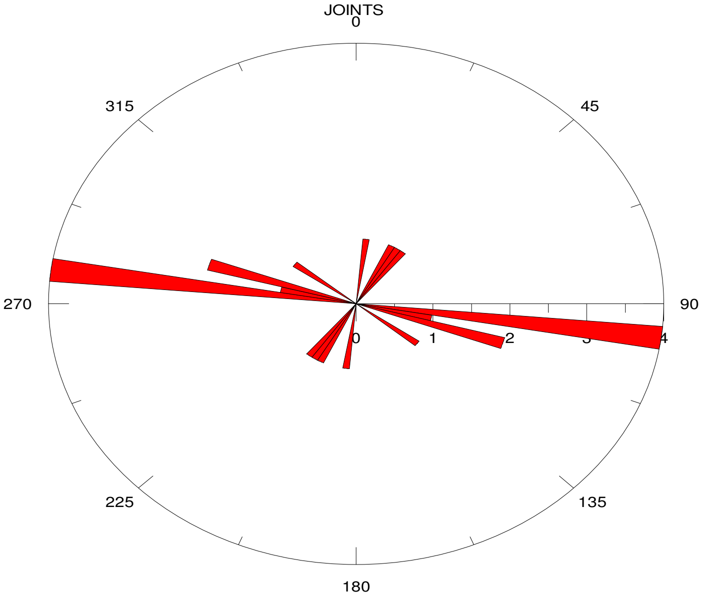

Figure 3e. Rossette diagram showing orientation of joints (trending WNW-ESE)

Table 1. Average modal composition (%) of minerals of representative samples in Ede study area

Minerals	Symbols	Loc1	Loc2	Loc3
Quartz	Q	23.4	29.0	18.6
Plagioclase	P	40.7	25.4	21.4
Microcline	M	22.7	17.2	18.4
Biotite	B	7.65	18.2	32.0
Hornblende	H	4.05	8.2	7.2
Opaque	O	1.5	2.0	2.4
Rock types		PEGMATITE	BANDED GNEISS	BIOTITE GNEISS

Table 2a. Orientation of intrusions

Azimuth	Azimuth	Frequency
1-10	181 – 190	2
11 -20	191 – 200	-
21 -30	201 – 210	1
31 -40	211 – 220	1
41 – 50	221 – 230	-
51 – 60	231 – 240	-
61 -70	241 – 250	-
71 – 80	251 – 260	-
81 – 90	261 – 270	-
91 – 100	271 – 280	1
101 – 110	281 – 290	-
111 -120	291 – 300	-
121 – 130	301 – 310	-
131 – 140	311 – 320	-
141 – 150	321 – 230	-
151 -160	331 – 240	-
161 – 170	341 – 250	-
171 – 180	251 – 360	-

Table 2b. Orientation of joints

Azimuth	Azimuth	Frequency
2-10	181 – 190	1
11 -20	191 – 200	-
21 -30	201 – 210	1
31 -40	211 – 220	2
41 – 50	221 – 230	-
51 – 60	231 – 240	-
61 -70	241 – 250	-
71 – 80	251 – 260	-
81 – 90	261 – 270	-
91 – 100	271 – 280	2
101 – 110	281 – 290	5
111 -120	291 – 300	-
121 – 130	301 – 310	1
131 – 140	311 – 320	-
141 – 150	321 – 230	-
151 -160	331 – 240	-
161 – 170	341 – 250	-
171 – 180	251 – 360	-

temperature for some hours. 4ml hydrochloric acid (HCl) was then added to the cooled solution and warmed to dissolve the salts. The solution was cooled; and then diluted to 50ml with distilled water. The solution is then introduced into the ICP torch as aqueous - aerosol. The emitted light by the ions in the ICP was converted to an electrical signal by a photo multiplier in the spectrometer, the intensity of the electrical signal produced by emitted light from the ions were compared to a standard (a previously measured intensity of a known concentration of the elements) and the concentration then computed.

RESULT AND INTERPRETATION

The analytical results for the Major elements are

Table 3a. Major element concentration of stream sediments of the study area (%)

SAMPLE LOCATION/OXIDES	Na_2O_3%	MgO%	Al_2O_3%	K_2O%	Ca_2O_3%	TiO_2%	Fe_2O_3%
L1	0.01072	0.0825	0.6426	0.0482	0.20985	0.031711	1.45962
L2	0.0067	0.0495	0.5292	0.03615	0.04197	0.01669	1.01601
L3	0.00804	0.0495	0.3969	0.0241	0.06995	0.031711	0.70119
L4	0.00804	0.0825	0.5481	0.04820	0.08394	0.03338	1.15911
L5	0.01072	0.1815	2.8728	0.13255	0.12591	0.035049	3.31992
L6	0.00134	0.0165	0.3402	0.01205	0.02798	0.041725	1.35945
L7	0.00938	0.396	0.9828	0.1928	0.34975	0.106816	1.78875
L8	0.00536	0.1815	1.0395	0.0723	0.11192	0.046732	2.44701
L9	0.00536	0.1815	1.0584	0.08435	0.12591	0.061753	2.16081
L10	0.00536	0.132	0.9828	0.06025	0.26581	0.030042	1.45962

Table 3b. Summary of major element concentration in stream sediments

ELEMENTS/OXIDES	Number	Ranges (%)	Mean	Standard deviation	Average Shale (%)
Na_2o	10	0.02798-0.34975	0.141299	0.54081	0.009
Mgo	10	0.0165-0.396	0.1353	0.07385	0.074
Al_2o_3	10	0.3402-2.8728	0.93933	0.02908	0.02
K_2o	10	0.01205-0.1928	0.071095	0.06663	0.025
Ca_2o_3	10	0.03378-0.42225	0.170589	0.01509	0.025
Tio_2	10	0.01669-0.106816	0.0435609	0.38756	0.0045
Fe_2o_3	10	0.70119-3.31992	1.687149	0.00216	0.047

presented in Tables (3a-b). Table 3a shows the major elements concentration and Table 3b shows the statistical summary of major elements with respect to their average shale content respectively .The major elements analyzed for include; sodium (Na), magnesium (Mg), Aluminum (Al), potassium (K), calcium (Ca), titanium (Ti) and Iron (Fe). The concentration of sodium ranges from (0.00134% - 0.01072%). The values are lower when compared to stream sediments around Abeokuta- Ibadan road (Benson, 2007), which ranges between (0.02% - 170%). Location 5 has the highest concentration of sodium (Table 3a). It has average background value of 0.009% (Table 3b). The geochemical map of sodium shows that it is more concentrated in the Northwestern and Northern parts of the Ede study area (Figure 4(i)). Concentration of magnesium ranges from (0.0165% - 0.396%) with average shale content of 0.074% (Table 3a and 3b). The concentrations of sediments around Abeokuta-Ibadan road (Benson, 2007) ranges from (0%-3.66%) %, which is found to be lesser than, that of the study area. The highest concentration of Mg is at Location 4 (Table 3a) which may be attributed to Mg-rich micas present in the study area. The geochemical map shows more concentration in the Northwestern area and low concentration in the southern part of the study area (Figure 4(ii)). The concentration of Aluminum ranges from (0.3402%-2.8728%), with the background value of 0.02% (Table 3b). When compared to sediments of Olode area (Folorunsho, 2004), it is found to be lower (0.38% - 1.9%). Location 5 has the highest concentration (Table 3a) which can be attributed to prevalence of clay minerals in the sample which may be derived from weathered feldspars from rocks. Its concentration on the geochemical map is in the Northeastern area of the map and the concentration is low towards the southern part (Figure 4(iii)). Potassium ranges from (0.01205% - 0.1928%) (Table3a).With Location 7 having the highest concentration and Location 6 having the lowest concentration with average value of 0.025% (Table 3b). This may be attributed to weathering of K-feldspar and micas. Also it could be anthropogenically introduced through soaps and detergents from the dwellers. The geochemical map shows a high concentration in the Northwestern area of the map and low concentration at the central of the study area (Figure 4(iv)). The concentration of Calcium ranges from (0.03378% - 0.42225%) in (Table 3a). Which is found to be higher than sediments of Oba area (Alao, 2006), ranging from (0.01% -0.37%). The highest concentration is observed in Location 10 with background value of 0.025% (Table 3b). The elevated concentration can be attributed to the presence of Ca-rich feldspars. The geochemical map of calcium shows more concentration in Northwestern area of the map and low concentration towards the southern portion of the study area (Figure 4(v)). The concentration

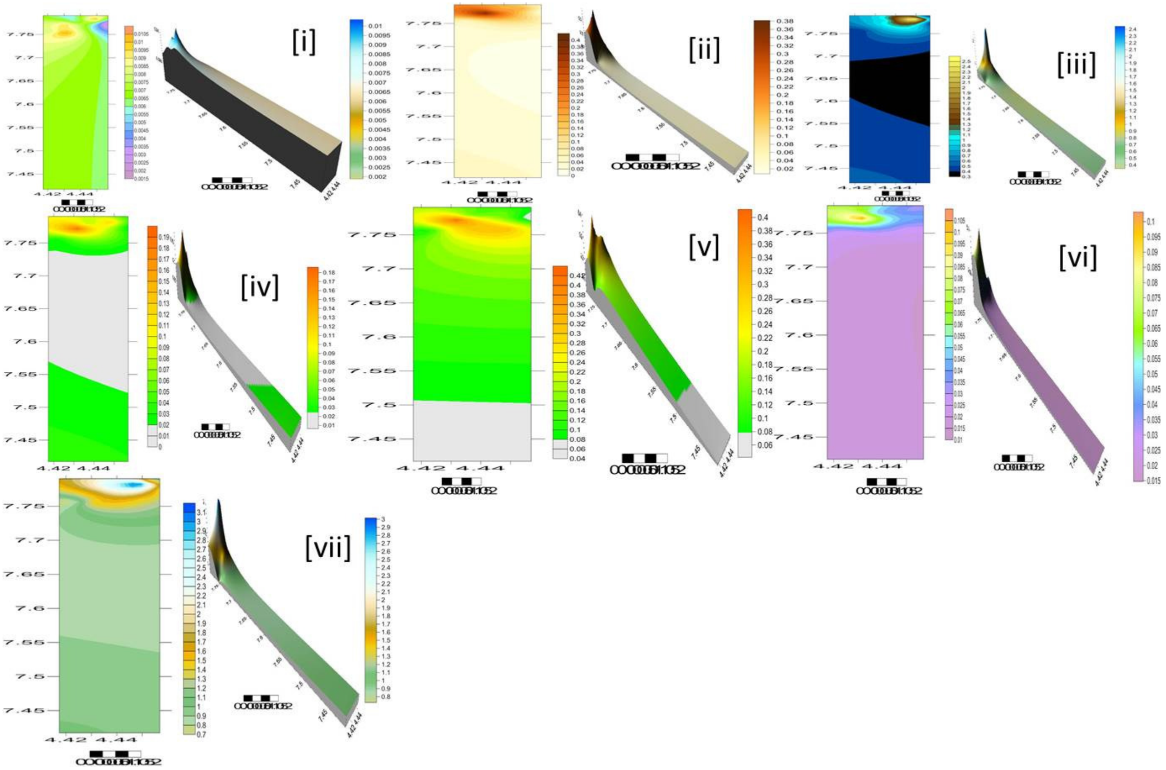

Figure 4. *[i]:* Showing the 2D and 3D geochemical map for sodium (Na). *[ii]:* 2D and 3D geochemical map for magnesium (Mg). *[iii]:* 2D and 3D geochemical map for Aluminium (Al). *[iv]:* 2D and 3D geochemical maps for potassium (K*)*. *[v]:* 2D and 3D Geochemical for Ca. *[vi]:*2D and 3D geochemical maps for titanium (Ti). *[vii]:*2D and 3D geochemical maps for iron (Fe)

of Titanium ranges from (0.01669% - 0.106816%). Its mean value is 0.0435609 (Table 3b), with the background value of 0.0045%. Concentration is found to be higher when compared to those of Oba area ranging 0.01% - 0.03%, (Alao, 2006). The highest value is recorded at Location7 (0.064%). It is usually linked to Ti-bearing minerals like illmenite. Titanum is more concentrated in the Northwestern portion of the geochemical map and is low at the center towards the south. (Figure 4(vi)). Iron concentration ranges from (0.70119% - 3.31992%), having average background value of 0.047%. Fe in all location is generally low in the study area with an average mean value of 1.687149%, (Table 3b). It is more concentrated in the northern portion of the study area and low in other areas of the map (Figure 4(vii)). The distribution of the Major elements is also shown in the Line diagram below (Figure 5); it depicts the highest or lowest level of the Major element concentrations within the Ede study area.

While the analytical results for the Trace elements geochemistry are presented in Tables (3c-d). The selected trace elements analyzed for include; Vanadium (V), Chromium (Cr), Manganese (Mn), Cobalt(Co), Nickel(Ni), Copper(Cu), Zinc(Zn), Gallium(Ga), Arsenic(As), Rubidium (Rb), Strontium(Sr), Zirconium(Zr), molybdenum (Mo),lead (Pb) and Tungsten (Y). The results of trace element analysis of the samples, the statistical summary of the concentration of the element and the distribution of trace elements in the study area are represented in Tables 3c and 3d respectively.

From the analytical results, Vanadium has minimum value of (12.00ppm) and maximum value of (52.00ppm) with mean value (27.9000ppm), Table 3d. When compared to the sediments of Oba area with value (5ppm -74ppm), it was found to be lower. The Highest concentration was observed in Locations 8 and 9 (Figure 7), the concentration of vanadium is more in the NE and it is low in the SW area of the map (Figure 6(i)). The values of chromium ranges from (16.60ppm -59.30ppm) with average mean value of (33.2400ppm) Table 3d. Its highest values were recorded at Location 5 and 7 respectively (Figure 7). The value obtained is lower than sediments from Ojota area with values ranging from (31-85ppm); chromium concentration is more in the NE area of the map (Figure 6 (ii)). Manganese value ranges from (225.00ppm -946.00ppm) with mean value of 541.0000ppm (Table 3d). The highest value for manganese was recorded in Location 8 and 7 respectively (Figure 7). From the geochemical map of manganese it shows that it is more concentrated in NW

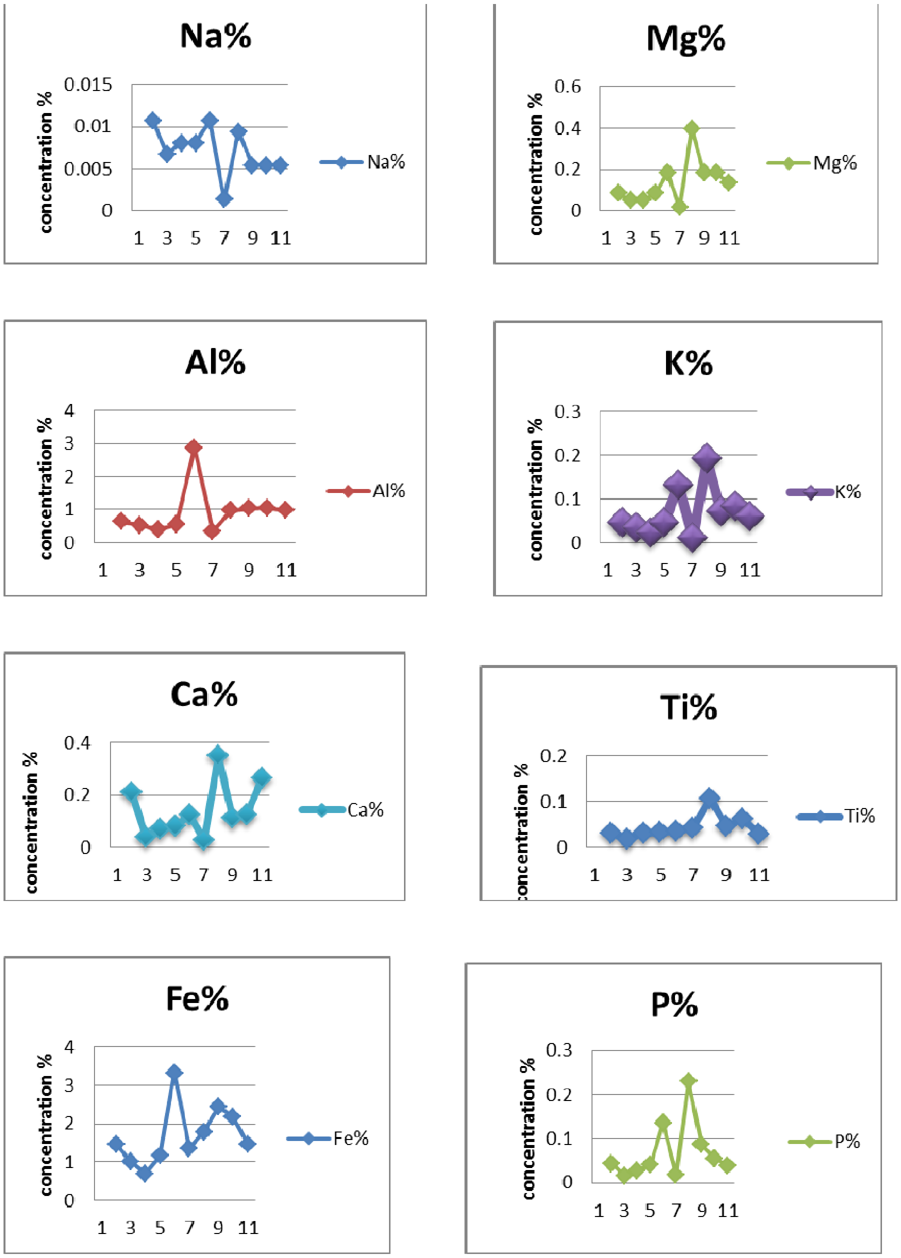

Figure 5. Line diagram showing the distribution of major elements

Table 3c. Trace element concentration of stream sediments of the study area in (ppm)

SAMPLE LOCATION	V	Cr	Mn	Co	Ni	Cu	Zn	Ga	As	Mo	Rb	Sr	Y	Zr	Pb
L1	23	27.4	548	8.1	5.8	16.76	41.9	1.9	0.3	0.35	7.7	9	3.52	0.5	12.32
L2	15	17.7	533	6.9	3.4	6.68	8.7	1.5	0.4	0.24	6.6	3.7	1.59	0.4	10.38
L3	12	16.6	303	3.7	3.1	7.48	11.3	1.1	0.2	0.1	3.8	8.8	4.05	0.4	7.43
L4	18	23.1	399	8.7	5.5	15.21	15.9	1.3	0.2	0.13	6.4	7	5.46	0.3	8.94
L5	52	59.3	225	9.5	18.5	24.16	30.3	7	0.6	0.3	29.9	13.4	21.01	0.9	20.4
L6	24	33	343	7.1	3.6	8.69	8.1	1	0.3	0.2	2.9	3.2	2.08	0.6	7.98
L7	28	51	771	11.8	15.5	49.72	36.6	2.4	0.6	0.33	14.8	13.7	7.37	0.3	8.01
L8	40	40.1	946	17.2	10.5	16.9	22.7	2.6	0.3	0.28	12.6	13.2	9.57	0.3	11.99
L9	40	37.2	834	19.8	9.8	24.25	21.5	2.8	0.3	0.37	14	14.8	9.14	0.7	15.56
L10	27	27	508	8.9	8.4	14.43	29.6	29.6	0.2	0.14	0.27	0.6	9.88	0.9	9.94

Table 3d. Summary of trace element concentration in stream sediments

ELEMENTS	Number	Minimum	Maximum	Mean	Standard Dev.
V	10	12.00	52.00	27.9000	12.60908
Cr	10	16.60	59.30	33.2400	13.95064
Mn	10	225.00	946.00	541.0000	240.33403
Co	10	3.70	19.80	10.1700	4.89105
Ni	10	3.10	18.50	8.4100	5.27140
Cu	10	6.68	49.72	18.4280	12.60556
Zn	10	8.10	41.90	22.6600	11.80397
Ga	10	1.00	29.60	5.1200	8.77583
As	10	0.20	0.60	0.3400	0.15055
Mo	10	0.10	0.37	0.2440	0.09743
Rb	10	0.27	29.90	9.8970	8.53123
Sr	10	0.60	14.80	8.7400	5.03746
Y	10	1.59	21.01	7.3670	5.68827
Zr	10	0.30	0.90	0.5300	0.23594
Pb	10	7.43	20.40	11.2950	4.04918

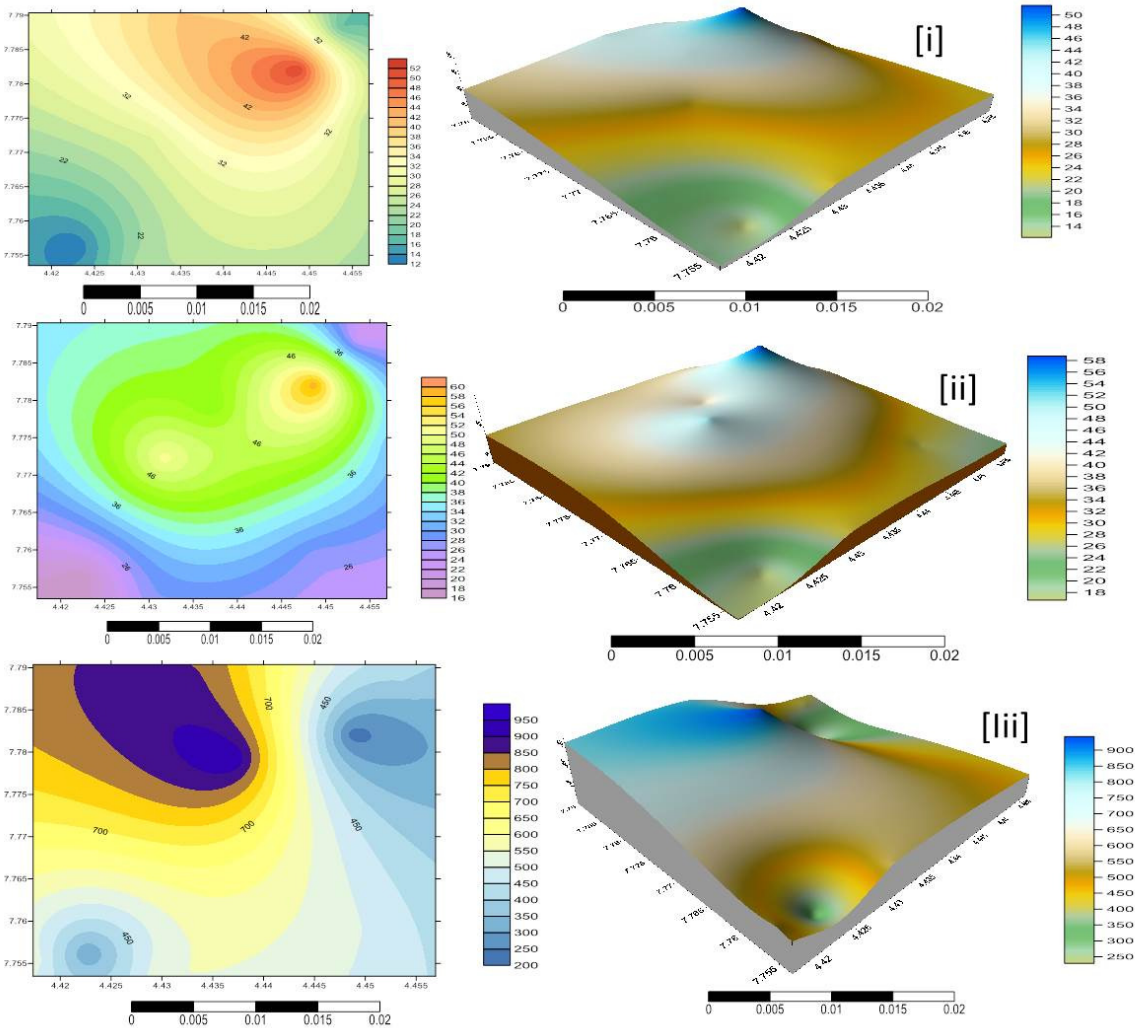

Figure 6. *[I ,ii, iii]:* Showing the 2D and 3D geochemical maps for trace elements (V), (Cr), and (Mn) respectively

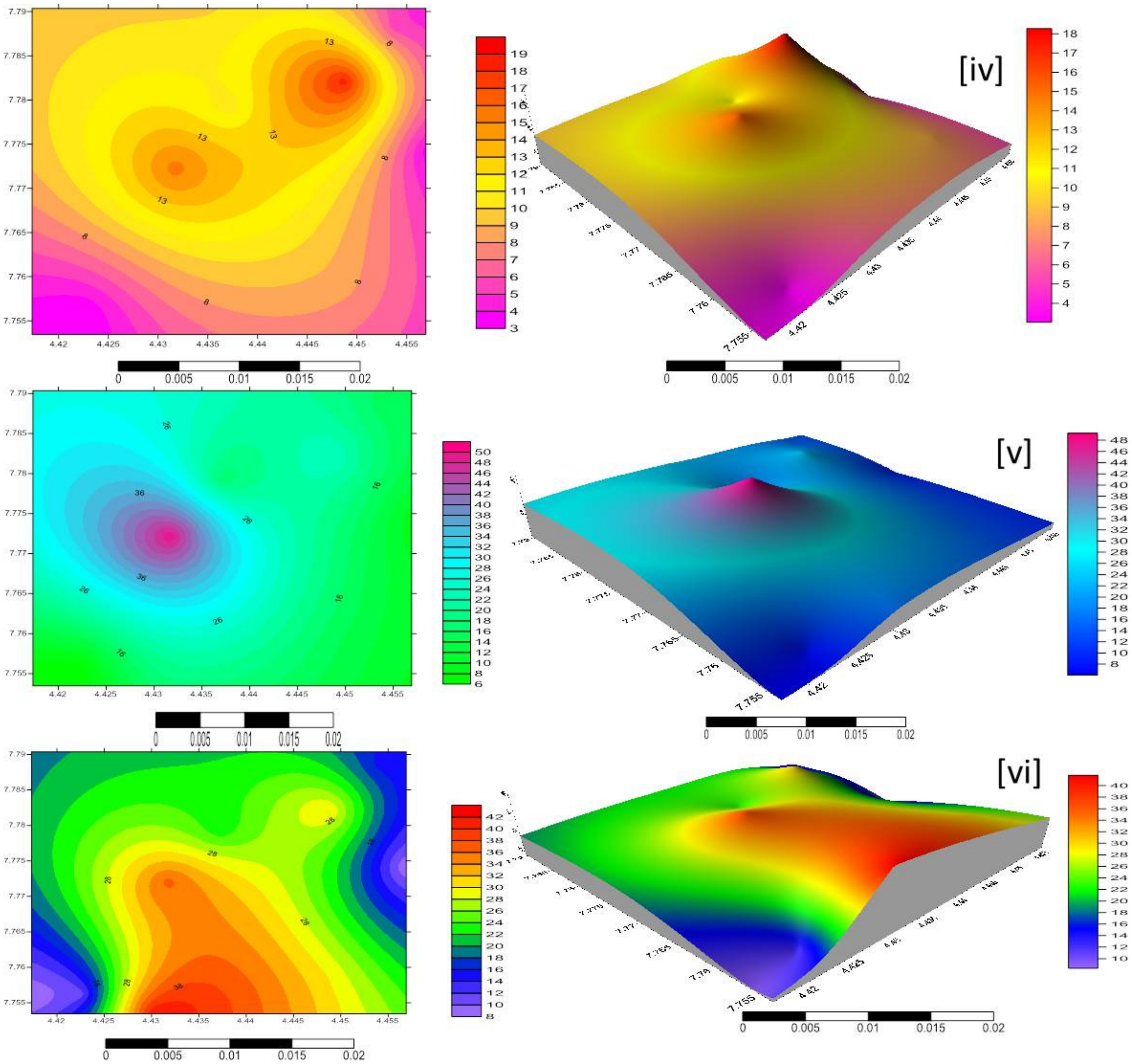

Figure 6. *[iv, v, vi]:* Showing the 2D and 3D geochemical maps for trace elements (Ni), (Cu), and (Zn) respectively

and low towards the NE and SW area of the map (Figure 6 (iii)). Nickel values ranges from (3.10ppm -18.50ppm) with an average mean value of (8.4100ppm); Copper has a minimum and maximum value of (6.68ppm- 49.72ppm) and a mean value of (18.4280ppm). Zinc has a mean value of (22.6600ppm) and it ranges from (8.10ppm - 41.90ppm) its concentration is high at the center towards the NE and decreases to the SW and eastern area of the map (Figure 6 (iv-vi)). Cobalt ranges between (3.70ppm - 19.80ppm) with a mean value of (10.1700ppm), Gallium has a mean value of (5.1200ppm), and their value ranges from (1.00ppm - 29.60ppm). While Arsenic has geochemical values ranging from (0.20ppm - 0.60 ppm) the geochemical map shows that it is more concentrated in the east to the NE areas and decreases towards the SW and SE portion of the study area (Figure 6 (vii-ix)). Lead ranges from (7.43ppm- 20.40ppm) with an average mean of (11.2950ppm) from the geochemical map it was observed that lead is more concentrated in the northern part of the map and decreases in other area especially to the SW area (Figure 6 (xv)). All other elements like Rb, Mo, Zr, Sr, and Y are observed to be lower than their respective background value So it can be inferred that such elements are depleted in the study are (Figure 6 (x, xi, xii, xiii and xiv)). In terms of the Inter – element relationship of trace elements and from general statistics, it is noted that;

When r ≥ 0.7- Very strong correlation,
0.5 < r > 0.7 – Strong correlation;
0.2 < r > 0.5 – Moderate correlation;
0.1 < r > 0.2 – Weak correlation;
r < 0.1 – No correlation or very weak correlation, where r is the correlation value.

It can be observed from the correlation matrix for

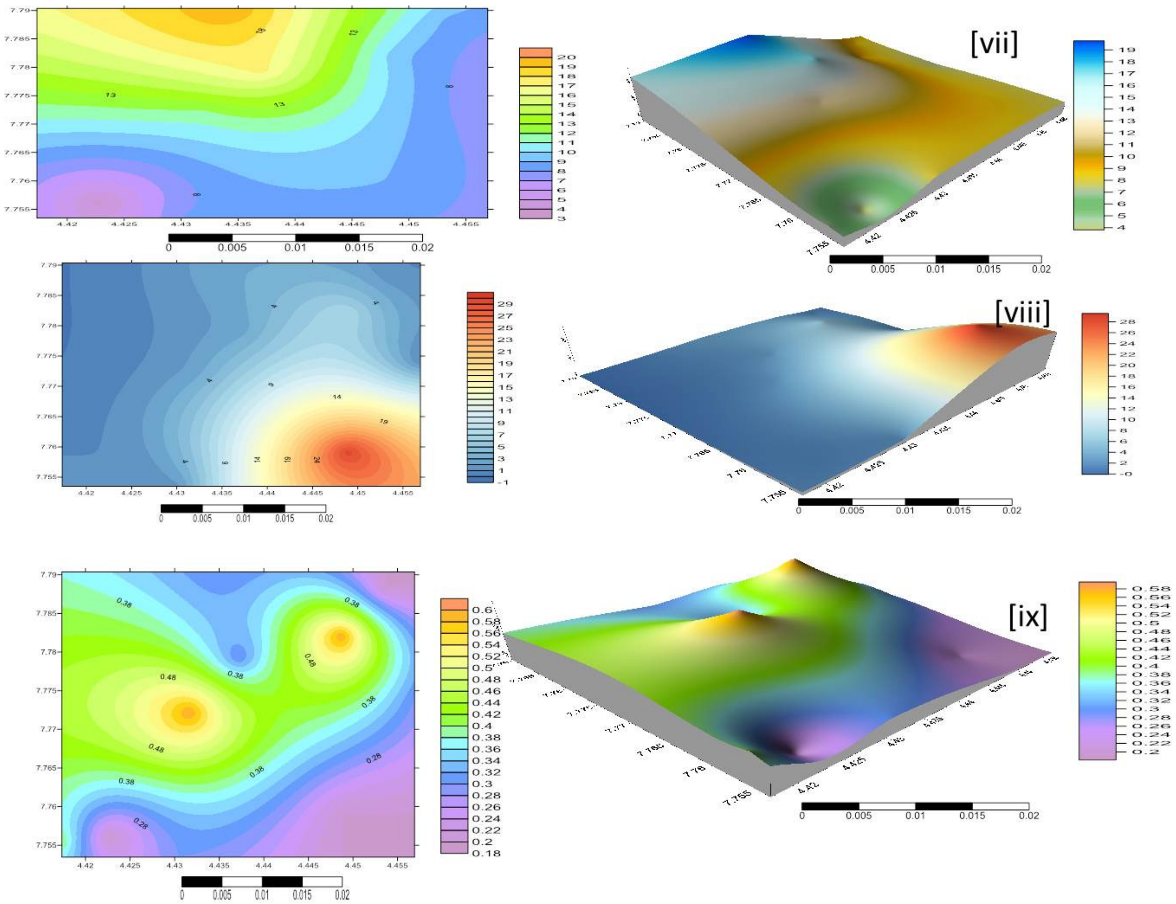

Figure 6. *[vii, viii, ix]:* Showing the 2D and 3D geochemical maps for trace elements (Co), (Ga), and (As) respectively

stream sediments of the Ede study area (Table 3e and Figure 8 (a-h)) that A very strong correlation exist between the following elements; Cr-V, Co-Mn, Ni-V-Cr, Cu-Cr-Ni, As-Cr-Ni, Rb-V-Cr-Ni-As, Sr-Rb-Y-V-Cr-Ni-Rb, Pb-V-Mo-Y with ‘r’ values of 0.860, 0.819, 0.828, 0.938, 0.728, 0.868, 0.770, 0.861, 0,861, 0.809, 0.837, 0.818, 0.801 respectively which shows a very strong correlation indicating that they are governed by the same geochemical factors and are from the same source. Also Co-V, Zn-Cr-Ni-Cu, As-V-Cu, Mo-V-Cr-Mn-Co-Cu-Zn-As, Rb-Cu-M0, Sr-V-Cr-Co-Ni-Cu-Mo, Zr-V-Ga-Y, Pb-Cr-Ni-Mo-Sr-Zr with ‘r’ values of 0.664,0.516, 0.614, 0.646, 0.506, 0.688, 0.591, 0.555, 0.636, 0.574, 0.570, 0.594, 0.532, 0.604, 0.611, 0.6480.632, 0.653, 0.631, 0.665, 0.513, 0.591, 0.602, 0.636, 0.653, 0.631, 0.567, 0.508, 0.592, respectively which shows strong correlation indicative of common origin.

Environmental Geology

In order to ascertain the degree of contamination and distinguish between natural and anthropogenic pollution sources, the Metal ratio, index of Geo accumulation (Muller, 1969); cumulative metal enrichment and contamination factor/degree of contamination was used to determine the environmental implication of trace element distribution in the stream sediments of the Ede study area and this was achieved using the afore listed geochemical parameters.

Metal ratio

Metal ratio is usually expressed with respect to average shale content to qualify the degree of pollution (Forstner and Wittman 1983). Table 4a; shows the computed values of metal ratio, while Figure 9; Shows a bar chart representing metal ratio of trace element in the study area. It is calculated thus; Cn/Cb

Where Cn–obtained concentration in ppm.

Cb – Average shale concentration in ppm.

The metal ratio of the selected trace elements is as follows : V, Cr, Co, Ni, Zn, Ga, As, Mo, Rb, Sr, Y and Zr, have values less than 1 in all locations, which means there is depletion of these elements in the study area

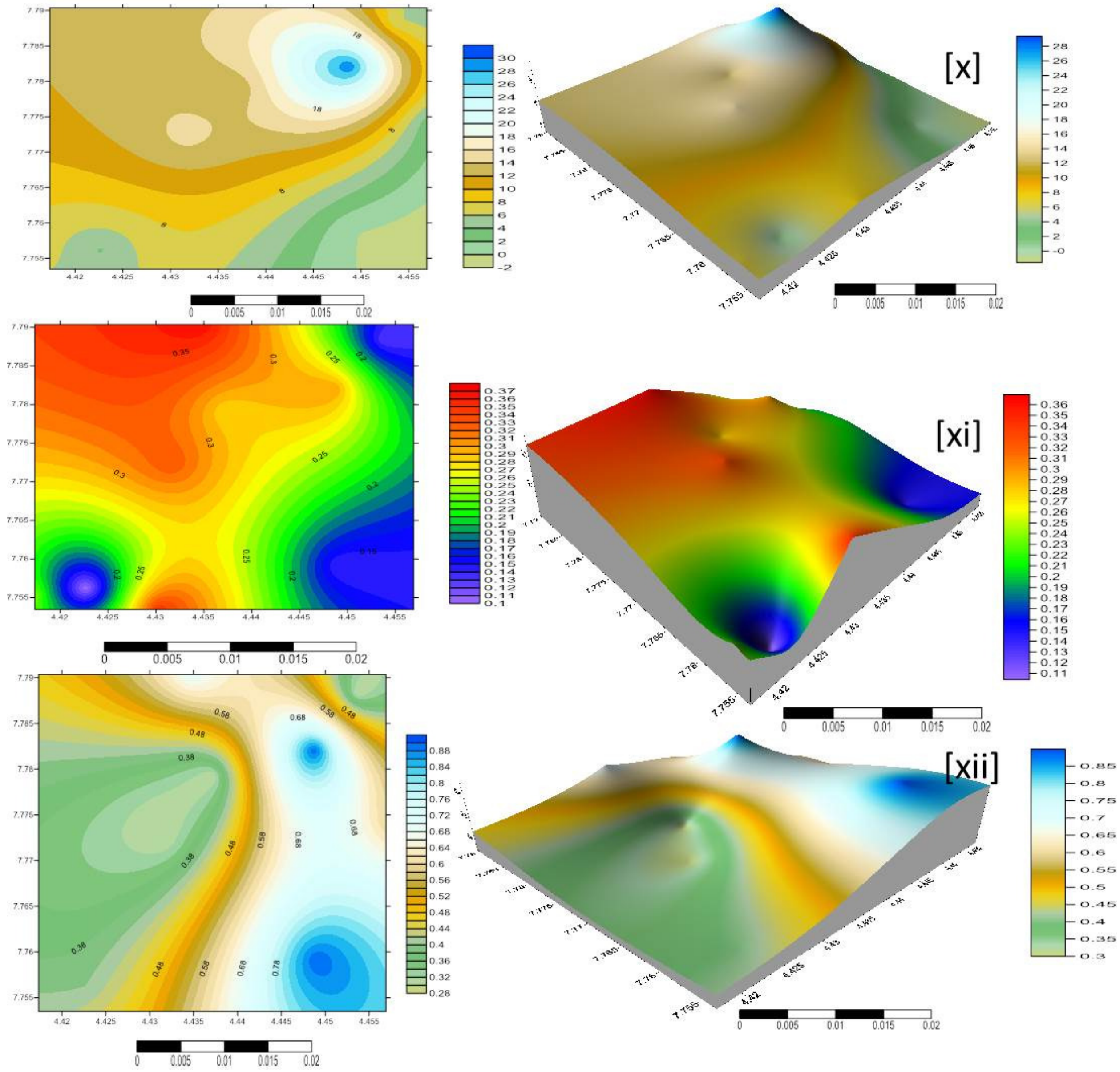

Figure 6. *[x, xi ,xii]:* Showing the 2D and 3D geochemical maps for trace elements (Rb), (Mo), and (Zr) respectively

(Figure 9). Mn and Pb values are greater than 1 which means there is enrichment of Mn and Pb in the study area.

Geo-accumulation Index (Igeo)

The index is used in assessing contamination. This is done by comparing current and background values which can be the World Health Organization standard. It is expressed as; (Igeo =$\log_2$ (Cn/1.5*Bn)

Where Cn = measured concentration of the element

Bn = Geochemical background value

1.5 = a constant allowed for natural fluctuation in the contents of a given substance in the environment and very small anthropogenic influences. There are six classes of geo-accumulation. These are shown below.

From (Table 4c and Figure10), the stream sediments are practically uncontaminated with respect to Strontium and Zirconium because they plot below zero value, while the stream sediments are uncontaminated to moderately contaminated with respect to Manganese, lead, cobalt, copper, chromium, zinc, rubidium, vanadium, yttrium, molybdnum, nickel, Arsenic and gallium.

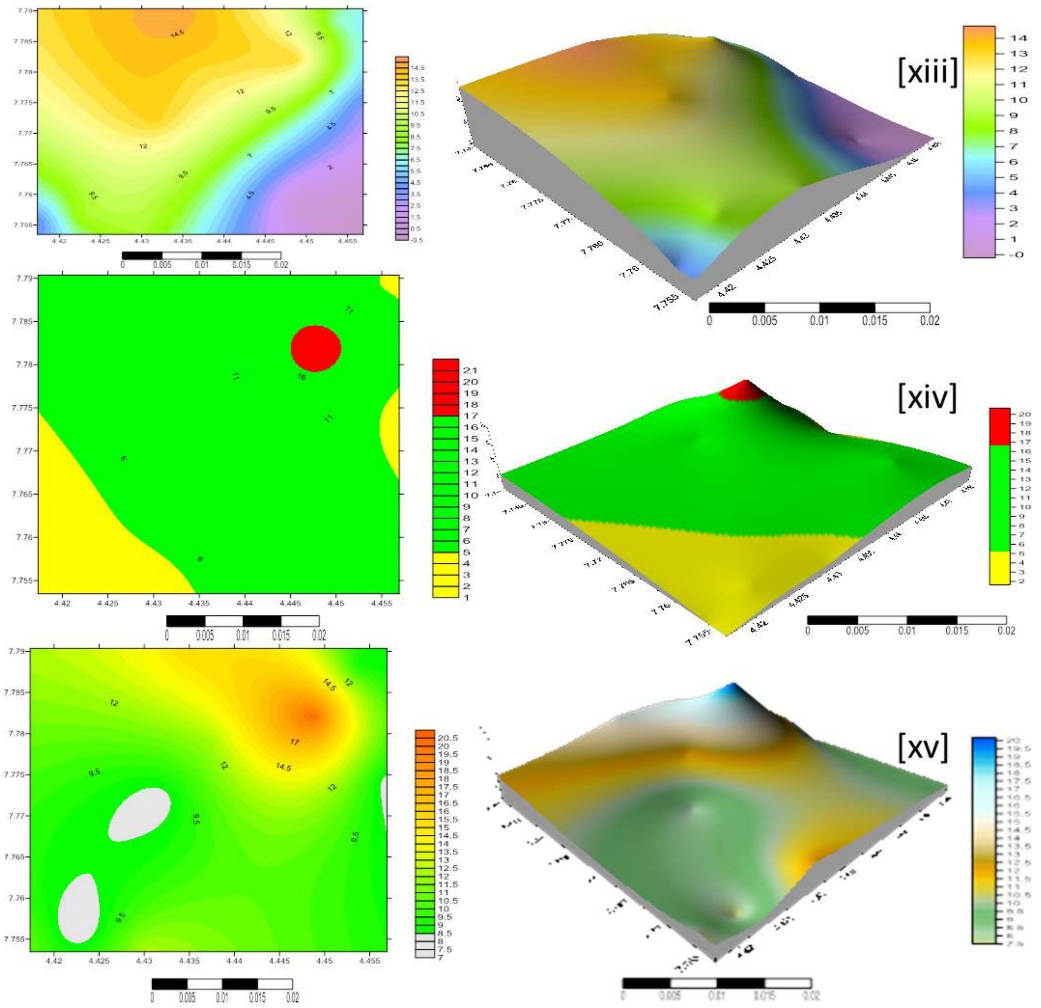

Figure 6. *[xiii, xiv, xv]:* Showing the 2D and 3D geochemical maps for trace elements (Sr), (Y), and (Pb) respectively

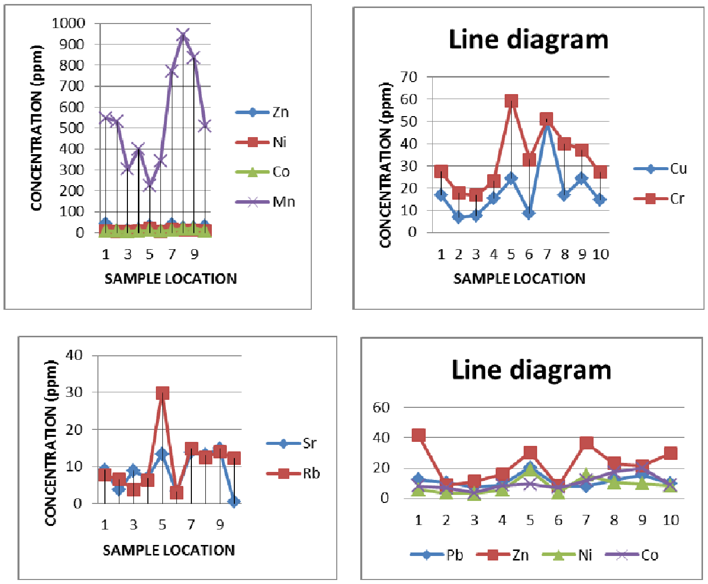

Figure 7. Line diagram showing the distribution of trace elements in Ede study area

Table 3e. Correlation matrix of trace elements in stream sediment of Ede study area

	V	Cr	Mn	Co	Ni	Cu	Zn	Ga	As	Mo	Rb	Sr	Y	Zr	Pb
V	1														
Cr	.860	1													
Mn	.254	.183	1												
Co	.664	.475	.819	1											
Ni	.828	.938	.206	.466	1										
Cu	.420	.728	.428	.441	.773	1									
Zn	.415	.516	.275	.254	.614	.646	1								
Ga	.145	.003	-.074	-.036	.168	-.038	.289	1							
As	.506	.788	.045	.133	.767	.688	.387	-.192	1						
Mo	.591	.604	.555	.636	.536	.574	.570	-.284	.594	1					
Rb	.812	.846	.041	.391	.856	.532	.384	-.211	.784	.604	1				
Sr	.611	.648	.449	.632	.653	.631	.390	-.459	.493	.665	.758	1			
Y	.868	.770	-.070	.350	.861	.377	.420	.341	.491	.270	.809	.482	1		
Zr	.513	.304	-.343	.036	.322	-.081	.209	.657	.088	.072	.242	-.166	.591	1	
Pb	.837	.602	-.015	.425	.631	.152	.349	.061	.440	.567	.818	.508	.801	.592	1

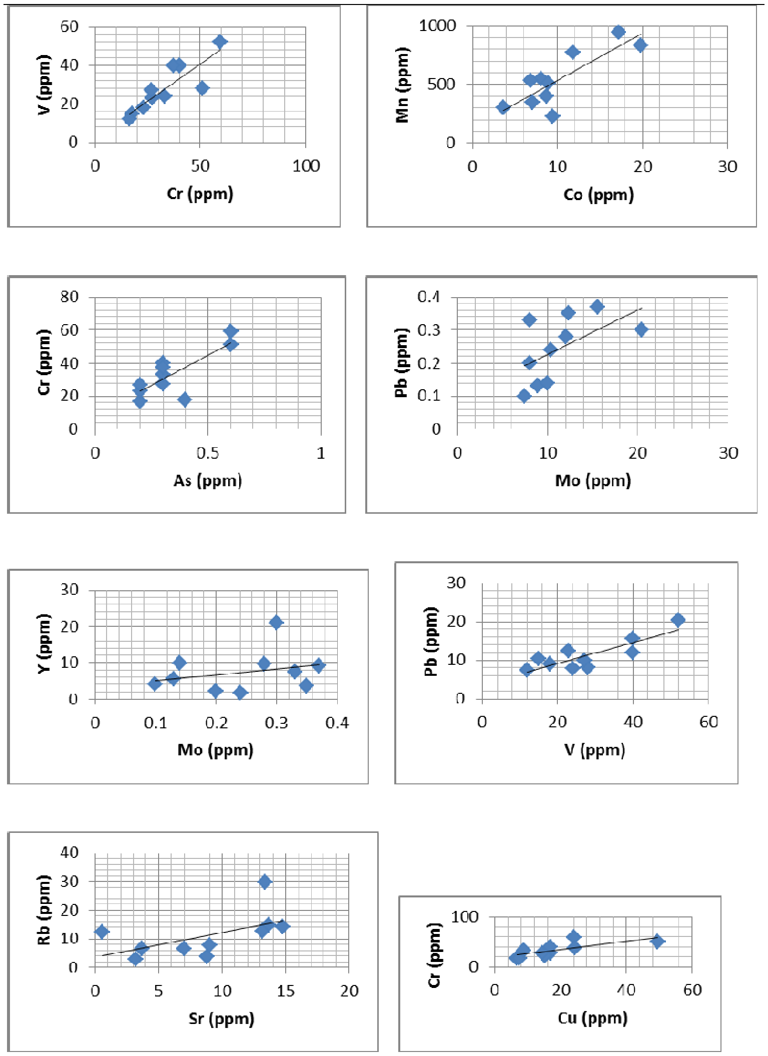

Figure 8 (a-h) .Scatter plots for correlation matrix of trace elements in Ede study area

Table 4a. Metal ratio of trace element in the Ede study area

SAMPLE LOCATION	V	Cr	Mn	Co	Ni	Cu	Zn	Ga	As	Mo	Rb	Sr	Y	Zr	Pb
L1	0.18	0.27	0.65	0.41	0.07	0.34	0.47	0.08	0.03	0.18	0.15	0.023	0.10	0.003	0.62
L2	0.12	0.18	0.63	0.35	0.04	0.13	0.09	0.06	0.04	0.12	0.13	0.009	0.05	0.002	0.52
L3	0.09	0.17	0.36	0.19	0.04	0.15	0.13	0.04	0.02	0.05	0.08	0.022	0.12	0.002	0.37
L4	0.138	0.23	0.47	0.44	0.07	0.30	0.18	0.05	0.02	0.07	0.13	0.018	0.01	0.002	0.45
L5	0.4	0.59	0.27	0.48	0.23	0.48	0.34	0.28	0.06	0.15	0.60	0.034	0.60	0.005	1.02
L6	0.19	0.33	0.37	0.36	0.05	0.17	0.09	0.04	0.03	0.1	0.06	0.008	0.06	0.003	0.40
L7	0.22	0.51	0.91	0.59	0.19	0.09	0.41	0.10	0.06	0.17	0.30	0.034	0.21	0.002	0.40
L8	0.31	0.40	1.11	0.86	0.13	0.34	0.25	0.10	0.03	0.14	0.25	0.033	0.27	0.002	0.60
L9	0.31	0.37	0.98	0.99	0.13	0.49	0.24	0.11	0.03	0.19	0.28	0.037	0.26	0.004	0.78
L10	0.21	0.30	0.60	0.45	0.12	0.29	0.33	0.10	0.02	0.07	0.24	0.040	0.28	0.004	0.50

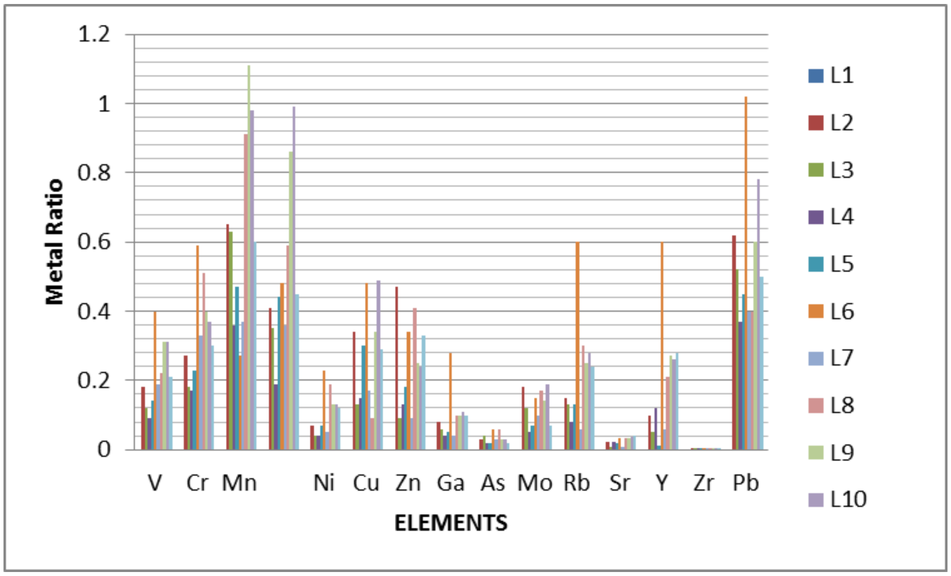

Figure 9. Bar chart showing the metal ratio of trace elements

Table 4b. Geo-accumulation index classes

CLASSES	RANGES	INDICATION/QUALITY
0	Igeo<0	Practically uncontaminated
1	0<Igeo<1	Uncontaminated to moderately contaminated
2	1<Igeo<2	Moderately contaminated
3	2<Igeo<3	Moderately to heavily contaminated
4	3<Igeo<4	Heavily contaminated
5	4<Igeo<5	Heavily to extremely contaminated
6	5<Igeo<	Exetremely

Cumulative Metal Enrichment

This is the cumulative representation of elements in stream sediments of the study area. For each of the element, the average shale is brought back to 100 making it a total of 500 for five (5) elements. The ratio of this value to the sum of measured concentration of the five (5) elements in each sample represent the cumulative effect of trace elements introduced into the stream sediments. The computed result is represented in Table 4d, while Figure11; shows a bar chart of the cumulative effect of the five (5) elements. Location 8 has

Table 4c. Geo-accumulation of Trace Element Concentration in stream sediments of Ede study area

SAMPLE LOCATION	V	Cr	Mn	Co	Ni	Cu	Zn	Ga	As	Mo	Rb	Sr	Y	Zr	Pb
L1	0.03	0.05	0.13	0.08	0.02	0.07	0.09	0.02	-0.06	0.04	0.03	-0.05	0.02	-0.006	0.124
L2	0.02	0.04	0.12	0.07	-0.08	0.03	0.02	0.01	-0.08	0.02	0.03	-0.02	-0.09	-0.005	0.104
L3	0.02	0.03	0.07	0.03	-0.07	0.03	0.03	-0.09	-0.04	0.01	0.02	-0.04	0.02	-0.005	0.075
L4	0.03	0.05	0.09	0.08	0.02	0.06	0.04	0.01	-0.04	0.01	0.03	-0.04	0.03	-0.003	0.089
L5	0.08	0.12	0.05	0.09	0.07	0.09	0.07	0.06	0.01	0.03	0.12	-0.07	0.12	-0.010	0.205
L6	0.04	0.06	0.08	0.07	-0.09	0.03	0.02	-0.08	-0.06	0.02	0.01	-0.02	0.01	-0.007	0.080
L7	0.04	0.10	0.18	0.12	0.04	0.20	0.08	0.02	0.01	0.03	0.06	-0.07	0.04	-0.003	0.080
L8	0.06	0.08	0.22	0.17	0.03	0.07	0.05	0.02	-0.06	0.03	0.05	-0.07	0.05	-0.003	0.120
L9	0.06	0.07	0.19	0.19	0.02	0.09	0.05	0.02	-0.06	0.04	0.06	-0.07	0.05	-0.008	0.156
L10	0.04	0.06	-0.13	0.09	0.02	0.06	0.06	0.02	-0.04	0.01	0.05	-0.08	0.06	-0.08	0.099

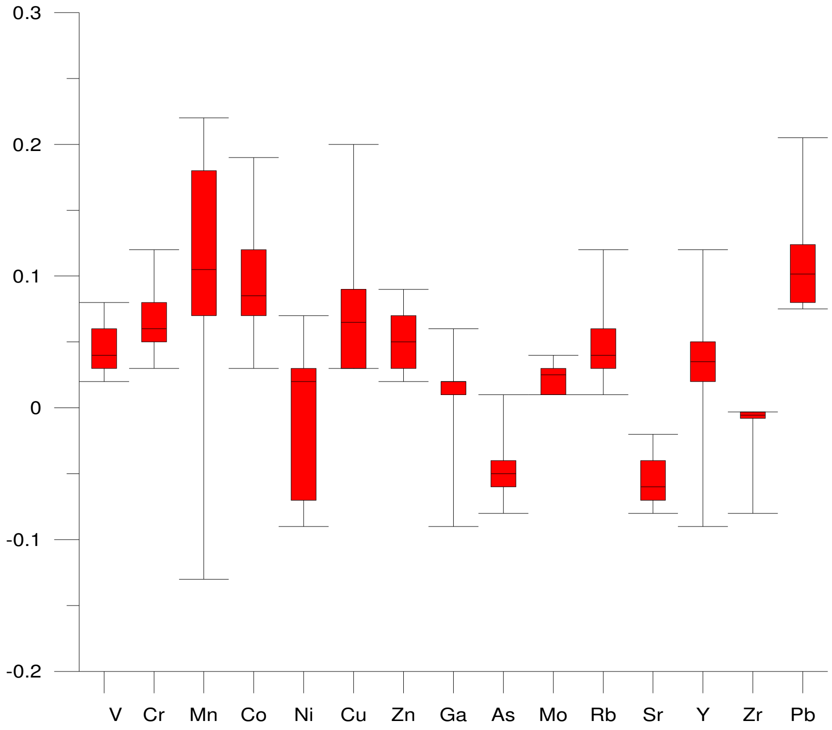

Figure 10. Box plot of geo –accumulation index for selected trace elements

the highest level of trace elemental input with a value of 2.1, while location 3 has the least cumulative enrichment with a value of 0.67 (Table 4d). The cumulative metal enrichment shows the concentration of trace element in all the locations. From the highest concentration to the lowest as depicted in Locations 8, 9, 7,5,10, 1, 2, 4, 6 and 3. (Figure 11) shows the bar chart distribution of metal enrichment where location 8, 9 and 7 has the highest metal enrichment and Location 3 has the lowest.

Contamination Factor and Degree of Contamination

The assessment of sediment contamination was also carried out using the contamination factor and degree of contamination. This enables an assessment of contamination through making reference of the concentration of the surface, to the background values (average shale content); Hakanson (1980). The contamination factor is calculated using the formula Cf=C-1/Mn, Where C-1; is the obtained mean concentration in (ppm) and Mn is the average background value of the elements. Contamination index is employed to determine the degree of contamination in the stream sediments. The assessment of the overall contamination of sediment was based on the degree of contamination index. The contamination factor is a single element index. The sum of the contamination factors for

Table 4d. Cumulative metal enrichment

Location	Total Conc. (%)	Background value	Cumulative metal enrichment
L1	603.52	500	1.21
L2	574.53	500	1.1
L3	334.53	500	0.67
L4	446.14	500	0.89
L5	613.20	500	1.23
L6	393.98	500	0.78
L7	856.61	500	1.71
L8	1027.89	500	2.1
L9	920.56	500	1.84
L10	580.24	500	1.16

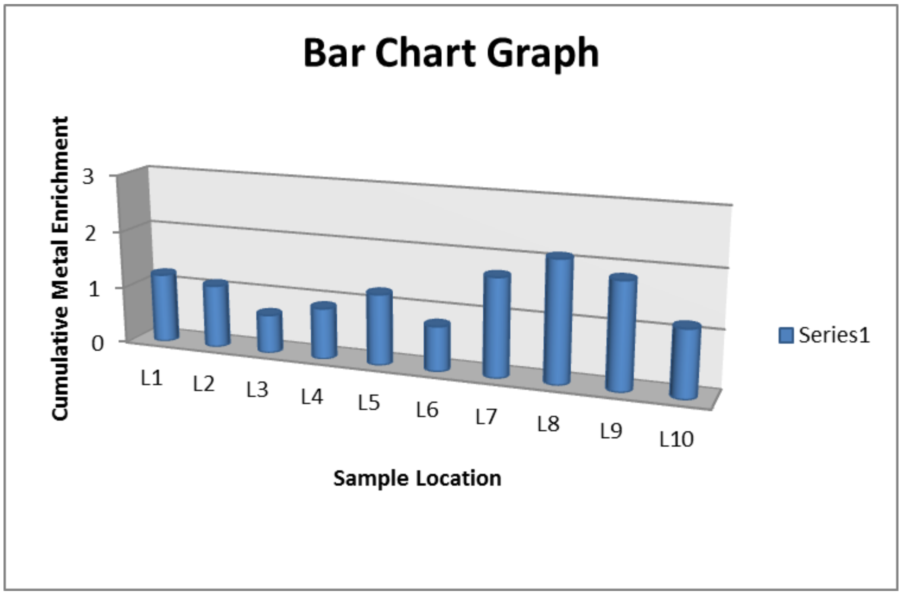

Figure 11. Cumulative Metal Enrichment of Trace elements in the Ede study area

all element examined represents the degree of contamination (Cdeg) of the environment and four classes are recognized (Table 4e).

Contamination Degree (Cdeg)

Contamination degree is the sum total of all contamination factors of all metals examined. It gives the overall contamination in the study area four classes are recognized (Table 4g).

Based on the contamination factor (Cf), the sediments has low contamination factor (Cf<1) indicating low contamination with respect to: V, Cr, Mn, Co, Ni, Cu, Zn, Ga, As, Mo, Rb, Sr, Y, Zr and Pb (Figure 12).

The degree of contamination for the mean elemental concentration in the stream sediments is 3.50˚, which fall in the class Cdeg<8, (Low degree of Contamination).

It is observed that Manganese (Figure 13 and 14) contributed most to the overall degree of contamination index with a value of 65.83 ˚, Pb – 57.6 ˚, Co – 52.50 ˚, Cu – 38.10 ˚, Cr – 33.94 ˚, V – 21.60 ˚, Y – 21.60 ˚, Ga – 20.57 ˚, Rb – 19.54 ˚, Mo – 12.34 ˚, Ni – 11.31 ˚, As – 3.10 ˚, Sr – 2.06 ˚, Zr – 3.08 ˚; (Table 4f).

From the result of the geochemical parameters used, the trace elements identified here are not pollutant (study area is not practically polluted).

CONCLUSION

Considering the geochemical analysis of the stream sediments as well as its interpretation, it can be deduced that the stream sediments of Ede area southwestern Nigeria; originated from rocks that are highly rich in ferromagnesian minerals also from the local geology of

Table 4e. Descriptive classes of contamination factor (Hakanson, 1980)

CLASSES	INDICATION
CiF<1	Low contamination factor
1<CiF<6	moderate contamination factor
3<CiF<6	Considerable contamination factor
6<CiF	Very high contamination factor

Table 4f. Degree of contamination of trace elements

ELEMENT	MEAN	AVERAGE(ppm)	CONTAMINATION FACTOR(F)	OVERALL DEGREE OF CONTAMINATION INDEX(˚)
V	27.9000	130	0.21	21.6
Cr	33.2400	100	0.33	33.94
Mn	541.0000	850	0.64	65.83
Co	10.1700	20	0.51	52.50
Ni	8.4100	80	0.11	11.31
Cu	18.4280	50	0.37	38.10
Zn	22.6600	90	0.03	3.10
Ga	5.1200	25	0.20	20.57
As	0.3400	10	0.03	3.10
Mo	0.2440	2	0.12	12.34
Rb	9.8970	50	0.19	19.54
Sr	8.7400	400	0.021	2.06
Y	7.3670	35	0.21	21.60
Zr	0.5300	180	-0.03	-3.08
Pb	11.2950	20	0.56	57.6
DEGREE OF CONTAMINATION INDEX			3.50	

Table 4g. Descriptive classes of contamination degree

CLASSES	CONTAMINATION DEGREE
Cdeg<8	low degree of contamination
8≤Cdeg<16	Moderate degree of contamination
16≤Cdeg<32	considerable degree of contamination
32≤Cdeg	Very high degree of contamination

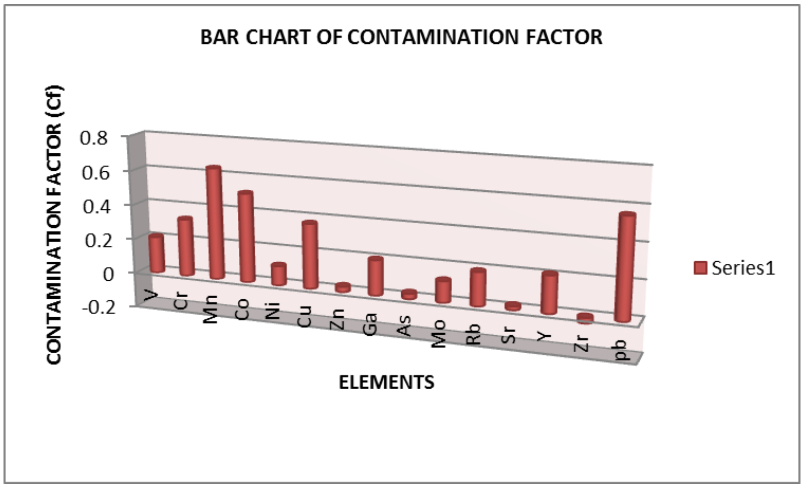

Figure 12. Bar Chart showing the contamination factor of trace elements

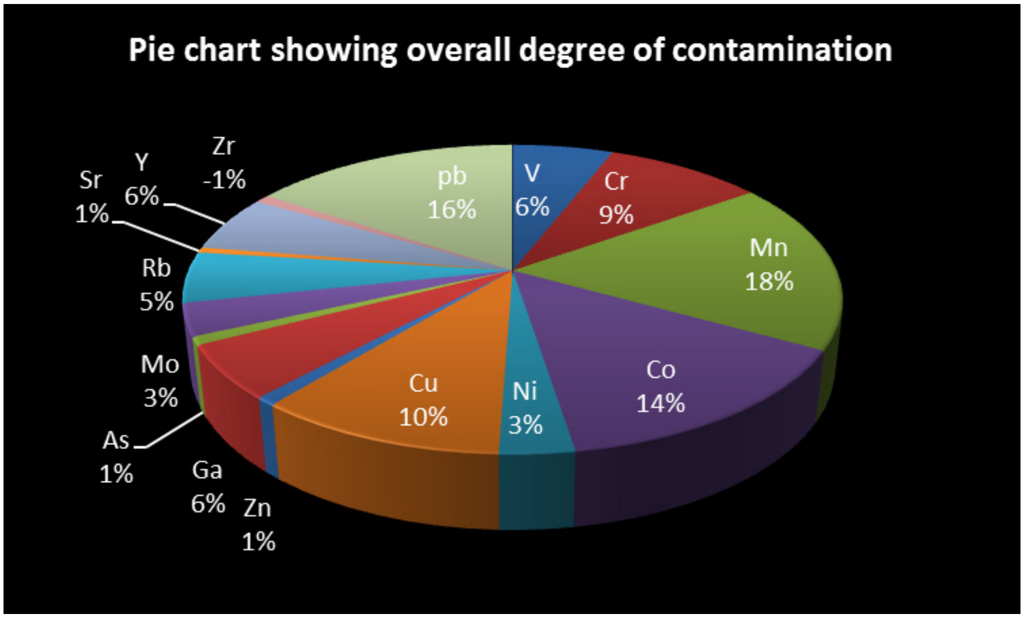

Figure13. Pie Chart showing the distribution of trace elements in Ede area

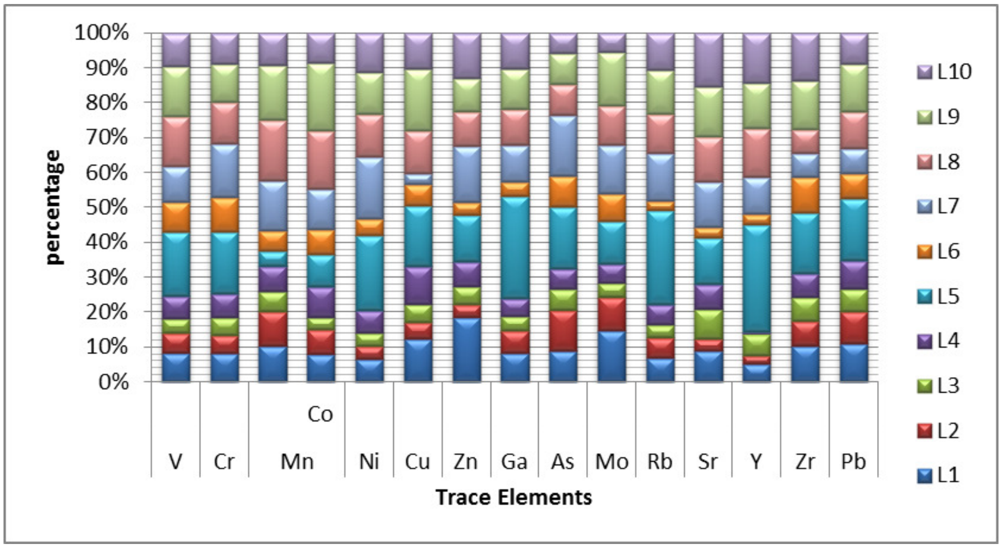

Figure 14. Percentage contribution of trace elements in stream sediments samples collected

the study area, the following lithologies; Pegmatite, Banded Gneiss and Biotite gneiss were recognized. The rosette diagrams show that; veins and intrusions trend in the (NNE-SSW) direction; while joints trend in the (WNW-ESE) direction**.** The geochemistry of the stream sediments originated from their surrounding rocks. Fe and Al are the dominant major elements in the samples. Mg, K, Na, Ca; shows high concentration in location 7 which could be attributed to anthropogenic influence around the location. Fe indicates the possible occurrence of iron-bearing minerals while Al indicates that the stream sediments are also rich in alumino- silicate minerals which are mostly feldspar and mica. The presence of potassium {K} analyzed shows that clay minerals may be present in relatively small proportions which might have broken down from feldspar. The presence of Phosphorus (P) indicates the possibilities of locating mineralization of apatite and monazite while manganese (Mn) might indicate possibilities of manganese bearing rocks. Co, Cr, Cu and Ni that is present are also basic rock indicator elements (Ako 1980); while the combination of Zr, Hf, Th, U, Ce and W is related to pegmatite intrusions found within the study area. It could be concluded that the element distribution patterns and chemical composition of stream sediments of Ede study area is greatly influenced by the local geology of the area. From the correlation matrix of major elements, a strong correlation exist between the following elements; Mg-Ca-P, Ti-P-Mg, Al-Fe, K-Ca-P-Mg-Ti with ‘r’ values of 0.769, 0.941, 0.941, 0.819, 0.876, 0.895, 0.711, 0.969, 0.782 respectively which shows a very strong correlation indicating that they are governed by the same geochemical factors and are from the same source; also from the correlation matrix of trace elements, a very strong correlation exist between the following elements; Cr-V, Co-Mn, Ni-V-Cr, Cu-Cr-Ni, As-Cr-Ni, Rb-V-Cr-Ni-As, Sr-Rb-Y-V-Cr-Ni-Rb, Pb-V-Mo-Y with ‘r’ values of 0.860, 0.819, 0.828, 0.938, 0.728, 0.868, 0.770, 0.861, 0,861, 0.809, 0.837, 0.818, 0.801 respectively which shows a very strong correlation indicating that they are governed by the same geochemical factors and are from the same source. From the results obtained from environmental geology, the tream sediments have a low contamination factor (Cf<1) value indicating low contamination with respect to: V, Cr, Mn, Co, Ni, Cu, Zn, Ga, As, Mo, Rb, Sr, Y, Zr and Pb. From the present study however, the present result provides baseline for geochemical information’s. Due to high concentrations of elements i.e. major and trace elements recorded in Locations L5 and L9 of Ede respectively. It is suggested that more detailed geophysical and geochemical surveys be done in these locations for possible mineralization of hematite and apatite. It is also ideal if a detailed geological mapping of the study area is achieved in order to evaluate the possible mineralization zones and potential mineable areas within then study area; as this will help in determining the quality and quantity (tonnage) of mineralization in the study area. Finally, I recommend that areas with weak Cu, Pb, Zn, As and Ni associated with Mn concentrations merit further investigation to ascertain if they can be pathfinders to gold mineralization in the area.

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