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Effective Factors on Environmental distribution of trace elements in the ChahMorra Cu Occurrence, Shahrood

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Abstract

The Chah Morra Cu occurrence is located 15 to 20 km north of Toroud village, south of Shahrood. In this area, Cu deposits are hosted by the andesitic sequence and most of rocks in this area are composed of andesite. Veins contain minerals such as digenite, bornite, covellite, malachite, cuprite, tenorite, native copper and Fe oxide and hydroxides. Also some orthomagmatic magnetite and chalcopyrrhotite are observed in polished sections. Study of heavy minerals shows that some minerals such as magnetite, titanomagnetite, hematite, limonite, oxidized pyrite, pyroxene, amphibole, epidote, oligist, ilmenite, zircon, apatite, barite and rutile are accumulated in stream sediments. Studies on 65 stream sediment samples analyzed for 44 elements by using ICP-OES method indicates that the Cu mineralization have not polluting effect, however the Chah Morra stream sediments indicate enrichment factor values higher than 1 for some elements including Bi, Co, Cu, Fe, Nb, Ni, Rb, U, Yb. Also the data higher than the standard values show that Cr, Pb, Sc and W in addition to above-mentioned elements are higher than the standard values. Calculation of I_{geo} shows that the Bi and Nb (second class of pollution), are among the pollutant elements in this area. Calculation of correlation coefficient and dendrogram shows that the pollutant elements aren't related to copper. Studies on Cu pollution were carried out on 276 litho-geochemical sample analyses. Analytical results show that contaminated points are accompanied by volcanic conglomeratic section (that include copper mineralized cobbles) and mineralized veins as the natural cause of pollution. Also distribution of Cu had been affected by the human activities such as historical and artisanal mining works. Fe contamination in the area is attributed to the alteration of andesitic rocks.

Keywords: Chah Morra, Stream Sediment, Litho-geochemistry, Heavy Minerals, Cu mineralization, Pollution.

1–Introduction

The environmental impact of mining pollution has been studied by various researchers. Stream sediments act as metals sink and can record effects of previous pollution. Also sediments can act as the metals source in variation of environmental conditions (Segura *et al*., 2006). As a result, metals could be released into drainage downward and also into groundwater (Alexakis, 2008).

The stream sediments geochemistry data are using for geochemistry map of the soil and water pollution (e.g. Darnley, 1990; British Geological Survey, 1990; Reimann *et al*., 1998; Rice, 1999; Key *et al*., 2004; Salminen *et al*., 2005; Johnson *et al*., 2005; Lapworth *et al*., 2012), the results are also used for the exploration targets, environmental hazards (natural and man-made), land use, and agricultural developments (Appleton and Ridgway, 1992; Plant *et al*., 2001; Lapworth *et al*., 2012).

Sediment content and geochemistry of stream sediments are not controlled just by physico-chemical weathering of source rocks, but other factors like climate, hydrologic and morphologic feature of the riverbed influence them. Congruent and incongruent dissolution in presence of aqueous solutions and their infiltration into the soils and rocks, can be cause of different chemical composition between source rocks and their weathering products (Nahon, 1991; Ranasinghe *et al*.,2009). Also channel bed morphology and stream bank slope can have an important influence on the mineral transportation and their grain size (Fletcher, 1996; Ranasinghe *et al*., 2009). Energy of the channel bed slope is directly related to the beginning of bed load transportation (Ranasinghe *et al*., 2009).

Although stream sediments geochemistry study is a promising tools for mineral deposit exploration, there was prevailed similar principles and methods (Dinelli *et al*., 2005).Basic geochemical differences were controlled by geologic sources and origin like chemical weathering and distributing processes. Smaller differences were made by human activities such as land use and it’s polluting (Lapworth *et al*., 2012).

Also litho-geochemical data used for correlation between stream sediment pollution with mineralized zone. These studies are also used to find source of the elements. The recorded geochemical distribution in litho- geochemical method is according to primary haloes of measured elements in the area. Many studies have shown that these haloes were common and because of their large extent, they usually have important applications (Hasani Pak, 2001).

The Torud- Chah Shirin Mountain are located in the south of Alborz Mountain and shows Characteristics of typical volcanic arcs. These mountains are hosted by many (but small) vein type deposits. In Chah Morra Cu bearing veins are hosted by andesitic rocks. Big and small ancient mining and vestige of oven and its slag, shows historic importance of Cu mining in this area.

Toroud region potentially was one of the mineral districts with a record of ancient importance because of copper, gold, zinc, lead, iron, manganese and industrial minerals mining. Because of these metals and minerals deposit existence, geochemical anomaly and thus elements pollution in this area is probable. The Chah Morra deposit was located in upstream of the Toroud village, so it is probable that the pollutions can be transported into village arable lands by running water (commonly as floodwater) or by groundwater (commonly as subterranean). Also the lands are used as rangeland of livestock grazing (including camels, sheep and goats). Thus if the lands have been polluted by potentially toxic elements, the elements can be transported from soils and rocks into herbage and subsequently to livestock and finally to human resulted in health disorders.

Checking the potentially toxic elements distributions in this area and the copper mineralization effects are the target of this research.

For environmental geochemistry study in this area, the stream sediments geochemistry and litho-geochemistry methods were used. The stream sediments geochemistry was selected because many minerals (especially sulfides) are unstable in weathered setting and oxidation condition and elements were distributed in the area by degradative reactions (Hasani Pak, 2002).

2– Materials and Methods

Environmental studies in Chah Morra Cu deposit are based on stream sediments geochemistry and litho-geochemistry. The sampling network of stream sediments and heavy minerals were designed for the study area. Because of the favorable outcrop of the rocks and extent of stream channels, the samples were taken from first and second order channels. The 33 heavy mineral samples were taken from two principal channels and the samples were sent to the Zar Azma laboratory for geochemical analysis. Also for stream sediment sampling a network with 550*550 m cells were designed and 2 to 3 samples were taken from each cell. To provide a representative sample for each cell, 100 grams of each sample were taking by riffle and were mixed with other sample of the same cell. By this method 154 samples were taken from the study area that after samples mixing their numbers were decreased to 65 and subsequently they were sent into laboratory. Stream sediment and heavy minerals sampling points and vein and chimney slag locations were shown in Attachment 1.

Samples were analyzed by ICP- OES (90ZR-0774Me Standard) in ZarAzma laboratory. Statistic analysis were done by SPSS 16 software. After primary screening and stream sediment samples analysis and statistical study, the polluted areas (for copper) were studied through litho- geochemical network sampling method with 50m and 100 m intervals (column interval was 50 m and rows interval was 100 m). The samples weight were between 1.2 to 2 kg and include at least 15 rock pieces that were taken in 5m radius of the sampling points. Sampling density were chosen 200 per each squire kilometer and because of financial constraints litho geochemical samples were analyzed by Atomic Absorption method for copper, iron, zinc, gold and silver in Zarshuran mine laboratory.

To determine the elements relationship with copper mineralization in the study area, 10 samples were taken from mineralized outcrop with hammer sampling method. These samples were sent to Zar Azma Laboratory and were analyzed by ICP-OES for 40 elements. Further, 30 thin sections from rock samples, 10 thin-polished sections and 17 polished sections from mineralized samples were prepared for other geological studies.

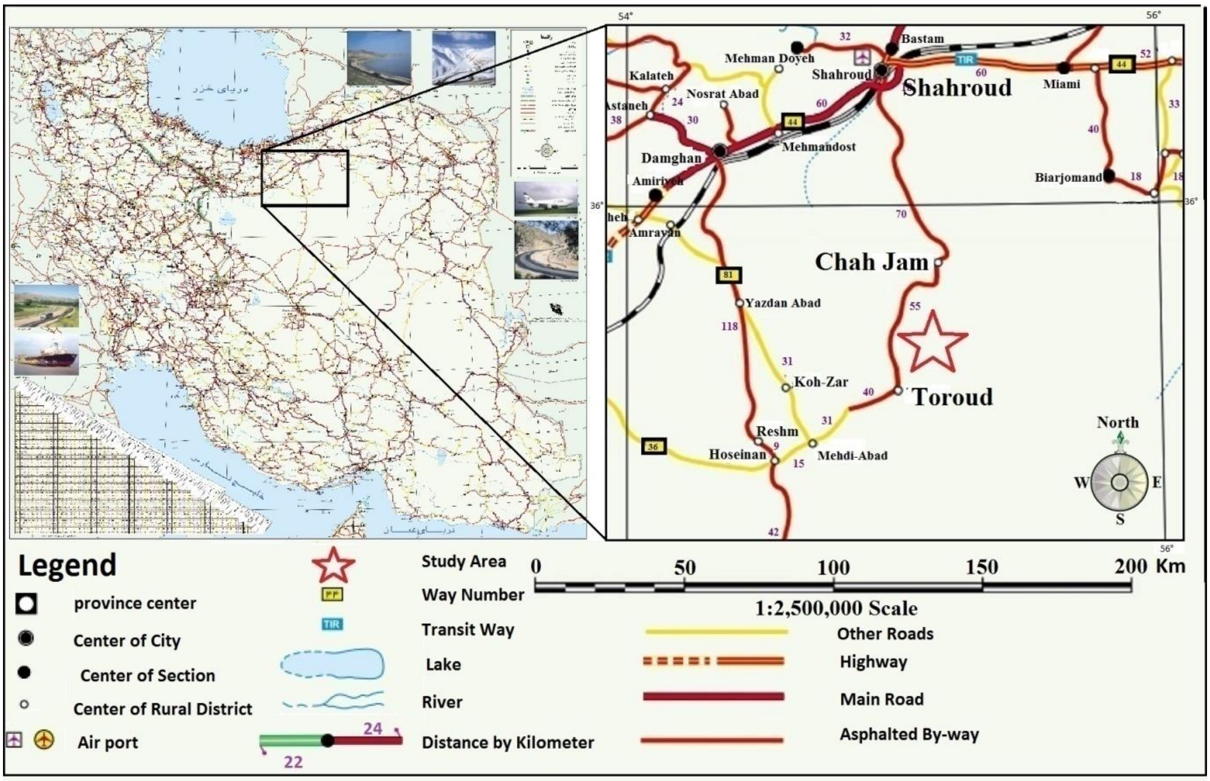

Figure 1) Chah Morra copper deposit location in Iran´s Road Map.

3– Geological setting of the study area

The Cah Morra copper deposit is located in center of the Toroud- Chah Shirn mountain ranges between 54°58´14´´ and 55°01´20´´ E longitude and 35°33´50´´ and 35°36´31´´N latitude. Access to the area is possible with a distance of about 100 km from Shahroud toward Toroud in their road and access to different part of the deposit done by local roads. Geographic location of this deposit is shown in Figure 1 on the Iran´s Road Map.

The Chah Morra deposit is located in central part of Toroud- Chah Shirin mountain range. This mountain range hasN-60°-70°E trend and is limited by Toroud Fault in south and Anjiloo Fault in the north with the same trends and nearly vertical slope and counter clockwise movements (Hoshmandzade *et al*., 1978). These main faults and their related subsidiary faults movement produced favorable setting for formation of numerous vein type deposits in this mountain.

Apart from the copper veins in some deposit such as Chah-Mousa, Cheshmeh- Hafez, Chah-Morra, … other vein type deposits in this area include gold deposit (such as Gandy, Abolhasani, Koh-Zar, Posideh and Darestan), Zinc and lead (Anaro, Golestani, Zarrin-Cheshmeh and etc), Iron (like Panj-Koh, Lajaneh and Hashdeh Robaei) and also some industrial deposit such as barite and silica.

The study area was limited by E_{V4} member of 1:250000 scale map of Torud and specifically E_v^2 member of 1:100000 scale map of the Rezveh that in spite of no active mines, there is a lot of mineralized copper veins and some evidence of historical mining excavations and oven remains, shows the area ancient significance.

3.1– Geological setting of the study area

Outcropped rock units in the study area based on 1:250000 scale geological map of Torud include tuff breccias and clastic rocks but their types based on 1:100000 scale geological map of Rezveh include intermediate to basic volcanic rocks (mainly andesite, andesite-basalt) and hyalo-clastic andesite- basalt and tuff breccias. Locally in association with basic feeder dykes. Petrographic studies on 30 thin sections in this research shows that outcropped rocks in study area are mostly andesitic, however other type of rocks such as conglomerate, lithic crystal tuff, rhyo- dacite and micro gabbro were identified there (Fig. 2).

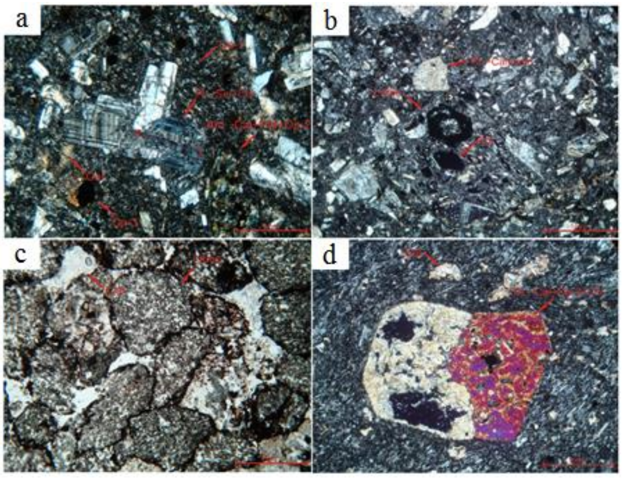

Figure 2a) Porphyritic andesite with plagioclase phenocrystal (xpl light); b) lithic pyroclastic tuff (xpl light); c) sandy conglomerate (ppl light); d) porphyritic andesit with pyroxene phenocrystal (xpl light).

3.2– Mineralization

In Chah Morra deposit 3 types of copper mineralization were recognized. These types include: 1) copper sulfides and carbonate veins with host rock gangue, 2) copper oxides and carbonates veins with prehnite and calcite gangue and 3) pebbles of conglomerate that are rich in copper sulfides and carbonates and with host rock gangue. Only the first type of mineralization has economically important and ore mineralography studies show that they include low sulfide mineral of copper such as digenite, bornite, covellite and Fe oxide and hydroxides, sulfide mineral remains and lepidocrocite. The second order vein mineral´s include native copper, cuprite and tenorite. Also the conglomerates pebbles mineral´s include digenite and covellite. Also the malachite is the copper carbonate mineral that exist in all the samples and some ortho- magmatic magnetite and chalco-pyrrhotite are present in some sections.

4– Data analysis

4.1- Veins geochemistry

Based on results of geochemical analysis of 8 first order mineralized samples, copper has highest correlation (spearman method analysis) with silver (0.738), As (0.732), Al (0.619), Zr (0.619), Mo (0.611) and P (0.595). Also the average concentration (maximum) for elements are: copper: 13218 (20912), Arsenic: 2.93 (3.2), silver: 0.965 (4.6), phosphor: 1146.75 (1685), zirconium: 95.88 (189), molybdenum: 0.9988 (1.13), zinc: 121 (179), lead: 13.88 (28) all in ppm and gold 7.88 (38) in ppb .

Because of the limited outcrop, no economic values and financial constraints, only one sample of each second and third type of mineralization were analyzed. The contents of elements in the second type vein is: copper: 11070, Arsenic: 7, silver: 1.2, phosphorus: 200, zirconium: 4, molybdenum: 0.5, zinc: 18 in ppm and amounts of elements in conglomerate pebbles is: copper: 84270, Arsenic: 11, silver: 2.6, phosphorus: 1600, zirconium: 22, molybdenum: 1.6, zinc: 17 in ppm.

4.2- Heavy mineral study results

The 33 samples were taken from 2 major channels for heavy mineral study. These samples were studied by Zarazma Mineral Studies Company. The resulted mean (and maximum) quantities for minerals are: magnetite: 30.55 (42.75)., titan-magnetite: 0.77 (6)., hematite: 22.09 (52/65)., limonite: 0.57 (5)., pyrite oxide: 0.50 (3.01)., pyroxene: 28.37 (67.5)., amphibole: 2.39 (27.5)., epidote: 0.19 (2.5)., oligist: 0.2 (3.5)., ilmenite: 5.69 (28)., zircon: 0.80 (4.5)., apatite: 1.30 (6)., barite: 0.91 (4.5)., rutile: 0.05 (0.5).

Other mineral quantities are lower than %0.3. The highest quantities are for Fe bearing ores (magnetite and hematite) that is expected because of rock outcrops (mostly andesitic rocks) and their alteration (hematitization and limonitization) in the area. After Hematite and magnetite the ilmenite have the highest quantities.

4.3-Stream sediment geochemistry

The 65 average samples were taken from stream sediments and were sent to Zar Azma Mineral Studies Company for doing ICP-OES analyses. Statistical calculations of analyses results were done with SPSS 16 software. The average, maximum, standard deviation, enrichment factors, percent of quantities higher than standard and in addition to the standard quantities (including quantities of sediment quality, earth´s crust and sandy soils) were shown in Table 1.

4.4-Enrichment factor

The enrichment factor was used to review the increase or decrease in elements concentration compared to their standards (sediment quality, earth´s crust or sandy soils in this research). This factor was presented by Boat-Menard (1979) and is calculated by:

$EF=S_c/R_c$

Where EF is enrichment factor, S_c is the elements concentration in sample and R_c is the element concentration in standard. The elements enrichment factors calculated in this research were shown in Table 1 showing that Bi, Ca, Co, Cu, Fe. Nb, Ni, Rb, U and Ybare enriched in comparison with the standard values.

4.5-Percent of quantities that are higher than standard (HTS)

Because of values higher than the standard, for some elements that their average is lower than standard, we use this factor in this research. By using this factor, the intensity and distribution of pollutions in the study area could be measured.

Table 1) The element quantities in sediments, earth´s crust and light sandy soils in addition to average, maximum, standard deviation, enrichment factors, percent of quantities that are higher than standard in study area. HTS: higher than standard percentage. (1: Batley and Maher, 2001., 2 and 3: Kabata-Pendias and Mukherjee, 2007; a: Enrichment factor calculated based on sediment quality; b: enrichment factor calculated based on earth´s crust and c: enrichment factor calculated based on sandy soils.)

Element	Sediment quality (1)	Earth´s crust (2)	sandy soils (3)	Average in study area	Max in study area	Standard deviation	Enrichment factor	HTS	I_{geo}
Ag(ppm)	1	0.08		0.31	0.42	0.04	0.31^{a}	0	-2.27^{a}
Al(%)		8.2		5.04	6.12	4161.8	0.6^{D}	0	-1.29^{D}
As(ppm)	20	2.5	30	3.46	4.4	0.3	0.1^{a}	0	-3.12^{a}
Au(ppm)		4	5	0.002	0.006	1.3	0.0004^{c}	0	-11.56^{c}
Ba(ppm)		584	780	285.06	328	16.9	0.3^{c}	0	-2.03^{c}
Be(ppm)		6	1.7	0.91	1.1	0.05	0.5^{c}	0	-1.5^{c}
Bi(ppm)		0.13		0.57	0.63	0.03	$4. 4^{D}$	100	1.5^{D}
Ca(%)	6.6	4.1		6.89	8.06	5249.3	1.04^{a}	68.2	-0.5^{a}
Cd(ppm)	1.5	0.2	0.2	0.34	0.5	0.6	0.2^{a}	0	-2.7^{a}
Ce(ppm)		60		29.22	36	1.6	0.5^{D}	0	-1.6^{D}
Co(ppm)		12	5.5	19.69	30	3.4	3.6^{c}	100	-1.3^{c}
Cr(ppm)	80	185	350	62.82	112	14.03	0.8^{a}	6.15	-0.9^{a}
Cu(ppm)	65	27	70	65.17	117	13.9	1.003^{a}	36.9	-0.1^{a}
Fe(%)		5	1	4.68	7.91	10641.7	4.7^{c}	0	-1.6^{c}
La(ppm)		30		16.49	20	0.9	0.5^{D}	0	-1.4^{D}
Li(ppm)		25	70	20.45	28	2.7	0.3^{c}	0	-2.4^{c}
Mn(ppm)		1400	2000	833.34	1086	83.3	0.4^{c}	0	-1.8^{c}

Mo(ppm)		1.1	3.7	1.04	2	0.1	0.3^{c}	0	-2.4^{c}
Nb(ppm)		26	8	38.88	71	9.2	4.86^{c}	100	1.7^{c}
Ni(ppm)	21	20	33	24.12	32	3.3	1.1^{a}	78.5	-0.4^{a}
Pb(ppm)	50	15	40	28.28	54	9.1	0.6^{a}	3.1	-1.4^{a}
Rb(ppm)		110	50	117.82	130	4.8	2.3^{c}	100	-.7^{c}
Sb(ppm)	2	0.9	1.33	1	1.1	0.03	0.5^{a}	0	-1.6^{a}
Sc(ppm)		30	14	12.47	17.1	1.7	0.9^{c}	18.5	-0.7^{c}
Sr(ppm)		370	1000	21.05	25	1.4	0.02^{c}	0	-6.1^{c}
Th(ppm)		9.6		8.87	9.4	0.2	0.9^{D}	0	-0.7^{D}
Ti(ppm)		0.57	1.7	0.42	0.68	846.9	2492.2^{c}	100	-2.6^{c}
U(ppm)		1.7		2.71	3.3	0.2	1.6^{D}	100	0.1^{D}
V(ppm)		60	260	200.22	407	61.9	0.8^{c}	15.4	-1^{c}
W(ppm)		1	2.7	1.17	3.8	0.3	0.4^{c}	1.5	-1.8^{c}
Y(ppm)		33	28	15.86	18	0.8	0.6^{c}	0	-1.4^{c}
Yb(ppm)		2.2		2.27	2.8	0.2	1.03^{D}	44.6	-0.5^{D}
Zn(ppm)	200	80	61	87.4	138	17.9	0.4^{a}	0	-1.8^{a}
Zr(ppm)		200	200	115.4	133	6.3	0.6^{c}	0	-1.4^{c}

The HTS for Bi, Ca, Co, U, Nb and Rb is 100% that show intense and widespread pollution of them. Also HTS for other elements is: Cr: 6.15%., Ca: 68.2%., Cu: 36.9%., Ni: 78.5%., Pb: 3.1%., Sc: 18.5%., V: 15.4%., W: 1.5%., and Yb: 44.6%. These HTS quantities show that some elements with environmental importance (such as Cr, Pb, Sc, V and W), despite the averages lower than standards, indicate small-scale pollution in study area.

4.6-Geo-accumulation index

The calculated accumulation index for elements were shown in Table 1 that calculate by below equation:

$I_{geo}= \log_2 C_n / (1.5*B_n)$

In this equation the C_n is element concentration in sample, B_n is element concentration in background (the sediment quality, earth´s crust or sandy soils in this research), and the coefficient of 1.5 is the lithology effects correction.

Table 2) Muller´s classification for the geo-accumulation index.

I_{geo}	Class	Sediment Quality
≤0	0	Unpolluted
0- 1	1	From unpolluted to moderately polluted
1- 2	2	Moderately polluted
2- 3	3	From moderately to strongly polluted
3- 4	4	Strongly polluted
4- 5	5	From strongly to extremely polluted
≥6	6	Extremely polluted

This index proposed by Muller (1969) for first time and was using for determination and description of elements concentration in 0 to6 classes (7classes at all) (Table 2). According to the Table, U locates in first degree of pollution (From unpolluted to moderately polluted), Bi and Nbstand in second class of pollution (Moderately polluted) and other elements are unpolluted (class 0). This means that other pollutant elements and their standards have very close concentration together and this matter was shown clearly in enrichment factor by quantities near 1. If the $I_{geo}$was calculated by maximum quantities, the Bi and Co stand in second class of pollution and Fe and Nb locate in the third class too.

4.7-Correlation coefficient

The elements correlation coefficients in sediments samples were calculated by spearman method (Index-1). The correlation coefficient of Nb with Mn, Co, Yb, V and Fe is higher than 0.7. Also the correlation coefficient of Nb with Zr, Sc, Zn and Cr is higher than 0.5 and its correlation coefficient with Cu is 0.151. But the U and Bi don not have any correlation coefficient higher than 0.5 with any other elements. In stream sediments, The Cu has highest correlation coefficient with Al, K, and P with quantities upper than 0.4.

4.8-Cluster analysis dendrogram

The cluster analysis dendrogram of elements was drawn based on normalized data for elements classification (Fig. 3). The elements were divided into two major classes (classes a and b). The class a elements are Fe, V, Co, Ti, Zn, Mn, Nb, Yb, Cr. Copper associated with P, K and Al stand in b- 2- 2- 1class and Bi stand in b- 2- 1- 2 class.

4.8-Geochemical map

To obtain the geochemical distribution pattern of different elements, geochemical map (based on elements concentration) was drawn and it is shown in Figure 4. In geochemical map, the Yb, V, U, Ti, Pb, Nb, Cr, Co and to some extent W have similar distribution pattern, but their distribution are different from copper. Although Bi did not show completely a pattern similar to the mentioned elements, its distribution pattern is different than copper. Ni accumulated in southeast part of the study area. Sample 7A shows high concentration of some elements such as U, Pb, W, and Cr. These concentrations show that this sample could be affected by pollutant processes.

5– Litho-geochemical study

To determine the relationship between elements and their origin, Litho-geochemical sampling was done in two polluted area (A and B based on the stream sediment study). Regular sampling network (with rows distance of 50m and columns distance of 100m) were designed and samples were taken. The 321 sampling points were determined, but because of the lack of outcrops, only 276 samples were taken. The samples were sent to Zareh-Shuran laboratory and analysis by Atomic Absorption for 5 elements (Au, Ag, Cu, Zn, and Fe). The Ag and Au results in more than 90% were censored data, so these two elements data were not processed. Statistical parameters (minimum and maximum) of raw elements data and number of outlier data and their replaced quantities in A and B areas were shown in Table 3. The statistical parameters of processed elements data in A and B areas were shown in Table 4.

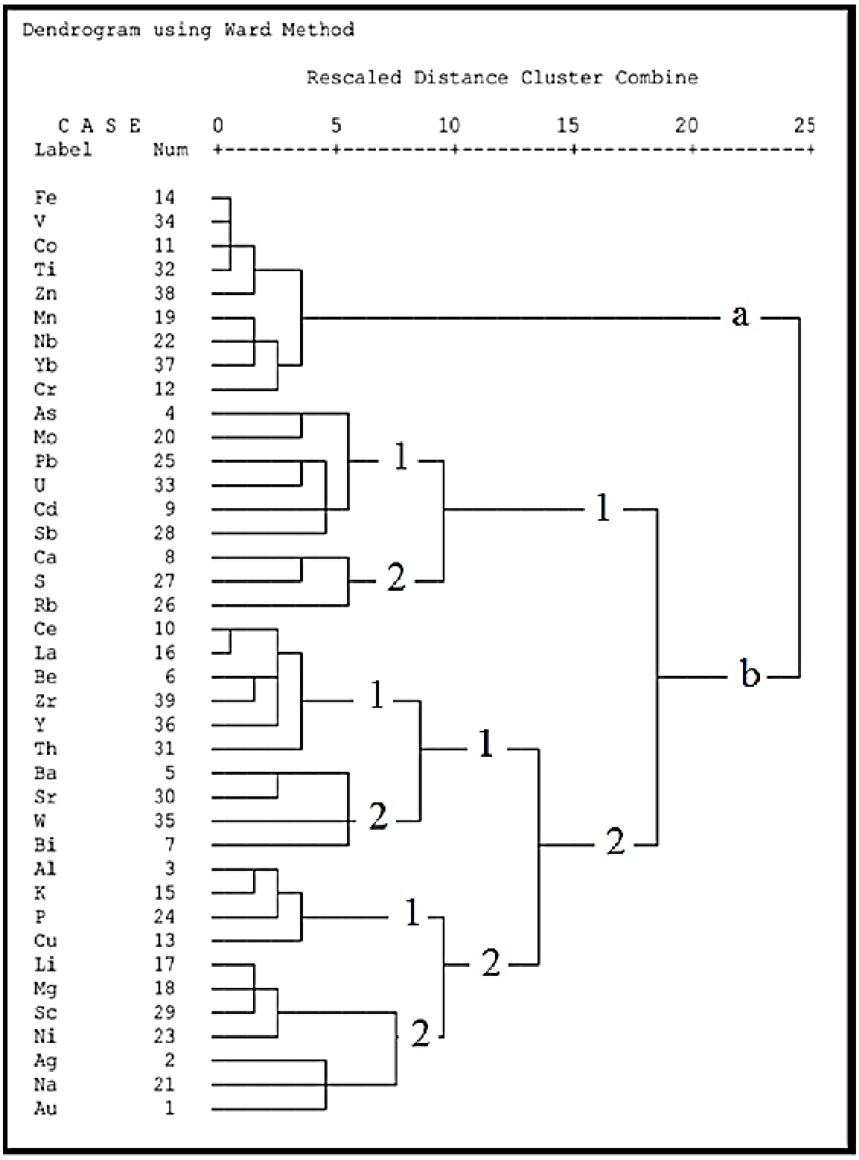

Figure 3) The cluster analysis dendrogram of elements.

5.1-Enrichment factor

According to Table 4, if enrichment factor calculation done based on average quantities, only copper in B area has higher than 1 quantity (1.21), although this quantity for copper in B area is near 1 (0.97). Other elements enrichment factors are lower than 0.75. However if the enrichment factors calculated by maximum quantities, the copper enrichment factor in both A and B areas have upper than 2 quantities (2.01 in area A and 2.14 in area B) and the zinc enrichment factors have higher than 1 quantities in both areas too (1.39 in area A and 1.08 in area B). Also if calculation done by maximum quantities of raw data, the results are: Cu_A: 62, Cu_B: 162, $Zn_{A\ and\ B}$≈2, $Fe_{A\ and\ B}$≈0.6.

5.2-Geo-accumulation Index (I_{geo})

In table- 4 geo-accumulation index was calculated based on the average ($I_{geo(by\ Ave)}$) and maximum($I_{geo(by\ Max)}$). If $I_{geo}$is calculated based on the average quantities of all metals are unpolluted (Zero class of pollutant).When the I_{geo} calculation is done based on maximum quantities, copper in both areas stands in first class of pollution (from unpolluted to moderately polluted) and Fe and Zn are unpolluted in the areas. But if the I_{geo} calculation done base on raw data maximums, the copper stand in sixth class of pollutant (Extremely polluted), zinc stand in first class of pollutant (from unpolluted to moderately polluted) and also the iron stand in zero class of pollutant.

5.3-Correlation coefficient

After data processing, the correlation coefficient of metals was studied. In area A correlation coefficient quantities are: Cu-Zn: 0.102, Cu-Fe: 0.078 and Zn-Fe: 0.04. These quantities show no correlation between these elements in this area. Also in area B correlation coefficient quantities are: Cu-Zn: 0.2, Cu-Fe: -0.16 and Zn-Fe: 0.2. These quantities also show no correlation between these elements in B area (Table 5).

5.4-Geochemical map

Based on the litho- geochemical data, geochemical maps of areas A and B were prepared and are shown in Figures 5 and 6. In the area A, the copper polluted area is limited but in the area B the polluted areas are extent. The extensive pollution of copper in the area B caused by the conglomeratic unit that have copper-rich pebbles (Fig. 7a).

6– Discussion

Copper mineralization in the north of Toroud is very extensive and the mineralization is resulted from tectonic and sedimentary processes. This study shows that Bi, Ca, Cu, Fe, Nb, Ni, Rb, U and Yb in the stream sediments have enrichment factors higher than 1. Also in addition to the mentioned elements, some other elements such as Cr, Pb, Sc and W have quantities higher than standard values. But I_{geo} calculation shows that Bi and Nb pollution exists in the stream sediments and also some elements like Pb have local (but important) pollution in the study area.

Table 3) Statistical parameters (minimum and maximum) of raw elements data and Number of outlier datas and their replaced quantities in A and B areas.

Area	Element	Min (ppm)	Max (ppm)	Number of outlier data	Replaced quantities instead of outlier data (ppm)
A	Cu	44.5	7441.67	4	234.4
A	Zn	35.67	225.34	2	162.4
A	Fe	23782.61	52550.04	0	-
B	Cu	36.67	19483.35	30	223.95
B	Zn	39.87	246.28	1	127.8
B	Fe	19991.68	52827.87	0	-

The ortho-magmatic magnetite in the polished sections is very abundant. These primary magnetites are not related to copper mineralization, but most of pollutant elements (based on their enrichment factors in stream sediments) have high correlation coefficient with iron in study area (Attachment 2). Study of the heavy minerals shows that magnetite, hematite, titan- magnetite, limonite, rotile, and ilmenite are present in stream sediments. This presence could be caused by andesitic rocks erosion (these minerals have high chemical resistivity) and accumulation in the sediments. The copper in veins has high correlation coefficient with silver, arsenic, aluminum, zirconium, molybdenum and phosphorous, but in the sediments copper has correlation coefficient higher than 0.4 with aluminum, potassium and phosphorous and its correlation with silver, arsenic, and molybdenum include negative quantities that show different geochemical behavior of these elements in surfical environment.

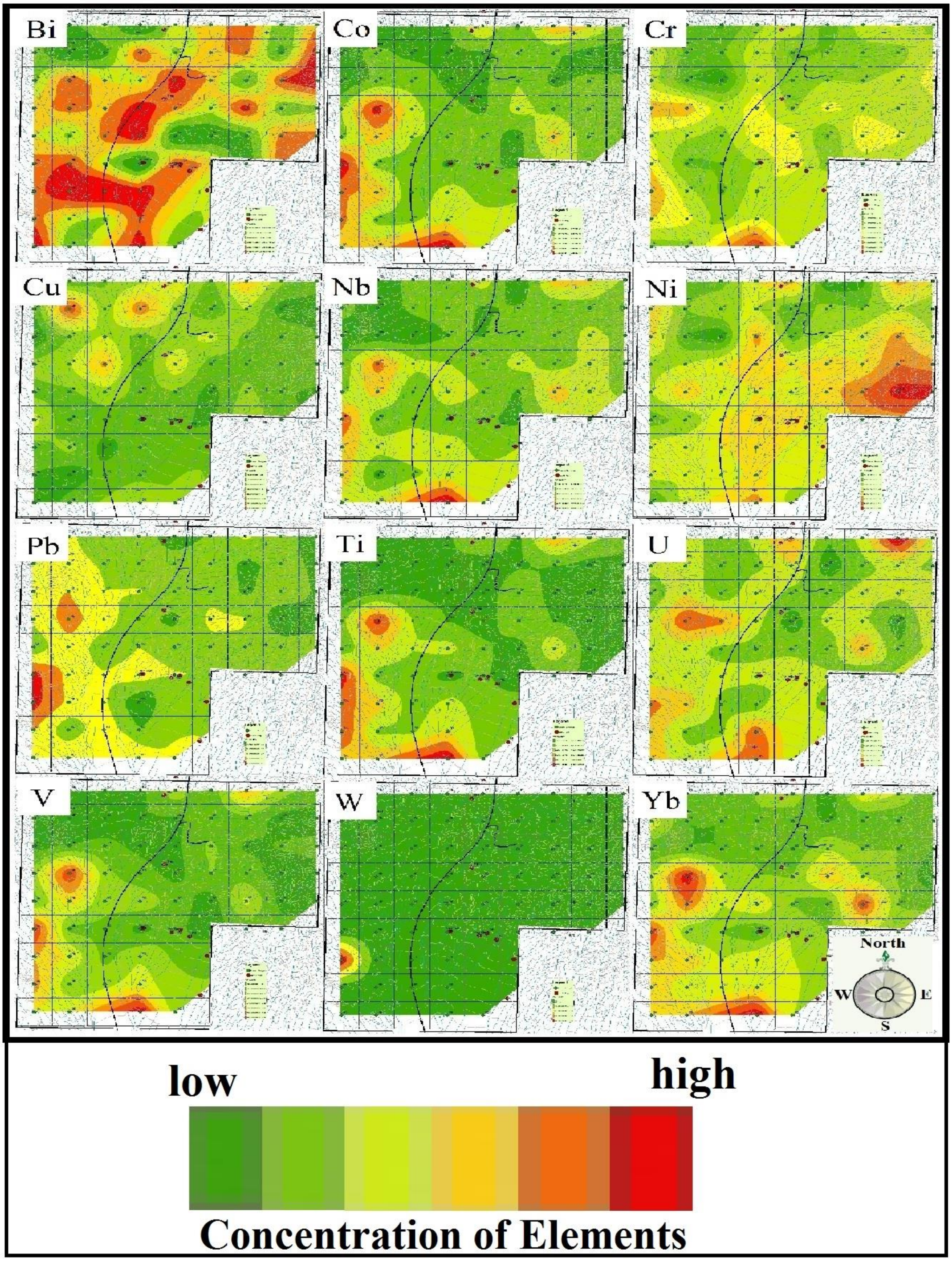

Figure 4)Geochemical map of the elements based on stream sediments analysis.

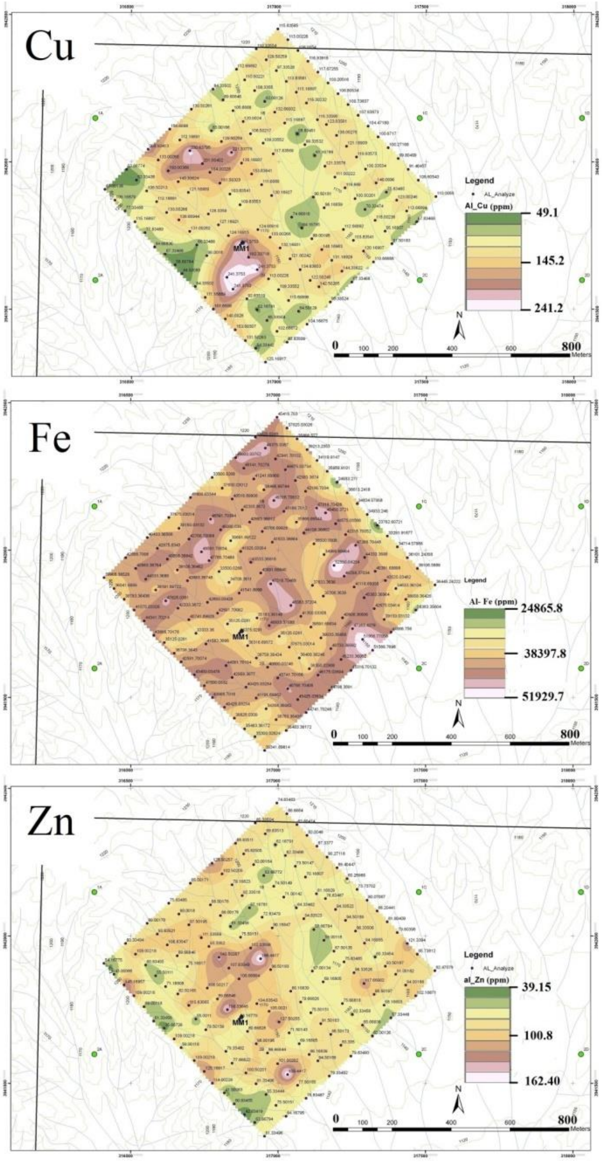

Figure 5) The element dispersion pattern based on litho- geochemical studies in the A area. Iron also shows no meaningful pattern in this area. As shown in the map, the zinc accumulated in two northern and southern side of copper anomaly.

In the litho-geochemical studies it is clear that in both A and B areas copper and zinc have higher than basaltic rocks quantities (based on raw data maximum). In the A area, the copper anomaly is related to veins and historical mining. Also in the area B, smaller anomaly is related to veins and historical mining, but the larger anomaly is related to conglomeratic unit that have copper-rich pebbles (Fig. 6a). As mentioned, these pebbles have higher than 8 percent copper and also play effective roles on natural pollution of copper in the study area. After conglomeratic unit, the historical mining and oven leftovers and their slag are most effective factors on the copper pollution (Figs. 6b, c, d). As it is evident in the Attachment 1, too many veins outcropped in the center and south-western part of the study area, but because of the limited mining activities, stream sediments are not polluted there. But in polluted areas, veins and their adjacent lands covered by a layer includes historic mining gangue with 0.1 to 1 meter diameter.

Table 4) Statistical parameters of processed elements data in A and B areas.

	$\mathrm{Cu_A}$	**$\mathrm{Zn_A}$**	**$\mathrm{Fe_A}$**	**$\mathrm{Cu_B}$**	**$\mathrm{Zn_B}$**	**$\mathrm{Fe_B}$**
Basic rock (ppm)	120	120	87000	120	120	87000
Minimum (ppm)	44.50	35.67	23782.61	36.67	39.87	19991.68
Maximum (ppm)	241.37	166.44	52550.04	256.94	129.58	52827.87
Average (ppm)	115.95	85.24	40816.92	145.78	74.33	37768.34
Standard deviation	38.30	22.63	4938.89	68.26	14.69	8063.74
Enrichment factor$_{(Ave)}$	0.97	0.71	0.47	1.21	0.62	0.43
EnrichmentFactor$_{(max)}$	2.01	1.39	0.60	2.14	1.08	0.61
Higher than standard (%)	36.11	6.25	0	50.38	0.75	0
$I_{geo(Ave)}$	-0.63	-1.08	-1.68	-0.30	-1.28	-1.79
$I_{geo(max)}$	**0.42**	-0.11	-1.31	**0.51**	-0.47	-1.30

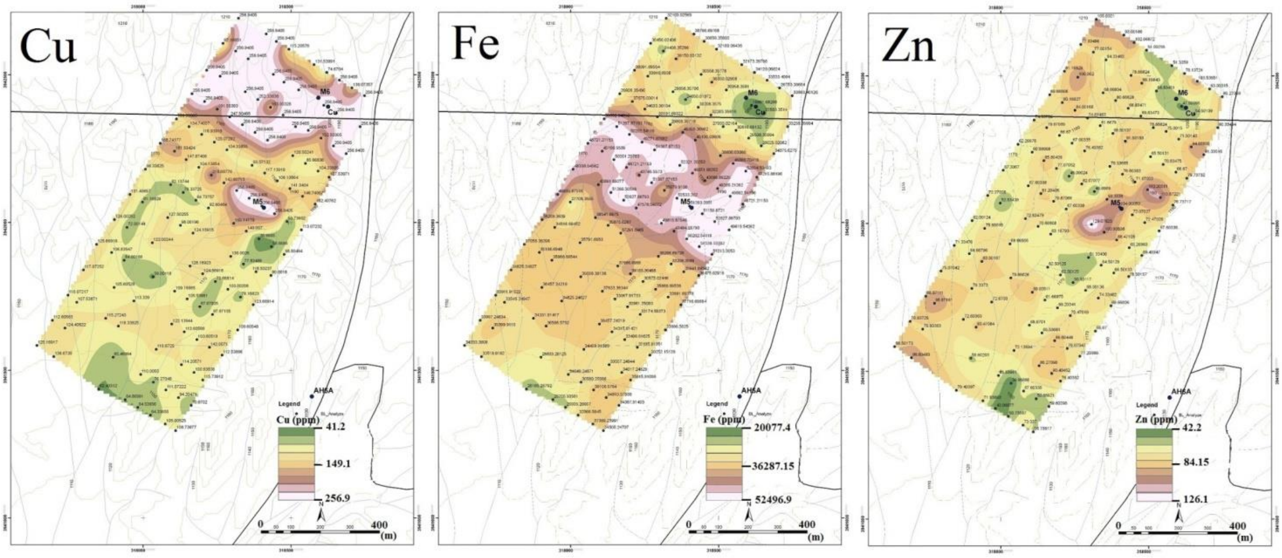

Figure 6) The element dispersion pattern based on litho- geochemical studies in the B area. As shown in the map, copper, zinc and iron have linear dispersion in this area. The larger copper anomaly is according to the conglomeratic units. In the smaller copper anomaly, zinc accumulated in the two northern and southern side of copper vein (m5).

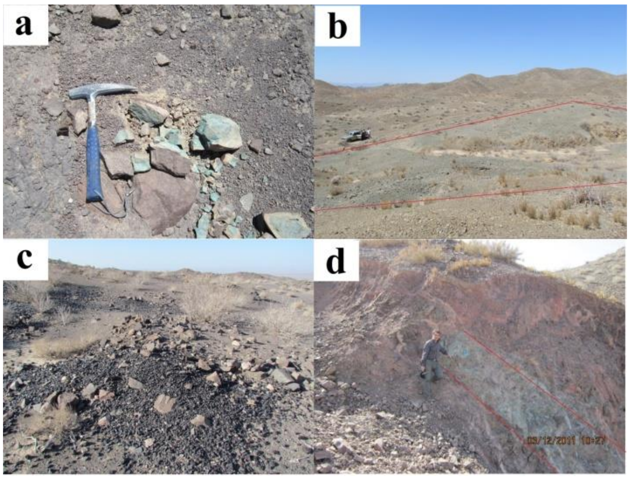

Figure 7a) The conglomeratic unit and its copper rich pebbles; b) the copper anomaly in A area, the mineralized zone is limited by red line; c) an oven leftover and its slag; d) vein type copper mineralization in B area (vein limited by lines).

Another effective factor on the low intensity of polluted areas is the little effect of alteration on rocks. Fluids could not seep to host rocks, so mineralization only occurs within the faults and fractures.

As Lapworth *et al* (2012) stated, the geochemical difference were controlled by geologic sources and origin like chemical weathering and distributing processes (as conglomeratic unit formation and vein- type mineralization effects on the copper distribution in the study area) and smaller difference were made by human activities like land use and its polluting (as ancient mining project effects on the copper distribution in the study area).

Table 5)Correlation coefficient between elements in A and B areas.

A area	**Cu**	**Fe**	**Zn**
Cu	1	0.08	**0.1**
Fe	0.08	1	**0.04**
Zn	0.1	0.04	**1**
B area	**Cu**	**Fe**	**Zn**
Cu	1	-0.16	**0.2**
Fe	-0.16	1	**0.2**
Zn	0.2	0.2	**1**

7– Conclusions

According to the mentioned studies, sediment pollution (instead of copper) in Chah Morra Cu deposit area is not related to the vein type copper deposition. But Cu pollution is related to conglomeratic unit, vein type deposits as natural source and historical mining project as man-made source. One of this pattern creation causes is low intensity of alteration in veins borders. The second cause is low concentration of pollutant elements associated with copper mineralization. Based on correlation coefficient values, the copper concentration in veins is related to silver, arsenic, aluminum, zirconium, molybdenum and phosphorous that none of them have high enrichment factor values. Also their concentration in veins is low and historic mining project could not affect their pollution.

Another important point is that those minerals that contain pollutant elements, because of climate condition and geochemical resistivity, were accumulated by physical processes in the study area sediments. Because of arid climate, no permanent river flowed in the study area and the running water includes the seasonal floods. Seasonal floods are not good subtractioning factor for elements and minerals, but strong winds could be the cause of light mineral differentiation from heavy minerals with pollutant elements components. Area from north to south become gentle topographically. This factor can have an important role in pollutant elements accumulation in the south. But the environmental pollutions in the study area are related to the high geochemical background of elements.

Two effective factors on copper pollution dispersion are natural factors and manmade factors. As the natural cause, the conglomeratic units include copper rich pebbles is the most important factor in copper pollution dispersion in the study area. After this factor copper mineralization in the veins is second natural cause of copper pollution- dispersion in the study area. The manmade factor is historical mining project including old excavation, melting furnaces and abandoned slag. Therefore, these issues should be considered in new mining operations.

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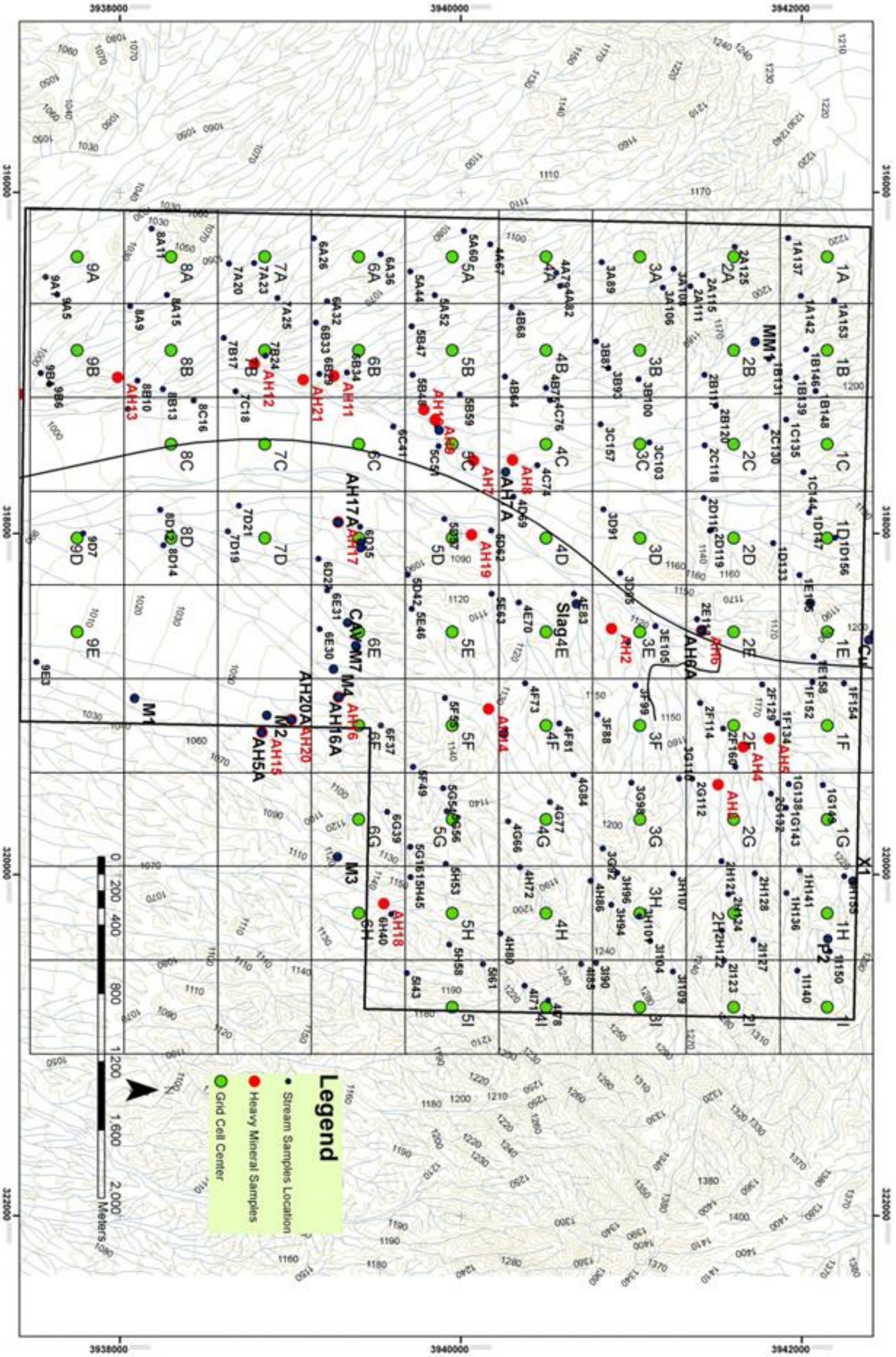
ATTACHMENTS:



Attachment 1) The sampling network in study area

Attachment 1) Attachment 2) Table of stream sediments correlation coefficients.

Elements	Cu	Au	Ag	Al	As	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Fe	K	La	Li	Mg	Mn	Mo	Na	Nb	Ni	P
Cu	1																							
Au	-0.1	1																						
Ag	-0.16	0.14	1																					
Al	0.47	0.31	0.15	1																				
As	-0.13	-0.32	-0.26	-0.39	1																			
Ba	0.1	-0.05	0.1	0.13	-0.06	1																		
Be	0.07	0.13	0.06	0.53	-0.16	0.02	1																	
Bi	-0.07	-0.04	-0.01	-0.06	-0.07	0.22	-0.29	1																
Ca	-0.21	0.1	0.1	-0.26	-0.06	-0.02	-0.12	-0.14	1															
Cd	0.13	-0.09	0.09	0.08	0.11	0.06	0.04	-0.25	-0.05	1														
Ce	-0.13	-0.22	0.01	0.07	0.18	0.1	0.43	-0.05	-0.03	0.1	1													
Co	0.3	-0.22	-0.12	0.29	-0.14	0.27	0.19	0.27	-0.59	0.15	0.15	1												
Cr	0.05	-0.16	-0.18	0.03	-0.23	0.05	0.09	0.23	-0.09	-0.05	0.2	0.49	1											
Fe	0.27	-0.35	-0.11	0.15	-0.03	0.37	0.07	0.313	-0.57	0.09	0.12	0.94	0.47	1										
K	0.43	0.1	0.15	0.65	-0.12	0.34	0.42	-0.16	0	0.08	0.28	0.03	-0.02	0.01	1									
La	-0.24	-0.3	-0.11	-0.07	0.26	0.16	0.38	0.02	0.05	-0.05	0.8	0.21	0.31	0.23	0.1	1								
Li	0.11	0.43	0.12	0.62	-0.33	-0.16	0.53	-0.26	0.11	-0.07	0.17	-0.12	0.05	-0.3	0.5	-0.02	1							
Mg	0.09	0.33	0.11	0.61	-0.54	-0.11	0.45	-0.05	0.07	-0.06	0.06	0.12	0.27	-0.05	0.32	-0.05	0.8	1						
Mn	0.36	-0.1	-0.13	0.47	-0.2	0.04	0.38	0.19	-0.45	-0.01	0.2	0.79	0.51	0.69	0.14	0.23	0.2	0.39	1					
Mo	-0.11	-0.17	0.01	-0.31	0.34	-0.04	-0.18	-0.27	0.18	0.15	0.16	-0.08	-0.02	-0.05	-0.1	0.19	-0.17	-0.43	-0.1	1				
Na	0.25	0.24	0.24	0.55	-0.12	0	0.27	-0.24	0.15	0.14	0.07	-0.19	-0.18	-0.26	0.49	0	0.52	0.49	0.09	-0.1	1			
Nb	0.15	-0.12	-0.14	0.3	-0.15	0.14	0.33	0.26	-0.4	-0.05	0.27	0.79	0.59	0.72	0.07	0.34	0.05	0.38	0.8	-0.29	-0.05	1		
Ni	-0.14	0.12	0	0.22	-0.2	-0.1	0.5	-0.07	0.12	-0.13	0.38	0.13	0.44	-0.01	0.26	0.35	0.56	0.6	0.3	-0.15	0.15	0.43	1	
P	0.43	-0.18	-0.03	0.47	0.07	0.44	0.22	0	-0.47	0.22	0.25	0.55	0.07	0.58	0.52	0.19	-0.11	-0.11	0.42	0.01	0.15	0.38	-0.09	1

Attachment 2) continued.

Element	Cu	Au	Ag	Al	As	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Fe	K	La	Li	Mg	Mn	Mo	Na	Nb	Ni	P	Pb	Rb	S	Sb	Sc	Sr	Th	Ti	U	V	W	Y	Yb	Zn
Pb	-0.02	-0.36	-0.39	-0.2	0.34	0.27	-0.07	0.04	-0.27	0.09	0.14	0.35	0.11	0.43	-0.16	0.34	-0.43	-0.43	0.19	0.19	-0.36	0.21	-0.16	0.25	1													
Rb	-0.15	0.07	-0.06	-0.23	-0.05	-0.22	-0.03	-0.38	0.13	0	-0.07	-0.18	0.05	-0.2	-0.22	-0.03	0.09	0.02	-0.11	0.07	-0.22	-0.08	0.09	-0.39	-0.03	1												
S	0.11	0	-0.08	-0.25	0.24	0.1	-0.28	-0.18	0.31	0.04	-0.18	-0.35	-0.29	-0.26	-0.08	-0.19	-0.34	-0.45	-0.38	0.3	-0.2	-0.36	-0.37	-0.03	0.01	0.01	1											
Sb	0.04	-0.12	-0.03	0.02	0.24	-0.01	0.03	0.02	-0.29	0.02	0	0.15	-0.01	0.16	-0.04	0.17	-0.04	-0.14	0.2	0.12	0.05	0.05	-0.1	0.17	0.11	-0.02	-0.08	1										
Sc	0.31	0.11	-0.06	0.59	-0.47	-0.01	0.41	0.13	-0.17	-0.01	0.16	0.5	0.45	0.35	0.28	0.04	0.55	0.79	0.71	-0.34	0.22	0.63	0.45	0.11	-0.14	0.01	-0.39	-0.15	1									
Sr	0.06	0.01	0.19	0.44	-0.05	0.41	0.2	0.08	0.04	0.14	0.15	0.3	0.04	0.29	0.31	0.13	0.01	0.21	0.3	-0.1	0.34	0.38	0.18	0.45	0.03	-0.25	-0.1	-0.18	0.24	1								
Th	-0.3	0	0.02	-0.09	-0.03	0.31	0.25	-0.02	0.29	-0.01	0.46	-0.08	0.13	-0.1	0.12	0.49	0.11	0.01	-0.04	0.13	-0.04	0.02	0.29	0.04	0.07	0.08	-0.04	0.02	-0.06	0.13	1							
Ti	0.17	-0.35	-0.1	0.06	-0.05	0.36	0.02	0.35	-0.42	0.1	0.15	0.9	0.52	0.94	-0.04	0.25	-0.32	-0.01	0.61	-0.08	-0.3	0.72	0.04	0.49	0.38	-0.21	-0.24	0.03	0.37	0.33	-0.04	1						
U	0.11	-0.31	-0.18	-0.01	0.2	0.09	-0.07	0.1	-0.17	0.2	0.21	0.43	0.36	0.43	-0.03	0.31	-0.06	0	0.41	0.13	-0.04	0.33	0.12	0.24	0.33	0	-0.13	0.27	0.12	0.06	0.01	0.4	1					
V	0.26	-0.38	-0.07	0.13	-0.06	0.37	0.05	0.34	-0.49	0.1	0.1	0.92	0.49	0.98	0.01	0.2	-0.32	-0.02	0.67	-0.09	-0.27	0.73	0	.56.38		-0.2	-0.24	0.11	0.37	0.36	-.12.09	0.96	0.39	1				
W	-0.13	0.02	-0.09	0	0	0.14	0.21	0.03	-0.15	-0.03	0.21	0.34	0.22	0.31	-0.11	0.35	-0.11	0.01	0.3	-0.23	-0.2	0.43	0.2	0.14	0.26	0.11	-0.1	0.11	0.12	0.22	0.28	0.31	0	0.29	1			
Y	0.06	-0.33	-0.13	0.17	0.06	0.02	0.43	0.07	-0.12	0.01	0.57	0.36	0.45	0.33	0.27	0.51	0.16	0.16	0.51	0.1	-0.05	0.42	0.43	0.33	0.16	-0.21	-0.09	-0.02	0.42	0.15	0.26	0.35	0.25	0.34	0.14	1		
Yb	0.15	-0.4	-0.22	0.08	0	0.22	0.27	0.25	-0.37	0.05	0.38	0.79	0.59	0.8	0.11	0.43	-0.16	0.05	0.69	-0.03	-0.26	0.75	0.26	0.47	0.45	-0.16	-0.31	-0.03	0.46	0.27	0.09	0.82	0.34	0.81	0.3	0.66	1	
Zn	0.24	-0.27	-0.08	0.22	-0.05	0.37	0.19	0.24	-0.58	0.09	0.19	0.88	0.44	0.9	0.08	0.31	-0.19	-0.09	0.7	0.07	-0.23	0.61	0.04	0.61	0.51	-0.18	-0.28	0.2	0.29	0.25	0.01	0.81	0.46	0.85	0.31	0.37	0.76	1
Zr	0.07	-0.14	-0.11	0.3	-0.08	0.25	0.55	0.12	-0.37	-0.02	0.6	0.62	0.37	0.53	0.28	0.54	0.23	0.27	0.59	-0.12	-0.09	0.64	0.37	0.41	0.21	-0.13	-0.41	0.07	0.52	0.18	0.29	0.54	0.26	0.5	0.4	0.54	0.65	0.57