

Delineation of Geochemical Anomalies Based on Cu by the Boxplot as an Exploratory Data Analysis (EDA) Method and Concentration-Volume (C-V) Fractal Modeling in Mesgaran Mining Area, Eastern Iran

Mohammadreza Agharezaei*, Ardeshir Hezarkhani

Department of Mining and Metallurgy Engineering, Amirkabir University of Technology (Tehran Polytechnic), Tehran, Iran

Email: *agharezai@aut.ac.ir

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Abstract

The target in this investigation is separation and delineation of geochemical anomalies for the single element Cu in Mesgaran mining area, eastern Iran. Mesgaran mining area is located in south part of Sarbishe county with about 29 Km distance to the county center. This region is part of an Ophiolite sequence and the copper anomalies seem to be related to a volcanic massive sulfide (VMS) deposit whose main part (massive sulfide Lens) has been eroded. In order to delineate Cu anomalies, the boxplot as an Exploratory Data Analysis (EDA) method and concentration-volume (C-V) Fractal modeling are employed. Both of the methods reveal low-deep anomalies which are highly correlated with geological and geophysical studies. As the main result of this study we show that Fractal modeling in spite of the Boxplot, is not recommended for complex geological settings. The proved shallow anomalies recorded by geophysical studies and defined by the used methods are in accordance to the stringer zone of a volcanic massive sulfide (VMS) deposit in Mesgaran mining area which means this region is the bottom of a VMS deposit and geochemical anomalies are related to the remained parts of the deposit.

Keywords

Mesgaran, Geochemistry, Fractal Modeling, The Boxplot, VMS Deposit

1. Introduction

Delineation of geochemical anomalies from background is one of the major targets in

exploration geochemistry. In order to achieve this goal, different descriptive and quantities methods have been employed. As early as 1962, several procedures had been recommended for selecting Threshold levels in order to identify outliers [1]. An alternative approach for understanding single-element distribution and defining outlier data is the use of Exploratory Data Analysis (EDA) [2]. The EDA methods have been firstly expressed by Tukey [3], then used and developed by other researchers for geochemical anomalies modeling [4]-[9]. The Boxplot is one of the EDA methods widely used before as a useful instrument. This method divides dataset into four quartiles, which identifies the outliers and gives a schematic concept of data distribution as well. The Boxplot function is most informative if the true number of outliers is below 10% [10].

Fractal/multi Fractal modeling is another method introduced by Mandelbort [11] for the first time and then developed in geochemical field. The primary forms of fractal method are known as concentration-area (C-A) [12], concentration-distribution (C-D) [13] and its 3D form concentration-volume (C-V) [14].

Mesgaran mining area is located in Sarbishe county, eastern Iran. The access to the study area is possible through Sarbisheh-Nehbandan road. The first guidance for exploration was prehistoric mining works on the area and slags left over from melting copper bearing rocks. The other clue was the name of the area “Mesgaran” which in Persian means copper producers which may refer to the mentioned mining works done centuries ago.

This is the first scientific study in Mesgaran mining area. According to the field observations and pre-exploration studies, we choose drilling boreholes then the samples have been analyzed and the dataset was created. The boxplot as a powerful Exploratory Data Analysis method and concentration-volume (C-V) Fractal have been employed to separate geochemical anomalies for the single element Cu. The final results of both methods are compared with geophysical studies and geological field observations.

2. Geological Settings

2.1. Regional Geology

This area is a small district of Iran eastern structural zone. This zone covers an area of about 160,000 Km² including thick flysch-like deposits in association with ophiolite basement related to ocean crust. Iran eastern structural zone is one of the drifts in consistency to neo-Tethys. This zone has been named “Sistan suture zone” by Tirrul *et al.* [15] or “Iran Eastern Mountain” by Alavi, [16]. Basic igneous rocks related to underwater activities and alluvial flysch sediments are observed in this zone. The ophiolitic rocks in accordance to upper part of Mantle can be detected largely as colored melange Sequences. According to geological study and field observations, the ophiolite Sequence in the area distinguished (Figure 1(a)) and compared to a mature ophiolite Sequence (Figure 1(b)).

The study area is the result of separation of Afghan and Lut blocks in Cenomanian stage which has suffered the process of transmission from oceanic to continental crust. In order to begin the study, a geological map covering the study area has been prepared

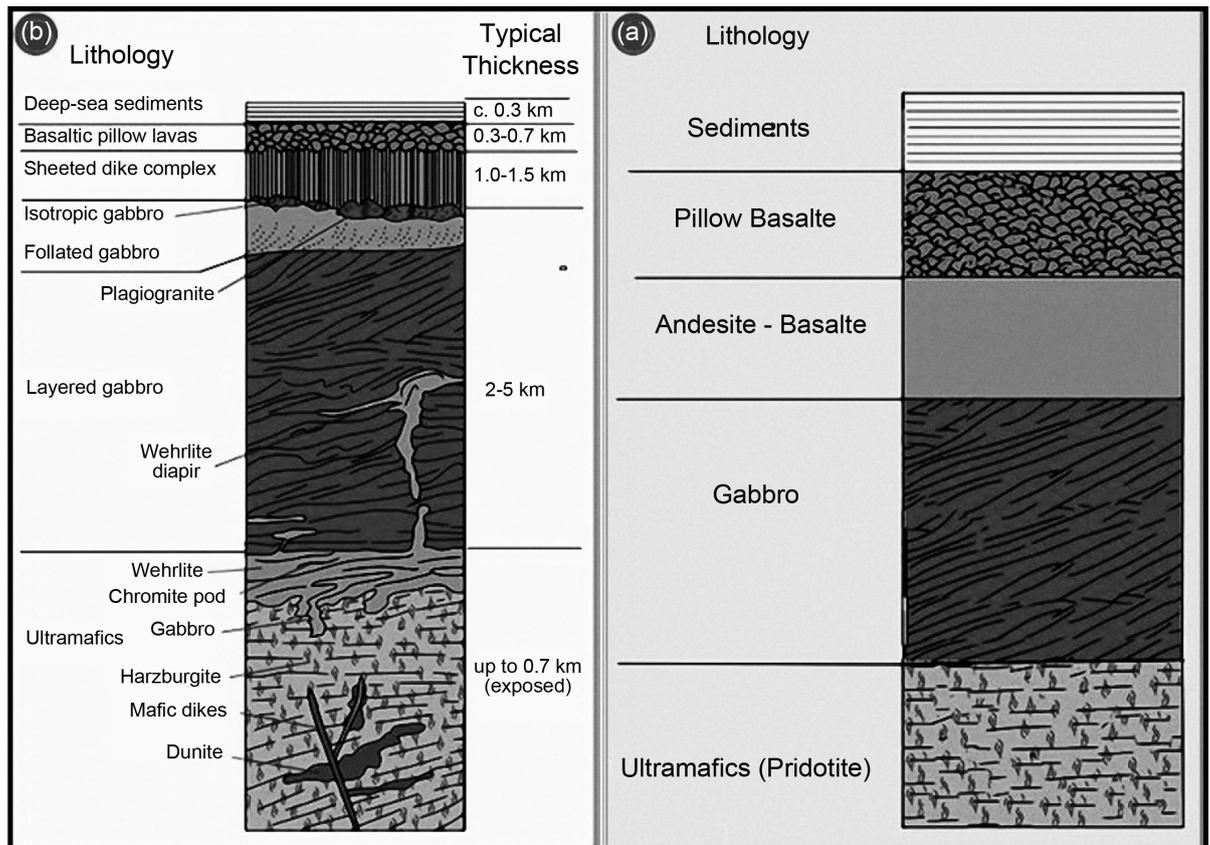


Figure 1. The ophiolite sequence observed in study area (a), a mature ophiolite sequence (b).

(Figure 2) which also shows boreholes locations.

2.2. Mineralization

In Mesgaran mining area Copper mineralization has occurred in pillow-lava and andesite-basalt sequences of eastern Iran. Two mineralization zones were identified as sulfide mineralization with silicified stockworks (primary mineralization) and supergene mineralization. The primary copper mineralization in this region is mostly in accordance to silicified or carbonate veins with epidote and chlorite in volcanic basalt.

These veins cross out the volcanic complex as stockworks which include Chalcopyrite, Bournite and Pyrite. In this region, we observed no evidence proving massive deposit or lens shape deposit creation. The main observed minerals are sulfide and oxide forms of copper. Malachite, Azurite and lower amounts of Tenorite and native copper in oxide supergene zone and chalcopyrite and bournite as the primary sulfides have been detected. Oxidation and erosion caused goetite and hematite around sulfide minerals like Chalcopyrite and Pyrite. Alteration is observed almost everywhere on the surface but the degree of alteration varies. Generally alteration occurs when rocks react to hydrothermal and magmatic fluids and this reaction leads to chemical and mineralogic changes. Chlorite alteration has occurred in large scale which is a specific form of Propylitic alteration. Al, Fe and Mg rich fluids caused chlorite alteration in basic rocks.

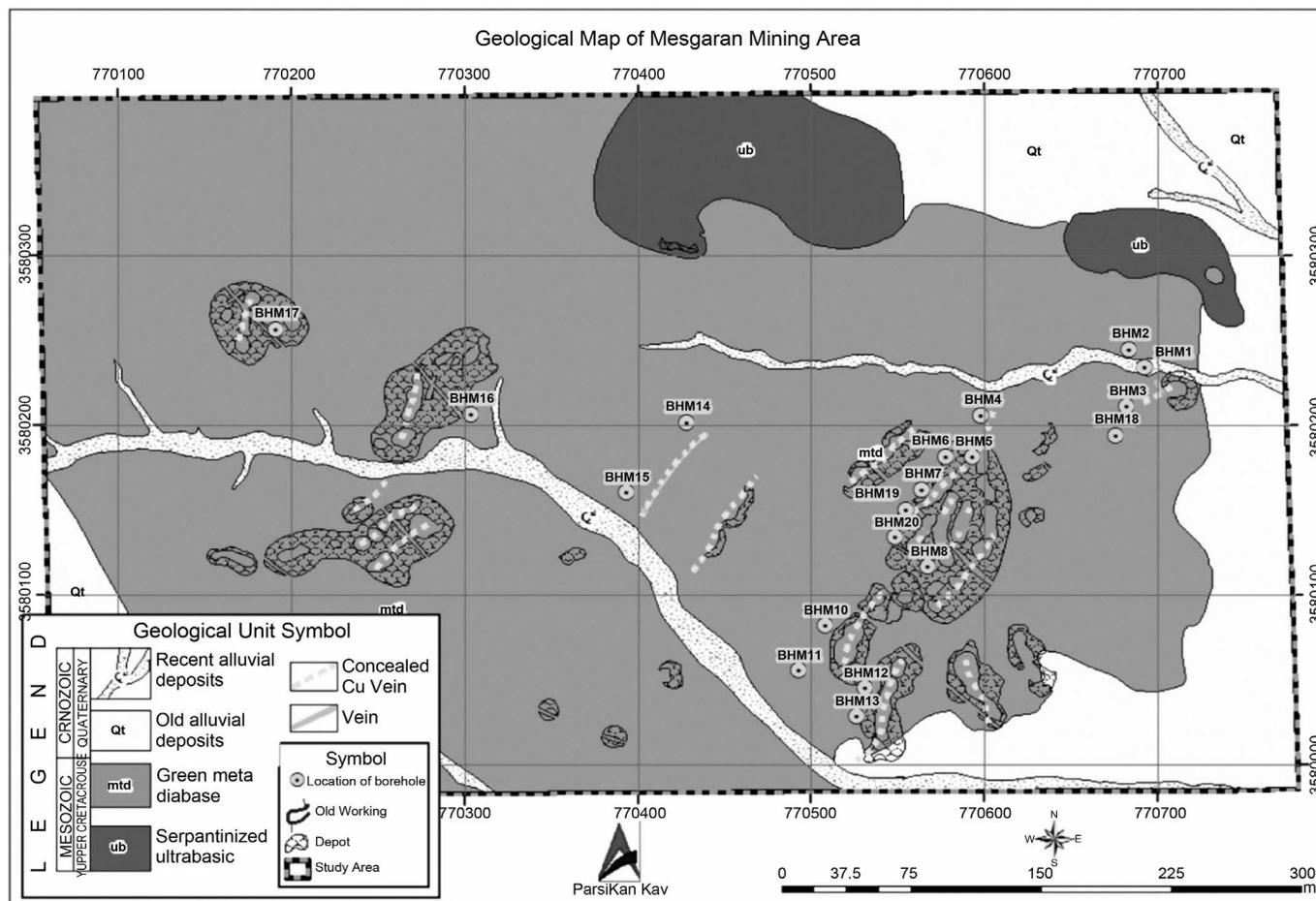


Figure 2. Geological map of Mesgaran region (the study area).

In this region, argillic alteration (presence of Montmorillonite mineral) as a secondary alteration process is observed too. Most of the copper is in oxide form on the surface and because of high degree of oxidation and erosion, sulfide mineralization is rare in outcrops so deeper samples are needed to study the deposit. Drilling is the best choice in such situations. According to the geological potentials defined for the element Cu, the best points were selected and drilled. In Figure 2 distribution of boreholes is also shown. According to mineralization and the host rock (pillow lava and andesite-basalt), the mineralization type seems to be categorized as a massive sulfide and redbed type. Generally the mineralization manner (copper mineralization as stockworks), the host rock (pillow lava and andesite-basalt), the deposit development environment (a volcanic part of an Ophiolite sequence) and the alterations (quartz-carbonate, epidote and chlorite) observed in this region and comparing them to the massive sulfide types leads to classify Mesgaran deposit as a Volcanic Massive Sulfide (VMS) type. But still more studies are needed to prove this claim with higher accuracy.

3. Methodology

Before starting any study related to statistics, data distribution type must be distin-

guished. In geochemical data analysis most of the times datasets are not normally distributed so best methods for analysis must be applied in order to have meaningful outcome. In this study delineation of geochemical anomalies for the single element Cu is the target. Among different methods suggested by Exploratory Data Analysis (EDA), the boxplot is the best one while the true number of outliers is lower than 10% as proved by Reimann *et al.* [10]. The boxplot divides dataset into four quartiles as shown in **Figure 3**.

The box consists of 2nd and 3rd quartiles which approximately contain fifty percents of the samples. The other segments are: lower and upper fences with the distance of 1.5 times of the box length from each side of the box, lower and upper hinges which are the 2nd and 4th quartiles (or the equal median of the first and second half of the dataset around the main median) and lower and upper whiskers extended to the two most extreme data values which are still inside the fences. The threshold value is the upper fence which denotes that samples with higher values than the upper fence can be defined as anomalies in dataset.

Concentration-volume (C-V) fractal modeling is similar to concentration-area (C-A) fractal modeling with the difference that instead of enclosed area, the volume is employed so the final result is expected to be a 3D anomaly model. This method as expressed by Afzal [14] can be explained as following: $V(\rho \leq v) \propto \rho^{-a_1}$; $V(\rho \geq v) \propto \rho^{-a_2}$ where $V(\rho \leq v)$ and $V(\rho \geq v)$ represent the two volumes with concentration values less than or equal to and greater than or equal to the contour value ρ ; v represents the threshold value of a geological zone (or volume); and a_1 and a_2 are the characteristic exponents. The break points in C-V log-log plot of concentration values versus volumes separate different geochemical populations with the related thresholds. The distinguished populations by this method can be in consistence to geological features of the study area if accurate and faultless dataset would have been employed.

4. Discussion

In this study 582 samples were obtained out of 19 boreholes. Out of 22 drilled boreholes, 3 of them (Boreholes: 9, 21 and 22) were completely barren so we omitted them

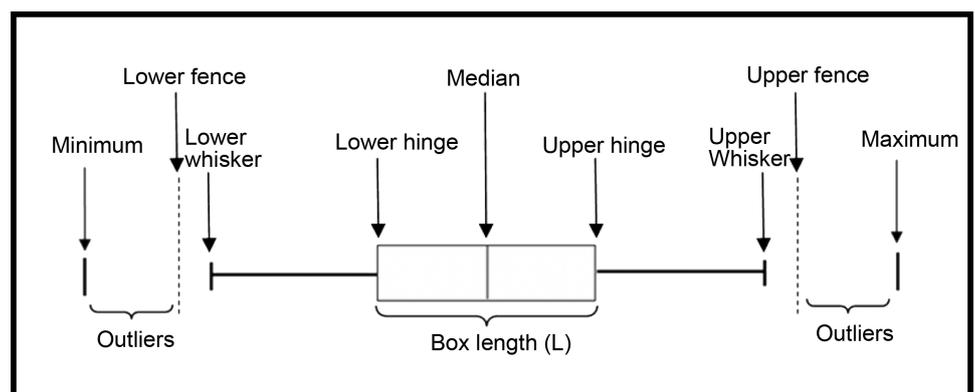


Figure 3. Schematic definition of the boxplot.

form the map. According to the number of samples to avoid large data table, we brought the average Cu content in each borehole in **Table 1**. The samples have been analyzed by atomic absorption method in Taknar Laboratory.

Among the samples, 2 out of 582 were selected as outlier and omitted from the dataset. The existence of these kinds of data may have different reasons like personal mistakes or equipment errors but in our dataset, according to the study area, the 2 mentioned samples which contained high values of Cu may have been obtained from the veins in stockwork cut by the boreholes. The 3D block model of the deposit (**Figure 4(a)**) for volume calculation and grade estimation for each block is done by RockWorks.14 software and Inverse Distance Weighting algorithm respectively. The final result of concentration-volume (C-V) Fractal is a 3D anomaly model. In order to make comparison possible, the boxplot output is applied to the 3D block model as well as concentration-volume (C-V) Fractal result.

According to the boxplot, our dataset is classified as shown in **Table 2**. In this research, the number of outliers is less than 10% so this method seems to be a strong analysis tool to bold anomalous values. The threshold defined by the boxplot is 1688 ppm for the single element Cu. The outcome of this method is applied to the 3D anomaly model (**Figure 4(b)**). This anomaly model shows all anomalous voxels which are

Table 1. Boreholes average Cu content.

Borehole number	Average Cu (PPm)
1	729.8939
2	2528.106
3	364.0348
4	373.375
5	2105.855
6	626.1944
7	1041.605
8	3265.1
10	2170.697
11	1103.551
12	1602.213
13	3010.352
14	2990.444
15	2071.617
16	320.8565
17	80.78519
18	641.79
19	1320.769
20	3111.132

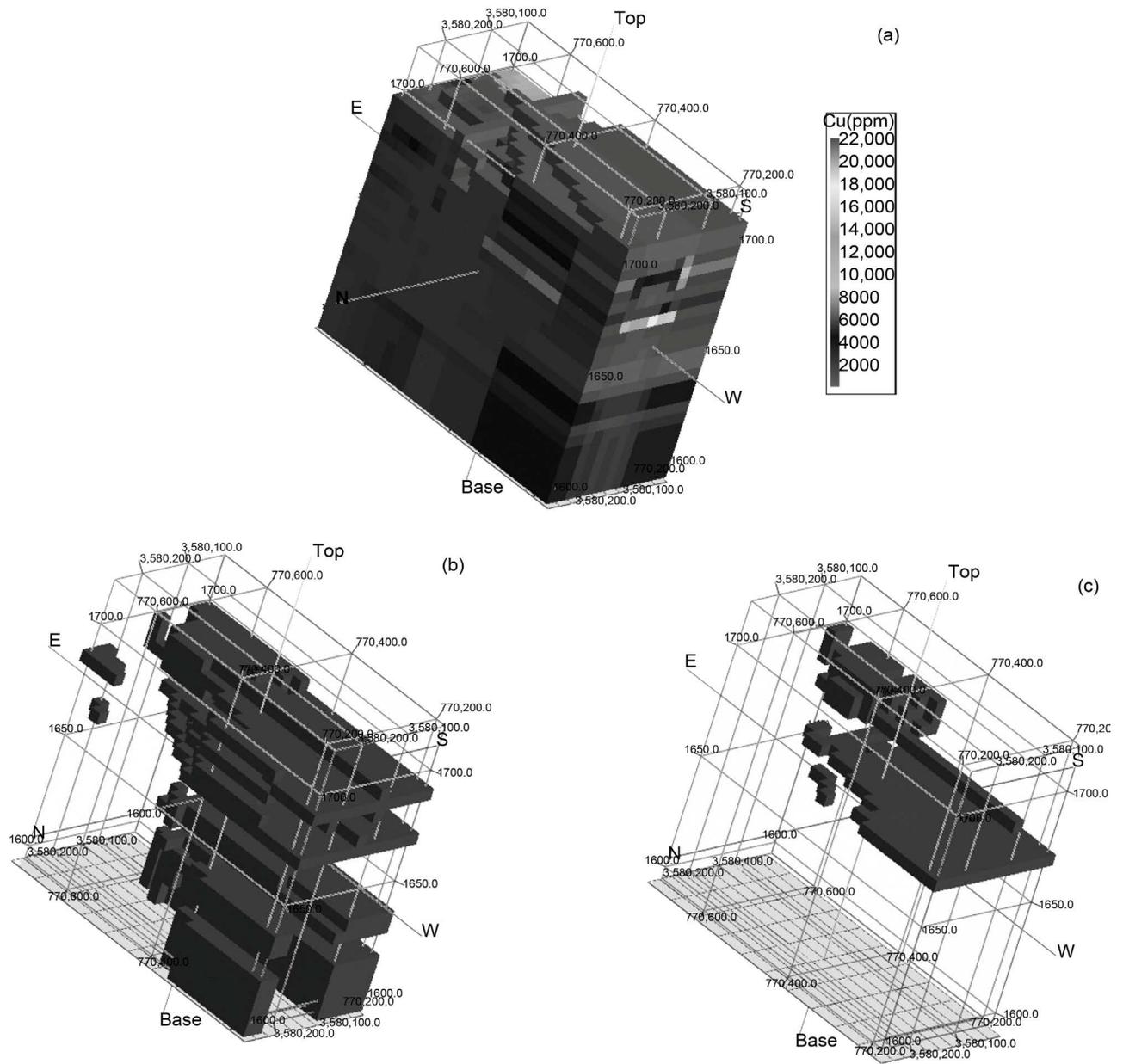


Figure 4. The 3D block model of the deposit (a), The boxplot 3D anomaly model (b), concentration-volume (C-V) fractal 3D anomaly model.

Table 2. Summary statistics of the boxplot for the element Cu.

	N	Min	Lower whisker	Lower hinge	Median	Upper hinge	Upper whisker	Threshold	Max
Cu (ppm)	580	1	1	125	149	750	1500	1688	22,192

delineated by the boxplot.

The concentration-volume (C-V) Fractal modeling as another method used in this study divided our dataset into four populations as shown in C-V log-log plot (Figure 5). In order to draw C-V log-log plot, volume per grade for every element is needed. In

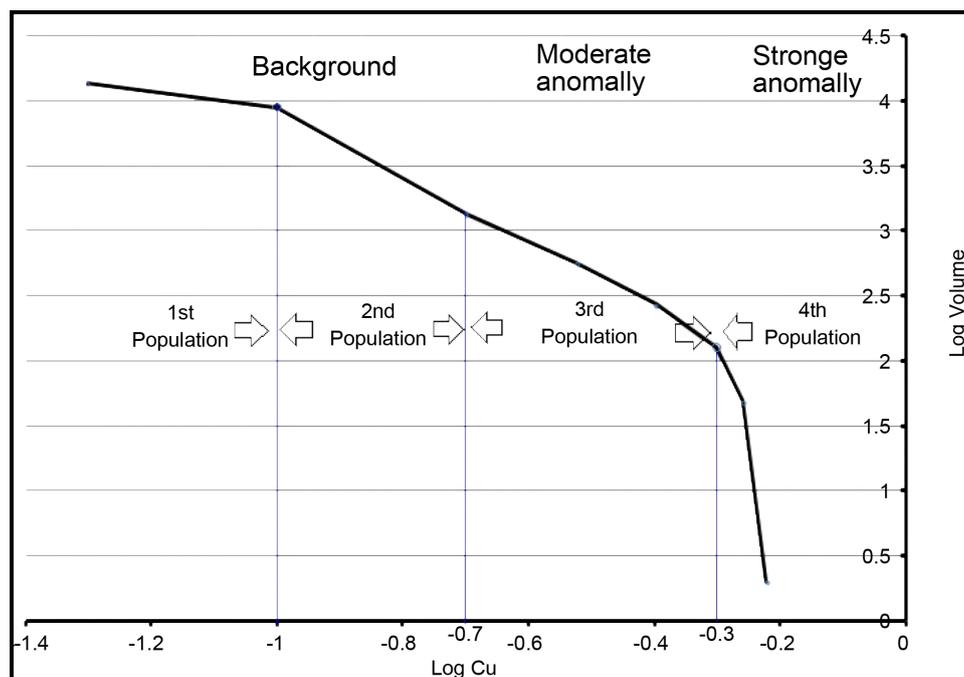


Figure 5. C-V log-log plot.

other words we need to know the volumes that different grades seize. So volume calculation is the first step. To calculate the volume, block model is needed firstly. We have created the block model in RockWorks 14 software. Each block with the related grade for Cu was distinguished. Now we can calculate cumulative volume for each grade. Then the log-log values can be calculated and the plot will be finally drawn. The break-points are the boarder values showing different populations. The first breakpoint is at 1000 ppm. The values lower than this grade are considered as background. The next break point is at 2000 ppm which is the starting value for a moderate anomaly. The last break point is 5000 ppm which is threshold for a strong anomaly. The defined populations with the related threshold values are applied to the 3D-model (**Figure 4(c)**).

The concentration-volume (C-V) fractal modeling shows more moderate surface anomaly since the defined threshold by this method is higher than the boxplot defined threshold. As shown in **Figure 4**, the boxplot reveals stronger shallow anomalies that are in more consistencies to geophysical sections (**Figure 6**) and field observations. **Figure 6** shows geophysical sections. These sections show strong shallow anomalies and in **Figure 4**. The boxplot 3D anomaly model is depicting stronger anomalies than concentration-volume (C-V) fractal 3D anomaly model. So the boxplot result is more correlated with geophysical studies.

5. Conclusion

Mesgaran mining area located in Iran eastern Ophiolite sequences has been studied in order to distinguish anomalies for the single element Cu. In order to delineate anomalies, two methods—the Boxplot as an Exploratory Data Analysis (EDA) method and

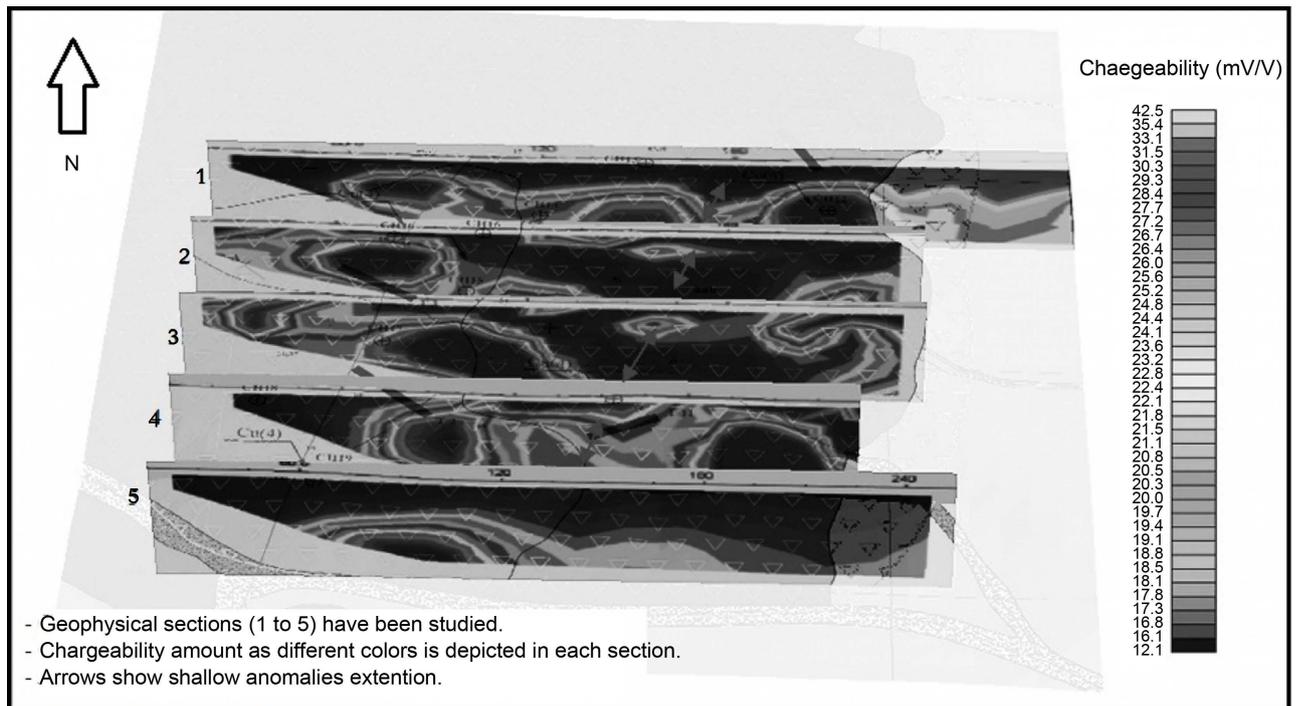


Figure 6. Geophysical sections of the study area showing strong surface anomalies.

Concentration-volume (C-V) Fractal modeling, have been employed. The final results of anomaly delineation by these methods are highly correlated with geophysical surveys which all show low-deep anomalies for the single element CU. Shallow anomalies as proved by this study are in consistence to the stringer zone of a volcanic massive sulfide (VMS) deposit in Mesgaran mining area. Field observations evince high degree of erosion in this area. So facing surface anomalies according to this study and comparing this fact to Mesgaran geological features and rock units, finally it results in that the recorded anomalies in Mesgaran mining area are low-deep and caused by the stringer zone of an eroded VMS deposit. In other words, the stringer zone which contains copper components has been exposed to weathering and secondary erosion processes and because of high degree of these processes, only oxide forms of copper were observed in outcrops. Since the main part of the deposit has been eroded, the next exploration/extraction activities must be performed with higher attention to exploration costs and economical factors. As another result of this investigation, we can claim that the boxplot as a useful Exploratory Data Analysis (EDA) method is highly recommended for studying nonsymmetrical deposits and those which are involved with elements with low-cutoff ranges (like precious metals or strategic ones) specially when the cases are in association with complex geological structures or effected by tectonic activities and erosion processes.

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