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APPLICATION OF POWER-LAW FREQUENCY FRACTAL MODEL IN DETERMINATION OF VERTICAL GEOCHEMICAL DISTRIBUTION OF Cu IN KAHANG PORPHYRY DEPOSIT, CENTRAL IRAN

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Abstract

Determination of the vertical distribution of geochemical elemental concentrations is of fundamental importance in mineral exploration. In this paper, four mineralized boreholes from the Kahang Cu porphyry deposit, Isfahan, central Iran, were drilled, and the collected samples were investigated and identified the vertical distribution directional properties of Cu values using power-law frequency fractal model. The vertical distribution of Cu values in mineralized boreholes shows a positively skewed distribution in the former and multimodal distribution in the latter types. The power-law frequency analysis reveals that Cu values in mineralized boreholes are bifractal in nature. The two portions of the plot define a crossover point about 0.2% - 0.3%, for Cu values less than and greater than this value, fractal dimensions range from 1.70 to 4.97, in the mineralized boreholes.

Key words: *Power-law frequency fractal model, Vertical distribution, Kahang, Porphyry, Iran.*

1. Introduction

Investigation of the distribution of geochemical elements in boreholes is of significance value and importance to evaluate the quality and interpret the quantity of mineral resources in the mine planning and extraction method selection. In the past decades, the nature of the distributions of geochemical elements in

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[#] ***Corresponding author:*** *rashid@modares.ac.ir* rocks has been extensively studied in order to present a universal geochemical law [1]. The proposed law states that the frequency distributions of most major, minor and trace elements in rocks and ore deposits were positively skewed and distributions of major elements are lognormal. The distributions of geochemical elements in boreholes also exhibit power-law relationships, which can be fitted into fractal models [2-4].

Fractal theory developed by Mandelbrot (1983) and widely applied during 1980s and also was applied in geosciences is based on fractal geometry proved to be especially useful in geochemistry [5]. This theory and its usage gained favor during 1980s and 1990s. In geosciences, this approach has mainly been used for the characterizing geologic structures, and some other geological features and also for separating geophysical and geochemical anomalies from background values [4-9]. Cheng et al. (1994) introduced famous and applied concentration-area (C-A) model for geochemical anomalies separation from background. Also, fractal models have been applied to mineral resources studies for determining quantitative particulars of mineralization and mineral deposit characters [2, 10-12]. Zou et al. (2009) investigated the application of three fractal models including the characterization of vertical distribution of Cu concentration in Qulong copper deposit in Tibet, western China. In this work, the power-law frequency model is used to characterize the vertical distribution of the major element (Cu) to evaluate the mineralization continuity based on borehole datasets in Kahang copper porphyry deposit located in central Iran is investigated. In this investigation the power-law frequency model is briefly presented for demonstrating the data processing involved.

2. Power-law frequency fractal model

The power-law frequency fractal model in this study is used to measure the frequency distribution of elemental concentrations. This model has been demonstrated by many previous workers, i.e., Turcotte, 1996; Sanderson et al., 1994, and has the general form of:

$$(N \geq c) \infty c - D \qquad (1)$$

$$\log (N \geq c) = C - D\log(c) \qquad (2)$$

Where $N(\geq c)$ is the number of samples with elemental content greater than c, C is a constant and D is the fractal dimension.

3. Geological setting and sampling

Kahang Cu porphyry deposit is a large porphyry copper deposit of Iran, located in the Cenozoic Urumia-Dokhtar magmatic belt, located NE of Isfahan, central Iran, as depicted in Fig. 1. This magmatic belt extends from NW to SE Iran. The host all of the Iranian large porphyry copper deposits whitin this belt, such as Sarcheshmeh, Sungun, Meiduk and Darehzar are shown in Fig. 1 [13].

A simplified geological map is also shown in Fig. 1. The mineralized belt is mainly consists of Eocene volcano-pyroclastic rocks, intruded by quartz monzonite, monzodiorite to dioritic intrusions in Oligo-Miocene rocks (Fig. 2). The extrusive rocks, including tuffs, breccias and lavas are dacitic to andesitic in composition. The details of geological characteristics of the Kahang deposit were studied by Asadi Haroni and Tabatabaei (2006) [14]. The Kahang porphyry copper deposit consists of 3 orebodies, eastern, central and western, among which the eastern body is being drilled for detailed exploration. Four boreholes were drilled up to now, and that four Cu mineralized datasets were obtained by continuous sampling every 2 m along and within borehole in the zones, respectively. The rock ore properties and the statistical results of analysis of the boreholes datasets are summarized in Table 1.

Figure 1. *Urumieh-Dokhtar volcanic belt (orange color) and the known porphyry deposits located within the belt [13]*

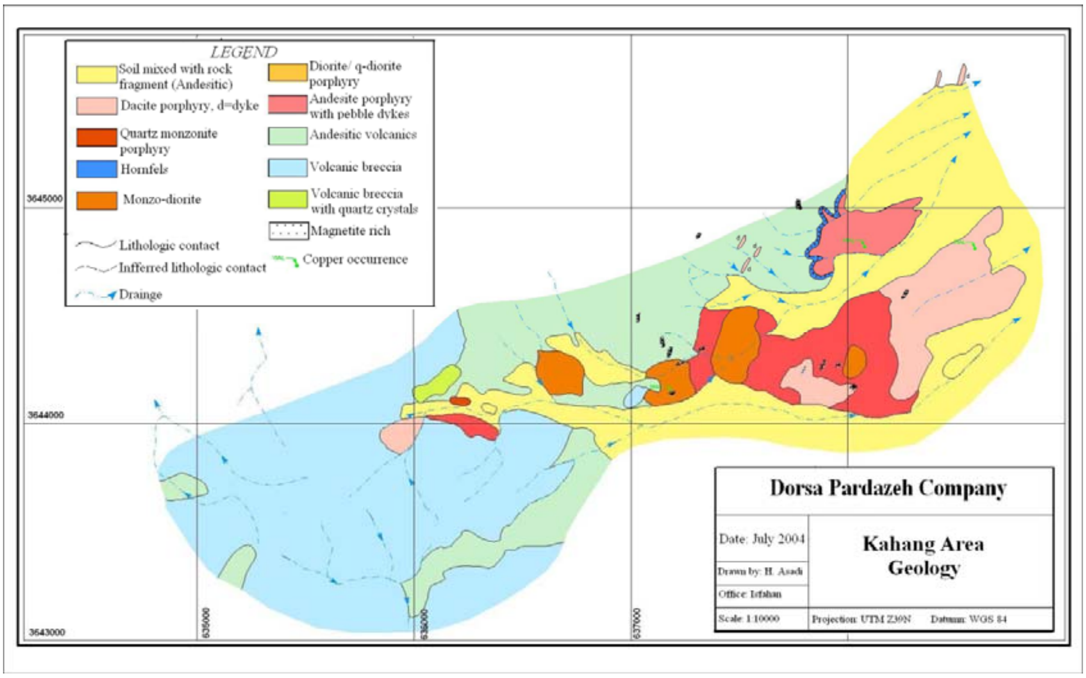


Figure 2. *Geologic map of Kahang Area, scale: 1:10,000*

Table 1. *The basic information and statistical properties of four mineralized boreholes data obtained from Kahang porphyry copper deposit*

Borehole Name	Depth (m)	Number of samples	Cu Max (%)	Cu Min (%)	Cu Average (%)	Std Dev.	CV
KH-DDH02	188.0	94	0.65	0.002	0.1	0.12	0.82
KH-DDH07	224.9	96	1.73	0.02	0.14	0.21	0.64
KH-DDH09	351.4	175	1.50	0.008	0.17	0.22	0.76
KH-DDH11	400.1	198	4.3	0.01	0.23	0.39	0.58

4. Discussions and results

4.1. Frequency distribution of Cu

The property of frequency distributions of element concentrations are usually evaluated by histograms that displays as arbitrarily chosen, linearly scaled concentration intervals on the frequency of individual analyses whose results fall in a particular class within the interval on the ordinates. The histograms are depicted in Fig. 3 and show that the distributions of Cu values in the mineralized boreholes are positively skewed.

4.2. Power-law frequency distribution of Cu values

The results obtained by the power-law frequency model for the mineralized boreholes are depicted in Fig. 4 and are listed in the Table 2.

The log–log plots of cumulative number versus Cu values show the distribution of Cu concentration variations in the mineralized boreholes satisfying a bifractal model. The two portions of the plot define a crossover point between 0.17% - 0.45%, values as shown in Table 2, for Cu values less than, and greater than these values, fractal dimension 1, and range from 1.70 to 4.97, in the mineralized rocks, i.e., fractal dimension 2, in this deposit.

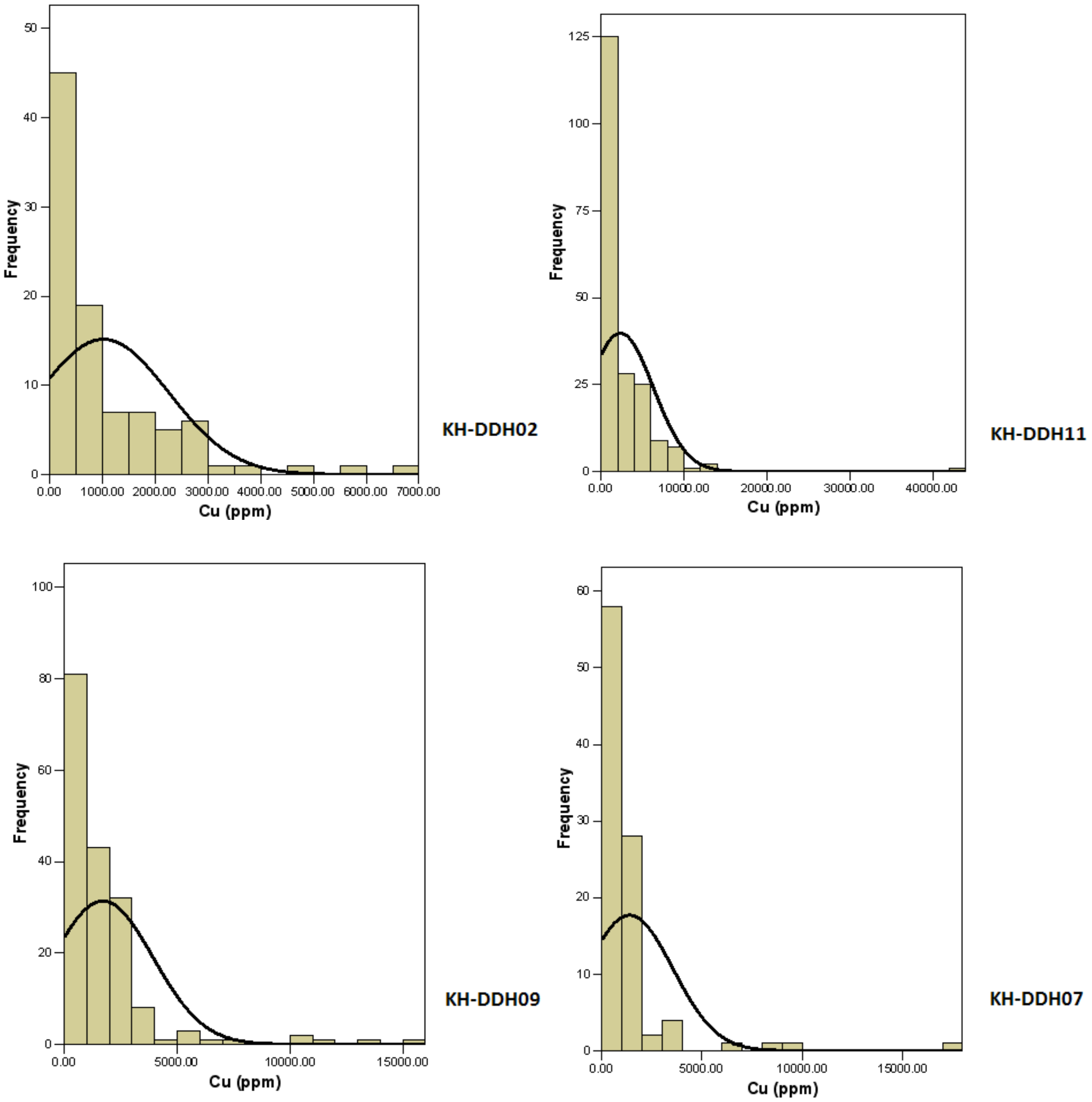
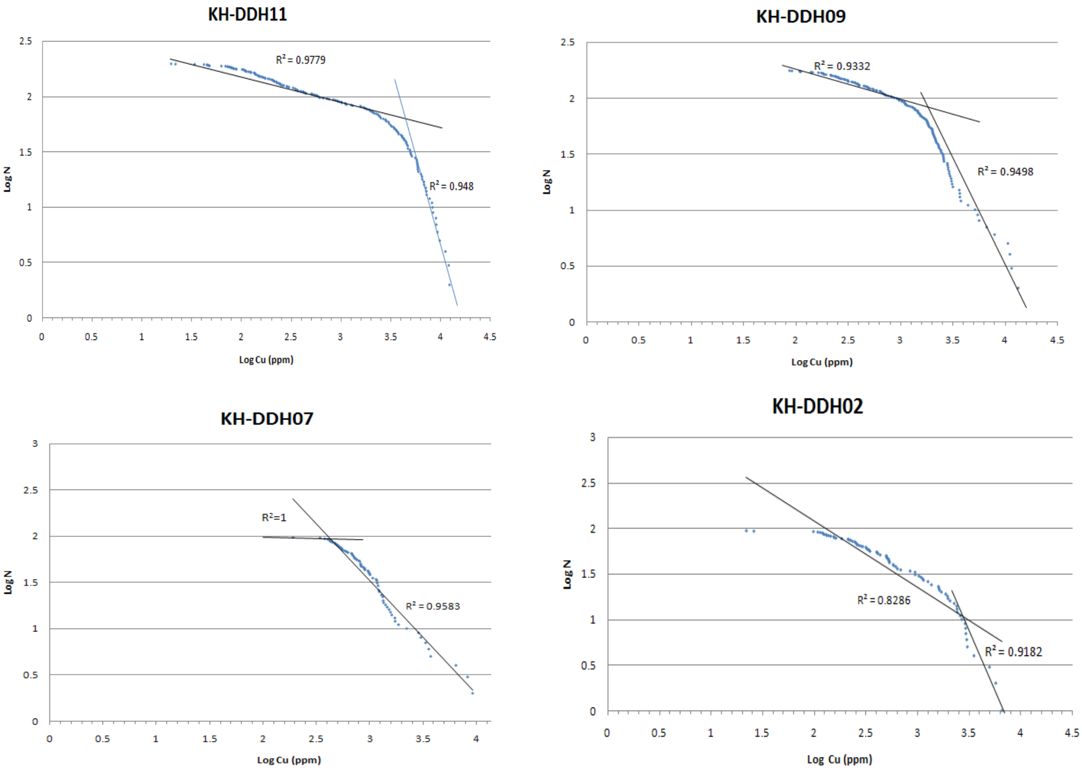


Figure 3. *The histograms of Cu values from four mineralized boreholes*



KH-DDH11

KH-DDH09

KH-DDH07

KH-DDH02

Figure 4. *Log–log plots of cumulative numbers versus Cu grade in four mineralized boreholes (Logs are base 10)*

Table 2. *The fractal dimensions of Cu in Kahang copper porphyry deposit calculated by power-law frequency model*

Borehole Name	Fractal Dimension 1	R^2	Break point	Fractal Dimension 2	R^2
KH-DDH02	0.97	0.82	0.30	1.73	0.92
KH-DDH07	1.01	1	0.17	1.70	0.96
KH-DDH09	1.08	0.93	0.21	2.45	0.95
KH-DDH11	0.76	0.98	0.45	4.97	0.95

Larger fractal dimensions of mineralization imply more homogeneous mineralization. It can be explained that fractal dimensions are estimated from the frequency of Cu values and can reflect the proportion of Cu concentration values. Larger fractal dimension also implies lower Cu values greater than certain specific Cu value. It means that the Cu value change slowly along the depth of borehole, indicating more homogeneous mineralization. The coefficient of variation (CV), which is the standard deviation divided by the average, identifies the degree or range of change. In the case of approximate average of Cu value, a low CV implies elemental concentrations changing slightly along the borehole depth. In other words, it means more homogeneous mineralization. Therefore, the fractal dimensions of mineralization are inversely related to CV values. The regression line existing between fractal dimensions and CV values is represented in Fig. 5. The squared correlation coefficient R^2 is 0.14, which reveals a weak correlation between the two variables.

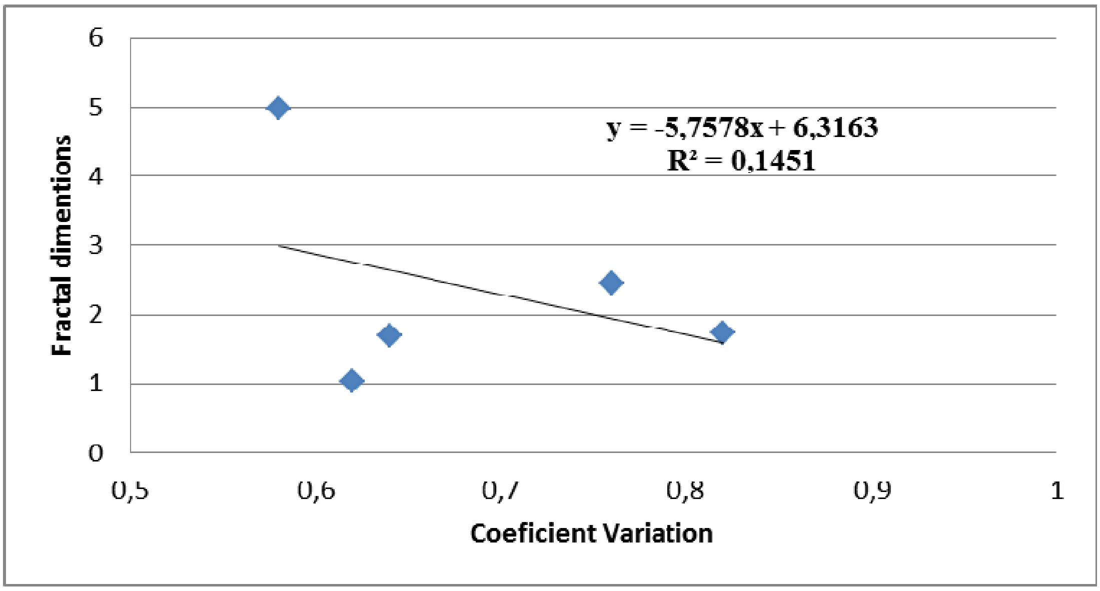


Figure. 5. *Plot of fractal dimensions for Cu mineralization versus coefficient of variation along with the illustrated regression line*

5. Conclusions

The continuity of mineralization is a key issue in interpretation of potential mineral resources assessment in a given deposit. The mineralization potential in depth can be recognized by characterizing the vertical distribution of geochemical concentration values of the mineralized element in borehole datasets. In this work, fractal dimensions obtained power-law frequency model was used to investigate and interpret the irregularities and the continuity of Cu mineralization. The obtained results demonstrate that the vertical distribution of Cu values in mineralized boreholes has different characteristics: the former has a positive skewed distribution character and exhibits bifractal model while the latter satisfies a multimodal distribution.

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