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DETERMINATION OF AN OPTIMUM VOXEL SIZE BASED ON STATISTICAL METHODS IN THE KAHANG CU PORPHYRY DEPOSIT, CENTRAL IRAN

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Abstract

The aim of this study is to determine an optimum voxel size in the Kahang Cu porphyry deposit (Central Iran) using statistical parameters and vector analysis based on the 26 drilled boreholes. The mean, median and Median Absolute Deviation (MAD) were calculated for total distances between 14 pairs of closest boreholes in terms of X and Y directions. Based on the results, three block models were determined with $3 \times 3 \times 10\ m^3$, $4 \times 4 \times 10\ m^3$ and $5 \times 5 \times 10\ m^3$ of voxel volumes for Cu distribution utilising inverse distance weighted (IDW) method. According to calculation of Non-Zero voxel numbers and decreasing of standard deviations and Cu average values, the block model with $4 \times 4 \times 10\ m^3$ voxel sizes determined as an optimum block model.

Key words: *Voxel size, Statistical parameters, Kahang, Standard deviation.*

1. Introduction

An important problem in the estimation of the three-dimensional regional variables in a studied deposit is the determination of optimum voxel sizes [1-2]. This problem has been affected on the estimated block models by different geostatistical methods such as ordinary kriging (OK) and inverse distance weighted (IDW). Results obtained by the estimation methods relate to the determination of voxel size in block modelling [3-5].

Utilising a larger voxel size will increase the averaging effect in the estimated block model in terms of concentrations, geophysical data, rock mechanical data and different attributes. Additionally, a smaller voxel size will show more details, but potentially more error in anisotropic environment [6-8]. On the other hand, decreasing of voxel size results the estimation error (variance and standard deviation) increased in the final block model. Moreover, increasing of voxel size in the block model corresponds to deletion of high or low mineralised zones by smoothing of those points with high or low values within a large voxel.

Identification of an optimised voxel size is one of the most important aspects of building an estimated 3D block model. Therefore, it is necessary to select an optimal voxel size with respect to the deposit geometry and drilling pattern because most of the geostatistical software, e.g. RockWorks which was employed in this study estimates an ultimate block model based on the closest points considering particular parameters such as ore elements especially in this scenario [9-10].

The grid drilling are not systematic in many cases of mineral exploration and statistical parameters such as mean and median which can be used for recognition of optimum voxel dimensions in various types of ore deposits [2, 3, 7].

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The aim of this paper is to determine of an optimum voxel size based on the statistical methods in the Kahang Cu porphyry ore deposit, central Iran.

2. Methodology

David (1970) proposed an applicable method for an operation based on geometrical particulars of the different types of ore deposits and grid drilling.

Based on the method, voxel dimensions are calculated as follows:

a) Length and width of each voxel is equal to between half and quarter of the distance between the drill cores according to along the least variability deposit.

b) Height of each voxel is delineated due to the type of the deposit. In massive deposits such as magmatic deposits (e.g., porphyry deposits), the parameter equal to height of excavating benches in the open pit mines [11].

For recognition of the optimum voxel dimensions in the Kahang Cu porphyry deposit, statistical characteristics consisting of mean, median and Median Absolute Deviation (MAD) were utilised. In addition, standard deviation (SD) was used for further comparison and validation through the obtained results in the different scenarios of voxel size. If SDs includes very low changes then voxel sizes' selection is carried out based on the Cu estimated mean.

The voxel sizes with the lowest value of Cu mean would better be selected because this is a worse scenario for mine planning and exploitation due to conservative mine strategy and risk analysis. Moreover, the median and MAD are used for determination of voxel sizes and development of conventional method which proposed by David (1970).

3. Kahang Cu deposit particulars

The Kahang deposit is situated about 73 km NE of Isfahan in the central Iran, which contains more than 80 million tonnes of sulphide ore.

The deposit is located in the Cenozoic Urumieh-Dokhtar magmatic belt of the Zagros orogen extending from NW to SE Iran which is hosting the Iranian large Cu-Mo-Au porphyry deposits such as Sarcheshmeh, Sungun, Meiduk and Darehzar [12-14].

This deposit is mainly composed of Eocene volcanic-pyroclastic rocks, which were intruded by quartz monzonite, monzogranite-diorite to dioritic intrusions in Oligo-Miocene rocks (Fig. 1). The extrusive rocks, including tuffs, breccias and lavas are dacitic to andesitic composition [8, 12, 15].

The major structural features are two fault systems trending NE-SW and NW-SE. The main alteration zones of potassic, phyllic, argillic/advanced argillic and propyliticwere accompanied by the vein/veinlets fillings of quartz, quartz-magnetite and Fe-hydroxides. Mineralisation within intrusive bodies and their surrounding host rocks includes chalcocite, chalcopyrite, pyrite, malachite, magnetite, limonite jarosite, goethite and chalcantite [16].

4. Discussion

The 2D map which indicated the location of 45 boreholes drilled in the Kahang deposit was constructed by RockWorks™ v.15 software. As a result, a grid model of the boreholes on the surface was created to illustrate a map of the drillcores' locations, reading the location information, symbol style and borehole's names for the studied area (Fig. 2).

Since the grid drilling in this deposit was not homogeneously and systematically carried out, 14 pairs of closest boreholes were selected for an optimum voxel size investigation because this action can improve the interpolation of voxel values (Cu grades in this scenario) that lie between data point clusters.

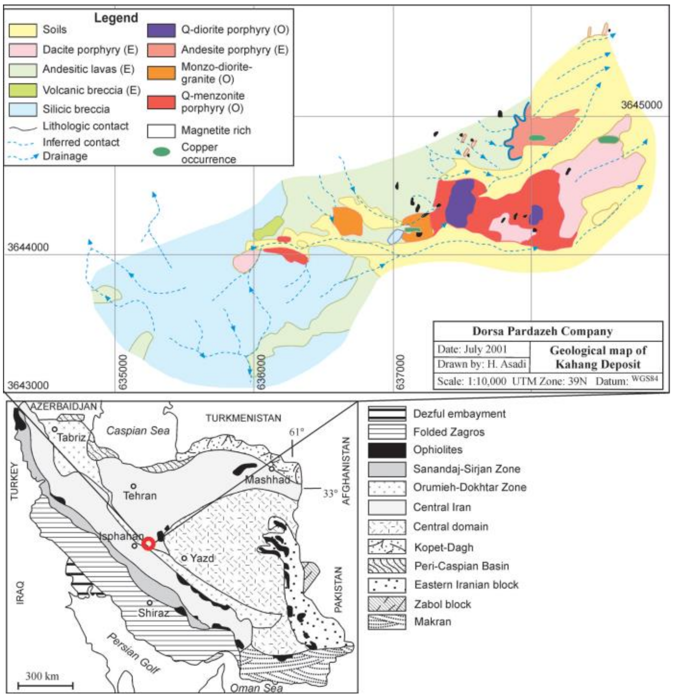

Figure 1. Geological map of the Kahang study area, scale: 1: 10,000 within the Urumieh-Dokhtar magmatic belt in the structural map of Iran

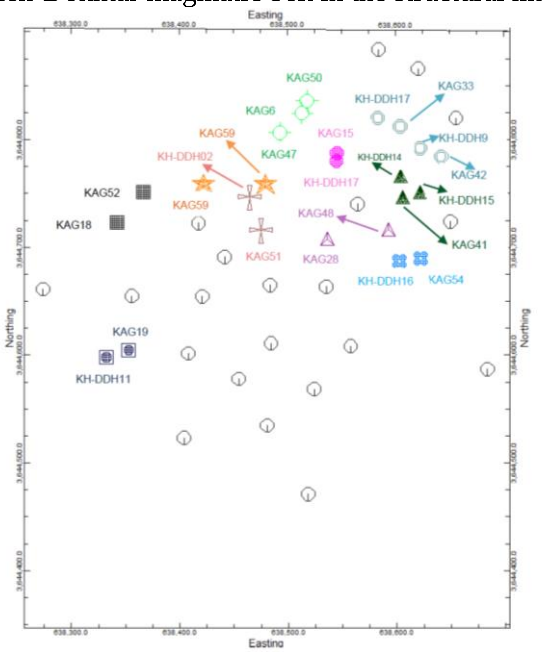

Figure 2. Boreholes location map in the Kahang deposit with selected closest boreholes' pairs

The particulars of these pairs are revealed in the Table 1. The distance range of the selected boreholes varies between 5 to 27 m.

Table 1. The particulars of the selected boreholes' pairs in the Kahang deposit

Borehole ID		Dist. m	Distance (m)	
From	To		X	Y
KAG50	KAG6	11	4.4	10
KAG6	KAG47	23	17.14	15.33
KAG15	KH-DDH17	5	0.38	4.98
KAG33	KH-DDH13	20	18.69	7.1
KAG42	KH-DDH9	14	12.88	5.47
KH-DDH14	KH-DDH15	21	16.32	13.21
KAG41	KH-DDH15	15	14.59	3.47
KAG59	KAG27	15	12.28	8.6
KAG54	KH-DDH16	16	15.58	3.59
KAG52	KAG18	28	17.77	21.63
KH-DDH11	KAG19	20	18.97	6.31
KAG51	KH-DDH02	22	7.41	20.71
KAG33	KH-DDH9	25	17.04	18.28
KAG48	KAG28	27	7.39	25.96

For identification of an optimum voxel size in the directions of X and Y, the vector analysis was employed. The ranges of distances in the X and Y directions are 0.38-18.97 m and 3.47-25.97 m, respectively (Table 1).

Based on the David (1970) method, the voxel size in the Z direction is determined 10 m in the basis of the ore deposit geometry and particularly height of the working bench.

In the first step, the distances mean of the selected boreholes in their pairs were calculated, as depicted in Table 2.

Table 2. Variation of voxel size based on mean, median and MAD

Statistical parameters	Total distances (m)	Distances in X (m)	Distances in Y (m)
Mean	4.67-9.34	3.23-6.46	2.94-5.88
Median	5-10	3.8-7.6	2.94-5.88
MAD	2.5-5	< 1	< 1

In the simple method, the range of voxel sizes in the X and Y directions was considered between half and quarter of the mean value which is equal to4.67-9.34 m.

Moreover, the ranges of the voxel size according to median and MAD values are 5-10 m and 2.5-5 m, respectively.

In second step, the voxel size was investigated via vector analysis between boreholes based on the closest surface location on the 2Dmapsince the closest points (two boreholes as a pair) is suited for data analysis that is gradational (e.g. massive orebodies as the porphyry deposits).The mean values in the directions of X and Y are 12.91 and 11.76 m respectively meaning that the voxel size varies between 3.23 and 6.46 m in X and between 2.94 and 5.88 m in Y. Based on the median values, the voxel size values ranges are 3.8-7.6 m and 2.32-4.65 m in terms of X and Y. The MAD values for X and Y are less than 3 m indicating that the voxel size is lower than 1 m resulting an increase in calculation which has a rise in error for construction of a final block model [17].

According to a massive ore body and homogenous expansion considering elemental concentrations in the porphyry deposits, X and Y directions have equal values in terms of voxel size [18].

As a result, three different voxel size scenarios of $3 \times 3 \times 10$ m^3, $4 \times 4 \times 10$ m^3 and $5 \times 5 \times 10$ m^3 have been allocated which corresponds to 694512, 1081080 and 1932840 total voxel number respectively to build the Kahang deposit Cu block model. 3D block models of the distribution for Cu were estimated by IDW utilising RockWorks software.

For determination of optimum voxel dimensions based on the statistical parameters depicted in Table. 2, standard deviation (SD) and an average Cu value have been calculated.

Topographical features of the deposit were formed into a 3D block model. Moreover, the upper and lower filtering was operated based on the topographic and surface data in order to produce the applicable Cu block model (Fig. 3). Those voxels located in upper and lower topographical surfaces are considered as the waste voxels and are not entered into the deposit block model as the voxels of negative significance [19]. As a result, the amounts of voxels with positive value (Non-Zero) are 468, 920, 263, 414 and 169,091 in orders of different voxel dimensions mentioned above. The more Non-Zero voxels consequently correspond to the voxel dimension of 3× 3× 10 m^3.

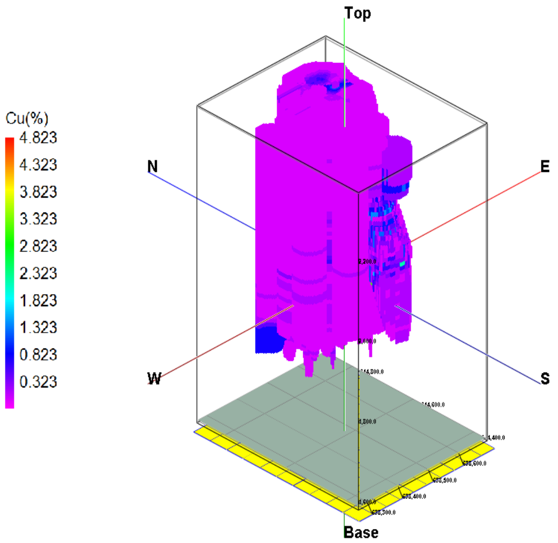

Figure 3. The 4 × 4 × 10 m^3 block model for Cu values in the Kahang deposit

The standard deviation values which were calculated for the different voxel sizes are similar in terms of values (Table 3).

Moreover, the averages for estimated Cu values were computed and the lowest value occurs in the 4 × 4 × 10 m^3 block model which is conservatively suited for identification of Net Present Value (NPV) and subsequently mine planning [11].

Table 3. Voxel numbers and Standard deviations and averages of Cu for different block models

Block model dimensions (m^3)	Total voxel No.	Non-Zero voxel No.	Standard deviation (%)	Cu average (%)
3×3×10	1,982,742	468,920	0.20055	0.15844
4×4×10	1,113,742	263,414	0.20134	0.15823
5×5×10	718,505	169,091	0.20101	0.15833

5. Conclusion

Choosing of a proper voxel size for evaluation of a reserve/resource with the minimum error is crucial in geostatistics. In this study, an optimum voxel size was recognised among three different scenarios based on vector analysis and statistical parameters. The use of IDW as a common estimator to construct 3D block model was employed in this research. The proper voxel sizes vary between 3 and 5 m in X and Y dimensions based on drilling pattern. Additionally, the X and Y values are equal since the studied deposit is a kind of massive porphyry system. Furthermore, the Z value in all cases was selected to 10 m corresponding to extractive benches. According to the similar standard deviations for all cases, averages of Cu estimated values and the amounts of Non-Zero voxels, the block model with dimensions of 4 × 4 × 10 m^3 in terms of X, Y and Z respectively has been identified because of lowest Cu average conservatively suitable for feasibility study and mine planning.

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