Evaluating the performance of non-linear geostatistical estimation methods to estimate tonnage-grade of the Chah-bashe iron deposit, Yazd province

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1-Introduction

Chah-bashe Ferromanganese deposit with 32 Km^2 area, is located in 62 Km eastern south of Naein in Yazd province. The region is oriented on 1:100000 geological sheets of Naein and Sarve-bala which has been performed by metamorphic lithology units related to Paleozoic and rhyolitic tuff, dolomite and rhyolite (Rizzo formation) of late Precambrian. Metasomatism is the most obvious characteristic of Chah-bashe region (Yousefi et al., 2013). In this deposit, iron is occurred as ferric oxide (Fe_2O_3) form and iron-manganese ore body mainly contains iron oxide minerals especially limonite. In this region 82 exploratory boreholes (called BH-4 to BH-107) with total length of 7618.8 m have been drilled yielding 977 cores with total length of 3673.5 m. Exploratory information especially assay data for iron and manganese elements are available from the mainly 2 m long cores from 75 exploratory boreholes. In the research, non-linear geostatistical methods containing block ordinary log-kriging, indicator kriging and sequential gaussian simulation as well as inverse squared distance from statistical methods (for comparison) have been employed to evaluate grade and ore reserve of the Chah-bashe iron deposit, Yazd provice. Inverse squared distance is one of the most highly accurate statistical methods whereas geostatistical kriging estimation method due to be unbiased having the minimum estimation variance (Hassani-Pak and Sharafodin, 2001; Rendu, 1981), is the most accurate method among the all ore reserve estimation methods.

2-Methodology

To evaluate the grade and modeling the deposit first, statistical studies of assay data of exploratory boreholes were performed through determination of descriptive statistics, plotting the histograms and cumulative probability distribution diagrams of the data (Ahmadi, 2010) as well as topography and geological maps. For modeling the deposit, the variography was also carried out via mapping the variety of directional variograms using SGEMs software (Bohling, 2007), MATLAB functions and short programming in this environment. Afterward 3-D block modeling of the deposit, determination of average grade, ore reserve estimation and plotting tonnage-grade diagrams by means of ordinary block log-kriging, indicator kriging, sequential Gaussian simulation and inverse squared distance methods were performed using Datamine software. To achieve these goals, depending on the mineralization type of Chah-bashe deposit, topography of the region, location distribution of exploratory boreholes and concentrating them in two separate areas, the region was divided to two zones, called 1 (southern) and 2 (northern) which the estimation was done for southern zone. In order to estimate the ore reserve first, the optimum dimensions of estimated blocks were selected based on spatial extension of ore body and designing mining steps, especially the thickness of the sequences of ore and gangue. Afterward the average grade and ore reserve were determined by the chosen methods.

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3-Results and discussion

In general, according to the 3-D variography of iron assay data through drawn directional variograms in the the variety of directions, the region is anisotropic meanwhile there are both of geometric and zonal anisotropy in the region. The theoretical models of variogram matched over the experimental data are mainly exponential and spherical type or their combination which the maximum and minimum ranges are along the directions with azimuth of 135 degree and drilling direction of boreholes with dip of 90 degree, respectively. The results of the research show that the indicator kriging, ordinary log-kriging, inverse squared distance and sequential Gaussian simulation methods have estimated the highest average grade, respectively. Also the correlation matrix of estimated iron grade in the southern zone of Chah-bashe deposit for the various estimation methods used in this study shows that there is the highest correlation (about 0.87) between the estimation results of ordinary Kriging and inverse squared distance methods, whereas the least correlation (about 0.56) was found between the sequential Gaussian simulation and inverse squared distance methods.

4-Conclusions

Comparison of the estimated average grades, grade estimation variances and ore reserves as well as drawn tonnage-grade diagrams for several cut off grades by geostatistical and statistical inverse squared distance methods for southern zone of Chah-bashe deposit reveal that there is no significant difference between the results of the methods. However the results of the research show that sequential Gaussian simulation, indicator kriging, ordinary log-kriging, and inverse squared distance methods have the minimum estimation variance, respectively. Although all chosen methods are the most accurate geostatistical methods, the results of sequential Gaussian simulation method by applying various filters on the data such as producing residual maps, is most highly accurate and more reliable so has more validity. In general, the close approximation of the results of grade estimation and ore reserve with accurate geostatistical methods containing indicator kriging and Gaussian sequential simulation is also a reason for the accuracy of the results and performance of the research. The results of this research are applicable to all geosciences users, in particular mining exploration engineers and economic geologists, who are always concerned with the accurate estimation of ore reserves.

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