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Research Paper

Determination of Potential Mineralization Areas by Hybrid Multi-Criteria Decision-Making Methods in the Khoynehrud Region of East Azerbaijan

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Abstract: The diversity of exploration data and the cost of borehole drilling necessitate the use of a suitable integration method for the analysis of the data of the semi-detailed exploration stage. In this paper, two hybrid multi-criteria decision-making algorithms, namely CCSD-EDAS and CCSD-MARCOS, are introduced. The data of Khoynaroud exploration area, in East Azerbaijan province, has been used to investigate the performance of these algorithms. The spatial data layers used include four geochemical, two geophysical and two geological layers in an area of 1400×2100 meters. The integration results show that the map obtained from the CCSD-EDAS algorithm has samples with weights approximately close to each other and above, while in the CCSD-MARCOS algorithm, the samples have more reasonable weights. The R statistics of the permutation method also show the relative superiority of the results obtained of the CCSD-MARCOS algorithm. The integration results show four potential mineralization zones in the study area. Zones I and II have the possibility of copper-gold porphyry mineralization and Zones III and IV have the possibility of mineralization of quartz-gold veins. Zone I, with an area of 400 × 1200 meters, has been proposed as the best zone for drilling network design. Also, the use of these two hybrid methods, especially the CCSD-MARCOS hybrid multi-criteria decision-making method, for integrating the exploration data is the most important suggestion of this paper.

Keywords: CCSD algorithm, EDAS algorithm, MARCOS algorithm, Mineral potential mapping, Khoynaroud exploration area.

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INTRODUCTION

Integrating data, due to the use of various exploration tools, is one of the most important part of an exploration project. The diversity of the exploration data and the cost of the borehole drilling necessitate the use of a suitable integration method for the analysis of the data of the semi-detailed exploration stage [1]. Integration methods are divided into data-driven and knowledge-driven algorithms [2]. In this paper, two hybrid multi-criteria decision-making algorithms, namely CCSD-EDAS and CCSD-MARCOS, are introduced. The data of Khoynaroud exploration area, in East Azerbaijan province, has been also used to investigate the performance ability of these algorithms in integration of exploration data. The aim of this integration is to propose the drilling network area for the detailed exploration stage in the study area.

METHODS

Correlation coefficients and standard deviations (CCSD) algorithm is a multi-criteria decision-making method used to weight variables or spatial data layers. This method uses a combination of objective and subjective weighting [3]. Evaluation based on distance from average solution (EDAS) and measurement of alternatives and ranking according to the compromise solution (MARCOS) algorithms are also two multi-criteria decision-making methods used to rank the samples or object. These algorithms apply a statistically average solution and the degree of usefulness of the objects in relation to the ideal and anti-ideal solution, respectively [4]. Therefore, the results obtained from EDAS Algorithm have high and close sample weights and in MARCOS Algorithm, the samples will have more reasonable weights. Combination CCSD with EDAS and MARCOS were caused to make two hybrid multi-criteria decision-making algorithms, namely CCSD-EDAS and CCSD-MARCOS that used in this paper.

FINDINGS AND ARGUMENT

The study region is Khoynaroud exploration area with an area of 1400×2100 meters. The spatial data layers used include four geochemical layers (contour maps of Cu and Au concentration, the PC2 scores and geochemical mineralization probability index), two geophysical layers (reduced to the pole residual magnetic intensity and upward continuation from 50 meters maps), and two geological layers (rock units and fault density maps). These data layers shown in Figure 1.

In the first stage, the spatial data layers are weighted according to expert opinions and then the weights are optimized using CCSD algorithm. Table 1 shows the initial (w), and optimized (w_{jC}) weights of the layers. In the second stage, the samples are ranked based on EDAS and MARCOS algorithms. The result will be the weight ranking of each sample. Then the contour map is drawn based on these weights. Figure 2 shows these maps with continuos and classified scales. The maps were classified into two classes based on the concentration-area fractal algorithm. The integration results show that the map obtained from the CCSD-EDAS algorithm (Figures 2A and 2B) has samples with weights approximately close to each other and above, while in the CCSD-MARCOS algorithm (Figures 2C and 2D), the samples have more reasonable weights. The R statistics of the permutation method are 67.6 and 69.2 percent for CCSD-EDAS and CCSD-MARCOS algorithms, respecitivetly. It show the relative superiority of the results obtained of the CCSD-MARCOS algorithm. The integration results also show four potential mineralization zones in the study area (Figures 2B and 2D). Zones I and II have the possibility of copper-gold porphyry mineralization and Zones III and IV have the possibility of mineralization of quartz-gold veins.

Zone I, with an area of 400×1200 meters, has been proposed as the best zone for drilling network design. In this zone, 6 exploration profiles with distances of 200 meters and 26 boreholes with distances of 100 meters have been designed (Figure 3). If the drilling results are appropriate, in the second step, the distances of the profiles and the distance of the boreholes can be reduced by half to one third.

The use of two hybrid multi-criteria decision-making algorithms on semi-detailed exploration stage data in Khoynaroud area showed following subjects:

1. The weight of the sample in the CCSD-EDAS algorithm is almost close to each other and as a result, most of the exploration area is composed of high weight samples; while in the CCSD-MARCOS algorithm, the samples have more reasonable weights.

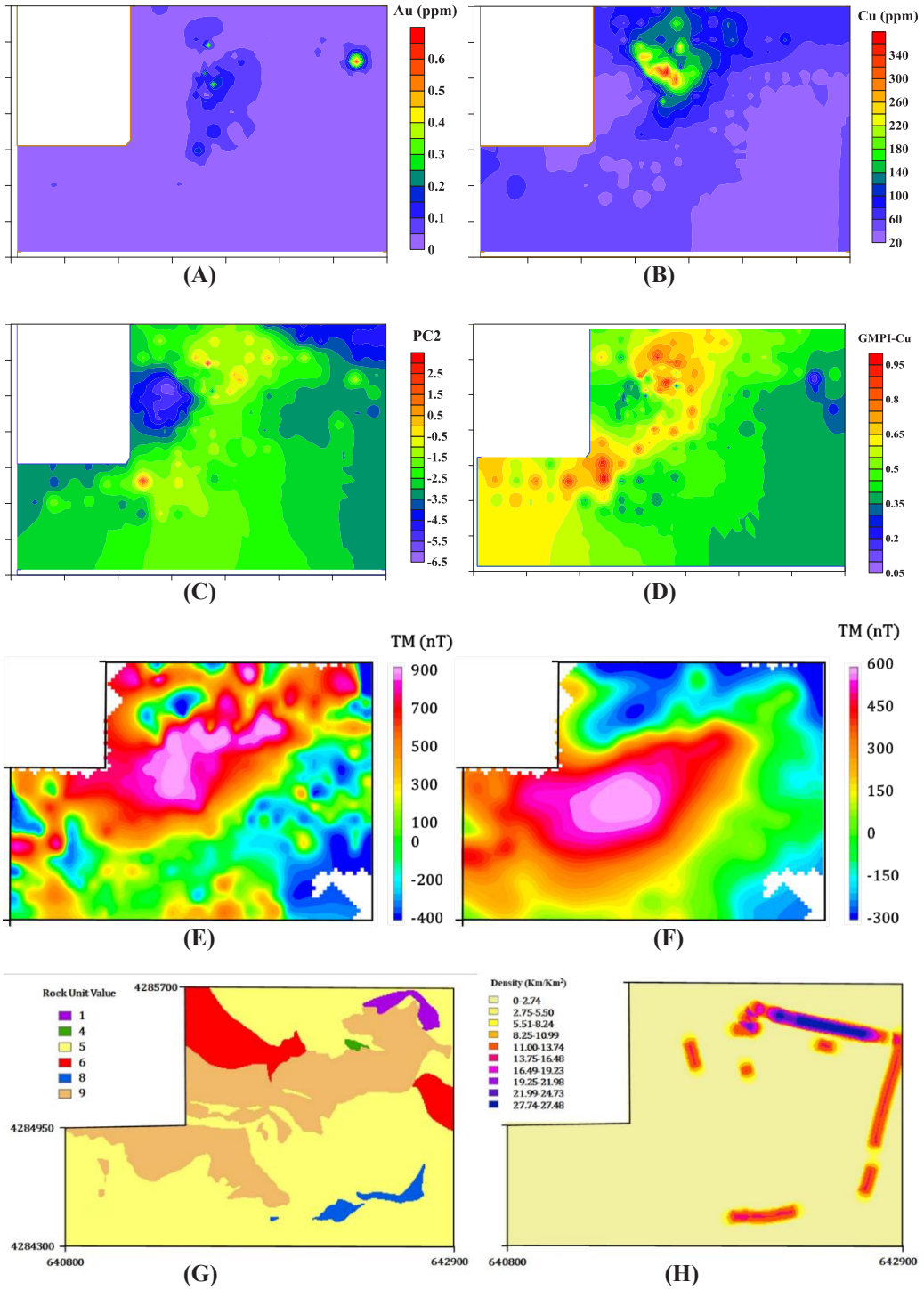

Figure 1. Spatial data layers in the study area, **A:** contour maps of Au concentration, **B:** contour maps of Cu concentration, **C:** contour maps of the PC2 scores, **D:** geochemical mineralization probability index map, **E:** reduced to the pole residual magnetic intensity map, **F:** upward continuation from 50 meters map, **G:** rock units map and **H:** fault density map

2. The results of the integration show four zones have potential to mineralization in the study area. Zones I and II have the possibility of copper-gold porphyry mineralization and zones III and IV have the possibility of mineralization of quartz-gold veins.

3. Due to the appropriate adaptation of the proposed zones to the geological conditions of the study area,

Table 1. Weight of each spatial data layer

Criterion	Spatial data layer	w	w_{jC}
Geochemistry	Au concentration	0.07	0.1153
	Cu concentration	0.18	0.1432
	PC2 scores	0.12	0.1124
	geochemical mineralization probability index	0.15	0.1188
Geophysics	Reduced to the pole	0.13	0.1215
	Upward continuation from 50 meters	0.10	0.1233
Geology	Rock unit	0.19	0.1343
	fault density	0.06	0.1312

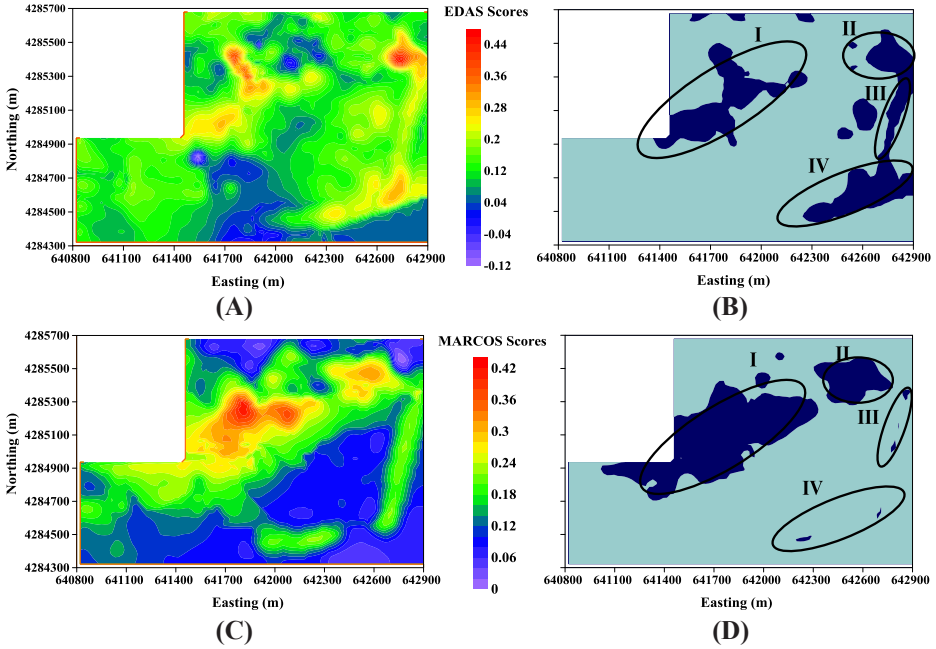

Figure 2. Maps of integration of the spatial data layers in Khoynaroud area by **A:** continuous scale and **B:** classified CCSD-EDAS algorithm, **C:** continuous scale and **D:** classified CCSD-MARCOS algorithm

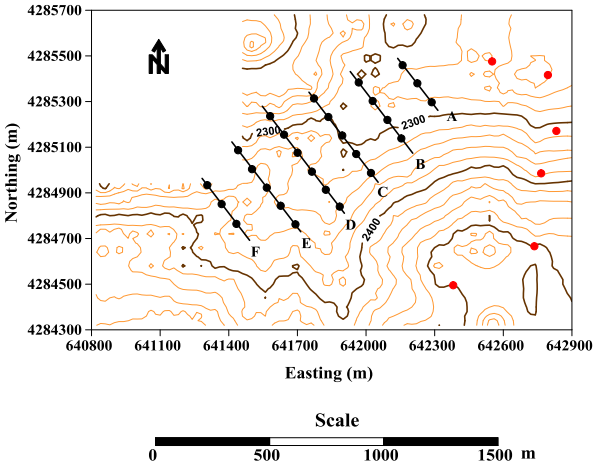

Figure 3. Location of the proposed drilling network on the topographic map of Khoynaroud area, 6 profiles (A, B, C, D, E and F) with 26 boreholes (black dots) and 6 experimental boreholes (red dots)

the use of these two hybrid algorithms, especially the CCSD-MARCOS hybrid multi-criteria decision-making method for integrating exploration data is the most important suggestion of this paper.

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