Application of AHP method in Copper potential mapping, Case study: Central Kerman metallogenic arc

Fardad Maghsoudi1*, Nader Fathianpour2

1*: Mining Engineering Department. Isfahan University of Technology, Isfahan, Iran (f.maghoudi@mi.iut.ac.ir)
2: Mining Engineering Department. Isfahan University of Technology, Isfahan, Iran

Abstract

Mineral exploration is a complex, time consuming and risky process. Reducing the risk level has always been aimed by mineral explorers and managers. As for the all anomalies obtained from different exploration data are not showing mineralization, integrating of these anomalies are used to determine the targets. Due to verification by different methods in such areas, the investment costs and risk will be low. The region which was investigated in this study was located at Kerman Cenozoic Magmatic Arc (KCMA). After preperation of geological, geochemical, geophysical, faults and remote sensing layers, using basin sample catchment, reduce to pole and analytic signal, band ratio and spectral angle mapper methods, paired comparisons between layers were performed by AHP method and results were used for mineral potential mapping (MPM). Results of the method were in a good agreement with the known mineralization at the zone and there could be used as a way to determine the vein and porphyry type of copper deposits in the zone.

Keywords: MPM, exploration, copper, AHP, KCMA

1. INTRODUCTION

Increasing demands for minerals is one hand and on the other hand reduction of mineral reservoirs with high grades, caused mineral exploration as a very important priority. Different methods have already been used to determine the mineral exploration. however, results of them is conclusiveness. In order to determine the mineral potential of an area, all geological, geochemical, geophysical, faults and alterations criteria should be in agreement [1]. Analytic hierarchy process (AHP) has been used to mineral potential mapping (MPM). Carranza (2011), has explained in details different methods of MPM [2]. Yousefifar et al. (2010), have compared the weighted sum, fuzzy logic and AHP methods to determine the Cu- Au potentials at north part of Dalli Deposit [3]. Pazand et al. (2012) have used Fuzzy AHP method to determine the Cu mineralization at Ahar- Arasbaran zone [4]. Abedi et al. (2013), were also used Fuzzy AHP method to integrate geophysical data in Seridun area [5]. In other study Najafi el al. (2015) used Fuzzy AHP method to evaluate and determine Iron Oxide- Copper- Gold (IOCG) deposits in eastern Iran [6].

Methods of data preparation and also several other criteria such as gravity radiometry were used for MPM. The above mentioned method has advantages over previous methods in determination of high potential areas.

2. GEOLOGY OF DEHAJ-KOUPANJ ZONE

Kerman Cenozoic Magmatic Arc (KCMA) is a part of Urumieh-Dokhtar Magmatic Belt (UDMB) which is a volcano sedimentary complex and located at the north-western part of Kerman province [7]. The origin of this zone was the result of subduction of Arabian plate under the Central Iran during Paleocene to Oligocene [8-10]. As a result, wide alkaline and Calk-alkaline taken in the area [8]. Sar Cheshmeh Calk-alkaline porphyry stock is an example of such activities during Oligo-miocene [11]. Nedimovic (1973), has determined a set of 62 of porphyry, vein and polymetal deposits in the KCMA [12]. Sar Cheshmeh and Darreh Zar mines are among the deposits in this zone which are located in a mass of Granodiorite and Meidouk mine is located in a Quartz monzonite mass [13]. Figure 1 shows the geological properties of the area.

3. PREPARATION OF LAYERS

A. Geological layer

Geological layer including 28 lithological units was prepared using the results of comprehensive reports, paper and dissertations [12, 14 and 15]. Results at direct observations on sediment, intrusive and volcanic rocks and host units of copper minerals (Granodiorite) were also used. Conceptual model of porphyry copper which is presented by the Geological Survey of United State (USGS) used to recapitulate the data and making the easier to process [14]. A questionery was also distributed among local expertise including some university professors who are working in copper exploration and the group of exploration in National Iranian Copper Industries Company (NICICO) and ask them to weight the units. Results are shown in table 1. Finally geological layer was made fuzzy using linear method (Fig. 2).

B. Faults

Processing and filtration of the 8th band of OLI imagery in combination with airborne magnetic survey, were compared to field observations. Those parts of results which were valid combined with the fault maps of Geological Survey of Iran (GSI). Then buffering was performed at intervals, considering the importance of the
faults at 250, 500, 750 and 1000 meter intervals which are the maximum interval of mineralization (Fig. 3) [12]. Linear density was calculated for faults (Fig. 4). Both results were converted to fuzzy state by linear method.

C. Alterations

Alteration of porphyry Copper systems is one of the most important factors at exploration. In order to determine the Phyllic, Argillic and Propylitic alterations, satellite images have been used. After preprocessing and atmospheric corrections such as FLAASH, different analysis methods such as band ratio, false color composite, principal component analysis and SAM were applied on the images. The 4:2 band ratio of Sentinel-2A sensor was used in order to extract the iron oxide minerals such as Jarosite, Limonite, Goethite and Hematite according to Van deer Meer and et al. (2016) [16]. Due to spectral properties of Chlorite and Kaolinite, Spectral Angle Mapper (SAM) methods was used to detect the Propylitic and Argillic alterations in ASTER imagery [7]. Determination of Phyllic alteration also Performed using RBD relationships which are mentioned by Maghsoudi and Fathianpour (2016) [7]. Finally, the validity of obtained results were evaluated by comparing them with direct observations and the results of Mars and Rowan (2006) [15]. Due to low importance of Propylitic alterations and wide spreading this alteration was not included in later process. Other alterations together with the Gossan zone converted to fuzzy state by linear method. Results of Phyllic, Argillic alterations and Gossan zone are shown in figure 5, 6 and 7.

D. Geochemical Layer

In order to make the geochemical layer, 2208 samples taken from stream bottom were used. At first data were check for outliers by multivariate T2 and MD2 methods and were discarded from data set wherever exist [17]. Censored data with the half sensitivity were replaced. Digital elevation map (accuracy= 10m) were used to determine streams and basin catchments in each sample [18]. Background effect was removed from the data using weighted mean method ($Y_i$). Ln transformation was used to normalize the residual values [18]. Geochemical layer value was calculated using the following equation (1):

$$SBC_{Cu}=100*A_i*Y_i$$

(1)

Where $A_i$ is the area of basin catchment [18]. Figure 8 show geochemical layer using sample catchment method.

E. Airborne geophysics

In this study geophysical later was obtained by Thorium (Th) and Potassium (K) radiometry assessment, magnetic survey and gravity. Radiometric data were used to determine anomalies related to Potassic alterations. De Quadros et al. (2003), proposed to use KD factor to recognize hydrothermal alterations [19]. Complementary method to determine K anomalies related to hydrothermal alterations (Fig. 9). After drawing the Thorium and Potassium anomalies, KD ratio was calculated and draw (Fig. 10). Due to direct relation of Potassium counting with the mineralization this method was together with KD method were used as radiometric layer.

After calculating of residual values from magnetic data, regional trending was removed from the data. Reduce to Pole (RTP) filter was used to transfer magnetic anomalies on the source of creating it (Fig. 11). Results of this stage was used to draw Analytic Signal (AS) (Fig. 12). Combination of RTP and AS was considered as the magnetic survey layer.

Gravity data used for recognize Intrusive [20]. After calculating the Bouger anomalies, regional trending was removed from the data (Fig. 13). In order to prepare data for final evaluation in paired comparison matrices.
All geophysical layer results were converted to fuzzy by using linear method.

4. INTEGRATION ALGORITHM

Before integrating the criteria, data were summarized considering uniform nature of some sub-criteria such as Potassium and KD factor, AS and RTP and Faults layers. The algorithm is shown in figure 14.

5. ANALYTIC HIERARCHY PROCESS

Tomas El Saaty (1980), has described the AHP method in which each two criterion and also two sub-criterion are comparing with each other in order to obtain weighs [21]. Paired comparisons were performed according to the experts. Table 2 shows the weight of each layer. It should be mentioned that well notes can increase the precision of the prepared map.

Figure 15 show the AHP integration result. As figure 15 show the Cu favorable areas are well agreement with Known deposits and mines such as Sar Cheshmeh, Meiduk and Darreh Zar.

1. CONCLUSIONS

The resulting map in this study shows that application of new processing methods for data layer analysis such as sample basin catchment can be helpful in determining high potential areas. Using subsidiary layers and also radiometric data may also be beneficial in recognizing favorable areas such as vein type mineralization. Therefore, it can be concluded that AHP is a suitable method in determining mineralization area.

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Figure 2 Geological fuzzy layer based on Cu importance weights.

Figure 3 Fuzzy layer of fault multiple buffer.

Figure 4 Fuzzy layer of fault density.
Figure 5 Fuzzy layer of Phyllic alteration.

Figure 6 Fuzzy layer of Argillic alteration.

Figure 7 Fuzzy layer of Iron oxide areas.

Figure 8 Fuzzy Cu concentration in stream sediments.

Figure 9 Fuzzy Potassium counting.

Figure 10 Fuzzy KD Factor of study area.
Figure 9.1 Inverse Fuzzy RTP

Figure 10.2 Fuzzy Analytic Signal of study area.

Figure 11.3 Fuzzy Gravity map of study area.

Figure 14. Integration algorithm.

Figure 15. Cu potential map.

REFERENCES


