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Prediction of Hidden Ore Bodies by New Integrated Computational Model in Marginal Lut region in East of Iran

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ABSTRACT

In southern Deh-Salm porphyry Cu (Mo)-Au area, deeply weathered mineralization is covered by 50-100 m of alluvium. Lithogeochemical surveys were conducted on the surface soil samples collected from grids over mineralized and non-mineralized areas. The identification of hidden ore bodies, derived from Zone Dispersed Mineralization (ZDM), requires the appropriate integration of computational model based on geochemical, geological and remotely sensed data. Weights of evidence (WofE) model and metallometry (statistical) model provided no interpretable patterns in the data. The results of hybrid BP-ANN model and vertical geochemical zonality may assist in discriminating hidden ore bodies from ZDM. The proposed model is an optimized integration of traditional (zonality) and Neuro-Fuzzy models. Based on current exploration drillings in the area, existence of porphyry copper deposits supports our theoretical findings.

INTRODUCTION

Although southern Deh-Salm area in east of Iran is one of the most important Cu-Au districts in Iran, exploration strategies need to be urgently updated to achieve a more predictive method for discovering hidden ore bodies. In this paper, we present a case study in which new exploration strategies are developed, and successfully used to discover a hidden ore body in eastern Lut region ore field of the Lut district. All previously discovered ore bodies in the Lut ore field are Cu-Mo porphyry mineralization type and located in the places where dilational fault zones cut the contact zone of the Deh-Salm granitoid complex.

METALLOGENETIC SETTING

In the study area (Figure 1), 12 occurrences contain Cu, Mo, Au (belt 2), and 5 occurrences contain Pb-Zn (belt 1). Of these occurrences in the belt-2, 11 are of Oligomiocene age (40-39 ma), and 2 of Mesozoic age (Gazo, 77-75 ma) (Sorkh-Khuh; 165-170 ma) (Tarkian et al., 1984). Moreover, 42 % of the ore mineralization that contain Cu (Mo) are of porphyry type (5 occurrences) and related to shallow intrusions: 1. Gazo, 2. Sorkh-kuh, 3. Maher-Abad, 4. Chah-Shalghami, 5. Deh-Salm. The Cu-Mo porphyry mineralization is located in the Cu metallogenic zone of east Iran (belt 2). The belt 1 and 2 is very near to the Nayband fault. It is believed that any newly discovered ore bodies are related to this fault. (Figure 1)(Ziaii et al., 1998).

PROPOSED APPROACH

In this section, we first present the traditional methods used for identifying geochemical anomalies.

The geochemical dataset of Sungun was used to examine geochemical patterns of blind mineralization from the ZDM. These include data from three different mineralization as defined by Grigorian (Gregorian, 1992) and Sungun I and Sungun II (Blind mineralization), and Astamal (ZDM).

Then we will discuss the proposed approach for quantitatively distinguishing blind anomalies from ZDM in the Lut ore field.

Sampling and analysis

A total of 811 samples have been collected from downstream. We have applied detailed litho geochemical surveys on secondary dispersion aureoles from two discrete landscapes. The minus 150 μm fractions of stream sediments were shown to be the optimum grain size fraction in the mountainous area. Whereas, in the peneplain area the most concentration of elements occurred in the coarse fraction in the range -840 and

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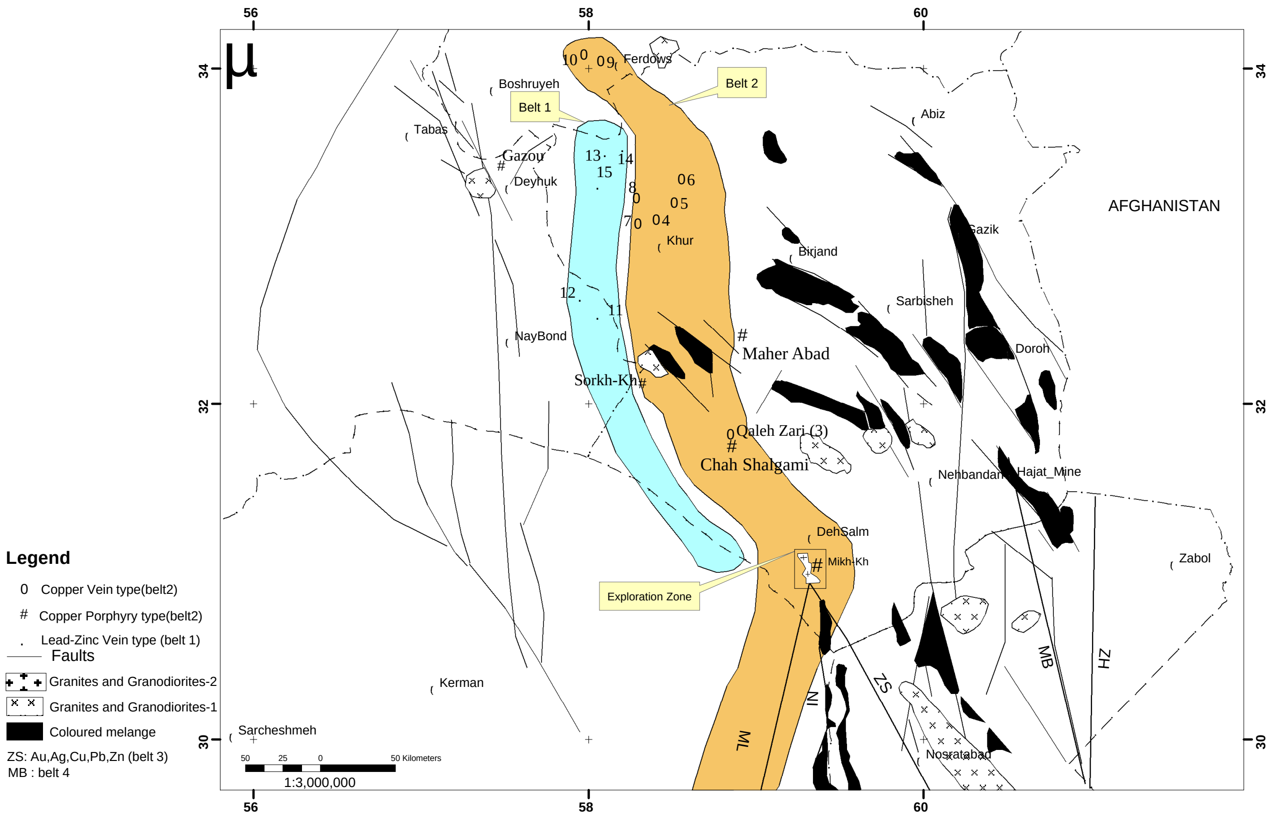

Figure 1: Metallogenic subdivisions of Khorasan province, east of Iran, metallogenic zones and subzones (the predominant mineralization is shown in parentheses), (marginal Lut=ML).

+297 μ m. Samples were analysed for 30 elements using emission spectral analysis by IMGRE RAS, Moscow, Russia.

Conventional exploration model

Integrating the indicator pattern in the traditional exploration particularly lithogeochemical modelling method are fundamental techniques to provide the basis for estimating the potential value of undiscovered deposits. Lithogeochemical methods are suggested by Solovov and Grigorian (Grigorian, 1992; Grigorian and Ziaii, 1997; Ziaii, 1996). The experimental application of this method in Iran was resulted in discoveries in Sungun ore field blind ore bodies of porphyry copper type (Sungun-I) and zone dispersed mineralization (Astamal) in north of Ahar (Figure 2 and Table 1). The above-mentioned unique geochemical methods of exploration for porphyry-copper deposits were also used in Iran for the assessment of ore potential of different areas. Taking into account traditional model, within the framework of this project in southern Deh-salm. Zone No 2 is positive and zone No 1 is negative (Figure 3). Innovative character of the above-mentioned geochemical methods of exploration for Cu-porphyry deposits and high effectiveness of their practical application in Iran are sufficient to come to a definite conclusion that these methods be called zonality or Gregorian's models (Gregorian, 1992).

Metallometery methods have not only been used for geochemical prospecting but also for quantitatively evaluating reserves of metals. We have applied this method to a specific area of southern Deh-salm. Therefore, combining metallometery and geochemical zonality methods can be applied for quantitative recognition of blind anomalies and ZDM "anomaly's patterns using" in mining geochemistry (Table 1).

Weight of evidence (WofE) model

WofE is a data-driven method requiring known deposits and occurrences that are used as training sites in the evaluated area. This research demonstrates that successful development of a WofE model for Cu (Mo) porphyry reconnaissance in a rugged terrain and difficult in access, such as southern Deh-Salm, requires: 1. investigation of the genetic concepts of particular mineral deposits and recognition of the spatial features that control the known mineralization (Figure 1); 2. analysis of cost-effective remotely-sensed data for a fast detection of the alteration signatures of deposit recognition criteria (Figure 3); and 3.application of WofE methodology, within a GIS

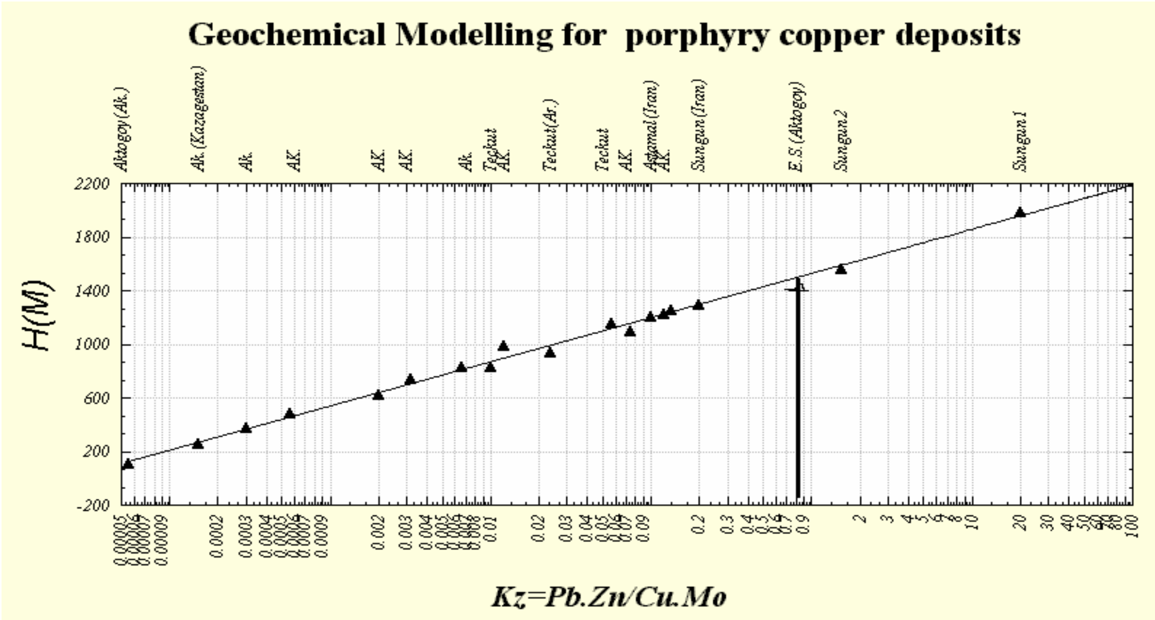

Figure 2: Geochemical model for porphyry copper deposit (Traditional model)

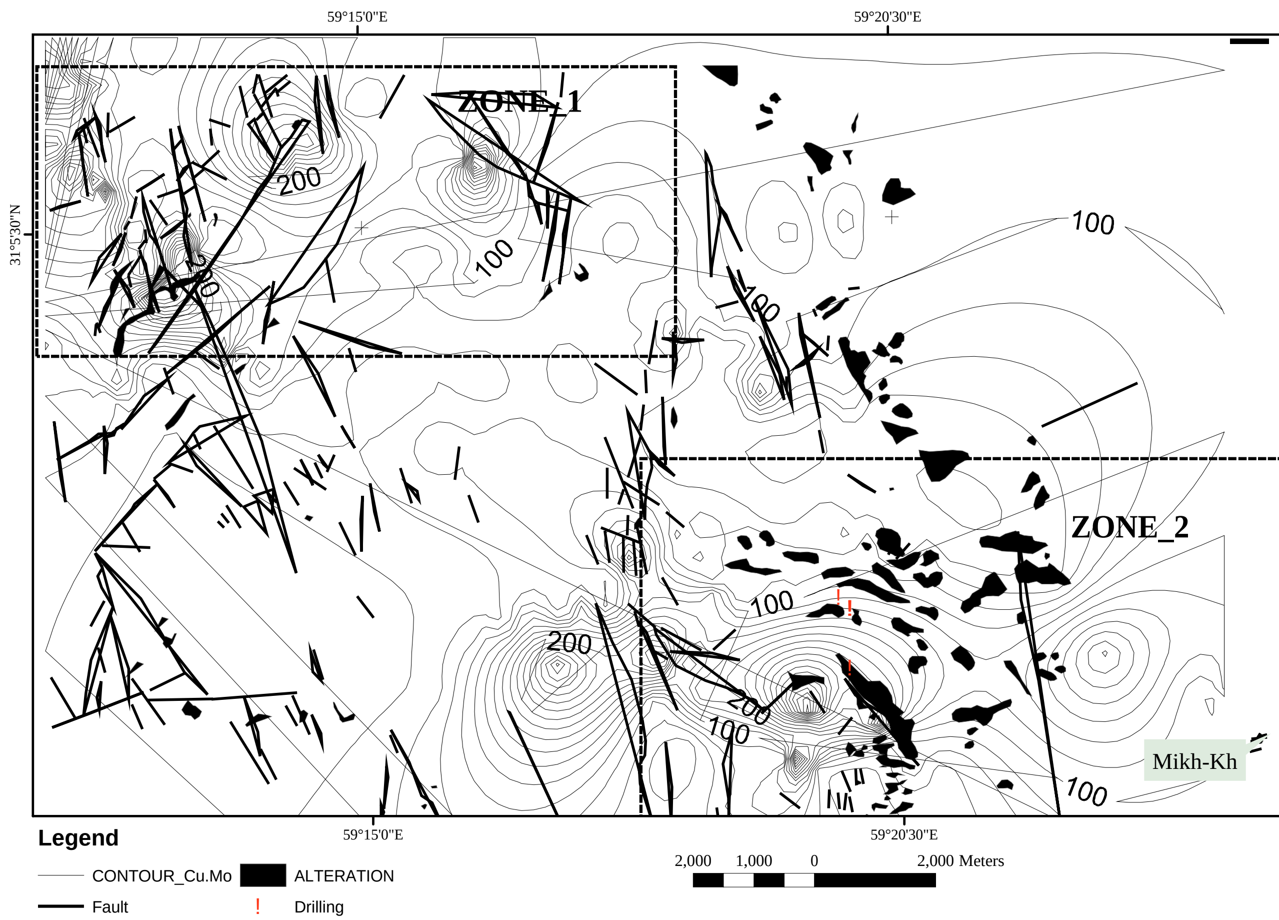

Figure 3: Geochemical Multiplicative zonality for CuxMo in the Deh-Salm area(zone 1 and Zone 2).

Table 1: Parameters of geochemical anomalies of the Sungun-I and Astamal(Geochemical model) and Deh-Salm(exploration zone).

	GEOCHEMICAL PARAMETER	SUNGUN-I (BM)	ASTAMAL **(ZDM)**	**Deh-Salm (Zone No 2)**
Cu	**C_f (ppm)**	36	39	36
	C_a (ppm)	42	71m	46
	ε	1.1	1.3	1.28
	P(m^2 %)	15271	2584.4	10400
	H (m)	1000	-	830
	Q(ton)	382000	-	215800
Mo	**C_f (ppm)**	1.48	2.2	2.2
	C_a (ppm)	2.3	4.9	3.5
	ε	1.16	1.3	1.6
	P(m^2 %)	1001.5	266.3	1128
	H (m)	1000	-	1000
	Q(ton)	25000	-	28200
Zn	**C_f (ppm)**	65	64	49
	C_a (ppm)	74	94	78.4
	ε	1.1	1.2	1.62
	P(m^2 %)	7146.6	1891	10600
	H (m)	600	-	600
	Q(ton)	107200	-	159000
PB	**C_f (ppm)**	23.2	19	28
	C_a (ppm)	31	31	37
	ε	1.1	1.2	1.33
	P(m^2 %)	17499.9	166	9200
	H (m)	600	-	600
	Q(ton)	262500	-	138000
K	$\frac{P(Pb).P(Zn)}{P(Cu).P(Mo)}$	**8.2**	**0.21**	**8.3**

framework, to quantify the spatial correlations between the deposit recognition criteria and the known mineral occurrences and to predict prospective areas. The major disadvantage of the WofE model is that it computationally unable us to distinguish ZDM from blind mineralization.

Neuro-Fuzzy model

Development of a Neuro-Fuzzy model is comprised of three steps: learning, validation, and application [7]. In this study, a four-layer Neuro-Fuzzy network, as shown in Figure 4, has been considered in which the nodes of the first layer represent the inputs. The output of this layer determines the activation level at the output memberships. As ordinary neural nets, the neuro-fuzzy one learns from a training data set, Tansing functions and rules, by means of a back-propagation artificial neural network (BP-ANN) algorithm. Tansing is a neural transfer function. Transfer function calculates a layer's output from its net input. This approach was established on the basis of geochemical characteristics and the origin of the various populations in the geochemical data, such as background, blind anomalies and ZDM. The topology of the BP-ANN with FCM was optimized

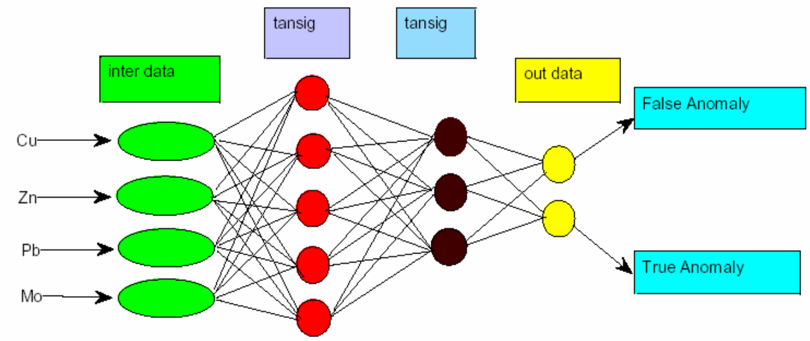

Figure 4: BP-ANN structure for geochemical model with four input parameters.

using the outputs of the BP-ANN and the correct rate. As shown in Figure 4 the output of the BP-ANN is in the form of two distinct types of ZDM anomalies and blind mineralization. The proposed approach is quantitatively recognition between anomalies' No 1 and No 2 patterns using BP-ANN with FCM analysis (Fig. 2, 4). It has been shown that the resultant output has significantly improved, comparing traditional and WofE models.

New hybrid model

To assess the generalization capability of the ANN model, a computational hybrid model was developed. The same dataset, used to construct the ANN model, was used for the statistical and ANN model. With statistical model of recognition, metallometric and WofE have not proven to be efficient indicators for hidden ore bodies in margins of Lut. However, the BP-ANN and zonality have indicated that these indicators are efficient and that areas of south Deh-Salm have potential reserves of mineralization in the anomaly No 2. Thus, the optimum predictive pattern clearly indicates that the hybrid model performs better than the statistical or only ANN model.

CONCLUSIONS

The new integrated computational model, presented here, has demonstrated some capability to detect hidden ore bodies considering geochemical, geological and remote sensing factors. The results obtained from direct assessment of raw data patterns and quantitative modelling procedure such as metallametric and WofE modelling are not practically appropriate, based on our findings.

This technique of data analysis may provide more efficient clustering of geochemical data, recognition of geochemical signatures. Other methods appear less capable and this may be critical to the successful use of combining BP-ANN and zonality methods to detect deeply buried mineralization. Specifically, in arid terrains the proposed hybrid method gives more reliable and informative results. In the peneplain area the most concentration of elements occurred in the coarse fraction in the range -840 and +297 μ m. Based on current exploration drillings in the area, existence of porphyry copper deposits supports our theoretical findings.

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