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ORIGINAL ARTICLE

Evaluation of Mineral Indices Using Fuzzy Logic in Gorazan

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ABSTRACT
Geochemical survey of stream sediment is one of the most effective reconnaissance methods in most important exploration project nowadays. Studies on stream sediment have been done in a part of 1:100000 sheet of Qayen map, in relation to identify more potentially regions. 147 sample of Stream sediment gathered in about 150 Km2 region in this project, and chemical analysis done for 44 elements, then Fuzzy c- means cluster analysis done. By using fuzzy logic as a robust multivariate technique in stream sediment geochemical exploration, data is divided into 9 clusters and residual values for the analyzed elements, calculated.
Keywords: *Geochemistry, Fuzzy Logic, Clustering, Stream sediment, Gorazan*

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INTRODUCTION

Stream sediment geochemistry is widely used in mineral exploration and environmental studies. However, it is difficult to judge from geochemical data due to the high number of analytic elements and dimensions (1). In such cases, in order for better analysis of the normalized findings, multivariate methods sound appropriate such as cluster analysis or factor analysis (2). Cluster analysis is done using different methods among which fuzzy logic is the strongest (3).

GEOGRAPHICAL AND GEOLOGICAL LOCATION OF THE INTENDED AREA

The study area is located in the southeastern of Qayen city, south Khorasan province in an enclosure with 150 square kilometer area and coordinates of 59° 20' to59° 30'Eastern and 33° 30' to 33° 35' Northern. As indicated in figure 1, the only road to get this area is through asphalt road of Qayen-Esfedan. After Mohammad Tower village and Gorazan, one can get to Esfedan.

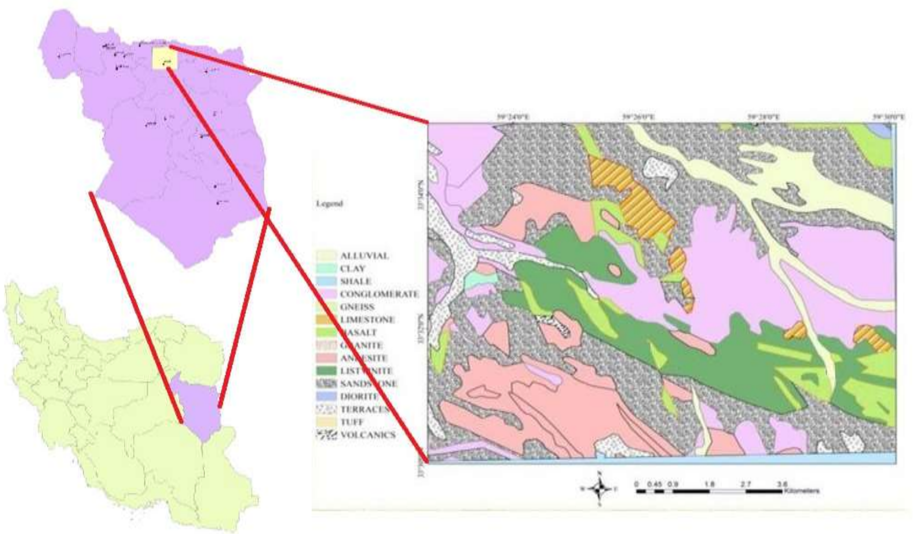

Fig 1: Geological and Location of study area

The study area is located in the end of north western of structural Sistan and northeastern of Lout area. The proximity of this rock complex of shale and sandstone units with Jurassic belonging to Lout block, from one side, and their proximity with ultramafic complex of oceanic lithosphere belonging to Sistan welded zone (4; 5), on the other side, have introduced this rock complex as Lout block in the transition zone of Sistan welded zone. Given this issue, it is expected to observe the characteristics of these two zones in the study area (6). Rock units with outcrops in the area are: peridotite complex, serpentinite cretaceous, sedimentary rocks (flysch sediments) with shale composition sandstone and limestone of Paleocene- Eocene, acidic volcanic rocks to mafic with dacite composition, andesite, tuff, basalt and Oligocene conglomerate bottom and alluvial redoubtable to loosePleo-quaternary. Alteration of this area is listonite (silicate- silicate-carbonate) associated with iron and argillic oxides. The considerable expansion of these alterations relates to listonite-peridotite rocks and flysch sediment (geological map).Given that there are squatty falls flysch-like deposits in the area with ophiolitic basement of oceanic crust (7); the explorations were based on the reserves with ophioliate complexes.

RESULT AND DISCUSSION

Data clustering aims at dividing the observations into homogeneous groups so each group observations bear the most similarity (8) and different groups bear the highest amount of difference. In inflexible clustering, observations (samples) are divided into two categories of member and non-member. However, in fuzzy clustering, the degree of similarity is determined through a continuous function called membership function with the production of values between zero (corresponding to the lack of membership of a sample or variable within the cluster) and one (corresponding to thorough belonging of a sample or variable within a cluster) (9). In this clustering, each object belongs to several clusters with membership degree between zero and one, so the total membership degree of each sample or variable must equal one across all clusters (10).

Suppose there are n samples with m variables for each. We tend to divide these samples into c clusters with a given center. In doing so, fuzzy c-means clustering algorithm analysis is used this way (Hasanipak, 2001).

Each sample's membership degree to each cluster is determined randomly. To do so, all we have to do is to find random values as many as the cluster's number for each sample. These values are in consistency with belonging of the intended sample to each of the clusters. It is essential for the total of each sample's membership to different clusters be equal to one. Therefore, any random value shall be divided into the total degree of membership or the intended sample shall be divided to the whole clusters. Using membership degree and cluster's center coordinates, it is necessary to calculate the new coordination's of clusters' center as following:

$$C_{ij} = \frac{\sum (\mu_{ki})^q X_{ki}}{\sum_{k=1}^{n} (\mu_{ki})^q} \tag{1}$$

Where C_{ij} is the value of j variable, μ_{ki} is the membership degree of K variable to I cluster and X_{ki} is the value for j variable in the K sample. Q is representative of j's degree of fuzzisation in K sample. If this value equals to one, fuzzisation will be at its minimum possible value. In this case, the algorithm of cluster analysis changes into inflexible cluster in which clusters' center is the same as the center of data and each sample's membership degree to this center is either zero or one. If q tends to infinity, all centers of the clusters converge to all data center and membership degree of all samples to centers of clusters would converge to all data and membership degree of all samples to centers of clusters equals $\frac{1}{C}$. To choose the value of q for each certain case, there is no theoretical base. However, the values between 1.5 to 3 can result in models, results of which have more consistency with empirical reality. Thus, in order to determine the most appropriate value of q, it is necessary to do it carefully and the results of the selected values shall be tested in some ways.

Clustering the new centers of the clusters, it is essential to calculate each sample's membership degree to any new cluster's center based on Euclideandistance as following (Hasanipak, 2001):

$$\mu_{ik} = \frac{\left(d_{ik}^2\right)^{-1/(q-1)}}{\sum_{k=1}^{c}\left(d_{ij}^2\right)^{-1/(q-1)}} \qquad (2)$$

Where μ_k is the membership degree of sample K to cluster I, d_{ik} is the distance of sample K to center cluster of I calculated as follows:

$$\left(d_{ik}\right)^2 = \sum_{j=1}^{m}\left[\left(X_{kj} - C_{ij}\right)/S_j\right]^2 \qquad (3)$$

Where X_{kj} is the value of variable j in the sample K, C_{ij} is the value of j variable in the cluster I and S_j is the standard of deviation of j variable.

Calculation of objective function: objective function of j variable in an environement with q degree of fuzzisation is defined as following: $J_q = \sum_{i=1}^{c}\sum_{k=1}^{n}\left(\mu_{ik}\right)^q\left(d_{ik}^2\right)^q$ (4)

Where values of μ_{ik} and d_{ik}^2 are calculated from previous functions.

Repeat the functions from the 2nd step to the 4th to the point that the difference of two consecutive steps of calculation J_q would be less than the precision required. In both inflexible cluster analysis and fuzzy cluster analysis, the right number of the clusters is determined based on empirical observations of H, classification entropy, and F, partition coefficient, are defined as following:

$$H = -\sum_{i=1}^{c}\sum_{k=1}^{n}\frac{\mu_{ik}\log\left(\mu_{ik}\right)}{n} \quad ; \; 0 \le H \le \log(c) \qquad \text{Upper and lower limit (5)}$$

$$F = \sum_{i=1}^{c}\sum_{k=1}^{n}\frac{\mu_{ik}^2}{n} \qquad \frac{1}{c} \le F \le 1 \qquad \text{Upper and lower limit (6)}$$

F value identifies a sort of intra-cluster diffraction proportion to inter cluster one. This value must be close to 1, otherwise the clusters haven't been chosen properly and there would be no balance between intra and inter cluster diffraction. Moreover, for a credible diffraction, cluster analysis is required and H value must be close to zero. These two parameters are mainly for describing the characteristics of clustering model to the data. The parameters' upper and lower limit depends on the number of clusters. If there is no specific way of appropriate selection of the number of clusters, one can resort to the criterion of change range of these parameters.

Given that fuzzy c-means cluster analysis allows one sample to be member of multiple clusters, samples which are influenced by upstream rock could take membership degree in proportion to upstream rock impact. Therefore, this is a fantastic method for Syngenetic parameter removal (10).

The calculated value of the variable at each point is not usually equal to its measured value. It happens for various reasons including the effects of pollution, measurement error, and the existence of epigenetic mineralization in the region. So, residual values are calculated as follows:

$$\sigma_{kj} = X_{kj} - \sum_{i=1}^{c}\mu_{ik}C_{ij} \qquad (7)$$

Where X_{kj} is the measured value and $\sum_{i=1}^{c}\mu_{ik}C_{ij}$ the calculate one:

If all the exploration and conclusion operations are done properly, in a way that (1) there is no pollution resource or error analysis (2) changeable Syngenetic parameter has been correctly neutralized (3). Epigenetic parameter of changeability relevant to potential mineralization we are seeking does not exist. (4) The selection of cluster numbers and other fuzzy analysis parameters are done correctly, then the mean of residual values shall be close to zero.

Here, the number of clusters has been determined considering the variety of rock units and the way they have been distributed in the region. Also, using K- means clustering methods, 9 appropriate clusters have been identified. Performing c-means cluster analysis in Matlab software for 70 items, membership degree of each sample to the clusters and each cluster's center are identified. The matrix relevant to clusters' center is a 42*9 matrix and the matrix for membership of the samples is a 147*9 matrix. Multiplying these two matrices together, there would be a 147*42 matrix showing each element's concentration degree for the sample's area. Then, using equation (7) the data was taken out of cluster mode and residual value was calculated. Ultimately, the map of residual values of every element was done in Surfer 10. Figures 2 and 3 represent residual value map for the elements of Cu and Zn.

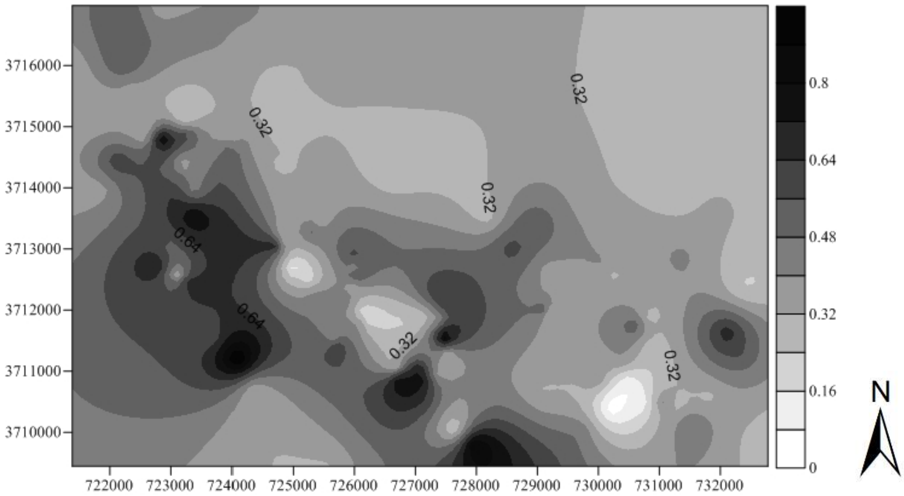

Fig2: residual value map for Cu

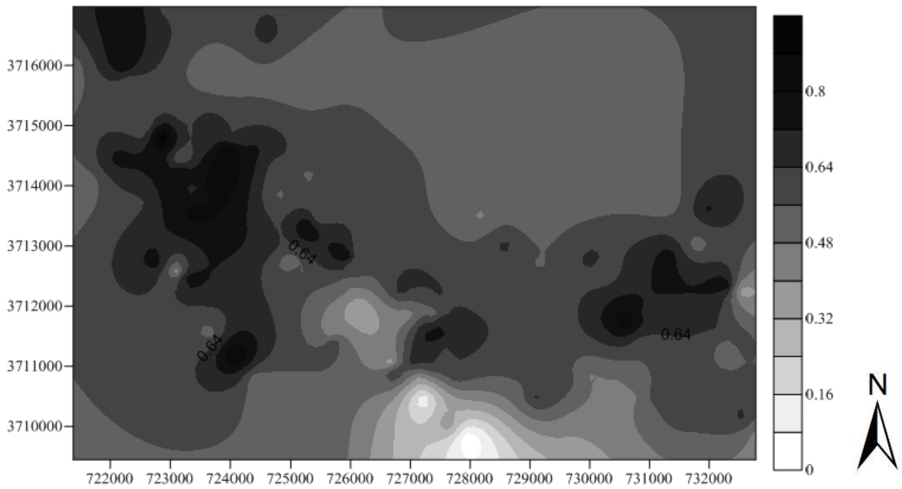

Fig3: residual value map for the Zn

CONCLUSION

Fuzzy logic is a multi-valued logic, one of the most powerful methods of geochemical data clustering. Using fuzzy c-means clustering, fuzzy logic is one of the best methods of neutralizing data Syngenetic effects and subsequently calculating promising mining areas. In the present study, fuzzy logic was used to calculate residual value for 42 elements under study in the intended area. Then they were added to the income plan confirming the efficiency of this method and representing the existence of anomalies of Fe, Cu elements in the south east of the area under study. Corresponding the results with geological map of the area, it can be seen that these anomalies associate with ultrabasic rocks of the region. Thus, it is recommended that the area go under close examination for removing rock samples and detailed explorations.

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