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Quaternary Sediments Clustering for Determining their Permeability

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Abstract: In the cluster analysis, a wide range of methods dividing data into pairs of discrete clusters are considered. In this type of classification, there is a certain boundary among existing clusters so that one sample either belongs to a cluster certainly or not. The present paper analyzes data by using fuzzy clustering method. In so doing, 190 sediment samples were collected from a region located at North East of Birjand City and sent to the laboratory. The samples were analyzed for 51 elements. With regard to the lithology and geology conditions of the region, 4 to 10 clusters were selected experimentally and finally 5 clusters were selected as the optimal cluster number in which there was the minimum negative deposit anomaly. Then center of clusters was calculated. Anomalies in the region can be obtained by subtracting the resulted matrix from matrix of primary data. Also by determining the optimal cluster number with respect to the region lithology conditions and finally calculating anomaly existing in the regions, promising areas for more explorations of Ba and Ni elements were identified which show a proper correlation with geology conditions of the regions and lithology units. Soil permeability is not a function of the impact of these elements and they do not have a significant effect on the soil permeability, and the relative percentage of clay and silt has a descending trend by depth increase.
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Key words: Quaternary sediments, fuzzy clustering, cluster analysis, permeability

Introduction

Although in some extant reports, quaternary have been regarded as a "period" of the earth history, there is nothing named as fourth period of geology based on International Union of Geological Sciences (IUGS) and it is from third period that systemic quaternary is divided into two subsystems namely Pleistocene and Holocene; thus using the term fourth period is inaccurate. Despite high diversity, our knowledge about Iran quaternary geology is very little; while nowadays quaternary geology is one of the basic branches of geological sciences to answer the existing questions regarding urban and industrial regions, natural events, creation of large construct, and Iran seismotectonics (Mohamadzadeh, 2011).

In the geology of Iran, rocks and sediments after the conglomerate formations of Pliocene – Pleistocene (Hezardarreh, Bakhtiari) have been regarded as old as quaternary that cover older rocks (except for southern coast of Caspian) and among them, alluvial-foothill, wind, and desert deposits have the most shares. Hence, it is believed that after Alpine tectonic event, Iran land was removed from water and its current morphology was shaped. Among its results, commencement of erosion cycles can be mentioned which has been imposed on Iran ground shell (Salehi, 1973). It is worth mentioning that in some structural – sedimentary areas of Iran, like Kappeh Dagh heights, Mountains of East of Iran, and even vast areas of Alborz and Center of Iran, the commencement of erosion phenomena is further elder than quaternary in which Pyrenean tectonic event has played a more fundamental role. Besides destructive rows accumulated in continental, lake and marine environments, magmatic prowls of quaternary period has created igneous rocks of the present time. With respect to such factors as deposition environment, origin, weathering and erosion processes, Iran quaternary rocks can be regarded among below types (Darvishzadeh, 1991).

Among quaternary deposits, alluvial deposits have the most share. These are erosion materials expanded from heights skirt to the plains lowlands, and away from the mountains, coarse grains are reduced. So they are called by different names including Dasht (i.e. plain), Hamun, Jolgeh, Kaffeh, Tagu, Dagh, and Shakh (Rasa, 2008). Alluvial deposits of Iran, despite great expansion, have been rarely studied. Quaternary alluvial deposits are fluvial- flood deposits accumulated after Pliocene – Pleistocene erosion cycles (Hezar Darreh formation).

Therefore, they have identical features in terms of origin; yet alternation of productive cycles and years with the low rainfall and even tectonic events influence alluvium. So particularly due to Sedimentary discontinuities, quaternary alluvium is divided into several groups (Asghari, 1996).

Permeability coefficient represents degree of water easy movement in the soil. This coefficient has the same flow rate unit. Permeability coefficient has been often used by geotechnical engineers. Geologists call it hydraulic conductivity coefficient. Permeability unit is stated based on centimeter per second, meter per second, or meter per day. Soil permeability coefficient is dependent upon multiple factors such as fluid viscosity, size and distribution of soil pores, aggregation curve, porosity ratio, grains surface roughness, and soil saturation. In the clayed soils, the ionic concentration and thickness of the aqueous layer surrounding the clay particles in the soil have an important impact on the permeability coefficient. Permeability coefficient varies highly for different soils. Permeability coefficient of unsaturated soils is smaller and increases by saturation increase. For soil permeability, important parameters in construction of water and surface constructs including road, irrigation channel, and residential buildings and some underground structures like water and sewer pipes and underground tunnels are studied (Memarian, 2008).

The region studied in this paper is a small part of 1:100.000 geological map in the North East of Iran and also there is a mountain with height of 2831 meters located at a distance of 105 km of North East of Birjand city. The area is very mountainous and rugged. Mountains of this area are extended along West North – East South and have low cretaceous limestone as the largest lithologic unit of the region. Besides mass limestone, lithologic units are dolomite and acidic tuff. Base stones at the four corners of Ahangaran are metamorphic, metagabro, and amphibolite units outcropped in the Northern part of the region. In the great mass of milestone, there are small layers and an alternation of metamorphic base stones. Ophiolitic rocks and flysch sediments are influenced by regional metamorphism and are seen irregularly in the region. Amphibolite glaucophane schist with garnet in these rocks indicates high pressure and low temperature in the region metamorphism phenomenon (Rahvar Construction Research, 2009).

Research Background

- Kuhian Afzal, F. (1996) concluded in his research carried out in Estahban, Fars Province, that soil permeability has been reduced four times during one season due to floodwater distribution.
- Shariati et al. (2000) concluded in their research regarding the impact of floodwater distribution on surface soil permeability in Ghusheh station of Damghan that 5 steps of preventing the flood reduced soil permeability 9.6 times compared to the control.
- Kamali (1997) studied the effect of deposited alluviums with different origins on soil permeability in Khorasan Province. The results of this study indicate that soil permeability has been reduced from 5.7 to 2.27 cm in average.
- Tavasoli and colleagues (2000) have regarded firstly increase in silt and clay soil and secondly increase in SAR as among reasons of soil permeability reduction in Kabudar Ahang in Tehran.
- Arab Khadari (1996) concluded in his studies carried out in Khorasan Province that soil physical features particularly aggregation is more effective on soil permeability than chemical properties.
- In Hubbell and Gardner research (1944), chemical properties changes have been discussed too.

Methodology

In this paper, 190 sediment samples were collected and sent to the laboratory for analysis. The collected samples were analyzed for 51 elements. Au,Ag,Al,As,B,Ba,Be,Bi,Ca,Cd,Ce,Co,Cr,Cs,Cu,Fe, Ga,Ge,Hf,Hg,In,K,La,Li,Mg,Mn,Mo,Na,Nb,Ni,P,Pb, Rb,Re,S,Sb,Sc,Se,Sn,Sr,Ta,Te,Th,Ti,Tl,U,V,W,Y,Zn, Zr.

Among raw data received from laboratory, Ta, Re, and B were removed from the set of elements as they were not within the range of sensitivity of laboratory analyzers. Moreover, Te, Se, S, Hg, and Au had high quantities of censored data and censored values in Te, Se, S, Hg elements were replaced by simple method and in Au element were replaced by old maximum likelihood method. Then off-row samples for each element that had these values were detected by Dorffel method and were replaced. Among the elements existing in the analyses, Ag, Au, Cs, Ge, Hg, Nb, Rb, S, Sc, Sn, T1, and W had slight off-row values that were replaced by Dorffel method. despite different methods for presenting information and also with regard to the objective of presenting information that is offering a full view of geology and parameter K (permeability coefficient) for an accurate understanding of the path and applicability in tunnel construction, the used information has been presented in the form of geology engineering section containing permeability coefficient and the related zoning. Following reduction of the number of elements, the elements that have little changes and created problem in the analysis were removed based on below formula.

$$CV = \frac{S_i}{X_m} \quad (1)$$

Where, S_i denotes standard deviation from i-th element and X_m is the mean of the same element. In fact, variation coefficient is a criterion applied for measuring relative variability in which both mean and standard deviation have been considered (Hosni Pak, 2008). Having calculated variation coefficient and removed the elements with variation coefficient less than 20 percent, 48 elements were listed in the Table 1.

Table 1- The elements variation coefficient

Element	Variation Coefficient (%)	Element	Variation Coefficient (%)	Element	Variation Coefficient (%)
Ag	46.18	Ge	29.82	S	52.58
Al	20.69	Hf	59.73	Sb	34.65
As	68.85	Hg	53.43	Sc	31.96
Au	47.20	In	16.70	Se	31.56
Ba	27.71	K	20.60	Sn	17.48
Be	17.82	La	10.26	Sr	36.73
Bi	31.15	Li	30.46	Te	42.29
Ca	45.57	Mg	84.99	Th	17.71
Cd	18.36	Mn	15.74	Ti	41.33
Ce	9.94	Mo	34.53	Tl	28.34
Co	38.86	Na	45.37	U	14.50
Cr	91.60	Nb	68.43	V	36.62
Cs	18.39	Ni	151.61	W	61.47
Cu	21.49	P	16.69	Y	12.51
Fe	14.77	Pb	29.40	Zn	14.31
Ga	21.24	Rb	19.91	Zr	62.67

With regard to the table, the elements U, Th, Sn, Rb, P, Mn, La, In, Fe, Cs, Ce, Cd, Be, Y, Zn were removed from data and analyses were continued with the rest 33 elements.

Fuzzy C-Means Clustering

In the cluster analysis, a wide range of methods dividing data into pairs of discrete clusters are considered. In this type of classification, there is a certain boundary among existing clusters so that one sample either belongs to a cluster certainly or not. In the other words, a variable must belong to only one cluster. These kinds of methods in which a sample or a variable must be attributed to a cluster are called inflexible clustering methods (Hosni Pak et al., 2011).

Fuzzy clustering method is a method shaped based on fuzzy logic in which membership function and dependency of one sample (variable) to several clusters are raised (Mohammadzadeh et al., 2011). In this model, full dependency of one sample or variable to a cluster is not considered because existence or lack of such a dependency is not the criterion; rather similarity of each sample or variable to the given cluster is taken into account. The rate of similarity is determined by a continuous function named as membership function by generating values between zero to one (Hosni Pak, et al., 2011). The fact that total membership degree of each sample in the clusters must equal one is among the most important hypotheses of this method.

$$\sum_i^c \mu_i = 1 \quad (2)$$

Where, c denotes number of clusters, and μ_i is the sample membership degree in i-th cluster (Mohamadzadeh, et al., 2009). Cluster analysis method has four steps as per below:

First stage: given n samples collected and m elements measured for them, samples are divided into c clusters with certain center. So, membership degree of each sample to each cluster is determined randomly. By using membership degree and coordinates of clusters center, it is necessary to calculate new coordinates of the clusters center by relation (3).

$$C_{ij} = \frac{\sum(\mu_{Ki})^q X_{kj}}{\sum_{k=1}^{n}(\mu_{Ki})^q} \quad (3)$$

Where C_{ij} denotes j-th variable value from i-th cluster center, μ_{Ki}, membership degree of k-th sample to i-th cluster, and X_{kj}, j-th variable value in the k-th sample; q represents phasing intensity j-th variable in k-th sample. As regards q, there is no specified theory; yet a value between 1.3 and 3 is considered which is more close to 1.3 – 1.5 in geochemical explorations.

Second stage: after calculation of new clusters centers, it is required to calculate membership degree of each sample to each new cluster center based on Euclidean distance by relation (4).

$$\mu_{ik} = \frac{(d^2 ik)^{-1/(q-1)}}{\sum_{k=1}^{c}(d^2 ij)^{-1/(q-1)}} \quad (4)$$

Where μ_k denotes membership degree of k-th sample to the i-th cluster, and d_{ik} is distance of k-th sample from the i-th cluster center which is calculated by relation (5).

$$(d_{iK})^2 = \sum_{j=1}^{m}\left[\left(X_{kj} - C_{ij}\right)/S_j\right]^2 \quad (5)$$

Where X_{kj} denotes j-th variable value in the k-th sample, C_{ij}, value of j-th variable of i-th cluster, and S_j, standard deviation of j-th variable.

Third stage: by using relation (6), objective function of J variable in an environment that has phasing intensity q is calculated.

$$J_q = \sum_{i=1}^{c}\sum_{k=1}^{n}(\mu_{ik})^q(d^2 iK)^q \quad (6)$$

Fourth stage: replication of calculations from first to third stages to the extent that the difference between two consecutive stages of J_q alculation is less than the required accuracy. Two parameters namely H and F that are called respectively classification entropy and separation coefficient are defined as below.

$$H = -\sum_{i=1}^{c}\sum_{k=1}^{n}\frac{\mu_{ik}\log(\mu_{ik})}{n} \qquad 0 \le H \le \log(c) \qquad \text{upper and lower limits}$$
(7)

$$F = \sum_{i=1}^{c}\sum_{k=1}^{n}\frac{\mu^2{}_{ik}}{n} \qquad \frac{1}{c} \le F \le 1 \qquad \text{upper and lower limits}$$
(8)

The value of separation coefficient represents somehow the ratio of intra-cluster diffraction to inter-cluster diffraction and this value must be close to one. Also for validity of cluster analysis, H value must get close to zero (Hosni Pak, et al., 2011). Through below conditions, clustering method is getting close to an optimal limit.

1) Number of clusters is determined by considering conditions of sampling environment.
2) Clusters are selected in a way that there are less negative deposit anomalies in general.

With regard to the region lithology and geology conditions, 4 to 10 clusters are selected experimentally and finally 5 clusters are selected as the optimal cluster number in which there was the minimum negative deposit anomaly. Then clusters center was calculated by relation (3) that results in generating a matrix with 5 rows and 33 columns. The results are presented in table 2 (it must be noted that to facilitate the subsequent calculations, transpose value of this matrix is presented in table 2). Then matrix of membership function values was calculated by relation (4) that results in a matrix with 190 rows and 5 columns.

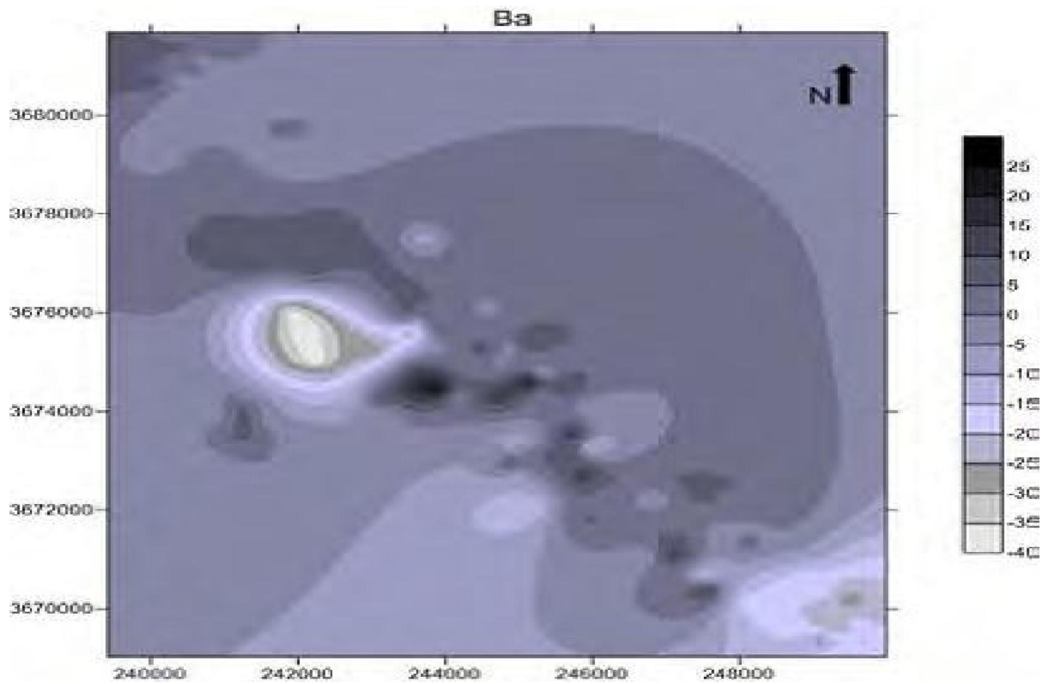
Conclusions

By considering 1.5 for phasing parameter (q), the best result was obtained. In this paper, by multiplying matrices of clusters center [5.33] and also values of membership function [190.5], a matrix with dimensions [190.33] will be obtained which represents the amount of elements existing in the research.

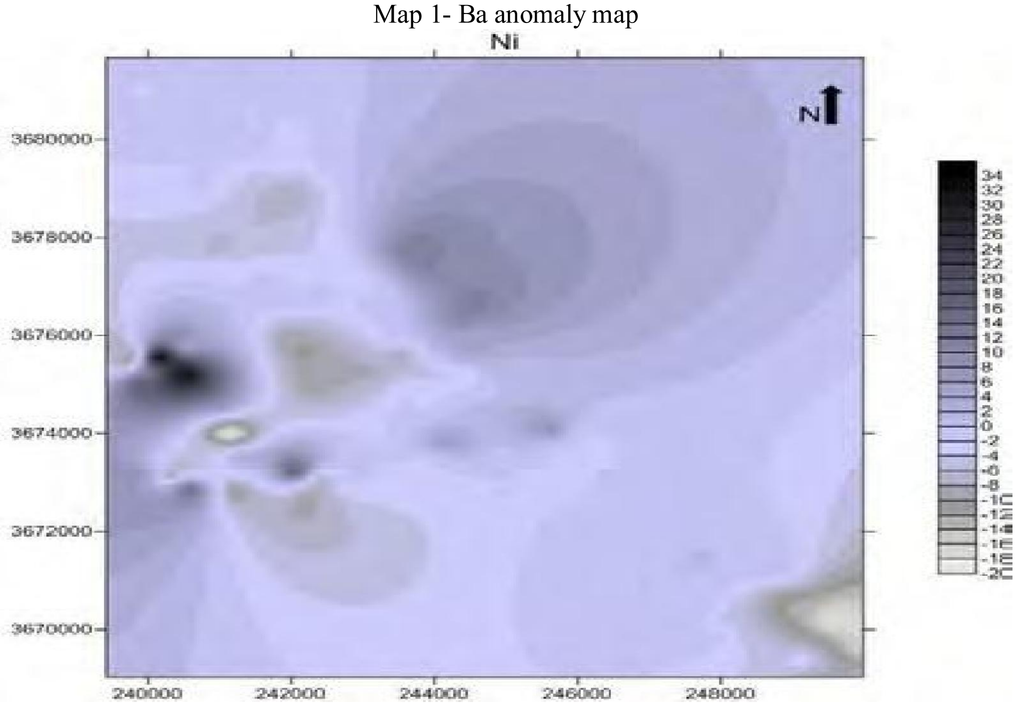
Table 2- Elements clusters centers

Element	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Ag	0.025	0.017	0.036	0.061	**0.029**
Al	1.93	1.42	1.46	1.10	**1.20**
As	31.68	6.78	9.51	14.85	**9.56**
Au	0.0011	0.0008	0.0012	0.0009	**0.0013**
Ba	94.9	50.7	93.7	131.5	**75.3**
Bi	0.07	0.09	0.12	0.16	**0.13**
Ca	7.4	9.5	3.6	7.7	**7**
Co	14.7	29.1	11.9	14.2	**15.3**
Cr	39.7	143.7	20.5	29.6	**30.3**
Cu	43.9	27.5	33.3	30.4	**28.7**
Ga	5.9	4	4.7	3.5	**3.7**
Ge	0.091	0.077	0.075	0.076	**0.069**
Hf	0.40	0.17	0.13	0.13	**0.12**
Hg	0.022	0.017	0.018	0.046	**0.036**
K	0.15	0.17	0.21	0.18	**0.21**
Li	11.03	18.21	8.54	9.72	**13.21**
Mg	1.48	5.68	1.04	1.21	**1.40**
Mo	0.54	0.43	0.95	1.06	**0.55**
Na	0.133	0.040	0.087	0.051	**0.049**
Nb	0.20	0.09	0.23	0.25	**0.31**
Ni	32	429.7	30.05	40.81	**44.24**
Pb	6.4	6.7	7.3	13	**10.4**
S	0.012	0.020	0.013	0.034	**0.021**
Sb	0.47	0.16	0.37	0.52	**0.34**
Sc	10.60	6.98	6.93	6.35	**6.14**
Se	0.63	0.45	0.41	0.39	**0.50**
Sr	229.7	180.7	100.2	126.3	**109.6**
Te	0.023	0.039	0.032	0.033	**0.026**
Ti	0.11	0.06	0.05	0.04	**0.03**
Tl	0.03	0.04	0.05	0.06	**0.06**
V	104.6	48.3	53.4	62.4	**46.5**
W	0.10	0.11	0.14	0.09	**0.21**
Zr	16.7	6.4	5.4	5.7	**4.8**

By subtracting the obtained matrix from primary data matrix, anomalies exiting in the region can be obtained. Maps 1 and map 2 show anomaly of Ba and Ni in the region.



Map 1- Ba anomaly map



Ma 2- Ni anomaly map

As shown in Ni anomaly map, anomaly of this element is in the west part of the region which has a proper adaptation with ultramafics of the region. Also Ba anomaly in the center of the region indicates existence of masses of barite in the region.

Discussions and conclusions

By implementing cluster analysis method on data obtained from Geochemistry sampling and also determining the optimal cluster number with regard to the lithology conditions of the region and finally calculating anomaly existing in the region, promising regions for exploring more Ba and Ni elements in the region were identified which shows a proper correlation with the region geology conditions and lithology units. The results reveal that although soil organic matter has been reduced in depth, the relative portion of soil components below 2 mm soil and relative portion of clay compared to other components are not remarkable. Thus soil permeability is not a function of the effect of these elements and they do not have a significant impact on soil permeability and relative percentage of clay and silt has a descending trend by depth increase. Sand percentage has been increased by soil depth increase. With respect to the remarkable reduction of permeability due to natural flood which has increased clay and silt percentage and also has changed texture in the soil surface, to keep the average percentage of total silt + clay fixed in 0 to 100 cm depth, floods containing low clay and silt are used and to achieve such floods, watershed operations are recommended in the upstream basin.

Suggestions

For excavation and implementation of a part of construct during executive operations and also during utilization, below matters must be considered (Asghari, et al., 1996).

a. Hazards during construction
For excavation, it is necessary to create conditions for excavation in a dry environment which increase operation efficiency and speed. Concentration of groundwater reduces stability of pit wall and this must be taken into account in designing guardian construct.

b. Hazards during utilization
With regard to the existence of water in a part of the buried construct, reduction of pressure on construct action or estimation of pressure exerted on the construct and supplying elements resistant against water pressure are necessary. Also the effect of pressure on the action must be investigated with regard to the station construction method. Lateral load of water in static and seismic loading must be considered in design. Besides important matters of design, preventing Corrosion of buried structures and preventing penetration of underground waters into the construct must be taken into consideration during executive operations.
Using common methods such as subterraneous drainage and underground water surface control through gravity, pumping, and insulation curtain methods will be beneficial. In the pumping method, deep wells or point wells are used depending upon underground water surface and analyses, water drop level, and soil type. Well with certain distances are delved in the region and wells are connected through a network of collector pipes and underground water is pumped to certain points. Another method is subterraneous drainage by insulation curtain method. In this method, insulation curtain or wall with a width of 50 or 60 cm and certain depth extends to an impenetrable layer. Excavation location is filled with a mixture of cement and bentonite. Hydraulic conductivity coefficient of this wall is very low and it creates in practice an impenetrable curtain against underground waters (Asghari, et al., 1996).

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