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REVIEW OF GEOCHEMICAL, ISOTOPIC AND FLUID INCLUSIONS STUDIES IN RAMAND REGION (QAZVIN PROVINCE)

ESTUDOS DA ANÁLISE GEOQUÍMICA, ISOTÓPICA E DE FLUIDOS NA REGIÃO DE RAMAND (PROVÍNCIA DE QAZVIN)

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ABSTRACT

Ramand copper deposit is an example of vein-bearing deposits with volcanic host located in the Urumieh-Dokhtar zone. The deposit host is an Eocene volcanic sequence and the main host's rock is the rhyolite mineral. The main minerals are chalcopyrite, pyrite, covellite and natural gold; and the tailings minerals include quartz, calcite and sericite. The average grade of gold in silica veins is 133.5 ppb, the average grade of copper is about 3.5% and the average grade of molybdenum is 135 ppm. Quartz-sulfide hydrothermal veins contain biphasic fluid-rich fluid inclusions and monophasic fluid-rich fluid inclusions. The homogenization temperature ranged from 73 to 307 ° C with an average of 141 ° C and in all samples, homogenization was carried out through the liquid phase and salinity variations ranged from 1.75 to 4.74 with an average of 3.65 wt% NaCl equivalent. Quartz and calcite oxygen isotope values range between 4.4 to 9.4 per thousand. Isotopic data indicate that the ore-generating fluids in the Ramand ore deposit have relatively low salinity and atmospheric-magmatic origin. According to this study, Ramand's mineralization range is the result of hydrothermal activity in the area where mineralization with simple mineralogical characteristics has occurred in siliceous veins and sub-veins.

Keywords: Lithology; Geochemical findings; Fluid inclusions; Isotopic; Ramand region.

RESUMO

O depósito de cobre de Ramand é um exemplo de depósitos contendo veias de origem vulcânica localizado na zona de Urumieh-Dokhtar. O depósito é uma sequência de origem vulcânica do Eoceno e a rocha principal encontrada na área é o riolito. Os principais minerais são calcopirita, pirita, covellite e ouro natural; e os minerais de rejeitos incluem quartzo, calcita e sericita. O teor médio de ouro nas veias de sílica é de 133,5 ppb, o teor médio de cobre é de cerca de 3,5% e o teor médio de

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molibdênio é de 135 ppm. As veias hidrotermais de sulfeto de quartzo contêm inclusões fluidas ricas em líquidos bifásicos e inclusões fluidas ricas em líquidos monofásicos. A temperatura de homogeneização variou de 73 a 307°C com uma média de 141°C e em todas as amostras, a homogeneização foi realizada na fase líquida e as variações de salinidade variaram de 1,75 a 4,74 com uma média de 3,65% em peso de NaCl equivalente.
Palavras-chave: Litologia; Achados geoquímicos; Inclusões fluidas isotópicas; Região de Ramand.

INTRODUCTION

Ramand region in Qazvin province is one of the areas in the country with the highest potential of containing numerous mineral reserves and indications. Very limited studies have been carried out in the region which include remote sensing and surface surveys, while further studies and application of specialized processing methods and software are likely to lead to the exploration of more valuable reserves in the region. An example of this likelihood is Hassanabad Fault which is the most important structural phenomenon in the region, extending from the east to the west of the region and on its north side, there is Mount Ramand with relatively rough and elevated topography. This fault was influenced by Paleogenic tectonic movements and was re-activated in the Quaternary. New branching of Hassanabad Fault with mostly northwest-southeast direction have been found in the study area, most of which have been instrumental in the formation of magmatic differentiation mechanisms and the penetration of hydrothermal fluids to the ground surface (Massoudi, 1989). Lithological units in the study area include Eocene volcanic units, andesitic lava, and Quaternary deposits. In order to better and more precisely identify the rock units in the area, sampling of existing units was done and thin sections were prepared and studied.

RESEARCH BACKGROUND

Ezzati *et al.* (2014), used remote sensing data to reveal alteration zones in the epithermal reserves of Ramand region in Qazvin province. By processing satellite images, they found that a vast alteration could be detected and tracked in the area. To this end, Ezzati *et al.* (2014) used techniques like feature-based selection of principal components analysis

(Crosta), Least Squares Fitting method (Ls-Fit) and Spectral Angle Mapper (SAM) to identify and discriminate alteration zones.

Ezzati *et al.* (2014), in addition to extensive remote sensing studies in the area, also performed petrographic and microscopic studies on the deposits to obtain mineralogical characteristics of the samples and mineral potentials in the area. They found in the studies that by the order of abundance, the minerals of illite, montmorillonite clay, kaolinite, quartz, and albite indicating a clay zone, respectively; and quartz, orthoclase and albite, were present in indicating a siliceous zone, respectively.

Ghorbani (2005) investigated the role of magmatic differentiation and partial crustal melting in the development of acidic volcanic rocks in southern Danesfehan (Ramand region) and concluded that geological and petrographic features of acidic volcanic rocks in southern Danesfehan suggest that these rocks are a product of different rock formation processes.

Ahmadi *et al.* (2010), studied the relationship between Cenozoic systems' strata and alteration units in Ramand region based on remote sensing data (ETM sensing images) and geophysical evidence (airborne magnetics).

MATERIALS AND METHODS

For petrographic studies, from various rock units, the host rock and intrusive masses; 7 thin sections, 7 XRF specimens and 11 specimens for XRD analysis were prepared to determine mineralogy. By studying these sections, systematic classification and description of the rocks, texture and structure, structural status, and physical and appearance characteristics of the rocks were investigated. According to XRD studies, the main sulfide minerals are covellite, chalcopyrite, pyrite, and quartz tailing minerals. Geochemical studies have been carried out according to the analyzes carried out at the Iran Minerals Processing Research Center. In total, 11 samples were submitted to Iran Minerals Processing Research Center for ICP-Mass analysis (solid sample under normal conditions), 7 of which were in common with petrographic section studies and the results of these analyzes were used in regional petrological studies. It should be noted that from the samples belonging to the mineralized areas of Ramand, 3 samples were selected that after being sent to specialized laboratories, the oxygen isotope behavior in carbonate (calcite) and quartz minerals was carefully evaluated.

GEOLOGY OF THE REGION

Ramand study area is located at the 1:250,000 Saveh and 1:100,000 Khiarj rectangle. Ramand region is part of central Iran and is tectonically part of the Urumieh-Dokhtar zone. In general, the northern part consists of alluvial plains and southern part has heights and rough terrain. The main rock outcrop in the Ramand region are often tuff with varying intensities of clay alteration. The presence of clay minerals indicates clay alteration and is important for mineralization (Ezzati *et al.*, 2014) (Figure 1).

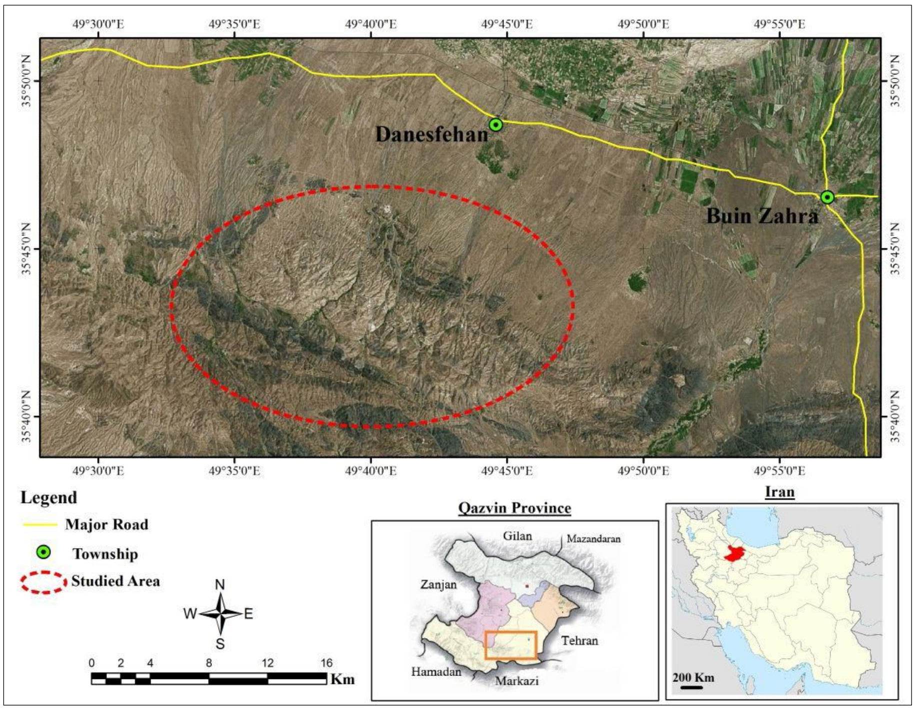

Figure 1. Geographical location of Ramand region at southwest of Buin Zahra and south of Qazvin.
Source: Authors (2020).

According to XRD results, acidic and intermediate volcanic rocks in the Ramand region have been affected by hydrothermal alteration and sometimes were altered by

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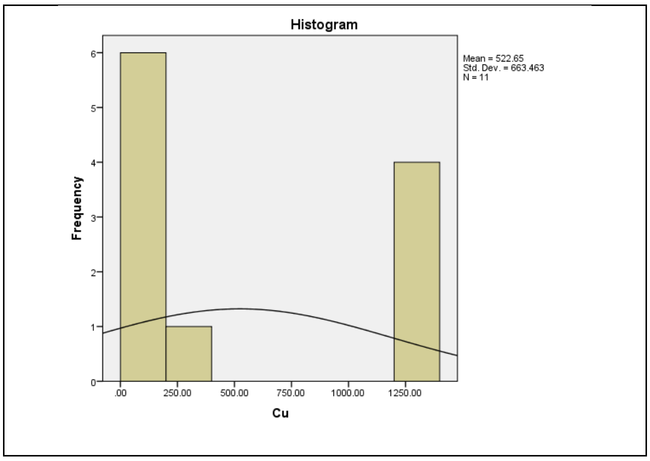
ascending hydrothermal fluids. From an economic-geological point of view, the magmatic-hydrothermal mineralization event is the most important cause of mineral vein formation in the alteration units of this area (Ezzati *et al.*, 2014). The geochemical and petrographic features of acidic volcanic rocks in the area indicate that they originated from different petrogenesis processes (Baratian *et al.*, 2018; Yazdi *et al.*, 2017 & 2019; Nazemi *et al.*, 2019). The occurrence of magmatic differentiation through fractional crystallization is the main process of formation of many of the Ramand region's lithological units (Mansouri, 1998). The presence of alteration minerals such as jarosite in the rocks in the region suggests a secondary effect of alteration phenomena on the rock units that has increased the intensity of alteration (Dabiri *et al.*, 2018; Jamshidibadr *et al.*, 2020).

DISCUSSION

Geochemical studies, Investigation of geochemical data of the study area showed that Al, As, Ba, Be, Ca, Ce, Cr, Cu, Fe, K, La, Li, Mn, Mn, Na, Nb, Nd, Ni, P, Pb, Rb, Sc, Sn, Sr, Th, Ti, U, V, W, Y, Zn and Zr have normal distribution. The elements Ga, Mo, and S also have lognormal distribution. The elements Ag, Hf, Mg, Sb, and Sm have neither normal distribution nor lognormal distribution. But by comparing the two raw data distributions and logarithm of the data, it was found that the raw data of the elements Ag, Hf, Mg, Sb and Sm have a relatively more normal distribution than the other two states. For example, in Figure 2, normal histograms are plotted for some elements (copper, molybdenum, silver).



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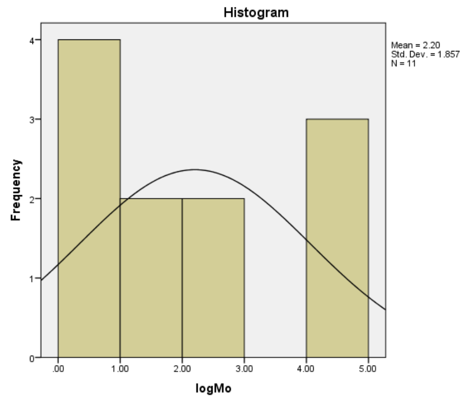
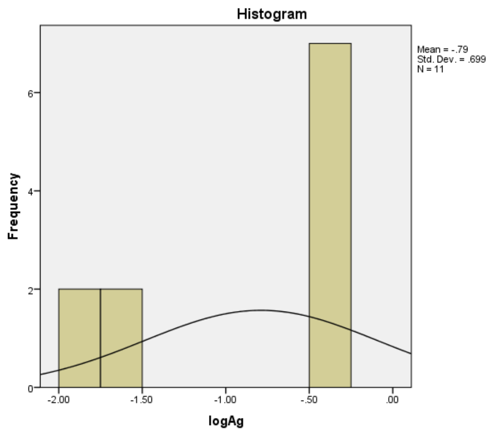
Normal data histogram of copper



Normal data histogram of molybdenum



Normal data histogram of silver

Figure 2. Normal histograms for some of the elements (Cu, Mo, Ag)
Source: Authors (2020).

Bivariate statistical analyzes, in geochemical investigations, some elements react similarly to certain environmental conditions and it can be searched for specific causes. Therefore, understanding the interrelationships between the elements can help to understand these conditions and provide a more accurate interpretation of geochemical environments. The optimal choice of the correlation coefficient's computational method is that it should not depend too much on the type of distribution function. Based on the above, in order to calculate the correlation coefficients between Ramand region data, Spearman and Pearson rank order correlation coefficients were used in SPSS software for calculating the correlation coefficients across Ramand region data (Tables 1 and 2).

logAg	1.000												
As	0.578	1.000											
Cr	0.488	0.754	1.000										
Cu	0.613	0.205	0.543	1.000									
Fe	0.566	0.675	0.943	0.600	1.000								
Li	0.631	0.757	0.795	0.437	0.758	1.000							
logMo	0.790	0.791	0.888	0.623	0.872	0.873	1.000						
Ni	0.762	0.659	0.715	0.468	0.668	0.615	0.794	1.000					
Pb	0.597	0.724	0.930	0.709	0.922	0.760	0.871	0.633	1.000				
logSb	0.406	0.781	0.967	0.467	0.878	0.853	0.865	0.589	0.890	1.000			
Sc	0.757	0.174	0.029	0.562	0.067	0.288	0.363	0.422	0.241	-.028	1.000		
V	0.719	0.388	0.214	0.345	0.238	0.544	0.569	0.491	0.198	0.242	0.632	1.000	
Zn	0.589	0.085	0.018	0.696	0.077	0.063	0.262	0.287	0.239	-.047	0.807	0.557	1.000
	logAg	**As**	**Cr**	**Cu**	**Fe**	**Li**	**logMo**	**Ni**	**Pb**	**logSb**	**Sc**	**V**	**Zn**

Table 1. Correlation coefficient matrix of geochemical data by Pearson method in the study area
Source: Authors (2020).

logAg	1.000									
As	0.587	1.000								
Cr	0.627	.717	1.000							
Cu	0.670	.198	.680	1.000						
Fe	0.760	.811	.770	.633	1.000					
Li	0.728	0.644	0.637	0.510	0.825	1.000				
logMo	0.826	0.708	0.881	0.759	0.875	0.781	1.000			
Ni	0.640	0.767	0.920	0.483	0.711	0.596	0.845	1.000		
Pb	0.741	0.646	0.731	0.616	0.743	0.744	0.833	0.684	1.000	
logSb	-0.095	0.449	0.563	0.301	0.396	0.411	0.332	0.428	0.341	1.000

Sc	0.845	0.246	0.278	0.459	0.445	0.551	0.556	0.237	0.651	-0.345	1.000		
V	0.728	0.338	0.290	0.400	0.560	0.607	0.575	0.358	0.320	-0.266	0.706	1.000	
Zn	0.760	0.232	0.232	0.450	0.464	0.451	0.433	0.146	0.588	-0.294	0.909	0.542	1.000
	logAg	**As**	**Cr**	**Cu**	**Fe**	**Li**	**logMo**	**Ni**	**Pb**	**logSb**	**Sc**	**V**	**Zn**

Table 2. Correlation coefficient matrix of geochemical data by Spearman method in the study area Source: Authors (2020).

The descriptive interpretation of tables 1 and 2 is also based on the severity or weakness of the correlation associated with the two variables' adherence direction to each other, as indicated later. In exploratory investigations, it is possible to derive different interpretations of a given correlation coefficient depending on the study conditions. Ranking the correlation severity of the two variables and rating them is often arbitrary. In this research, the following rating is used for descriptive interpretation:

1) r<0.2: Very poor correlation
2) 0.2> r <0.4: Poor correlation
3) 0.4> r <0.6: Medium correlation
4) 0.6> r <0.8: Strong correlation
5) r>0.8: Very Strong correlation

These tables show good and positive correlations (usually greater than 0.6) with yellow. Elements associated with copper are also indicated in orange. It should be noted that at first, the complete element table was calculated for 39 elements, and since the representation was not possible in a matrix, the important and correlated elements were separated and recalculated in a 13-element matrix. According to the Pearson's correlation coefficient, the Cu element has a high correlation with Pb (0.709), Zn (0.696), molybdenum (0.623), silver (0.613) and iron (0.6), respectively. Also, according to Spearman method, copper element has acceptable correlation with molybdenum (0.759), chromium (0.680), silver (0.670), iron (0.633) and lead (0.616), respectively.

MULTIVARIATE STATISTICAL ANALYZES

In this study we used a multivariate method called cluster analysis. This method helps to find real groups and also reduces data congestion. By applying the cluster analysis method on the elements that have played a key mineralization role in the Ramand region, the dendrogram in fig.3 was obtained, but what is important in this method is the selection of the classification criteriaو and in this study, the elements are clustered based on their relative correlation coefficient and thereafter, the elements are arranged in 4 separate clusters as follows:

- First group: Ce, La, Mg, Sn, S, Be, Th, Y, U, W
- Second group: Sb, Fe, Pb, Li, Mo, As, Ag, Cu
- Third group: Mn, Zn, Sc, K, Nd, Sm, Ga, Rb, V
- Fourth group: Hf, Nb, Sr, Ba, Zr, P, Al, Ti, Ca, Na

It should be noted that the third and fourth groups can be regarded correlated. According to cluster analysis, copper is associated with molybdenum, silver, arsenic, antimony, iron, lead, and lithium.

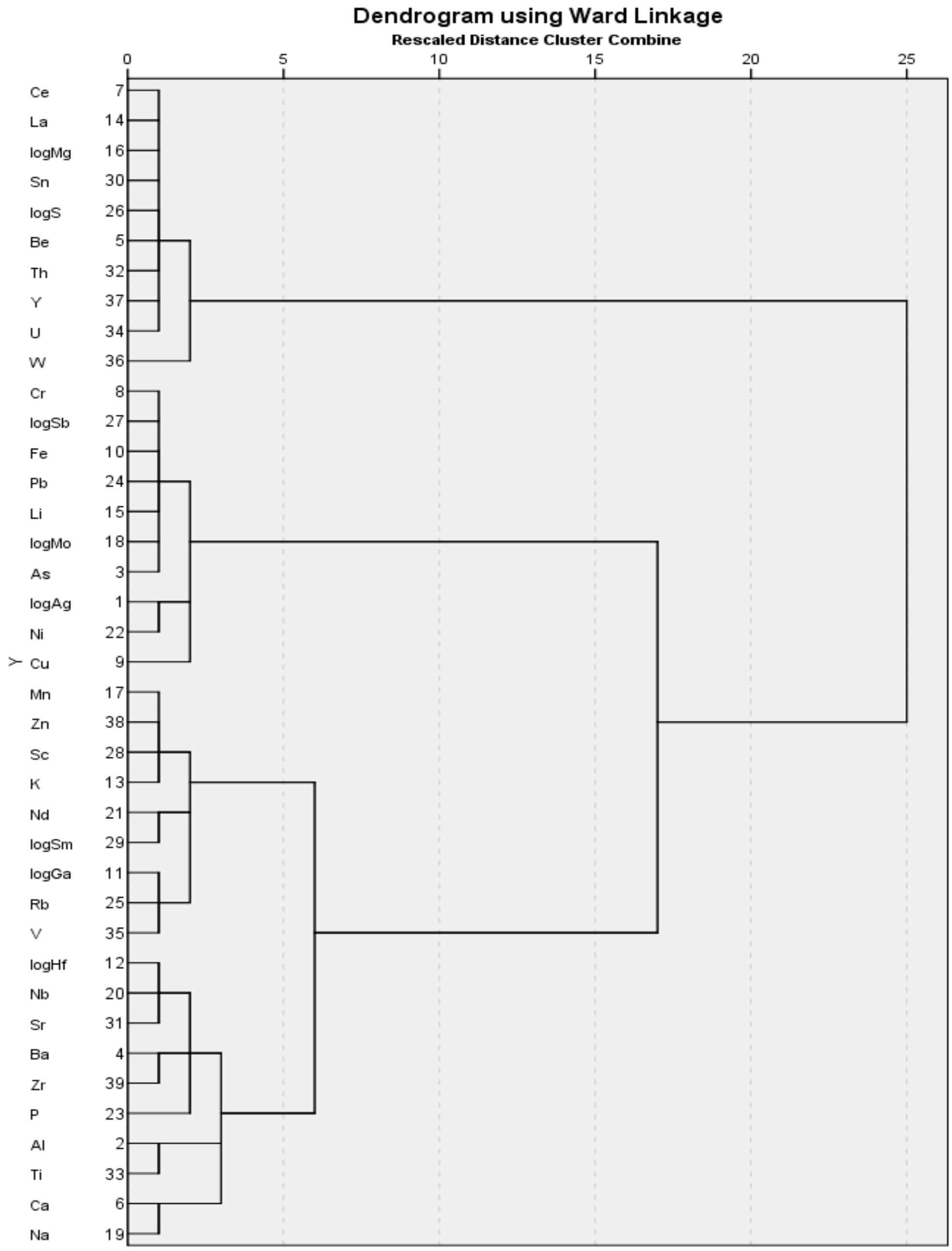


Figure 3. Result of cluster analysis of normal data in the region.
Source: Authors (2020)

ISOTOPIC STUDIES ON THE MINERALIZED VEINS OF THE RAMAND REGION

To identify the reproductive origin of gold-bearing veins in the exploration zone, especially to determine the type of ore-bearing fluids and the mechanism of probable combination of atmospheric water with magma water (Tohidi, 2016), in addition to microthermometrical studies of fluid inclusions, particular attention was paid to the behavior of stable oxygen isotopes of the promising areas. In this regard, isotopic changes of oxygen in carbonate (calcite) and silica (quartz) minerals were studied. The role of isotopic studies, in addition to determining the reproductive pattern of mineralized veins, has been associated with recognizing the origin of ore-bearing fluids and identifying similar thermal phases in the mineralogical sequence of the samples, carried out based on variation ratio (O16 / O18) and some commonly used calculations in geothermometric discussions.

SELECTION AND SUBMISSION OF SAMPLES TO THE ISOTOPE LABORATORY

Among the samples belonging to the mineralized areas of Ramand, 3 samples with the characteristics set out in table 3 were selected and after being sent to specialized laboratories, oxygen isotope behavior in carbonate (calcite) and silica (quartz) minerals was carefully evaluated.

Sample number	**Sampling location**		**Gold amount**	**Mineralogical background containing oxygen isotopes**		
	longitude	**latitude**	**mg/ton**	**Silicate**	**Carbonate-sulfate**	**Oxide**
5A	49°44’22”	42°32’35”		Chlorite, quartz, calcite	Pyrite	N/A
3A	49°45’30”	35°42’00”		Chlorite, quartz, calcite	Pyrite	Goethite
6B	49°45’30”	35°42’11”				Fine and scattered hematite

Table 3. Characteristics of selected samples for oxygen isotope studies in central Ramand region
Source: Authors (2020)

RESEARCH METHODOLOGY

Isotopic studies were performed by mass spectrometry method using Europa Geo 20-20 measurement system in accordance with SMOW standard (Standard Mean Ocean

Water). In these experiments, it is possible to make isotopic measurements based on IRMS (Isotope Ratio Mass Spectrometry) method in CO2 vapor phase and for the preparation of this gas, phosphoric acid reaction on carbonate minerals was used. Thus, a precise measurement of the oxygen isotope ratio of changes in carbonate and quartz minerals was made and the heavier isotopic component (δ18O) was calculated as per million (with a % notation) according to equation below:

- The ratio of the above variations is usually very minor but due to the relative richness of oxygen isotope 18 in magmatic fluids, there is a probability of partial increasing of heavy isotopes in minerals associated with magmatic systems (deep regions, hypogene). Therefore, after calculating and comparing it with existing standards, one may discover the origins of generation of some minerals (calcite and quartz) in samples belonging to promising areas;
- Evaluation of mineralized samples from the perspective of isotopic studies.

Oxygen isotope measurement in samples belonging to Qazvin's Ramand area is important for two reasons:

- Determination of the origin of minerals in metal sequences
- According to international standards, the range of oxygen changes in samples containing igneous minerals is determined between + 16% to -2%. As you can see, the comparison of the isotopes of the samples with Standard Mean Ocean Water (SMOW) isotope proves the magmatic origin of calcite and quartz in the composition of the samples. The affinity of heavy oxygen isotopes to establish rigid bonds in the crystalline structure of minerals is described as follows: Quartz> Feldspar> Calcite> Barite> Water;

Therefore, when forming Ramand alteration zones, the preferred concentration in calcite and quartz crystalline network has been consistent with the existing criteria in magmatic environments and is far from the isotopic standard of sedimentary rocks (with atmospheric origin).

Oxygen isotope changes in silica and calcite minerals in sample 5A* indicates the effective role of magmatic-hydrothermal cycles in the occurrence of Ramand's mineralized units. A similar behavior can be observed in the carbonate-silica background of sample 3A*.

Also in sample 6B (with amorphous silica background) oxygen's isotopic behavior showed the magmatic origin of the fluids during crystallization of minerals.

Isotopic geothermometry of mineralogical sequence of sample 5A*

Now, considering the isotopic balance coefficient in the mineralogical composition of sample 5A*, the temperature T is calculated for the calcite-quartz composite phase. Thus, the isotopic exchange of oxygen in the silica-carbonate phases of this sample is considered as an effective indicator for determining the temperature governing the thermodynamic environment of magmatic fluids (at the time of mineralization of the veins), *a.k.a.* stable isotopes geothermometry.

In Sample 5A*, the quartz and calcite backgrounds were formed at the same temperature conditions and with similar magmatic origin. According to the mineralogical sequence of this sample, the geochemical behavior of mineralized fluids and the origin of Ramand's pyrite veins can be deduced from the results of isotopic studies. As mentioned above, in addition to sample 5A*, oxygen isotope results were obtained for samples 3A* and 6B. The oxygen's isotopic content of both samples is consistent with the results of sample 5A* indicating the effect of magmatic loops on the Ramand region's hydrothermal system.

Results of oxygen isotope studies in mineralized samples of Ramand region

The Results of these Studies are as follows:

1) The origin of ore-bearing fluids is often related to magmatic fluids, and this is inferred from the results of oxygen's isotopic studies on quartz and calcite minerals. The image shows the isotopic composition status of Ramand region's samples compared to other global sources.

2) The probability of mixing atmospheric waters with carbonate halos is more than quartz veins, therefore, in samples belonging to the propylitic regions, the oxygen's isotope content in the calcite is lower than that in quartz or quartz-carbonate samples. In these conditions, the probability of mixing atmospheric waters with magmatic-hydrothermal systems of Ramand region increases.

3) Geothermometry results of oxygen isotope and microthermometry of fluid inclusions in two samples 5A* and 3A* indicate similar thermodynamic conditions in the sequence of quartz-carbonate phases and explain the origin of reproduction of pyrite veins in promising areas of Ramand. According to geological surveys, most mineralized outcrops have the same mineralogy composition as those samples, so their reproductive patterns can be examined by the results of isotopic and microthermometry study of 5A* and 3A* (Figure 4).

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Sample no.	18O-Calcite (0/00)	18O-Quartz (0/00)	Qtz/Cc fractionation
*5A**	5.9	6.9	302.6
*3A**	9.4	5.8	310.1
6B	4.4	6.9	287/4

Table 4. Results of changes in stable oxygen isotopes in samples obtained from Ramand region
Source: Authors (2020).

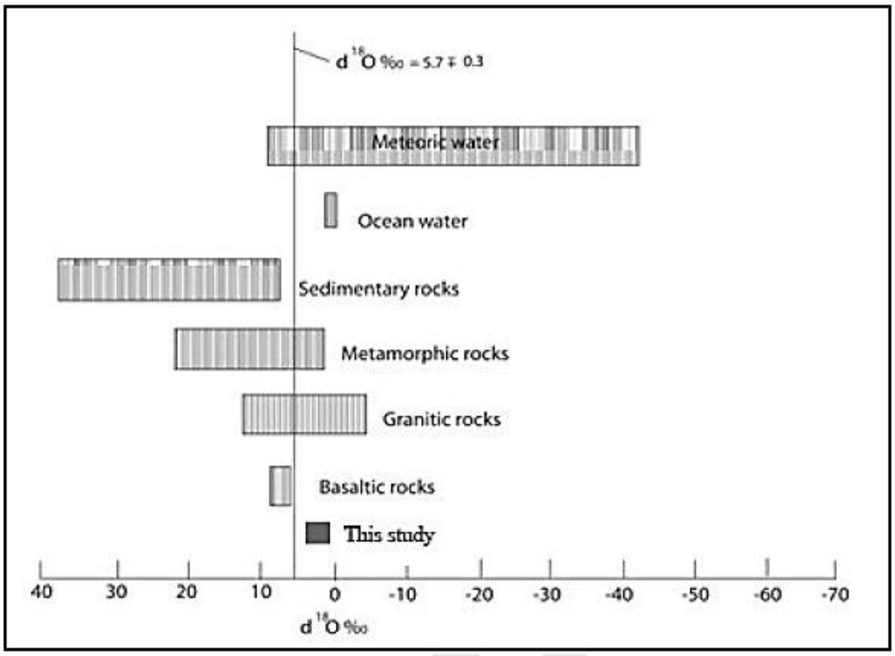

Figure 4. The status of oxygen isotope composition in important global.
Source: adopted from Hoefs (1997).

THE COMBINED RESULTS OF ISOTOPE AND FLUID INCLUSION STUDIES

The study of the primary fluid inclusions along with the study of changes in oxygen isotopes in Ramand's mineralized specimens, confirms the dominance of quasi-epithermal conditions with scattered outcrops of vein-type gold (Au Lode). This outcrop is associated with the mineralogical sequence of chalcopyrite, pyrite, and galena. The results of microscopic studies also indicate the regenerative relationship of gold with a variety of sulfide compounds located in a background of silica (especially quartz), clay, feldspar and calcite minerals. The average grade of gold in fertile veins is 1000 mg/ton with a maximum of 1750 mg/ton (Hassani Pak., 2010). Fertile veins have a good spatial relationship with Oligocene rhyodacite and trachyandesite outcrops. The veins are usually surrounded by a halo of silica alteration, argillic and propylitic (with abundant chlorite and calcite). The structural extension of the veins is in line with the northwest-southeast faults and in some cases, parallel to the east-west faults.

Ramand’s isotopic studies confirm the hypogenic origin of the ore-bearing fluid, as follows:

A - The origin of ore-bearing fluids (based on the results of table 5) is often related to magmatic fluids, and this can be proved by inferring from the results of oxygen isotope studies in quartz and calcite minerals.

Sample no.	18O-Calcite (0/00)	18O-Quartz (0/00)	Qtz/Cc fractionation
*5A**	5/9	6/9	302/6
*3A**	9/4	5/8	310/1
6B	4/4	6/9	287/4

Table 6. Specifications of selected samples for isotopic tests are shown
Source: Authors (2020).

Rank		Sampling location		Gold amount	Mineralogical background containing oxygen isotopes		
	Sample number	longitude	latitude	mg/ton	Silicate	Carbonate-sulfate	Oxide
1	5A*	49°44’22”	35°42’32”	820	Chlorite, quartz, calcite	Pyrite	N/A
2	3A*	49°45’30”	35°42’00”	1250	Chlorite, quartz, calcite	Pyrite	Goethite

<table>
<tr><th rowspan="2">Rank</th><th></th><th colspan="2">Sampling location</th><th>Gold amount</th><th colspan="3">Mineralogical background containing oxygen isotopes</th></tr>
<tr><th>Sample number</th><th>longitude</th><th>latitude</th><th>mg/ton</th><th>Silicate</th><th>Carbonate-sulfate</th><th>Oxide</th></tr>
<tr><td>3</td><td>6B</td><td>49°45’03”</td><td>35°42’11”</td><td>980</td><td>Fine-crystal quartz-glass</td><td>Pyrite and chalcopyrite</td><td>Fine and scattered hematite</td></tr>
</table>

Table 6. The origin of ore-bearing fluids is often related to magmatic fluids.
Source: Authors (2020).

B - The probability of mixing atmospheric waters with carbonate halo is higher than quartz veins, so that in samples belonging to the propylitic regions, the oxygen isotope content in calcite is less than the samples containing quartz. In these conditions, the probability of mixing atmospheric waters with magmatic-hydrothermal systems of Ramand region increases.

Table 6 shows the specifications of the selected samples for isotopic tests. In all three samples, the stable oxygen isotopes were used to determine the source of minerals.

Study of Ramand’s Fluid Inclusions Confirms a Hydrothermal Source Approximating the Epithermal Systems, as follows:

The results of micrometry studies have shown a delayed differentiation of magma in post-magmatic environments, resulting in medium magma differentiation, increased ore-bearing fluids, and the emergence of alteration halos around mineral veins, and according to the Tohidi (2016) diagram, the locus of the samples is in the Au-Lode range, which indicates the possibility of traces of vein-type gold. Also, the reproductive similarity of the fluid inclusions and the range of homogenization temperature fluctuations of the fluid inclusions (mainly containing liquid and vapor phases) are consistent with the mechanism of epithelial systems, but due to the lower salinity of Ramand specimens, veins are more likely to occur under quasi-epithermal conditions rather than a real epithermal system (Figure 5).

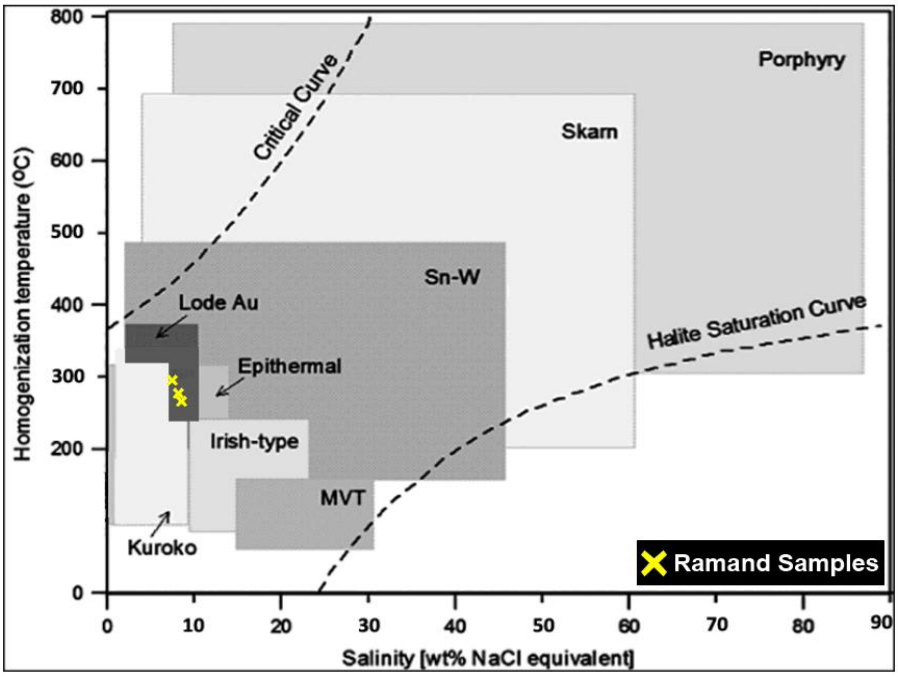

Figure 5. The status of Ramand specimens in the Wilkinson (2001) diagram. Salinity changes and homogenization temperature are more consistent with vein reserves.
Source: Authors (2020).

By localized examining of inclusions and carefully studying their salinity changes and homogenization temperatures, the following diagram is obtained according to the salinity changes versus temperature, broken down between samples 1 to 3.

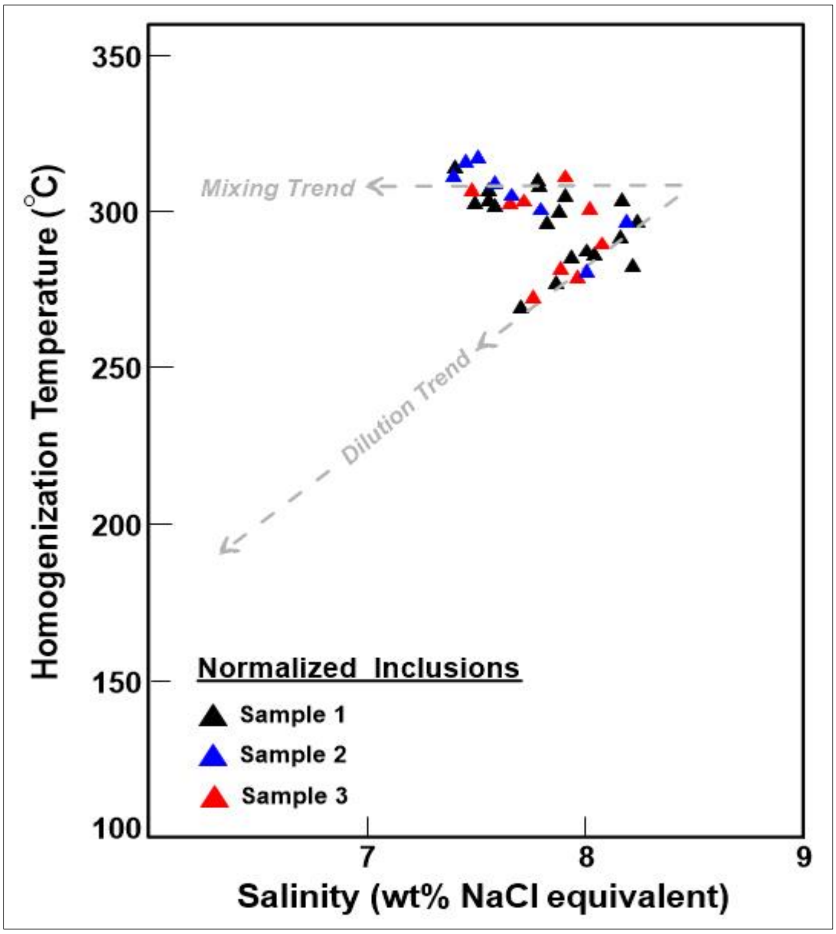

Figure 6. Inclusions are placed in two mixing and dilution phases.
Source: Authors (2020)

It is evident that most of the inclusions are in two phases of mixing and dilution, and this is a sign of the fusion of magmatic waters with each other and with the atmospheric waters of Ramand region. In the mixing process of this diagram, there is a possibility of mixing ore-bearing fluids with hypogenic origin. Such that some inclusions have a lower salinity while maintaining the homogenization temperature. In contrast, we are witnessing the process of dilution of fluid phases in some other inclusions, which, in addition to the decrease in the degree of salinity of the ore-bearing fluid, are accompanied by a significant decrease in salinity. These inclusions indicate fluid dilution and confirm the possibility of magmatic water mixing with atmospheric water. From the statistical point of view and after normalizing the inclusions distribution, it can be seen that in sample 2 contents, there is a small noticeable dilution and most of the inclusions are positively in line with the composition process. However, the inclusions for samples 1 and 3 have undergone both mixing and dilution phases and are more likely to be impregnated with magmatic fluids as well as submerged atmospheric waters than sample 2 (Figure 6).

Based on isotopic and microthermometry results of inclusion fluids, the origin of Ramand region's sulphide ores is magmatic and is related to the differentiation and formation process of hydrothermal-epithermal systems. The oxygen's isotopic differentiation index for the two minerals of quartz and calcite in three samples obtained from mineralized areas of Ramand corresponds to the isotopic criteria of the hypogene areas, although the probability of surface water mixing is not unexpected with respect to the boundary limits of Fractionation Qtz / Cc (minor mixing is probable). From the microthermometry point of view and the degree of salinity of fluid inclusions, the mineralized samples of Ramand are proportional to the oxygen's isotopic content, reflecting a magmatic environment during differentiation which due to proximity to the boiling point has caused the relative increase of the liquid-vapor (L + V) biphasic fluids. The nature of the fluids differs from what is seen in porphyry systems. The homogenization temperature mechanism is also closer to hydrothermal-epithermal systems. Therefore, according to the samples' conformance to Wilkinson diagram, the temperature range and salinity degree of the samples are similar to vein-type gold and in case of a relative increase in the salinity degree of the samples, it is close to epithermal reserves. Thus, samples located deeply in the alteration outcrops having salinity and homogenization temperatures corresponding to epithermal environments are likely to be found. However, the current type of mineralization of iron, copper, lead and gold (mainly embedded in the sulphides network) is of the vein type and should be evaluated and acted upon based on exploration criteria of these deposits.

CONCLUSION

Alteration halos in Ramand region are fairly extended and include a variety of clay (argillic), iron oxides and hydroxides, and dispersed silicification. The simultaneous presence of alteration halos and their spatial relationship with the junctions of fault systems in Ramand region indicate post-magmatic phases formation and production of ore-bearing fluids with hydrothermal origin that has caused rock alteration and vein-type mineralization in the region.

There is a high correlation between copper element and lead, zinc, molybdenum, silver, iron and chromium. Also by cluster analysis, the elements of the samples taken from the region were placed into four groups, according to which, copper is also associated with molybdenum, silver, arsenic, antimony, iron, lead, and lithium.

Based on the isotopic and microthermometry results of the fluid inclusions, the origin of Ramand's sulphide minerals is magmatic and is related to the differentiation and formation process of hydrothermal-epithermal systems.

From the microthermometry point of view and the degree of salinity of fluid inclusions, mineralized samples of Ramand are consistent with oxygen's isotopic content and reflect the magmatic environment during differentiation that, due to its proximity to the boiling point, resulted in a relative increase in the liquid-vapor (L + V) biphasic fluids.

The homogenization temperature mechanism is also closer to hydrothermal-epithermal systems. Therefore, based on the matching of samples with Wilkinson diagram, the temperature ranges and degree of salinity of the samples are similar to the vein-type gold and in the case of a relative increase in the salinity degree of the samples, it is close to epithermal reserves.

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