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Structural Controls of Polymetal Mineralization in North Kashmar, Iran

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Abstract: The North part of Kashmar is located about 250 Km Southwest of Mashhad, Northeast Iran. It is part of the structural Darouneh fault zone and contains rhyolitic, andesitic, pyroclastic and lava flows. Based on results obtained from AFM and Miyashiro diagrams the igneous rocks classified as a subalkaline and calcalkaline. From the data obtained the Kashmar strike-slip fault geometry (distribution of shear fractures such as R,R´,P surfaces, Riedel structures) plays an important role in controlling the location and emplacement of polymetal mineralization of copper, lead and zinc ore deposits. The Riedel structure which was observed along the northern border of Darouneh fault indicates a top-west sense of motion. Similar structures were observed along the southern border of Tanourcheh fault as well. In altered regions along R, R´ and P surfaces, intrusion of plutonic rocks into volcanic rocks have caused the development of propylytic, argillic and silisic hydrothermal alteration, hosting copper, gold, lead and zinc ore deposits. To show that the observed shear fracture surfaces are indeed not significantly different from classical Riedel shear pattern a fractal analysis has been done to compare field observations and classical Riedel shear pattern. The result shows that the estimated fractal dimension for schematic Riedel is about 1.17, which is in agreement with fractal dimension of field measurement.

Key words: Mineralization, Structural controls, Riedel, Fractal analysis, Kashmar

INTRODUCTION

Northern Kashmar region in Khorasan province is of paramount importance due to such geological features as Granite-Granodiorite intrusions, relatively wide alteration zones and Darouneh big fault (Darvishzadeh, 2002; Geotraverse, 1986). Geochemical explorations undertaken within Semnan-Torbat Heidariah zone have demonstrated this region among those greatly potential for gold and copper explorations (Jianxi, 1995). In line with this, anomalies of Tanourcheh and Ghuchpalang area have been identified.

This study aims to identify the tectonic mechanism of this area linked with petrologic features. To this end, a large number of specimen of various lithologic units as well as plane and linear structures of the faults were surveyed and examined using satellite images of alteration zones linked with fractures.

Map of prospective mineral areas was developed using fault maps and adapting the same to anomalies of the area. In view of the fact that the study of irregular figures such as faults through statistic techniques is not fully precise, fractal dimension (Wang, 2001) of the faults in the region was calculated using fractal geometry through box count system. Taking into account similarities between schematic diagram fractal dimension, Riedel mechanism (Cowans and Brandon, 1994) and other tectonic evidences, Riedel mechanism was introduced as the model for part of the faults in the area.

Geological Setting:

In view of geological divisions, the zone under study is located in central Iran in Sabzevar geotectonic unit parallel with Darouneh great fault (Schtocklin, 1976; Geotraverse, 1986).

Exposure of rock units in this zone mainly includes Paleogen (Eocene-Oligocene) magmatic activities so that the main volcanic activity continue during the period between lower Eocene to mid-Eocene and contains a large volume of andesite, trachyandesite, quartz trachyandesite lava as well as volcanic breccia and riodacite and altered andesite (Fig. 1). Simultaneous with volcanic activities and formation of EV units in wide sections of the zone, volcanic-sedimentary rocks began to form which include an alternation of green and gray tuffs, sandy tuff, grit thin layers, nummulitic limestone, micro-conglomerate, and in some parts andesite and trachyandesite flows.

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In upper Eocene pyroclastic activities (Ebt) including tuff, breccia tuff, sandy tuff and aglomerate together with a large volume of lava, with trachyandesite as the predominant compound, are observed. In late Eocene-Oligocene simultaneous with closing and swelling of basin, the above-mentioned system was influenced by granodiorite, diorite and granite (gd) masses and basic and acid dikes. And as a result of the development of differentiation, the final phase of magma was enriched by volatile materials and mineralizing elements, altering host rocks through fractures which led to mineralization. Ultimately, Oligocene conglomerate (Os, Oc) overlapped older units by unconformity.

Petrography:

For petrography study, rock samples of differents lithology were collected. Selected representative samples of the chemical analyses of igneous rocks are ploted on Barger diagram. The igneous rocks are classified as a subalkaline (Fig. 2). Using AFM and Miyashiro diagrams, the tholeitic rock series distinguished from calcalkaline series. Based on the results obtained from above diagrams the type of igneous rocks in study area classified as a calcalkaline.

Sampling:

Study area is a part of geological Fezabad quadrangle sheet (1:100000). Jianxi Company of china has done geochemical studies. Base on these studies, five anomalies for Au, Pb, Cu and Zn were presented. For completion present data, lithogeochemical samples were collected using chip sampling method from study area and were analysed in Iranian Industry Copper Company.

Data processing:

The statistical descriptive of three elements have been listed in table1. The coefficient correlation of Sperman after data normalization shows that lead and copper elements have been positive correlation with 99% of confidence level. Lepletie method has been used for separation of geochemical anomalies from background (Jianxi, 1995; Zhang *et al.,* 2005).

Table 1: Descriptive of Cu, Zn and Pb elements (ppm).

Element	Number	Range	Minimu	Maximu	Mean	Std.	Variance	Skewnes	Kurtosis
	Statistic	*Statistic*	*Statistic*	*Statistic*	*Statistic*	*Statistic*	*Statistic*	*Statistic*	*Statistic*
Cu	47	125980	20.00	126000	4101.06	18612.47	3.5E+08	6.39	42.38
Zn	47	697.00	3.00	700.00	72.21	116.94	13673.95	3.78	17.99
Pb	47	312.00	8.00	320.00	49.11	57.69	3328.18	3.79	15.29

Structural Setting:

Ore deposit areas are situated in north along Darouneh strike-slip fault with left-ward movement and Tanourcheh fault with right-lateral movement. Darouneh fault has east-west trend and Tanourcheh fault has northeast-southwest trend. These faults along with other faults as well as joints and associated fractures play a significant role in the young geomorphologic image of the area and have caused this area to be regarded among tectonically active areas.

Activities of strike-slip fault and consequent displacements have brought about lots of disruptions in volcanic units. In most localities these faults well conform with alteration zones. Through drawing rose diagrams as well as plane structures surveys, two predominant trends NWW-SEE and NE-SW which follow Darouneh and Tanourcheh faults trends together with few minor fractures systems with NW-SE and S-N trends are observed.

Faults Alterability:

In order to study fault density a square network with dimensions of 300m was developed (Fig. 3). Then, the length and azimuth of fault in each square unit measured. Histogram of fault density distribution is shown based on meter/square kilometer in Fig. 4. The average length of faults in each network is 534 m and minimum length of faults in each unit is 1/5 m and its maximum 1664 m. In spite of these dramatic changes, alteration coefficient is about 319. Frequency number is 692. This figure forms the basis of development of maps and determination of high fracture areas. Based on fault strike measurements, strike distribution histogram and rose histogram were developed. Predominant strike is N100 E, which indicates Darouneh fault. Two series of fractures with strike N130 and N170 are observed in this diagram. Craging technique and data variogram were used to draw fault density map (Fig. 4). Frequency figures of 25%, 50%, 90% were used as the basis of area division. The rose diagrams of the anomaly areas as well as the region's fault maps show that the first order of strike-slip feature of Darouneh fault has led to formation of faults with different strikes in the region. It shows the most frequency percentage of fault strikes in the region.

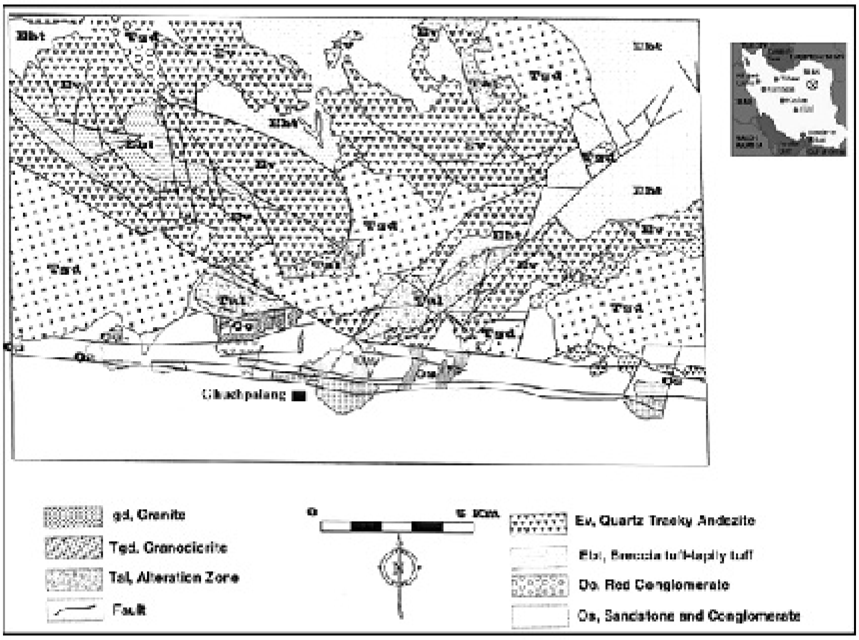

Fig. 1: Geological and structural map of north Kashmar.

Fractal Analysis of Fault Distribution:

In order to measure the fractal dimension of fault distribution, box count dimension technique was used. By drawing the fully-logarithmic diagram (Mandelbrot, 1993) the number of boxes occupied by the case (N(s)) against number of network scale photos (1/S) is specified. The straight line fitted to these points which has a slope of Db is referred to as box count dimension (Wang and Shi, 2006; Foroutan-pour *et al.,* 1999).

Box count technique was used for calculation of fractal dimension of the faults. Calculation of curve slope and the line in the fully-logarithmic plane with N axes (the number of squares containing fault) and S or 1/S (length of measurement network) are intended. In this process the formula of the line in this coordinates plane is as follows (Wang and Shi, 2006; Quiming, 1995):

$$LogN_s = a + K\log(1/s) \tag{1}$$

Where K is the slope of line and *a* is the coefficient related to the slope of line. Fig .5 has been drawn based on fault density map and the above relation. Fractal dimension values for the region under study are 1.16 and 1.58.

Fractal Analysis of Schematic Riedel Shape:

Most of the breccia regions with Riedel mechanism are formed by a number of elements with different orientation having a complicated and integrated geometry in general. In regions of brittle shear type, five major types of fractures have been identified (Cowan and Brandon, 1994).

These fractures, based on their positions relative to breccia region and general trend of the region, include:

- Riedel Shear fracture with small angle (R): fractures which clearly make a 15-degree angle with the general trend of the region and their angles close in contact with shear region align displacement of the block where they are located (Fig. 6).

-Riedel Shear fracture with large angle (R): fractures which make a 75-degree angle with general trend of the region and their acute angle close in contact with shear region align the displacement of the block where they are located.

-Pressure Shear fractures (P): a group of fractures which make a 15-degree angle with general trend of the region and their acute angle opens in contact with shear region along block displacement where they are located.

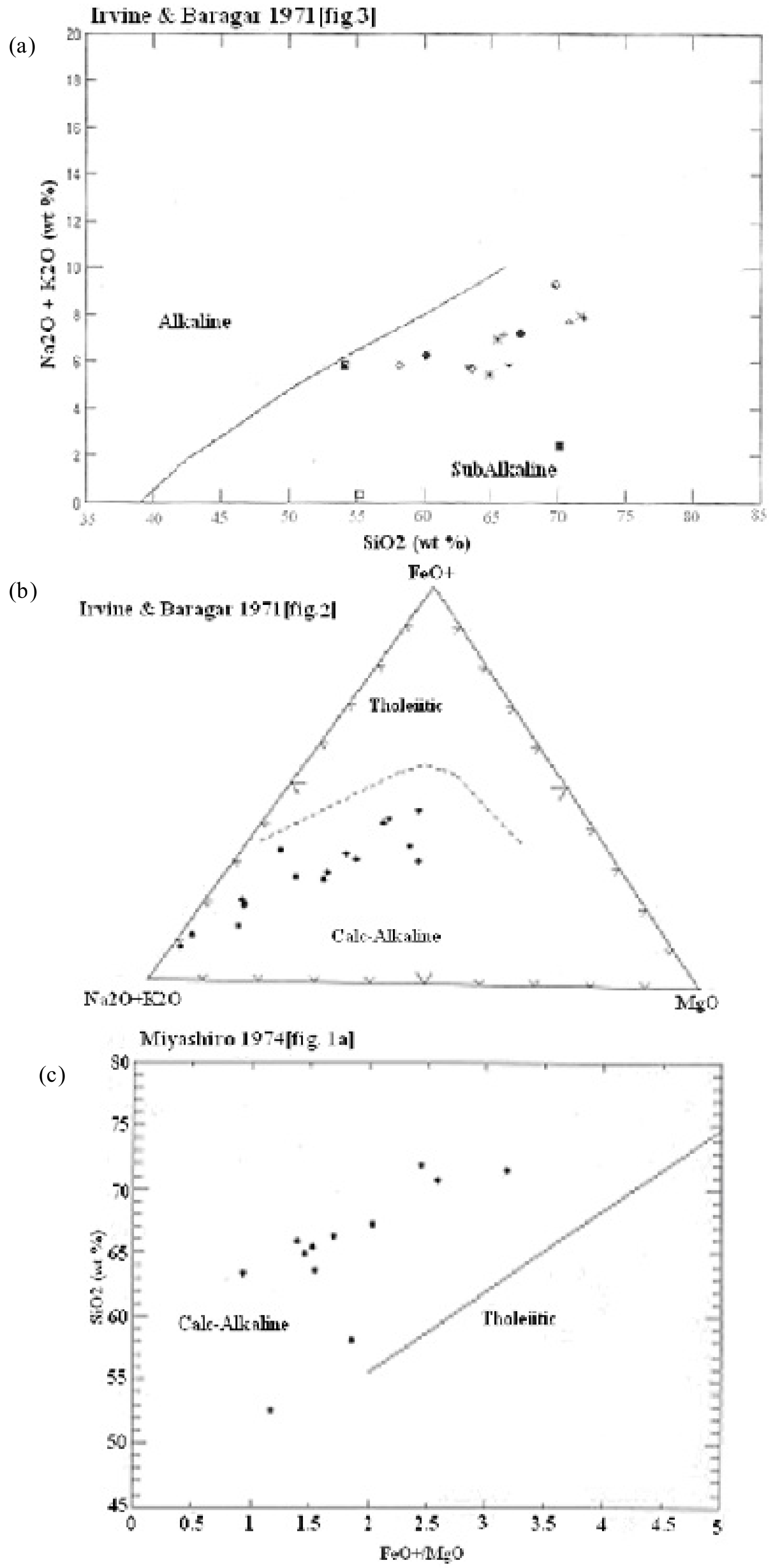

Fig. 2: a Barger, b) AFM and c) Miyashiro (1993) diagrams show rock series in study area.

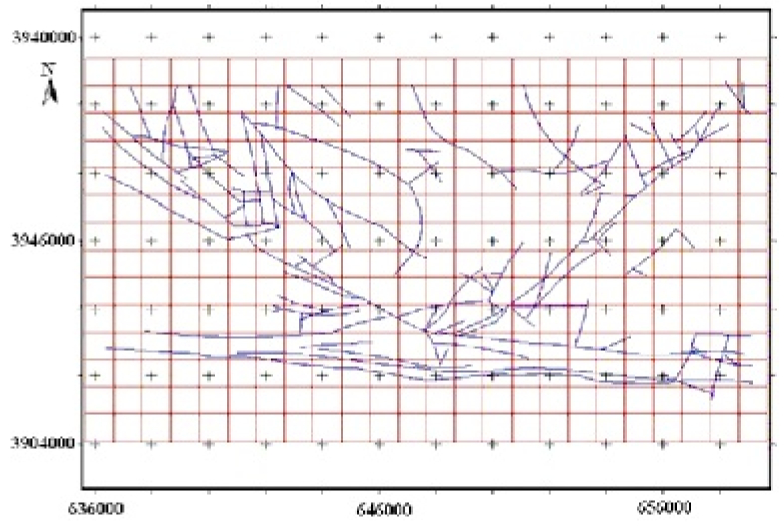

Fig. 3: A square network of faults (1000×1000) in the study area.

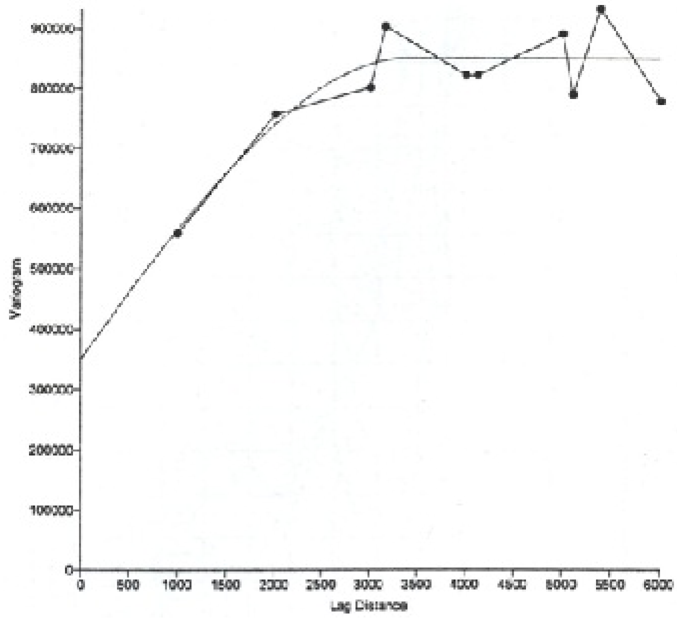

Fig. 4: Variogram of fault density in a line to the north.

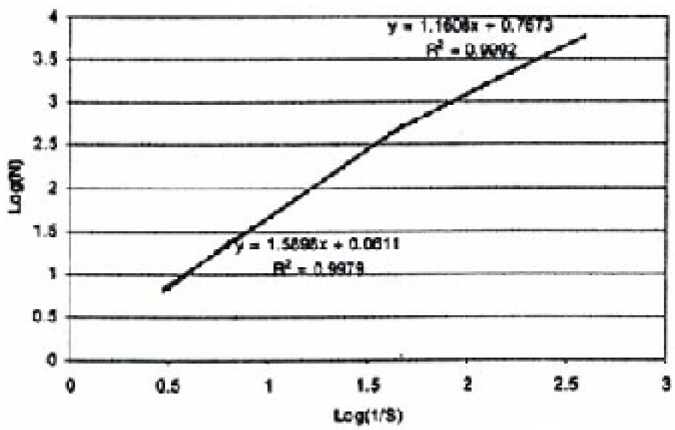

Fig. 5: Klog(1/s) to LogN diagram of northern Kashmar.

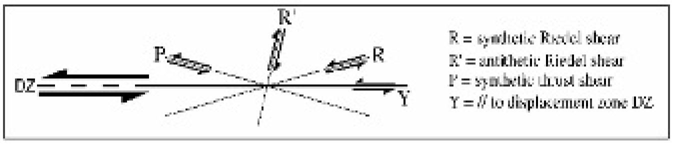

Fig. 6: Schematic diagram of common elements within a Riedel shear system (Cowan and Brandon, 1994).

-Shear fractures of (C) type are in parallel with shear region contact and tensile fractures (T) have strike between shear fractures R and R. Displacement direction of fractures R, R and C is the same as the direction of shear region displacement while shear fractures R have a displacement strike opposite to shear region strike. Shear veins are the most common veins in the shear area of the region. These veins usually take their position parallel or oblique to the edge of the shear region and the oblique type is very common. These veins make an angle relative to the edge of the shear region (Darouneh and Tanourcheh faults) which represents fracture of P type. This is indicative of the fact that oblique shear veins have been probably created in shear fractures of P kind as a result of tension.

The findings drawn from rose diagrams demonstrate the similarity of Riedel mechanism in this region. Fractal dimension of these fractures have been calculated through box count technique (Fig. 7). Fractal dimension of Riedel mechanism shows D=1.17.

Comparison of above diagram with fracture diagram of the region (figure 6) and the values obtained confirms the Riedel mechanism in the region.

Faults and Alteration:

One of the factors to recognize areas containing minerals is identification of alteration zones. In case the kind of alteration is determined in identification of these areas, appropriate model for mineralization in the area would be determined. For studies of correlation of faults and alteration, the remote sensing methods were used (Lillesand *et al.,* 2004). Image processing softwares such as ER-DAS, ENVI and Arcview with landsat satellite data were used. Straight or slightly

Oblique lines show strike-slip faults. Thrust faults are observed with irregular effect which follows topography and ordinary faults with corrugated effects (Fig. 8). Using different processing techniques as well as mathematical functions and statistical methods, thermal alteration zones were highlighted with specific color.

Faults in Anomalies Area:

The faults characteristic of three anomalies area inclusive of Emamzadeh, Kallateh Chubak and Madan Matroukeh (the abandoned mine) are listed in table 2. Rose diagrams of this area (Fig. 9) indicate that Darouneh fault cause to formation of faults with various trends and confirm the Riedel mechanism in this area. The main trend of fractures in anomalies area is N100.

Correlation Between Mineralization and Structural Controls:

Shear veins and fractures are pervasive structure within shear zones (Bursnall, 1996). In the study area, shear veins oblique to shear boundaries are located in the same angle as P shear fractures in Reidle mechanism. The anomaly mineralization of middle part of Tanourcheh fault which is one of minor fracture of great Darouneh fault is in agreement with P fractures. Also at Kouhzar area the trend of polymetal mineralization show same orientation as P fractures of Riedel mechanism with small deviation. The above deviation is related to rotation (locally) of Darouneh fault. To find structural orientation of polymetal mineralization, Roze diagrams of Tanourcheh, Kouhzar and Ghouchpalang areas were drawn using Dips software. Figure 10a, b shows the main trends of mineralization within Kouhzar and Tanourcheh areas about N110^0. The trend of Ghouchpalang mineralization (Fig. 11) is N110^0. These trends are all in agreement with P fractures of Riedel shear mechanism.

Conclusion:

The results of geochemical analysis in alterated regions along R, R´, P surfaces show that intrusion of plutonic rocks into volcanic rocks have caused the development of propylytic, argillic and silisic hydrothermal alteration, hosting copper, gold, lead and zinc ore deposits (poly metal mineralization).

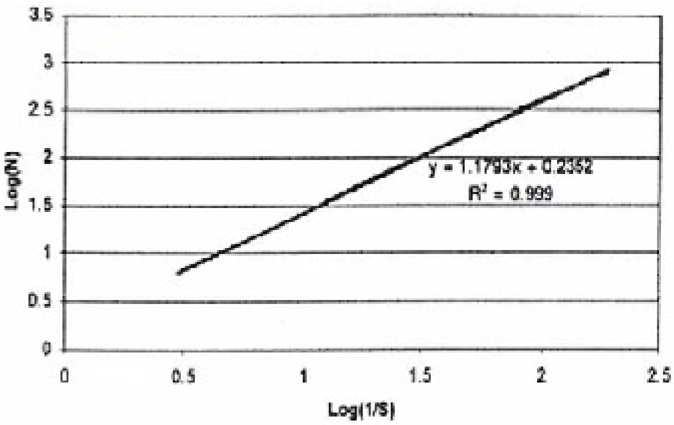

Fig. 7: Klog(1/s) to LogN diagram of Schematic Riedel shear system.

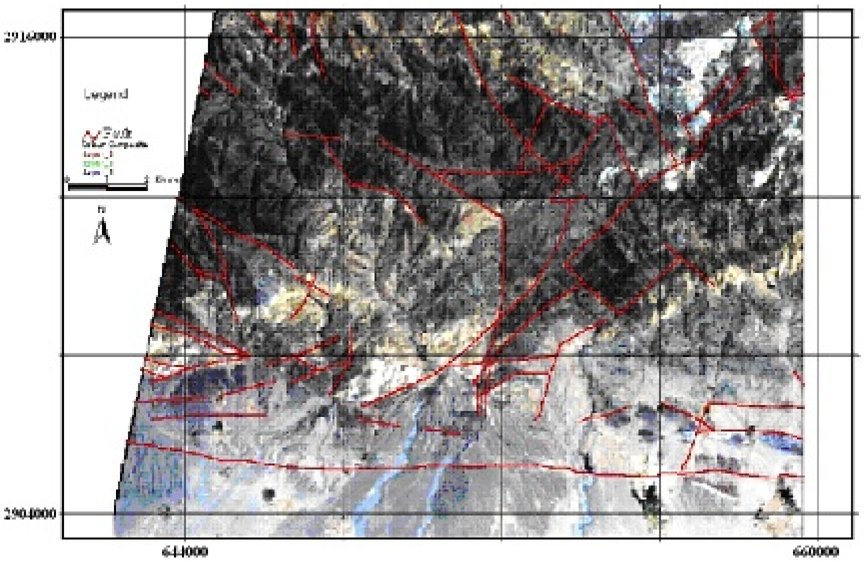

Fig. 8: Faults and filtration image of area.

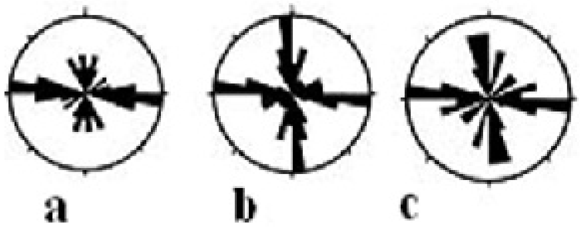

Fig. 9: a Rose diagram of Emamzadeh, b) Rose diagram of Kalateh Choubak and c) Rose diagram of Madan Matroukeh.

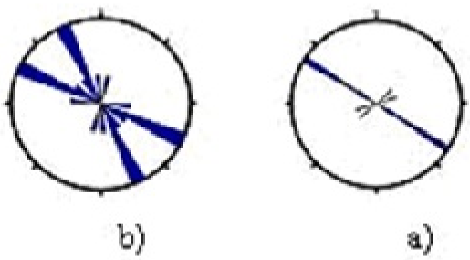

Fig. 10: Rose diagrams of polymetal veins a) Kouhzar, b) Tanourcheh.

Fig. 11: Copper mineralization in a fault with trend 1150 in north of Ghouchpalang area.

Table 2: Dip and dip direction of faults within three ore deposit areas.

Madan Matroukeh			Emamzadeh			Kallateh Chubak		
No	Dip	Dip/Dir	No	Dip	Dip/Dir	No	Dip	Dip/Dir
1	60	5	1	80	10	1	70	5
2	70	20	2	85	8	2	75	10
3	75	360	3	80	2	3	62	15
4	65	6	4	75	10	4	85	2
5	70	2	5	65	5	5	80	12
6	78	5	6	60	10	6	85	360
7	78	10	7	62	5	7	80	5
8	56	10	8	55	2	8	60	10
9	58	15	9	80	20	9	55	5
10	80	330	10	80	70	10	50	5
11	70	325	11	80	85	11	75	335
12	75	310	12	75	70	12	70	320
13	70	305	13	82	88	13	82	350
14	70	355	14	88	65	14	80	340
15	75	350	15	76	107	15	85	355
16	80	345	16	80	70	16	60	345
17	85	340	17	85	95	17	62	350
18	78	330	18	81	60	18	85	325
19	85	80	19	75	105	19	80	355
20	84	110	20	82	80	20	80	70
21	80	85	21	85	107	21	78	110
22	87	95	22	77	75	22	75	72
23	85	90	23	72	85	23	80	95
24	75	105	24	60	340	24	70	85
25	80	75	25	62	355	25	80	105
26	82	95	26	80	358	26	75	90
27	87	70	27	78	345	27	88	102
28	85	65	28	80	320	28	85	65
29	80	107	29	82	315	29	88	110
30	82	80	30	75	345	30	82	60
31	78	105	31	85	315	31	78	105
32	80	65	32	65	325	32	85	68
33	60	70				33	80	92
34	62	85				34	65	80

Faults density map provides a good guide in semi-detailed explorations. Statistic and fractal studies of faults approve Riedel mechanism for fractures surrounding Darouneh fault. The result of fractal analysis shows that the estimated fractal dimension for schematic Riedel is about 1.17 that is in agreement with fractal dimension of field measurement.

The polymetal mineralization process and siliceous and calcite veins are located with an angle of 15-20 degree relative to Darouneh and Tanourche faults. Considering the main Darouneh fault as a shear zone with epithermal mineralization and that central part of this fault in north of Kashmar has east-west direction, mineralization of Emamzadeh, Kallateh Choubak and Madan Matroukeh areas well in agreement with P type fractures of Riedel mechanism. Also, in Ghuchpalang region, the direction of P fracture changes with rotation of Darouneh fault and mineralization of Kouh Zar veins containing gold can be considered part of P fracture.

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