Geochemistry and genesis of Qareh Qotoo copper index, Sanandaj-Sirjan, Iran

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The Qareh Qotoo copper deposit has been located in the south of Kerman province and Sanandaj-Sirjan metamorphic belt. Petrologically, the study area has been formed from crystalline limestone, phyllite, amphibolite, serpentinite, green schists, calcareous sediments, tuff and diabase units. The host rocks of copper mineralization in this area are generally the greenschists which their protoliths are basic to intermediate igneous rocks (basalt to dacite), based on geochemical studies.The nature of these igneous rocks are tholeiitic sub-alkaline and are related to igneous arcs basalts in terms of geological dispositional environment. The main copper minerals of the ore deposit are chalcopyrite, malachite and covellite.The average grade of copper in the analyzed specimens was calculated equal to 0.92%.

Keywords: Sanandaj-Sirjan, Qareh Qotoo copper deposit, geochemistry, genesis

INTRODUCTION

The Qareh Qotoo region has been located in the southern part of Sanandaj-Sirjan metamorphic belt. This belt is one of the structural states of Iran which has been named by Stocklin [20] for the first time. The Sanandaj-Sirjan state in south is separated from Zagros folded state by the main thrust of Zagros. The metamorphic activities in the state have continued from Paleozoic to Cenozoic and cause this state have the uttermost metamorphic rocks out cropping among Iran's structural states. Some of these activities have resulted copper mineralization at various points of Sanandaj-Sirjan that has been reported by different researchers [1, 3, 10-17, 19, 21]. One of these copper mineralization areas is Qareh Qotoo region that its geochemistry and genesis has been investigated in the current studies.

GEOLOGICAL SETTING

Sanandaj – Sirjan is a narrow strip of the south-western of central Iran which is in the immediate North-East of the main thrust of the Zagros zone. The lithological and structural features of the state represents a trough or a bloc crevasse in the Precambrian Shield of Iran and Saudi Arabia [5-6]. Therefore, its geological features have obvious differences with the adjacent zones. The significant differences of this zone has attracted the geologists' attention since distant past. The most original lithic collection of Sanandaj-Sirjan zone are gabbro and metamorphic ultramafic rocks which mainly have Precambrian age. Lithologically, Qareh Qotoo region has been formed from crystalline limestone, phyllite, amphibolite, serpentinite, green schists, calcareous sediments, tuff and diabase units (Figure 1). Among the mentioned rocks, green schists are the host of copper mineralization event in the area and Figures 3 to 5have displayed an outcrop of that important geological unit .Figures 6 and 7 have been prepared from microscopic sections of the schists, hosting copper mineralization.

STUDY METHOD

In order to identify the rocks and minerals, the handy specimens as well as thin and polished sections were studied after field investigations. Then, 10 specimens were selected from stones suitable for chemical analyses and were analyzed using XRF method. Considering the data obtained from the chemical analyses, the changes in the magmatic phases in the region were perused, the primary chemical composition of the magma was recognized, and type of magmatic series governing the region was identified and regional tectonic environment that the results of this part of studies will be presented accordingly.

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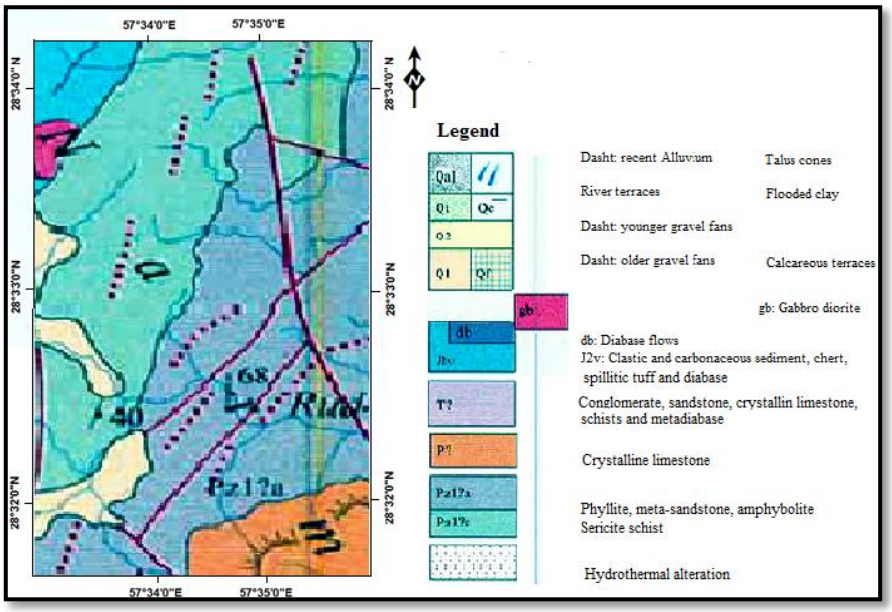

Fig. 1.The geological map of the range of Qareh Qotoo's copper (derived from the Sabzevaran's 1: 100,000 scale map).

Fig. 2. A close-up from green schists out cropping in Qareh Qotoo's mineral range (the host rock of copper mineralization).

Fig. 3. The general state of outcropping of alteration basic rocks (green schists) within the range of Qareh Qotoo's copper. The field and microscopic studies has determined the combination of these rocks from green schists to amphibolite.

Fig. 4. The sulfidic mineralization (pyrite and chalcopyrite) in the green schists of mineral range of Qareh Qotoo. In this picture, nota bene to the effects of analysis and sulfide minerals alteration which has led to the release of iron oxides and hydroxides.

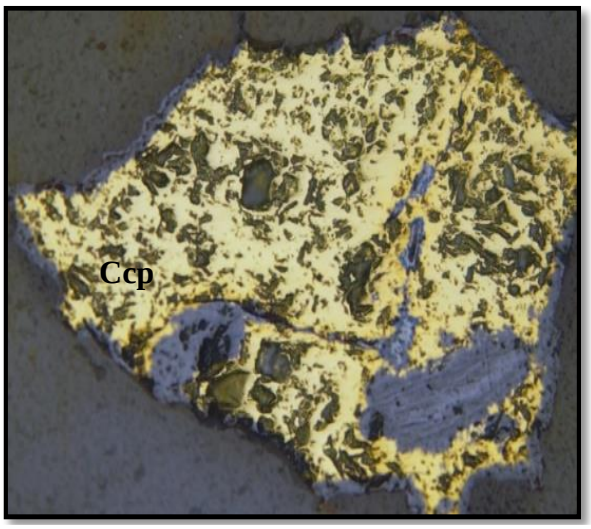

Fig. 5. The Chalcopyrite mineral with a vein tissue in green schists of the region.

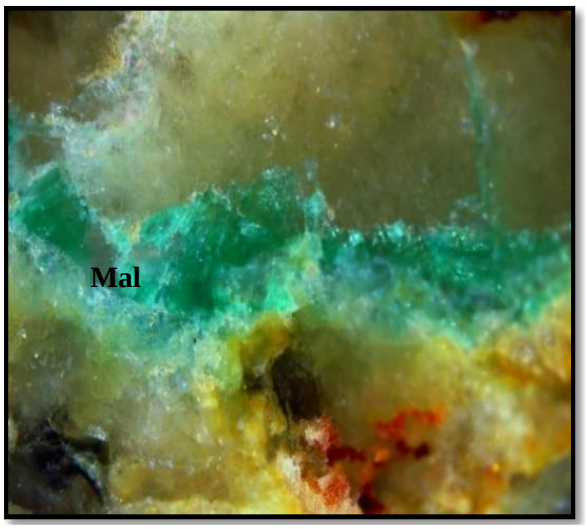

Fig. 6. The Malachite mineral in green schists of the region.

STUDY RESULTS

The results obtained from the chemical analyses on rocks in the environment of GCDKit and Minpet software have been processed that its results will be presented separately.

The results of geochemical studies

The XRF method was used to study the basic elements. In this method, the values of major oxides including SiO_2, Al_2O_3, Fe_2O_3, CaO, Na_2O, K_2O, MgO, TiO_2, MnO, P_2O_5, S, LOI was determined. Here, considering the diversity of taken specimens, 8 specimens of copper ore were selected for the geochemical study. The studies show that the oxides of silicon, iron and aluminum are the most important oxides available in the rocks (Table 1). Also can see that the average frequency of Cu in the sample is 0.92% and its maximum rate was determined equal to 2.69% that it is considered economic for copper massive sulfide deposits resembling Qareh Qotoo region in Jiroft and it confirms the need for further exploratory studies. In this research, Le Bas et al. diagram [9] were used to determine the type of rocks (Figure 8). The obtained results show that the Protolith of green schists of the region, or in fact, the primary rock, hosting the copper mineralization in Qareh Qotoo region have been basalt to dacite rock series. Additionally, according to this diagram, the rocks under study have been located within the range of sub-alkaline. The AFM diagram was used to determine the magmatic series type (Figure 9).The resulting graph shows that most of the specimens have been positioned within the tholeiitic range. Therefore, the Protolith of rocks hosting the copper mineralization in the studied specimens are part of tholeiitic sub-alkaline series.

The genetic studies results

Verma et al. (2006) diagram has been used to determine the origin of protoliths, hosting copper mineralization in Qareh Qotoo region (Figure 10).According to the diagram, the majority of the investigated specimens have been located within the igneous arc basalts (IAB) range that this issue is confirmed considering the tholeiitic nature of these rocks.

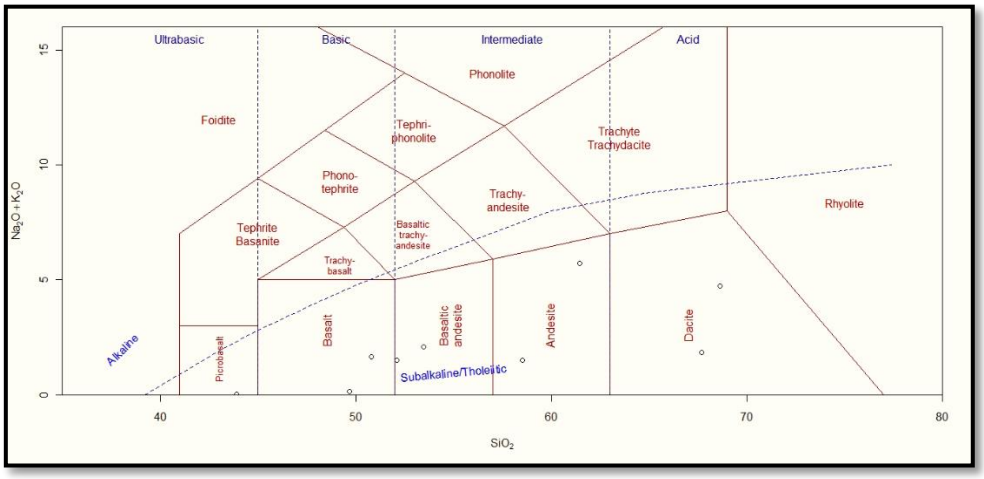

Fig. 7. The position of protoliths of green schists in Qareh Qotoo region in the Le Bas *et al.* diagram [9].

Table 1.The results of XRF analysis.

Sample	Si_2O	Al_2O_3	Fe_2O_3		CaO	Na_2o	K_2O	MgO	TiO_2	MnO	P_2O_5	S	L.O.I
	%	%	%		%	%	%	%	%	%	%	%	%
T4S3	40.03	14.85	14.62		14.58	0.02	0.01	6.75	0.166	0.148	0.043	0.147	4.87
T4S5	48.75	10.74	12.61		11.79	1.39	0.02	7.85	1.654	0.275	0.142	0.001	3.64
T4S13	60.68	15.21	12.01		0.23	0.01	0.23	9.41	0.398	0.370	0.103	0.002	0.020
T4S15	44.25	13.75	12.02		6.54	1.35	0.37	8.25	1.114	0.475	0.064	0.002	9.35
T4S15	11.68	0.58	80.12		0.35	0.02	0.02	0.04	0.121	0.007	0.002	0.204	6.55
T5S4	95.85	1.22	0.96		0.31	0.14	0.08	0.02	0.001	0.002	0.002	0.183	0.48
T5S10	52.78	9.35	10.59		11.41	0.62	0.72	2.78	0.216	1.862	0.071	0.002	9.12
T6S1	72.85	1.77	2.14		11.76	0.15	0.01	1.81	0.070	0.029	0.009	0.002	9.05
T6S2	58.35	17.85	3.49		3.96	9.73	0.15	2.57	0.230	0.061	0.010	0.113	3.13
T6S4	45.68	15.68	18.30		0.60	1.45	0.03	7.85	0.674	0.302	0.032	0.002	5.77
AVR	53.09	10.10	16.69		6.15	1.49	0.16	4.73	0.464	0.353	0.048	0.066	5.18
MAX	95.85	17.85	80.12		14.58	9.73	0.72	9.41	1.654	1.862	0.142	0.204	9.35
MIN	11.68	0.58	0.96		0.23	0.01	0.01	0.02	0.001	0.002	0.002	0.001	0.02

Sample	Cl	Ba	Sr	Cu	Zn	Pb	Ni	Cr	V	Ce	La	W
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
T4S3	73	89	265	27451	38	1	134	94	164	8	3	1
T4S5	59	5	197	8654	170	4	158	494	259	6	4	1
T4S13	97	43	32	6879	1934	139	35	82	124	30	13	1
T4S15	62	61	65	15424	924	16	120	366	258	21	8	1
T4S15	456	2	43	1013	241	4	31	372	168	17	11	2
T5S4	94	34	18	4785	14	41	46	26	22	21	15	3
T5S10	61	112	208	246	109	4	140	149	146	46	18	1
T6S1	88	16	18	338	66	13	42	5	26	14	9	1
T6S2	90	34	135	674	43	8	61	28	56	16	11	5
T6S4	66	74	14	26857	412	3	157	203	286	22	14	1
AVR	114.6	47	99.5	9232	395.1	23.3	92.4	181.9	150.9	20.1	10.6	1.7
MAX	456	112	265	27451	1934	139	158	494	286	46	18	5
MIN	59	2	14	246	14	1	31	5	22	6	3	1

Sample	Zr	Y	Rb	Co	As	U	Th	Mo	Ga	Nb
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	Ppm	ppm
T4S3	45	5	15	1	116	2	2	1	6	1
T4S5	96	22	13	2	71	1	1	1	8	1
T4S13	57	13	21	2	860	2	8	1	8	2
T4S15	67	34	29	112	25	1	1	1	4	1
T4S15	11	2	18	4	88	1	3	1	19	1
T5S4	37	5	13	7	39	1	1	1	11	1
T5S10	92	32	32	2	117	1	1	1	12	1
T6S1	27	4	12	2	4	1	1	1	9	1
T6S2	62	12	15	1	36	1	1	1	14	1
T6S4	40	21	17	562	164	2	3	1	4	1
AVR	53.4	15	18.5	69.5	152	1.3	2.2	1	9.5	1.1
MAX	96	24	32	562	860	2	8	1	19	2
MIN	11	2	12	1	4	1	1	1	4	1

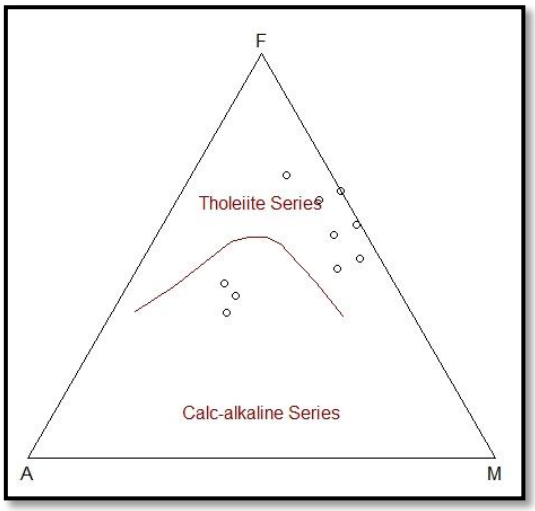

Fig. 8. The position of protoliths hosting the copper of Qareh Qotoo region in the AFM diagram (basis diagram of Irvine&Baragar [8]). The majority of specimens have been located within the range of tholeiitic series.

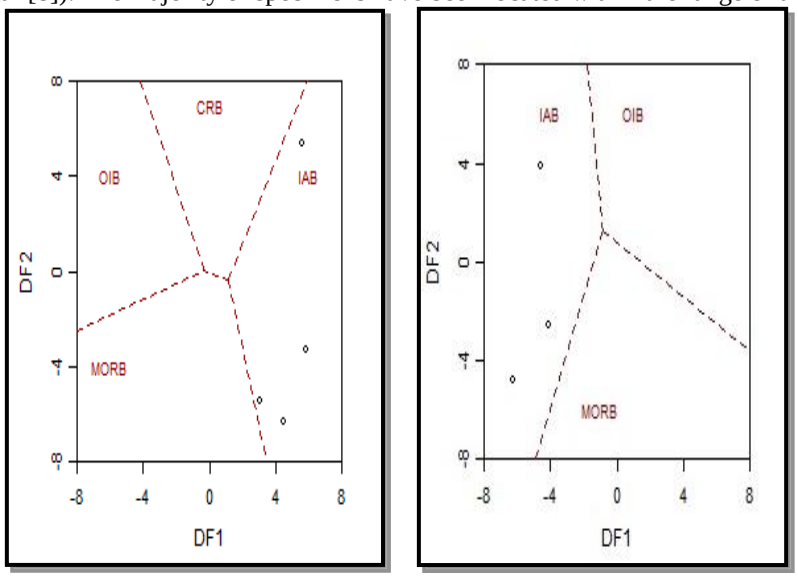

Fig. 9. The position of protoliths of basic schists containing copper in position of igneous arc basalts, basis diagram of Verma *et al*. [22].

DISCUSSION AND CONCLUSION

The most important results obtained from this study can be summarized as follows:

- The Qareh Qotoo region in the south of Jiroft is a part of Sanandaj–Sirjan. Thus, it follows the lithological and tectonic features of this state.
- The copper minerals of the region generally consist of chalcopyrite, malachite and covellite which can be seen in keeping with the minerals such as hematite and goethite which are as a host rock in the green schists.
- The protolith of green schists, hosting copper mineralization in Qareh Qotoo region, were basic igneous rocks up to intermediate within the range of basalt to dacite.
- The Protolith of green schist, were geochemically in tholeiitic sub-alkaline series and were originally very similar to geological environments of igneous arcs basalts rocks.
- Based on geological geochemical evidence as well as identification depositional environment for Protolith of green schists, hosting copper mineralization in Qareh Qotoo region, it can be concluded that studied copper deposit is very similar to the copper deposit of massive sulfides type. Accompaniment with basic igneous rocks up to intermediate with the submarine origin, the existence of sub- tholeiitic alkaline series, impact of alteration processes on rocks hosting copper mineralization, confirms that the copper deposit of Qareh Qotoo in the south of Jiroft, is very similar to the Besshi-type massive sulfide copper deposits. Table 2 has shown a comparative study of the results in more details and using studies carried out by Cox [2], Seal et al.[18], Fox [4] and Hy [7].

Table 2. A comparative study of copper deposit of Qareh Qotoowith Besshi-type massive sulfide.

Geological conditions \ Deposit type	Besshi-type massive sulfide*	Qareh Qotoo deposit
Host rock	Altered basic rocks	Greenschist, amphibolite
Associated rocks	Carbonate and siliciclastic sedimentary rocks	Crystalline limestone, phyllite and schist
Protoliths	Basic igneous rocks up to intermediate	Basalt to dacite rock series
Magmatic series	Sub-alkaline and tholeiitic	Sub-alkaline and tholeiitic
Geological environment	Sedimentary basins, such as back-arc basins	Igneous arcs basalts
Metamorphic processes	Up to greenschist to amphibolite	Generally in the range of green schist, sometimes amphibolite
Geological age	Upper Paleozoic	Permian (upper Paleozoic)

*According to Cox [2], Seal et al. [18], Fox [4] and Hy [7].

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