

## Petrographic Evidences for the Origin of Iron in IOCG Iron Deposits of Kuh-E-Faryadoon and Kouli-Kosh, Southeast Central Iran

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### Abstract

Kuh-E-Faryadoon and Kouli Kosh iron deposits are hosted by regional metamorphic rocks of Sanandaj-Sirjan zone around Deh-Bid area. Plugs and domes of acid rocks protrude these metamorphic rocks. A mylonitization event is super imposed on acid rock and metamorphic complexes. Field, petrological and geochemical studies have shown that (1) Iron mineralization have occurred during mylonitization in N45W shear zones. (2) Mineralization have many characteristic peculiarities of IOCG hydrothermal deposits. (3) Mylonitization is super imposed on regional metamorphism therefore early paragenesis of regional metamorphism are destabilized and new paragenesis are formed. (4) Iron is released through destabilization of biotite, clinopyroxene, epidote, ilmenite and titanomagnetite of mafic metamorphic rock (mainly greenschists) and acid rocks during mylonitization event. Petrographic evidences and relevant reaction are presented and discussed. (5) Iron is mainly and preferentially released from greenschists. (6) Transport of iron by carbonile complexes are proposed based on direct evidence of CO<sub>2</sub> rich solutions during mylonitization.

**Keywords:** IOCG iron ore; Kuh-E-Faryadoon; Kouli-Kosh; Sanandaj-Sirjan; Dehbid

### Introduction

Several IOCG type iron deposits have been discovered in recent years in part of Sanandaj-Sirjan zone around Deh bid, northeast of Fars province southeast central Iran. The origin of these iron deposits have not been studied until 2009. Mirzaei [8], and Mostafavi [9], have studied part of these belt in Kuh-E-Faryadoon [8], and Kouli - Kosh area [9]. Figure 1 shows geological framework of these deposits in large

scale Iranian structural zones.

Several aspects of iron mineralization in these two areas are touched of which the most interesting and challenging aspect, that is, origin of iron is presented in this article.

### Geological Setting

The two areas are parts of Sanandaj-Sirjan metamorphic zone around Deh bid in Fars province of

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Iran. Figures 2 and 3 show the general geological features of these two areas. Metamorphic complexes are composed of greenschists (metabasic rock), mica schist, metabanded cherts, metasandstone, marble (calcitic & dolomitic). Metarhyolite is widely associated with this metamorphic complex. In Kuh-E-Faryadoon metarhyolite are more wide spread than Kouli - Kosh area. Geological observations have showed that these metaacid rocks (hypabyssal acid intrusions) have been invading metamorphic complexes in form of domes and plugs after their main metamorphic event. Metamorphic complexes and acid rock bodies were simultaneously suffered a severe phase of mylonitization. The main metamorphic event of metamorphic complexes is probably pre - Permian. This is materialized by the occurrence of nonmetamorphosed Permian volcano - sedimentary rock at Kuh-E-Faryadoon area (Fig. 2). Metamorphic complexes as well as Permian rocks and acid hypabyssal masses are later on strongly mylonitized in a post lower Jurassic event. Iron mineralization is concomitant with this mylonitization event. According to Pour kermani [12], this event has occurred in a period between Cenomanian and late Miocene.

The general structural trend of these areas is NW\_SE (N 45° W) parallel to general trend of Zagros range. According to Shahidi [13], these two areas' structure is characterized by an imbricate structure. He concluded that thrust faults of these areas are in fact lystric contraction thrusts.

Dynamic activity of these thrusts have caused severe mylonitization of acid rocks and turned them into a gneissic type rock. Brecciation of marbles and concomitant iron mineralization, dolomitization of calcite marble next to iron ore occurrences are other manifestation of this tectonic event. This observation proves that these lystric thrust have the role of channel ways for mineralizing solutions.

## Materials and Methods

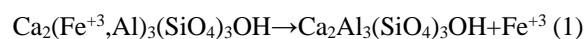
### Petrography and Mineralogy

#### a) Greenschists

Greenschist are metabasic rocks (basalts and probably andesitic basalt) which show a blastoporephyritic to granoblastic textures. Mineral associations of these rocks are as follows:

Plagioclase (Oligoclase - Andesine) ± Biotite + Chlorite + Opaque minerals + Quartz + Calcite + Muscovite + Sphene ± Epidote ± Clinozoisite ± Rutile ± Actinolite ± Alkali-feldspars ± Pyrite ± Augite

(magmatic relict). In some of greenschists primary ophitic texture is still preserved. The major parts of greenschist do not show preferred orientation (PO). PO is widely developed in greenschist near the thrust faults. PO is superimposed on primary metamorphic minerals or pre mylonitization metamorphism (PMM). Epidote of PMM phase is transformed into clinozoisite during mylonitization according to following scheme:



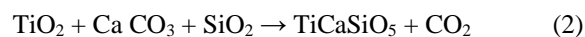
Epidote

Clinozoisite

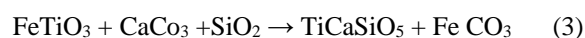
Minerals formed during mylonitization and PO development are as follows:

Muscovite + Calcite + Quartz + Clinozoisite + Sphene + Hematite

Calcite is a predominant phase during mylonitization which implies that hydrothermal solutions present during mylonitization are rich in CO<sub>2</sub>. Muscovite is absolutely formed during mylonitization which implies transport of K<sup>+</sup> during mylonitization. Sphene is formed at the expense of rutile during mylonitization, according to following scheme:



In some instances sphene are formed around titanomagnetite or ilmenite. This reactions also causes the liberation of Fe<sup>+3</sup> according to following scheme:



Ilmenite + calcite + quartz → sphene + siderite

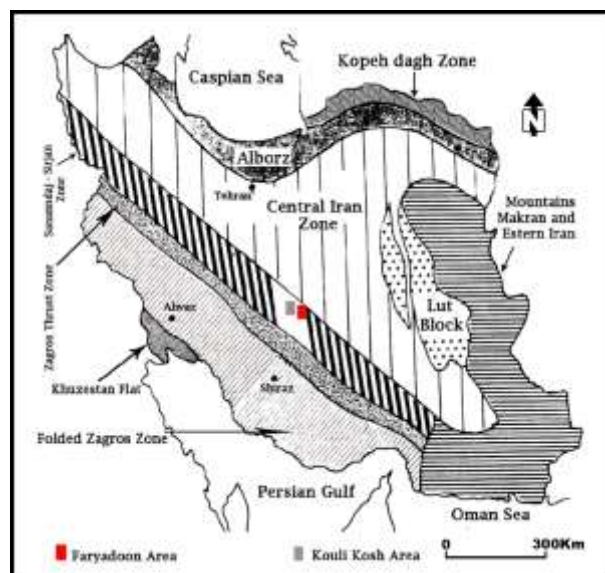


Figure 1. Position of iron ores in structural zones map of Iran, in his opinion Stocklin and Ruttner taken from Alavi Naini (1972).



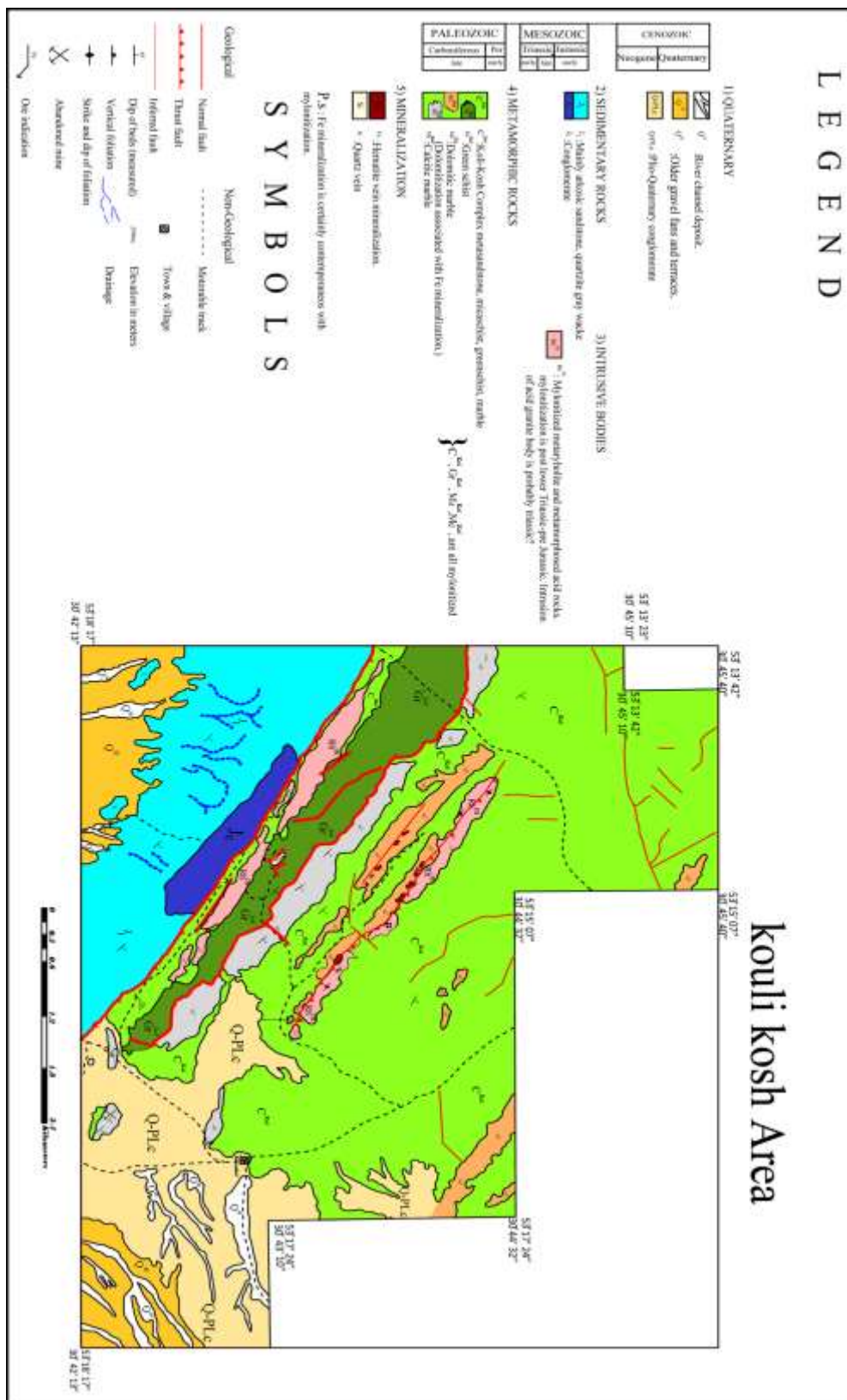
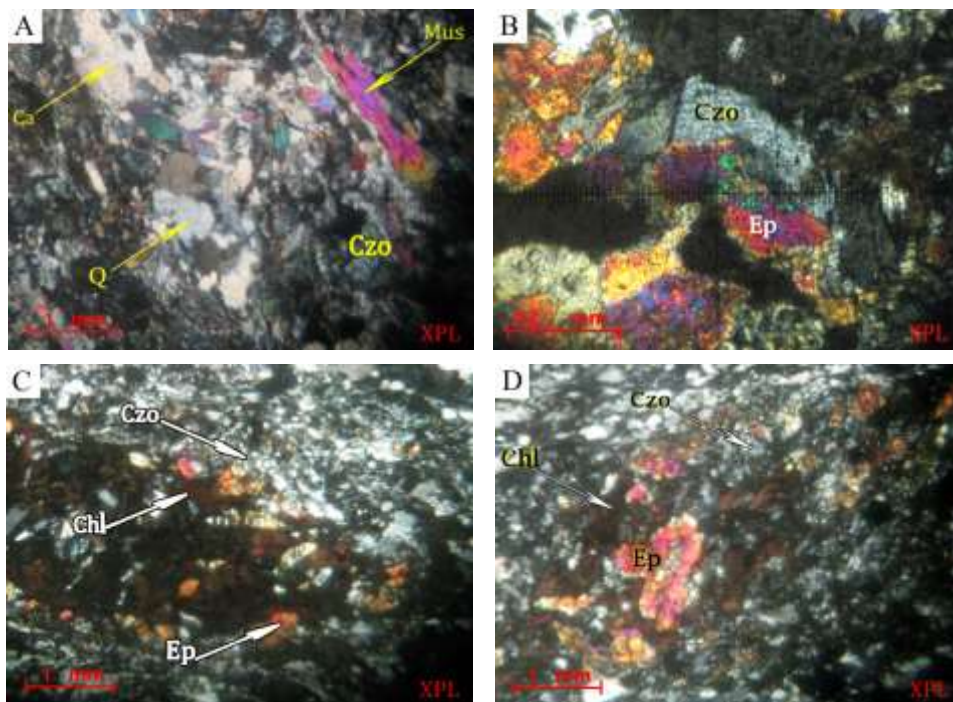
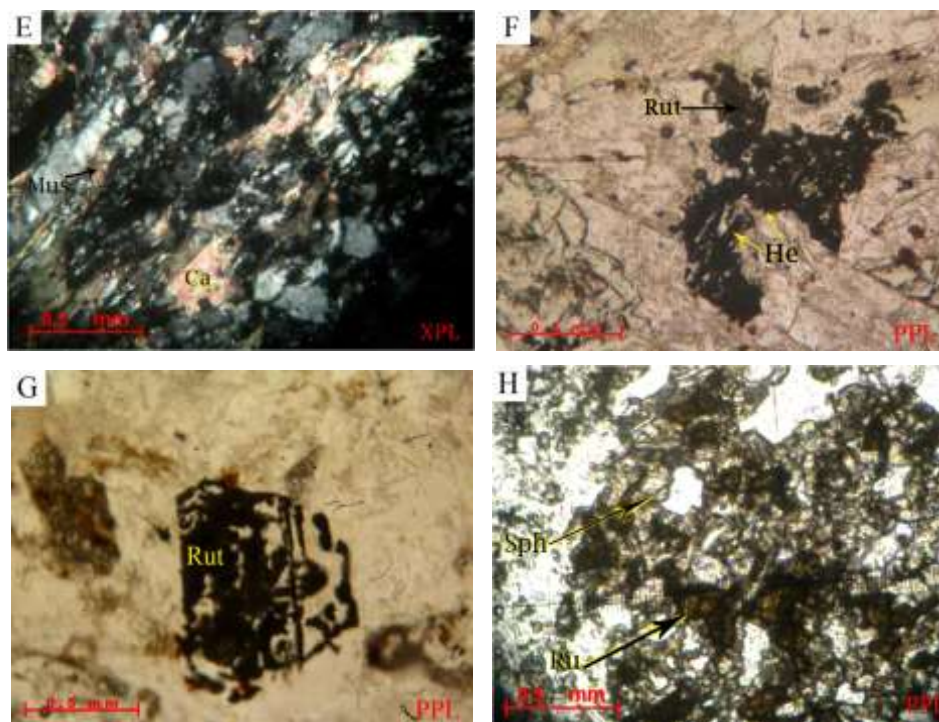


Figure 3. Geological map of Kouli Kosh, Mostafavi [9].

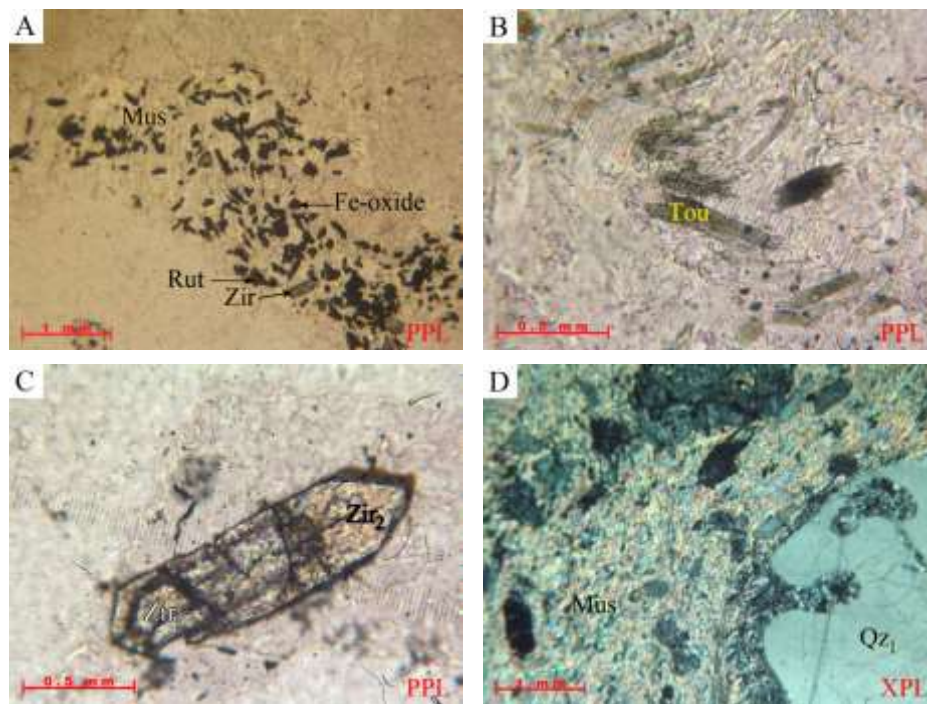




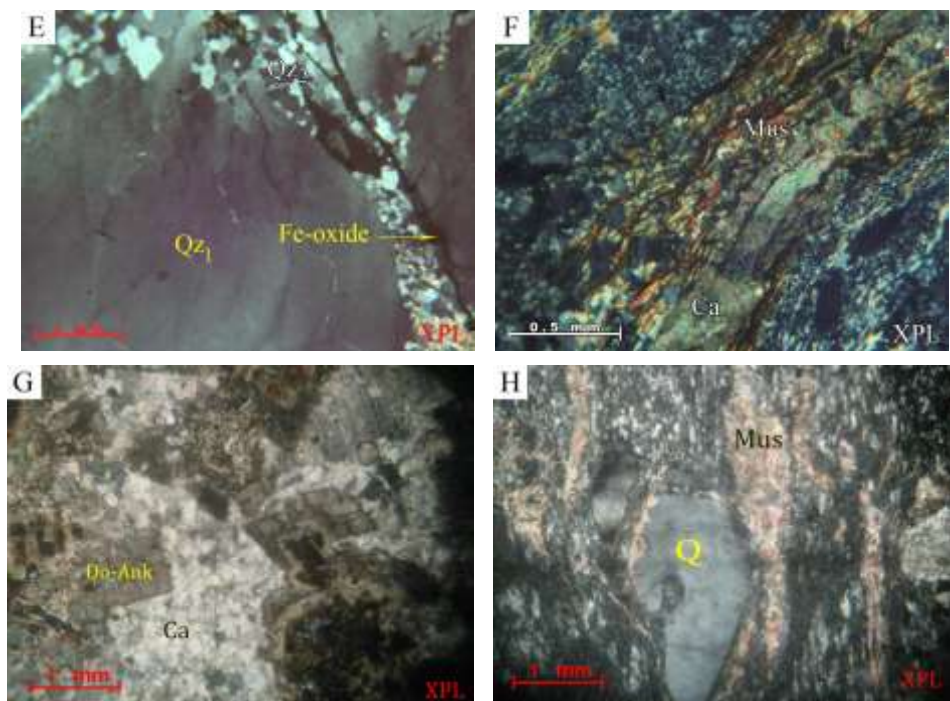
**Figure 4.** A: Formation of Muscovite (Mus) + Calcite (Ca) + Quartz + Clinozoisite (Czo) in greenschist. B: Transformation of Epidote (Ep) to Clinozoisite (Czo). C: Patches of Chlorite(Chl) + Epidote (Ep) superimposed by a foliation during mylonitization. D: Clinozoisite (Czo) formed after Epidote (Ep).



**Figure 5.** E: Calcite (Ca) and muscovite formed in mylonitized greenschist. F: Probable Titanomagnetite transformed into Rutile (Rut) and Hematite (He). G: Skeletal Titanomagnetite transformed into Rutile (Rut). H: Rutile (Rut) transformed into sphene.

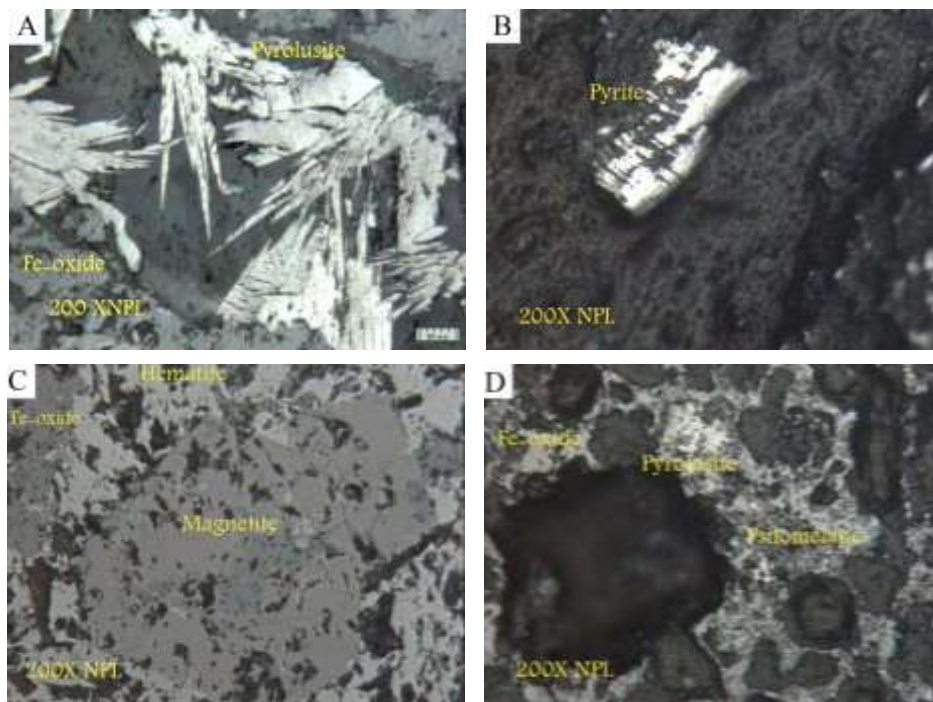


**Figure 6.** A: Probable Biotite transformd into Muscovite (Mus) + Fe-oxide, Rutile (Rut). B: Tourmaline (Tou) in metarhyolite. C: Zoned Zircon (Zir1 and Zir2). D: Porphyroclast, of Quartz (Qz 1) which embayed borders Muscovite (Mus).



**Figure 7.** E: Two generations of Quartz, primary magmatic Quartz (Qz1) and Quartz formed during mylonitization (Qz2). F: Calcite (Ca) and muscovite (Mus) showing preferred orientation in metarhyolite. G: Dolomite – Ankerite formed in metacarbonate rocks. H: Preferred orientation (PO) in metarhyolite note the embayed Quartz. Muscovite (Mus) metarialized foliation.





**Figure 8.** A: A view of Pyrolusite and Hematite in Iron ore. B: Pyrite in Iron ore. C: Magnetite in Iron ore transformed into Hematite. D: Fe – oxide, Psilomelane and Pyrolusite in Iron ore.

combination of (1), (2), (3) equations already indicate that:

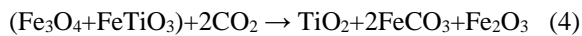
(1) Fe is liberated by transformation of (PMM) minerals during mylonitization.

(2) Solutions present during mylonitization are rich in  $\text{CO}_2$ ,  $\text{SiO}_2$ ,  $\text{K}^+$ ,  $\text{H}_2\text{O}$ .

(3) This implies that  $\text{CO}_2$  rich solutions transport iron in the form of carbonyl complexes.

In mylonitized Permian basic rock following phenomena are occurred:

(1) Titanomagnetites are transformed into rutile and Fe is liberated according to following scheme:



titanomagnetite      rutile+siderite+hematite

(2) Siderite is a common alteration product of Clinopyroxenes and Titanomagnetite. These observations also indicate that liberation of Fe from Clinopyroxene and Titanomagnetite are the net result of  $\text{CO}_2$  reacting with these minerals and the most probable mechanism of transport of iron is possibly carbonyl complexes. Figures 4 and 5 indicate petrographic observations in greenschist (Metabasites).

*b) Acid Rock (Metarhyolites)*

These rocks were certainly acid rock type with

porphyritic texture and holocrystalline groundmass which are mylonitized. They have actually a porphyroclastic texture materialized by the existence of embayed quartz porphyroclasts which still exhibit corroded magmatic borders. Quartz crystals are present in groundmass as granoblastic aggregate which cut very often the magmatic quartz porphyroclasts. Microcline and microcline perthite are alkali – feldspars of these rocks probably formed during mylonitization event at the expense of primary magmatic Alkali – feldspars Vernon [15]. Muscovite show a very strong (PO). It is formed during mylonitization. Ankerite + Siderite + Calcite + Opaque minerals (probably hematite) are formed in the groundmass. They have also a very good PO as muscovite. Primary biotite of these rock are strongly destabilized during mylonitization. They are transformed into Alkali – feldspars + Magnetite + Hematite + Rutile. Zircons are very often zoned which manifests an earlier magmatic zircon and later metamorphic one. Biotites are in some instances transformed into: Muscovite + Rutile and Fe-oxides. Tourmalinization is - in some instances - very widespread during mylonitization event. Boron is probably provided by destabilization of Biotite. It is clear that Muscovite + Calcite + Ziron (second zone) + Rutile + Fe-oxide ± Chlorite + Tourmaline +

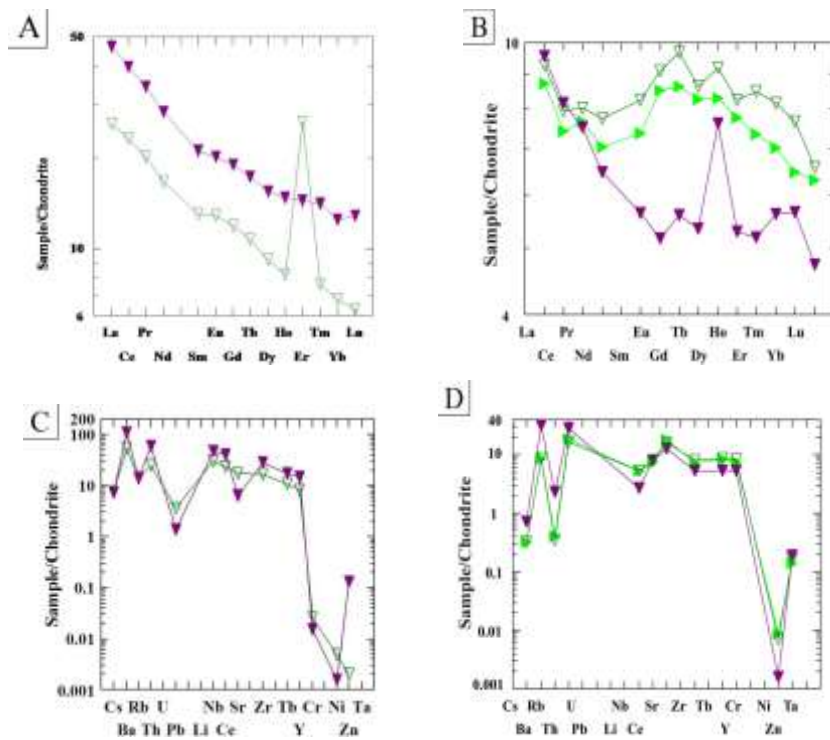


Figure 9. A and C: Spider diagram of Kuh-e-Faryadoon metabasites. B and D: Spider diagram of Kouli-Kosh metabasites.

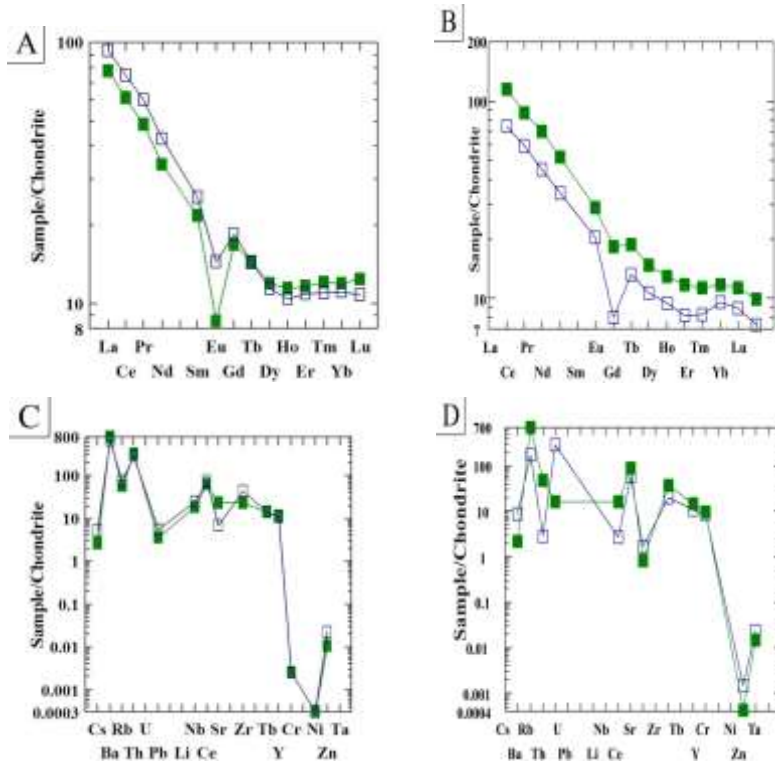


Figure 10. A and C: Spider diagrams of Kuh-e-Faryadoon metarhyolites. B and D: Spider diagrams of Kouli-Kosh metarhyolites.



Microcline are product of destabilization of magmatic Biotite + Plagioclase + Alkali – feldspars during mylonitization. Figures 6 and 7 show petrographic observations on metarhyolites.

### C) Iron Ore

Iron ore is essentially composed of Hematite and Goethite with minor amount of Pyrolusite, Psilomelane, Pyrite, Chalcopyrite and Magnetite. Gangue minerals are Quartz, Siderite, Dolomite, Ankerite and Muscovite. Malachite and Chrysocolla are present in small amount as secondary minerals after chalcopyrite.

Most of iron ore hosted by carbonate rock such as dolomitic and calcitic marbles. Field and petrographical evidences show that dolomitization and ankeritization as well as transformation of calcite and dolomite to siderite and ankerite have been occurred along with iron mineralization in brecciated contact of metarhyolite and marbles.

It seems that Mg expelled from destabilization of biotite during mylonitization is accommodated by calcite to form dolomitic alteration halos around iron ore. The occurrence of muscovite in iron ore is a clear evidence of  $K^{+1}$  transport in mineralizing solution expelled during destabilization of biotite in metarhyolites.

It should be finally noted that petrographic description of other metamorphic rocks like micaschists, marbles, metasandstone were not treated here as they are not interesting in depicting our goals on the origin of iron mineralization. Figure 8 shows petrographic observation on iron ore.

### Geochemistry

Four chemical analysis of metaacid rocks (Table 1) and eight analysis of greenschists (Table 2) as well as nine analysis of iron ore (Table 3) are carried out in order to try to establish a sort of geochemical parentage between iron ore and one of the candidates (greenschist or metarhyolite) giving more evidences on the origin of iron ore. The geochemical studies are all done in Kanpajouh research center in iran and Amdel laboratories of Australia, mostly by Induced Coupled Plasma and XRF methods. In Figures 9-11 chondrite normalized of metarhyolite, greenschists (metabasics) and iron ore are presented. It seem that the general scheme of element variations in iron ore are similar to metarhyolite and metabasic rocks, of course the similarities are more striking for metabasic rocks. We can postulate that iron is preferentially released from basic rocks during hydrothermal activity. The role of acid rocks in providing iron is less prominent. We believe that these geochemical datas are not sufficient

for a concrete postulation on the origin of iron, that is why we have stressed on the field and petrographic evidences. Evidently the subject of geochemical parentage of iron should be treated in future with more geochemical datas.

## Results

Based on all aforementioned data we can conclude that:

1. Kouli-Kosh and Kuh-e-Faryadoon iron deposits can be nominated as of IOCG type deposits.
2. The iron metal for these deposit is produced by reaction of hydrothermal solutions with crustal metamorphic rocks such as greenschists and metarhyolite. Breakdown of minerals such as Epidote, Biotite, Ilmenite, Titanomagnetite, Clinopyroxene causes formation of new minerals and release of iron.
3. Carbonile complexes are the most plausible agent of iron transport in hydrothermal solutions.
4. Reaction of carbonile complexes with  $K^{+}$ ,  $H^{+1}$  and finally with oxygen rich, surface waters results in iron deposition in form of hematite.

## Discussions

The first most important question is the genesis of iron ore in these two areas. By comparison of all geological, petrographical and mineralogical studies of these deposits with the so called iron-oxide-copper-gold deposits elaborated by Porter [10,11], Sillitoe [14], Williams et al [16], strongly suggest that these iron deposits are of IOCG type. Williams et al [16], in a comprehensive review of IOCG type indicate following global characteristics for IOCG type deposits:

1. Cu with or without Au as economic metals.
2. Hydrothermal ore styles and strong structural controls.
3. Abundant magnetite and/or hematite.
4. Fe-oxide with Fe/Ti greater those in most igneous rocks.
5. No clear spatial association with igneous intrusions.
6. Fluid inclusion evidence suggest that geochemically complex brines commonly with carbonic component were involved in IOCG genesis.

Many of the aforementioned characteristics are in clear accordance with specific character of the deoposits under discussion and leaves no doubt that they are of IOCG type. Gold minerals are not detected in these deposits. Some scantly sample have shown to bear 2 ppm of gold. The presence or absence of gold is still to be defined by more detailed studies.

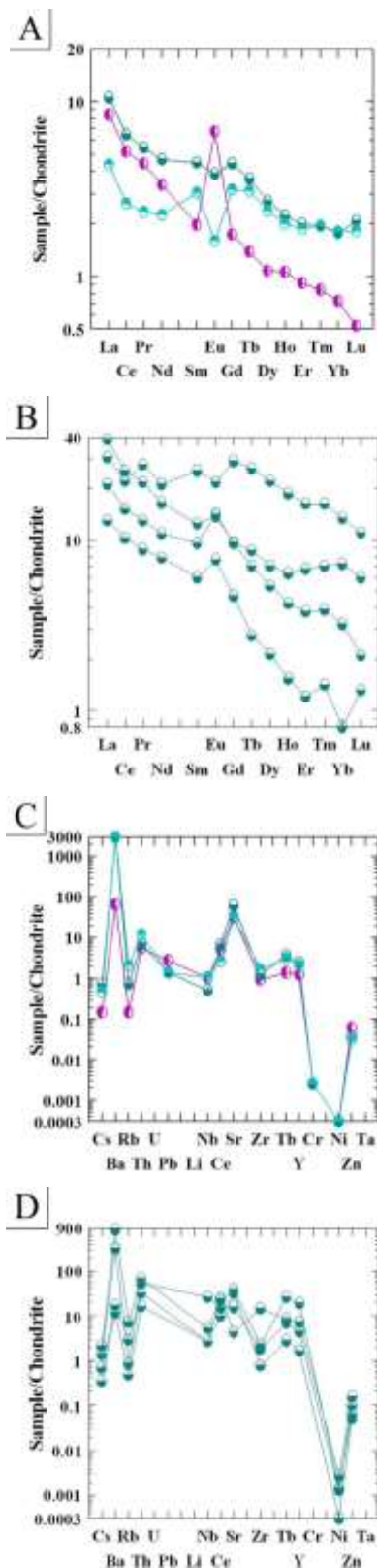


Figure 11. A and C: Spider diagrams of Kuh-e-Faryadoon iron ore. B and D: Spider diagrams of Kouli-Kosh iron ore.

Table 1. Chemical analysis of acid rocks

Acid rocks	Kuh- E- Faryadoon	kouli kosh		
SiO <sub>2</sub>	74.40	68.00	65.9	70.2
Al <sub>2</sub> O <sub>3</sub>	10.30	13.30	10.3	12.6
Fe <sub>2</sub> O <sub>3</sub>	2.37	4.75	3.75	3.29
TiO <sub>2</sub>	0.13	0.37	0.13	0.35
CaO	1.72	0.15	5.48	0.15
MgO	0.24	0.42	0.37	0.19
Na <sub>2</sub> O	0.09	0.12	0.1	0.1
K <sub>2</sub> O	7.46	9.16	6.28	9.28
Cr <sub>2</sub> O <sub>3</sub>	0.01	0.01	0.01	0.01
LOI	2.62	1.37	5.87	1.34
P <sub>2</sub> O <sub>5</sub>	0.02	0.10	0.03	0.10
MnO	0.26	0.12	0.13	0.01
BaO	0.29	0.25	-	-
SrO	0.04	0.01	-	-
Sum	-	-	98.3	97.7
Ag	1	1.00	1	1
Ba	2670	2350	590	2370
Ce	58.8	71.30	56.7	83.6
Co	1.1	2.20	1.7	1.9
Cr	10	10.00	-	-
Cs	0.71	1.46	2.4	0.6
Cu	12	9.00	14	6
Dy	4.55	4.35	3.6	4.96
Er	2.89	2.71	2.07	2.81
Eu	0.74	1.26	0.7	1.59
Ga	11.5	18.10	14	16
Gd	5.16	5.62	4.08	5.77
Hf	4	6.30	3	5
Ho	0.97	0.89	0.7	1
La	28.5	34.00	27.5	42
Lu	0.47	0.41	0.28	0.38
Mo	2	2.00	2	2
Nb	7	8.90	10	10
Nd	24.3	30.30	24.3	37
Ni	5	5.00	7	7
Pb	13	20.00	-	-
Pr	6.66	8.24	6.21	9.58
Rb	194.5	259.00	169	143
Sm	5.01	5.88	4.7	6.7
Sn	3	2.00	2	1
Sr	271	78.70	20	10
Ta	0.8	0.80	0.6	0.7
Tb	0.84	0.83	0.62	0.86
Th	13.85	12.65	12.2	11.4
Ti	0.5	0.50	0.5	0.5
Tm	0.43	0.39	0.34	0.42
U	4.42	2.39	2.97	2.32
V	10	30.00	19	30
W	1	3.00	2	2
Y	25.2	24.20	20	30
Yb	2.97	2.74	2.2	2.8
Zn	5	10.00	11	7
Zr	124	235.00	110	210

**Table 2.** Chemical analysis of basic rocks

Basic rocks	Kuh-E-Faryadoon				kouli kosh			
SiO <sub>2</sub>	41.70	49.70	56.30	48.50	50.30	46.60	51.20	53.80
Al <sub>2</sub> O <sub>3</sub>	13.40	12.80	13.20	13.20	14.00	13.40	15.00	15.00
Fe <sub>2</sub> O <sub>3</sub>	12.05	11.85	9.87	11.50	9.39	12.10	8.84	10.30
TiO <sub>2</sub>	1.65	2.00	0.80	0.87	0.44	0.90	0.36	0.48
CaO	8.69	5.86	4.43	9.85	7.10	10.10	7.73	4.67
MgO	5.83	4.52	3.66	8.37	5.40	7.40	7.01	4.96
Na <sub>2</sub> O	1.43	3.33	3.20	3.70	2.30	3.50	4.10	5.60
K <sub>2</sub> O	0.78	0.99	0.05	0.03	0.38	0.06	0.28	0.18
Cr <sub>2</sub> O <sub>3</sub>	0.02	0.01	0.01	0.04	0.01	0.02	0.05	0.01
LOI	12.5	7.11	3.44	2.95	5.81	3.78	3.17	4.68
P <sub>2</sub> O <sub>5</sub>	0.18	0.21	0.06	0.06	0.05	0.07	0.06	0.06
MnO	0.18	0.16	0.14	0.17	0.14	0.17	0.14	0.15
BaO	0.02	0.04	–	–	–	–	–	–
SrO	0.03	0.01	–	–	–	–	–	–
Sum	–	–	95.10	99.10	95.30	98.00	98.00	99.00
Ag	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Ba	180.5	375	40	30.00	110	30.00	60.00	20.00
Ce	22	38.10	8.30	7.10	7.80	7.60	4.00	5.20
Co	46.2	35.30	25.00	53.40	33.50	54.50	37.10	35.00
Cr	100	60.00	–	–	–	–	–	–
Cs	2.06	2.03	0.10	0.10	0.20	0.10	0.30	0.20
Cu	53	32.00	203.00	116.00	118.00	186.00	111.00	83.00
Dy	3.49	5.87	3.35	3.16	2.09	3.50	1.95	2.06
Er	6.53	3.59	2.40	1.83	1.29	2.11	1.28	1.45
Eu	1.12	1.75	0.72	0.74	0.45	0.79	0.55	0.52
Ga	16.4	18.00	16.00	16.00	15.00	18.00	13.00	15.00
Gd	3.63	5.77	2.83	2.64	1.71	2.96	1.50	1.51
Hf	2.3	4.00	2.00	1.00	1.00	1.00	1.00	1.00
Ho	0.7	1.25	0.77	0.66	0.45	0.70	0.41	0.47
La	9.5	17.00	3.20	3.20	3.50	3.40	1.60	2.00
Lu	0.24	0.49	0.36	0.24	0.18	0.25	0.21	0.21
Mo	2	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Nb	11.3	17.30	10.00	10.00	10.00	10.00	10.00	10.00
Nd	11.8	20.10	6.90	5.00	4.60	5.00	3.00	3.70
Ni	80	26.00	12.00	142.00	26.00	115.00	83.00	25.00
Pb	13	5.00	–	–	–	–	–	–
Pr	2.76	4.67	1.30	1.05	1.03	1.10	0.56	0.75
Rb	48.5	48.00	1.70	1.40	8.00	1.20	4.80	3.10
Sm	3	4.86	2.20	1.70	1.30	1.90	1.00	1.10
Sn	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sr	204	75.40	170.00	210.00	150.00	190.00	310.00	100.00
Ta	0.7	1.10	0.50	0.50	0.50	0.50	0.50	0.50
Tb	0.62	1.00	0.52	0.48	0.31	50.00	0.28	0.28
Th	1.02	2.45	0.70	0.80	1.20	0.70	0.50	0.80
Ti	0.5	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Tm	0.27	0.50	0.33	0.25	0.20	0.29	0.19	0.22
U	0.32	0.89	0.33	0.22	0.60	0.20	0.27	0.41
V	212	275.00	259.00	328.00	300.00	350.00	275.00	347.00
W	1	3.00	2.00	1.00	2.00	2.00	3.00	1.00
Y	18.1	32.30	20.00	20.00	10.00	20.00	10.00	10.00
Yb	1.68	3.10	2.40	1.60	1.40	1.90	1.30	1.50
Zn	92	60.00	65.00	64.00	87.00	74.00	58.00	74.00
Zr	90	155.00	50.00	40.00	30.00	40.00	20.00	20.00



Table 3. Chemical analysis of iron ore

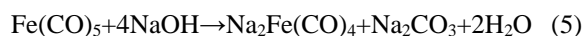
Iron ore	Kuh-E-Faryadoon				kouli kosh				
SiO <sub>2</sub>	3.21	4.28	22.00	5.99	1.51	6.27	6.56	5.04	16.60
Al <sub>2</sub> O <sub>3</sub>	0.30	0.36	0.53	0.26	0.14	1.94	0.08	0.63	0.65
Fe <sub>2</sub> O <sub>3</sub>	68.4	71.30	56.50	70.40	72.60	68.20	58.50	59.70	52.60
TiO <sub>2</sub>	0.04	0.03	0.03	0.01	0.01	0.10	0.01	0.04	0.02
CaO	5.90	1.76	1.10	0.90	0.32	0.46	0.92	1.03	1.75
MgO	0.15	1.09	0.61	0.14	0.06	0.11	0.37	0.30	0.27
Na <sub>2</sub> O	0.04	0.33	0.25	0.10	0.10	0.10	0.10	0.10	0.10
K <sub>2</sub> O	0.04	0.10	0.25	0.04	0.06	0.66	0.04	0.28	0.32
Cr <sub>2</sub> O <sub>3</sub>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
LOI	12.80	10.45	9.84	4.60	4.93	6.97	11.60	11.40	9.42
P <sub>2</sub> O <sub>5</sub>	0.01	0.15	0.05	0.15	0.03	0.13	0.10	0.23	0.15
MnO	7.5	4.74	4.95	1.56	5.93	0.56	5.26	5.95	6.48
BaO	0.01	3.51	2.64	–	–	–	–	–	–
SrO	0.05	0.09	0.04	–	–	–	–	–	–
Sum	–	–	–	84.1	85.6	85.5	83.5	84.6	88.3
Ag	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Ba	232.00	10000	10000	1110	60	2840	40	100	60
Ce	5	6.20	2.50	14.50	26.60	24.50	9.80	13.80	21.30
Co	1.3	0.50	1.30	8.60	19.30	15.40	1.20	2.10	21.40
Cr	10	10.00	10.00	–	–	–	–	–	–
Cs	0.04	0.20	0.13	0.40	0.20	0.60	0.10	0.20	0.20
Cu	13	76.00	6.00	44	217	313	10	8	25
Dy	0.41	1.03	0.91	2.06	3.09	2.69	0.82	1.34	8.40
Er	0.23	0.50	0.47	0.95	1.10	1.67	0.30	0.53	4.03
Eu	0.59	0.34	0.14	1.23	2.83	1.20	0.67	1.00	1.91
Ga	3	2.30	3.20	2	8	6	8	11	11
Gd	0.53	0.96	0.96	2.91	4.93	2.99	1.43	2.61	8.88
Hf	0.2	0.20	0.20	1	1	2	1	1	1
Ho	0.09	0.17	0.17	0.36	0.49	0.54	0.13	0.21	1.59
La	3.1	3.90	1.60	7.80	11.50	14.30	4.80	9.00	11.20
Lu	0.02	0.08	0.07	0.08	0.08	0.23	0.05	0.05	0.42
Mo	7	4.00	2.00	15	26	17	2	2	14
Nb	0.4	0.20	0.40	10	10	10	10	10	10
Nd	2.4	3.30	1.60	7.70	17.60	11.70	5.60	6.90	15.20
Ni	5	5.00	5.00	21	26	44	5	5	24
Pb	10	5.00	5.00	–	–	–	–	–	–
Pr	0.61	0.08	0.32	1.79	3.75	2.99	1.21	1.61	3.08
Rb	0.5	2.60	7.30	3.00	2.60	25.60	1.70	8.40	10.00
Sm	0.46	1.04	0.70	2.20	5.30	2.90	1.40	2.10	5.90
Sn	1	1.00	1.00	1	1	2	1	1	1
Sr	405	756.00	366.00	180	300	50	390	410	450
Ta	0.1	0.10	0.10	0.5	0.5	0.5	0.5	0.5	0.5
Tb	0.08	0.21	0.18	0.41	0.65	0.50	0.16	0.30	1.53
Th	0.23	0.29	0.51	2.2	1.3	3.0	0.7	1.2	1.4
Ti	0.5	0.50	0.50	0.5	0.5	0.5	0.5	0.5	0.5
Tm	0.03	0.07	0.07	0.14	0.14	0.25	0.05	0.06	0.58
U	4.14	3.61	2.38	3.31	2.12	4.03	0.92	1.53	2.70
V	5	5.00	5.00	22	42	64	5	9	16
W	1	1.00	3.00	4	9	3	2	4	2
Y	2.7	5.50	4.70	10	10	20	10	10	40
Yb	0.18	0.44	0.45	0.8	0.8	1.8	0.2	0.4	3.3
Zn	28	18.00	14.00	46.00	73.00	72.00	24.00	20.00	30.00
Zr	5	7.00	9.00	10	20	90	10	20	20

Three major questions are to be reviewed in these deposits:

1. What is the origin of iron metal?
2. What is the mechanism of hydrothermal transport of iron?
3. What is the mechanism of deposition of iron ore?

The most important result of this study was the observation of mineral instability to release iron from their lattice during mylonitization. Petrographical observation clearly demonstrate that CO<sub>2</sub>, H<sub>2</sub>O, K<sup>+</sup> bearing solutions are the main agents of destabilization of Epidote, Feldspars, Biotite, Clinopyroxene, Ilmenite and Titanomagnetite. Iron, therefore, is released certainly by reaction of fluids channeled by shear zones with crustal metamorphic rocks.

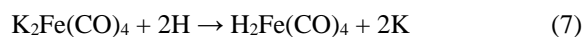
The fluid were rich in CO<sub>2</sub> so the most possible complex for iron transport is carbonile complexes such as Fe(CO)<sub>2</sub>, Fe<sub>2</sub>(CO)<sub>9</sub>, Fe<sub>3</sub>(CO)<sub>12</sub> and Fe(CO)<sub>5</sub>. Andlieva et al [1], McCarley et al [7], Huheey [4], Youchang et al [17], Guangxian et al [2], also stressed on the role of carbonile complexes in transport of iron in hydrothermal solutions. According to Kleinberg [5,6], Huheey [4], and Hieber et al [3]. The pentacarbonile iron complex Fe(CO)<sub>5</sub> is readily solved in solution rich in K<sup>+</sup> or Na<sup>+</sup>. Solution reaction is as follows:



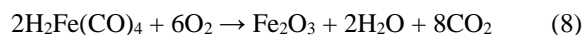
Or



In the case of our deposits the second reaction is more plausible, as we showed our hydrothermal solutions are rich in K<sup>+</sup>. If K<sub>2</sub>Fe(CO)<sub>4</sub> complex reacts with H<sup>+</sup> in hydrothermal solutions H<sub>2</sub>Fe(CO)<sub>4</sub> is formed according to following reaction:



If fugacity of oxygen is raised in upper portion of crust due to mixing of hydrothermal solution with surface atmospheric water hematite is formed according to following reaction:



Deposition of iron and manganese will augment Mg in hydrothermal solution which in turn cause dolomitization of host calcitic marble.

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