Formation of Magnesian Iron Skarn at Bashkand, SW of Soltanieh, NW Iran

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Abstract
Bashkand iron deposit is located 16 km southwest of Soltanieh, in northwestern part of Central Iran structural zone. Rock units in the area include alternations of phyllite, slightly recrystallized dolostone and meta-tuff of Kahar Formation as well as subvolcanic bodies of granite composition and dolerite-diabase dykes intruding Kahar Formation. Mineralization in the deposit has the same trend as contact of the intrusive body. Ore textures are vein-veinlet, diffusion, replacement, banded, dendritic, residual and massive. The main ores at Bashkand are magnetite, hematite (specularite), pyrite and chalcopyrite.

Secondary minerals include goethite, limonite, lepidocrocite and malachite. Gangue minerals are quartz,calcite, garnet, pyroxene, amphibole, epidote, serpentinized forsterite, talc, chlorite, tourmaline, actinolite and tremolite. Epidotization, actinolitization, sericitization, serpentinization, carbonatization and silicification are the most important alteration types in the area. Based on congruency of mineralization with the contact of granitic intrusions and carbonate-dendritic rocks, textures such as banded, dendritic, residual and massive, occurrence of magnetite simultaneous with garnet formation, replacement of epidotic and actinolitic pyroxene for dolomite, occurrence of forsterite casts filled with antiguritic serpentine, presence of alterations such as actinolitization, epidotization, carbonatization, serpentinization and silicification, it is likely that the Bashkand iron mineralization formed as a result of intrusion of a subvolcanic granite into the Kahar Formation. Main oxides distribution patterns in igneous rocks in the surroundings of the deposit suggest that they were formed in an oceanic island environment.

Keywords: *Iron mineralization, alteration, textures, oceanic island, Bashkand, Soltanieh*

Introduction
Bashkand iron deposit is located 16 km southwest of Soltanieh, 54 km southeast of the city of Zanjan in northwest Iran between 48˚40´00˝ - 48˚41´00˝ longitude and 36˚24´19˝ - 36˚26´00˝ latitude. Nabavi (1976) suggested that the region is situated in Western Alborz – Azarbaijan zone. However, recently, Sheikholeslami et al. (in press) proposed that the region is in the edge of northwest Central Iran structural zone. Other iron deposits in the region include Arjin (Andarz, 2006), Shahbolaghi (Esmaili, 2006), Gouzal-darreh and Kardaragh (Ghorbani, 2002).

Discussion
Geology
Based on field and microscopic studies, rock units in the area can be divided into four groups that according to age include (Fig. 1):

1) Alternation of recrystallized dolomite and phyllite with intercalations of meta-siltstone, and meta-tuff belonging to upper parts of Kahar Formation.

2) Recrystallized limestone layers of Bayandor Formation which rest over the Kahar Formation through a normal fault.

3) Subvolcanic granitic body that cuts Kahar layers, so that phyllite xenoliths can be noticed within the body (Fig. 2).

4) Doleritic-diabasic dykes with unclear source and age which cut Kahar and Bayandor formations.

Kahar and Bayandor layers have N35-50W trend and S30-50E dip. The majority of faults and fractures in the area which triggered the movement of the host rocks have N35-50W trend.

Most of the ore zone trends conform to this trend. There are also some faults and fractures with NE-SW trend which mainlymake the boundaries between the layers.

Ore mineralization

Ore mineralization in the Bashkand area occurred between debris and carbonate units particularly wherever the intrusion body is outcropped (Fig. 2). In this area, ore formation has occurred wherever subvolcanic tectonized microgranular porphyritic body intruded recrystallized dolomite, meta-siltstone and phyllite units. Ore zones have a range of thickness from millimeters in the banded parts to 7-8 meters in the massive parts. Joints and fractures cutting foliation of the host rocks are suitable places for ore mineralization; however, those are less important as compared with the boundaries between recrystallized dolomite, metasiltstone and phyllite.

Meinert et al. (2005) believed that in skarns related to intrusion body, exist bearing there is a relationship between replacing, crystallization and cooling events of intrusion body with metamorphism, metasomatism and retrograde alteration in surrounding rocks. In other words, during intrusion of the body, surrounding rocks undergo metamorphism. Recrystallization arising from metamorphism and phase change shows the protolith components. Local bimetasomatism and circulating fluids form various calc-silicate minerals (reaction of skarn and skarnoid). Crystallization and releasing of liquid phase form metasomatism skarn.

Cooling of intrusion, separating of volatile phase and circulating of cooler meteoric waters, cause retrograde alteration of calc-silicate minerals that had formed during metamorphism and metasomatism stages. It is noted that in deeper parts, metamorphism is more extensive and the temperatures are higher; while in shallow parts, retrograde alteration has more extent (Meinert et al., 1992).

In conformity with the above-mentioned sequence, it must be said that metamorphic halos in the Bashkand area were not found. This could be due to the following reasons:

1) The intrusive body in the Bashkand area was quite fractionated, acidic and therefore had experienced a very low temperature

2) The magma intruded the shallow parts of the crust, forming a subvolcanic body.

3) The surrounding rocks, before intrusion of the body, during an older phase (probably Katangai), metamorphosed in greenschist facies, therefore, the intrusive could not increase the metamorphic grade and could not create a metamorphic halo.

However, during crystallization of the intrusive, bands of garnet and pyroxene with some magnetite formed within the recrystallized dolomite, phyllite, meta-siltstone and meta-tuff units (Fig. 3). In the next step, simultaneous with cooling of the intrusive and separation of vapor phase and circulation of cooler meteoric water, retrograde alteration caused garnet turn into epidote, olivine into serpentine (antigorite) and pyroxene into amphibole, serpentine and epidote. Most part of ore mineralization occurred in this step. Finally, siliceous and carbonaceous vein-veinlet cut all of the assemblage.

Ore structure and texture

Ore textures in the area include banded, diffusion, replacement, massive and dendritic.

Banded texture is mostly seen in parts where host rock include intercalation of recrystallized dolomite, meta-siltstone and meta-tuff (Fig 3). Ciobanu and Cook (2004) reported similar texture from Ocna de Fier - Dognecea ore field (a Pb-Zn deposit). Replacement is seen in recrystallized carbonate parts (Fig. 4). Dendritic texture is observed in both recrystallized carbonate and phyllite (Fig. 5). Within the rims of the veins, sulfide minerals such as pyrite and chalcopyrite can be seen.

Meta-tuffic and meta-siltstone parts have scatter magnetite crystals which cut the rockforming minerals. In some instances, magnetite crystals together with potassic alteration that has originated from the intrusion body, intrude these parts (Fig. 6). Since the recrystallized dolomite, meta-tuff, meta-siltstone and phyllite have each a thickness of less than 10 cm, usual regional zoning of skarn deposits is seen in the Bashkand area in millimeter to centimeter scale and has alternately been repeated.

Mineralogy

The main minerals at the Bashkand deposit are magnetite, hematite (specularite), pyrite and chalcopyrite. Secondary minerals include goethite, limonite, lepidocrocite, chalcocite and covellite. Gangue minerals are quartz, calcite, pyroxene, garnet (spesartin), amphibole, epidote, chlorite, alumino-silicate, tourmaline, serpentine, clay minerals (according to XRD analysis illite and kaolinite), actinolite and tremolite. According to field and microscopic studies, ore paragenesis includes magnetite, hematite, pyrite and chalcopyrite, chalcocite, covellite, goethite, malachite, azurite and limonite.

Alteration

Alteration in igneous rocks include epidotization, sericitization, carbonatization and chloritization (sosoritic alteration) (Fig. 7). In phyllite include sericitization and in recrystallized dolomite include epidotization, carbonatization, actinolitization (Fig. 8) and serpentinization. During alteration of olivine and pyroxene serpentine, iron is released (Fig.9).

Tectonic environment

Four samples were chosen for ICP analysis and drew tectonic environment diagram.

According to TiO2, MnO*10, P2O5*10 diagram, Bashkand iron deposit formed in an island arc environment (Fig. 10).

Conclusion

Considering the mineralization being parallel to the contact of metamorphosed carbonate and detrital rocks adjacent to the intrusion, showing textures such as banded, dendritic, residual and massive, replacement of epidotic and actinolitic pyroxene for dolomite, presence of alterations such as actinolitization, epidotization, sericitization, carbonatization and silicification, it is likely that the Bashkabd iron mineralization formed due to intrusion of granitic body and related fluids related into the Kahar Formation. The deposit formed in an island arc environment.

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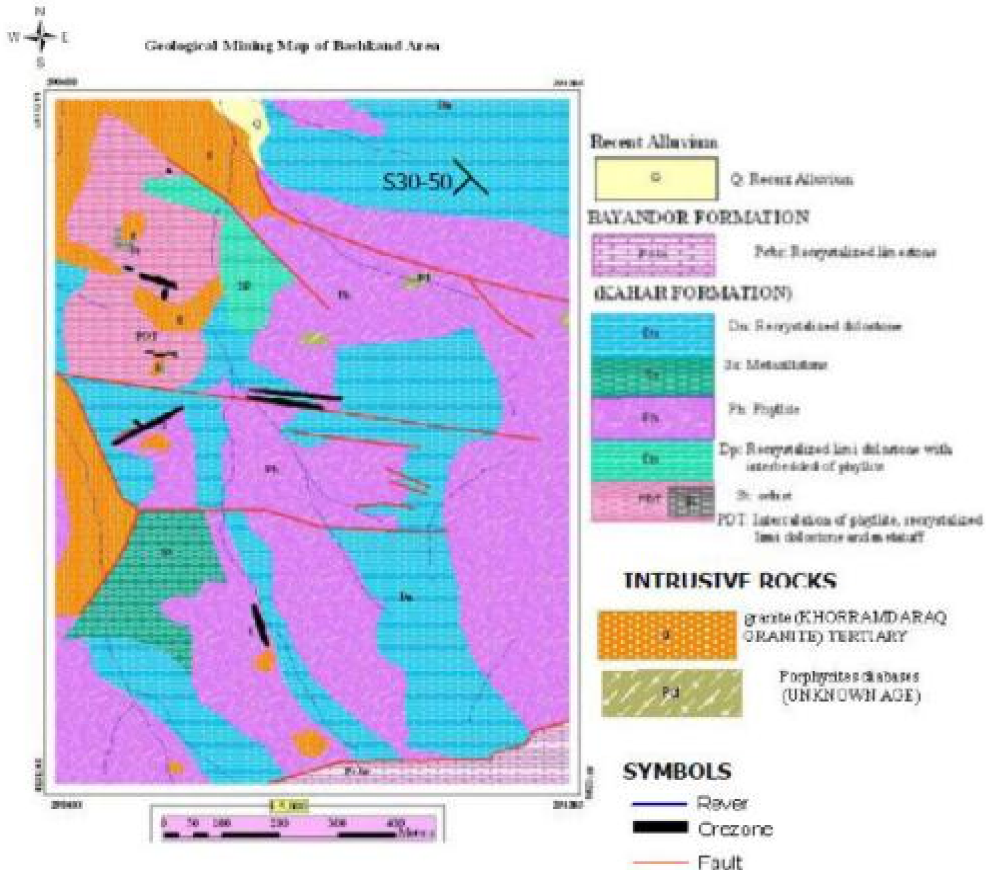

Fig1: Geological map of Bashkand area1:5000.

Fig. 2: Granitic subvolcanic, phyllite, recrystallized dolomite and banded skarn at Bashkand.

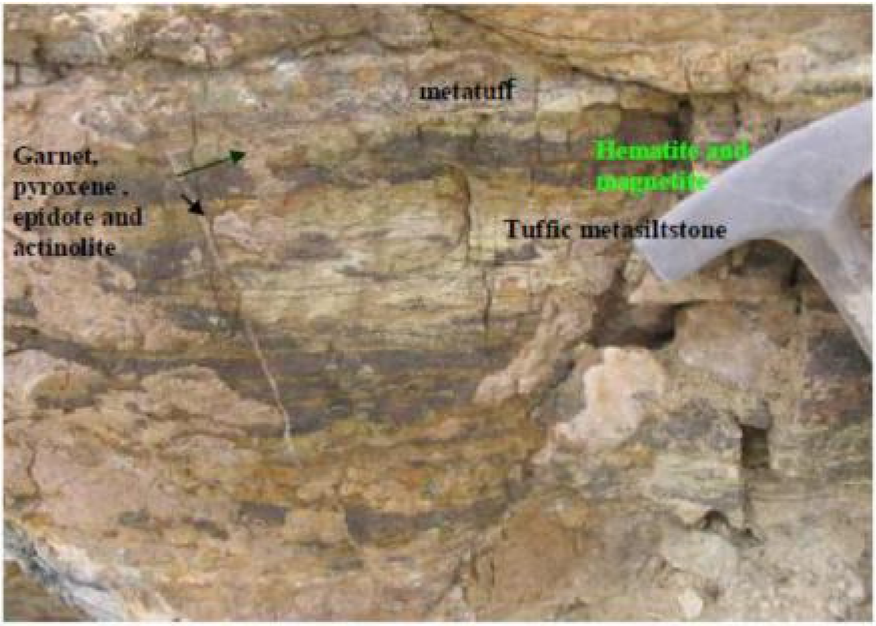

Fig. 3: Bands of ore, skarn minerals and metamorphic host rocks.

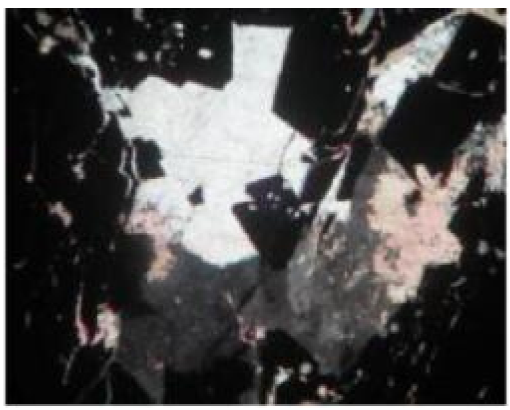

Fig. 4: Replacement of mineral host rock by magnetite.

Fig. 5: Dendritic texture of ore in the recrystallized dolomite.

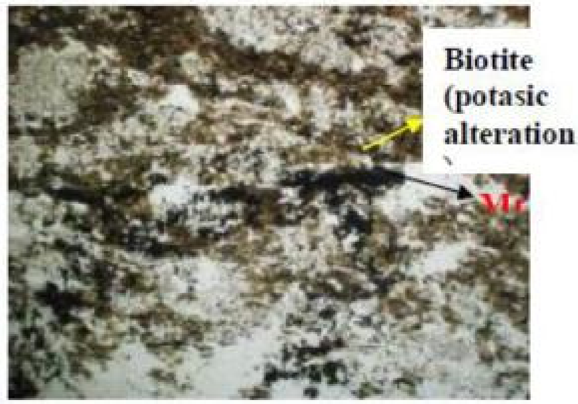

Fig. 6: Assistance of magnetite with potassic alteration (brown bands in the picture) in phyllite.XPL light, 10 x.

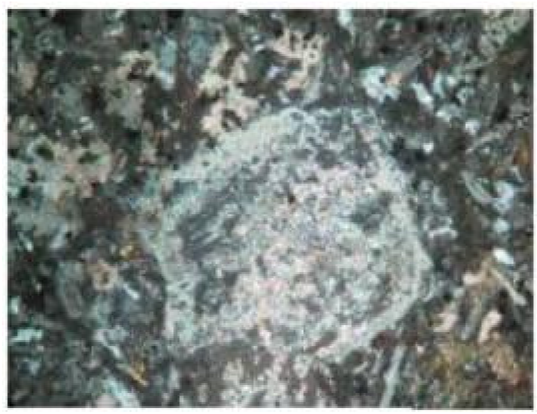

Fig. 7: Sosoritization in the granite subvolcanic.

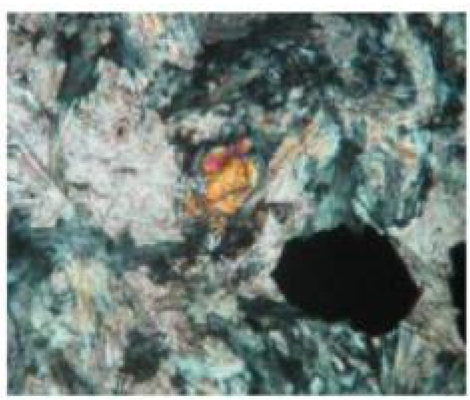

Fig. 8: Actinolitization and epidotization in impure and tuffic recrystallized dolomite.

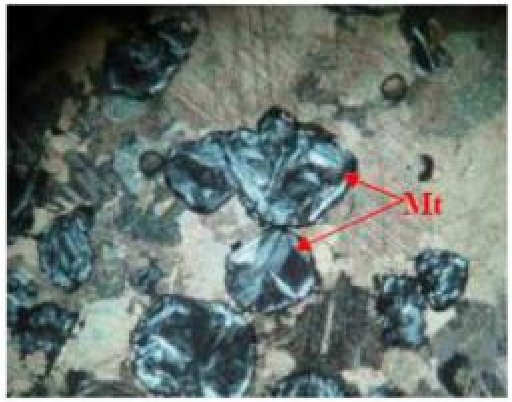

Fig. 9: Changing pyroxene and olivine to serpentine and to be released of Iron.

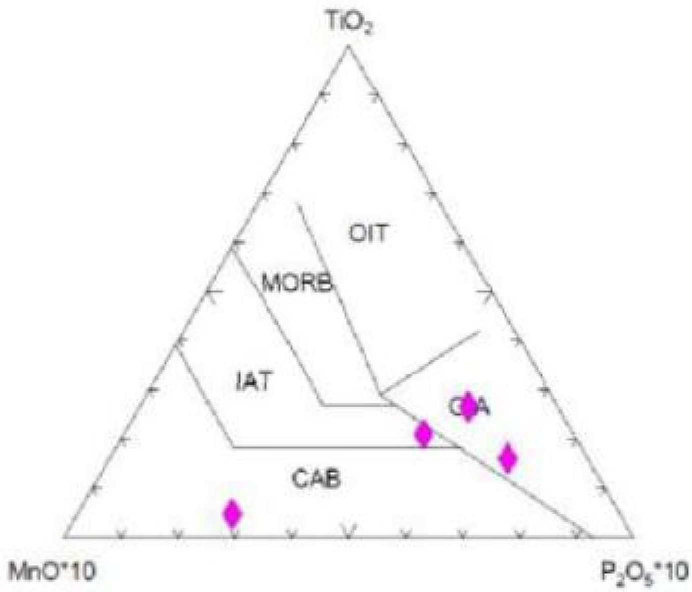

Fig. 10: Diagram showing tectonic environment. CAB: Calcalkaline basalts of island arc. IAT: Tholeiites of island arc. MORB: Mid Ocean Ridge Basalts. OIA: alkali basalts of Island arc. OIT: Tholeiites of island arc. Bon: Boninites (Mullen,