Tectonic Setting and Petrogenesis of Darreh-Zereshk Granitoids (SW Yazd, Iran) and Comparison with Some World Skarn Granitoids

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Abstract

Many studies have shown that there is a systematic correlation between the composition of plutons worldwide and the metal content of associated skarns. This paper is the first attempt on such a study to Darreh-Zereshk granitoids and their related skarns.

The Darreh-Zereshk granitoid intrusions, 60 km southwest of the Yazd City (Iran), are located in the Sahand-Bazman Tectonomagmatic Belt. This belt is well known for its porphyry copper deposits, and in some parts is hosted by calcic skarn zones. According to geochemical studies, strong negative anomalies for Nb, Ta, P and Ti, and enrichment in the REE, LILE, Ba, Rb, Sr, and Pb for the mineralizing igneous rocks suggest they are of calc-alkaline metaluminous to weakly peraluminous I-type range in composition from granodiorite to quartz-diorite like most worldwide skarn granitoids. REE patterns, major, and trace element data suggest that these rocks were derived from partial melting of enriched upper mantle, modified by variable crustal contamination. Intrusion of Darreh-Zereshk granitoid intrusions into the Cretaceous limestone of Taft formation has developed skarn-type mineralization.

A syn-collisional tectonic setting is proposed on the basis of field evidences and trace element geochemistry. Plots of harker diagrams suggest that Darrehzereshk granitoids are result of a magma differentiation. Major and trace elements when plot on binary diagrams, especially, MgO vs SiO_2, FeOt + CaO + Na_2O /K_2O vs. SiO_2, Fe_2O_3/Fe_2O_3 + FeO vs. SiO_2 and V vs. Ni, are resemble the geochemical characteristics of plutons associated with worldwide Cu and possibly Au skarns. Furthermore this skarn like some typical copper skarn commonly is zoned, with massive garnetite, near pluton, increasing pyroxene away from the contact, and finally vessuvianite and wollastonite occuring near the marbel contact. This suggests new exploration possibilities for copper and gold in the Darreh-Zereshk district.

Key words: *porphyry copper; skarn; SW Yazd; granitoid; geochemistry*

1. Introduction

Darreh-Zereshk porphyry copper deposit (23 Mt; 0.9% Cu) is located about 6o km southwest of Yazd City within the central part of the Sahand-Bazman Tectonomagmatic Belt (SBTB), at about 31° 31′ to 31° 42′ N and 53° 45′ to 53° 53′ E [1]. The petrology, mineralogy, geochronology and structural characteristics of Darreh-Zereshk is discussed by Zarasvandi [2]. Since porphyry copper deposits are the best known from this district and skarn deposits are of secondary importance, only a few data is reported about mineralogy and geochemistry for the Derreh-Zereshk skarns [3][4][5][6]. The relationship between skarns and associated granitoid, the geochemistry and mineralogy of individual skarn zones and the potential for different types of mineralization associated with the Darreh-Zereshk granitoid have not ever been investigated up to now. However, experimental and field studies in other parts of the world have shown a systematic association between the mineralogical and chemical composition of plutons and the metal content of associated skarns [7]. The present study is the first report of correlation between Darreh-Zereshk granitoids and their associated skarns.

2. Geology

The Darreh-Zereshk district is located within central part of SBTB. This belt is the result of subduction between the Iranian and Afro-Arabian plates during the Mesozoic. Most of the porphyry copper deposits in central Iran are associated within the SBTB, which forms a NE-SW linear intrusive-extrusive complex with approximately 2000 km lenght. Volcanic activity in the SBTB during Eocene led to widespread extrusion of trachy-basalt, andesite and dacite as lavas and pyroclastic rocks. These rocks were in turn intruded by granitoids of Oligocene-Miocene age, which are host to the copper mineralization [8].

The oldest rocks exposed in the study area are Lower Cretaceous Sangestan Formation (conglomerate, sandstone, and shale) in the western and eastern parts of the Darreh-Zereshk district. This Formation was covered unconformably by the Cretaceous Limestone of Taft Formation (Tf.) [9]. The Mesozoic sedimentary sequence is in turn overlain by the Eocene volcano-sedimentary series (rhyolitic tuffs, andesitic lavas and pyroclastic rocks). These rocks were in turn intruded by granitoids of Oligo-Miocene age (granite, granodiorite, quartzmonzodiorite, quartzdiorite and diorite); host igneous rocks for copper mineralization in the study area. Intrusion of these granitoid stocks into the Cretaceous carbonates appears to have been responsible for contact metamorphism and skarn formation. The skarns show simple mineralogy (garnet + pyroxene +quartz+ calcite +epidote) and contain both endoskarn formed within the calcareous wall rock, and exoskarn formed within the associated granitoids.

3. Petrography

A total of 40 samples have been collected from the Darreh-Zereshk granitoid stocks, unaltered Tf. Limestone and various parts of the skarn zones for petrographical examinations; polished and thin sections were prepared for all of these samples. Sixteen representative samples of the least altered igneous and sedimentary rocks analyzed by X-ray fluorescent (XRF) in the Kian Teif Zagros Laboratory in Isfahan, Iran. REE data published Zarasvand incorporated into the data set [10].

Surface sampling and drillings show that the Darreh-Zereshk deposit lies within a granitoid composite stock from granodiorite to quartzdiorite-monzodiorite rock types [2][5], and make up approximately 80% of the exposed stocks in the study area. They have a similar mineralogy and appearances, and occur in scattered outcrops mainly in the central part of the study area; principal host for Cu ore mineralization. They are light to dark gray color, medium grained with equigranular to porphyry texture, and composed mainly of plagioclase (50-70 vol.%), quartz, K-feldspar and ferromagnesian minerals (amphibole and biotite, 5 vol.%) phenocrysts in a fine matrix of the similar mineralogical composition. Twinned and zoned plagioclase phenocrysts are variably altered to sercite, calcite, epidote and clay secondary minerals. Accessory minerals include apatite, titanite, zircon, magnetite and various opaque phases (pyrite, chalcopyrite, bornite), which occur randomly, both in the silicate phases and interstitial to them. Sulfide disseminations and quartz veins filled with Cu-Fe minerals are variably distributed through the rocks.

4. Alteration

Porphyry-style alteration and mineralization in the both igneous and sedimentary rocks occurred in the Darreh-Zereshk deposit. Hydrothermal alteration of igneous rocks (potassic, phyllic, propylitic and arjillic alterations; pyrite, chalcopyrite and magnetite mineralization are located within the potassium silicate and phyllic zones.) has been summarized by Zarasvandi [2]. The impure carbonate sedimentary rocks around the granitoid porphyries have undergone three stage changes: (1) the thermal metamorphism of Tf. Limestone, in which no component were added to the rocks yielded wollastonite and diopside; the XRF analyses results of Tf. Limestone showed CaO and SiO_2 to be the major nonvolatile components of the rocks, with only minor Mg and less than 1% Al_2O_3. (2) contact metamorphism led to pervasive replacement of iron-free limestone by iron calc-silicate and oxides (andradite, magnetite) near the intrusive body. (3) hydrothermal alteration of early-formed minerals such as andradite by secondary minerals (chlorite, quartz and calcite) accompanied by the filling of fractures with silicates and pyrite- chalcopyrite sulfides.

5. Skarn formation and mineralization

Darreh-Zereshk calcic skarn consist both exoskarn and endoskarn. Three major zones in the exoskarn delineated in the study area. (1) The garnetite zone borders the altered intrusive and consist mainly of massive andradite garnet and diopside prograde assemblage minerals, which can be correlated with potassic alteration within endoskarn intrusions, plus later retrograde products such as quartz, calcite, chlorite and magnetite. Sulfide (pyrite and chalcopyrite) occur mainly as veinlets, accompanied by retrograde alteration minerals. This zone is coeval with endoskarn phyllic alteration (2) Silica-Pyrite zone generally lies above and/or outside the garnetite zone and is characterized by quartz veining, pyrite and minor clay; much more calcite remains than in the garnetite zone. (3) Peripheral zone generally lies outside the garnetite zone and consist of wollastonit, diopside and tremolite mineral assemblages. These minerals are typically low in iron and resulted from recrystalization of impure limestone caused by heated fluid along fractures.

6. Geochemistry

According to the modal QAPF classification [11], Darreh-Zereshk igneous rocks are mainly in the range of granodiorite to quartzmonzonite/quartz-monzodiorite. Geochemical analysis of Darreh-Zereshk display SiO_2 and MgO contents ranging 57.63 to 74.81 and 0.34 to 2.23 wt.%, respectively. With increasing SiO_2, there is a general increase in K_2O, Zr, Y, Nb, Ba, Ta, REE and a corresponding decrease in Al_2O_3, Fe_2O_3, TiO_2, CaO, MgO, MnO and Sr. These trends are consistent with fractional crystallization of plagioclase, hornblend and magnetite.

On the AFM diagrams [12], Darreh-Zereshk granitoid rocks are subalkaline and plot in the calk-alkaline field. Classification of these rocks by the aluminium saturation index [13] indicates that most of the igneous rocks are metaluminous to peralminous. The peraluminous nature of these rocks attributed to differention of hornblend. The SiO_2 and Na_2O contents, molecular A/CNK ratio, K_2O/Na_2O ratio, abundance of Cr and Ni, Key modal minerals (such as horblend and titanite), distribution patterns of REE on chondorite-normalized spider diagrams and trace element discrimination diagrams [14], all suggest that Darreh-Zereshk I-type granitoid formed in a syncollisional volcanic arc tectonic setting.

7. Comparison of the composition of the Darreh-Zereshk granitoids with world skarn granitoids

The correlations between pluton bulk composition and type of the skarn formed have been described by many workers. These authors suggested that systematic correlation of magma composition with skarn type is a strong evidence for a direct genetic connection between magmatic processes and mineralization. The major and trace element composition of the Darreh-Zereshk granitoids was compared with the worldwide average of granitoids associated with Fe, Cu, and Au skarns [7], and with skarn granitoids of the Boc a Ocna De Fier, Romania [15]; McKenzie, Canada [16]; Millstream, Canada [17]; British Columbia, Canada [18]; Irian Jaya, Indonesia [7]; RNGB Caries, Spain [19] and Celebi, Turkey [20] using Harker diagrams similar to those used by Kusku [20]. In these diagrams, the distinction between the Cu, Fe and Au-skarns and other skarn granitoids is best observed in SiO_2 vs. MgO, SiO_2 vs. K_2O, SiO_2 vs.FeO+CaO+Na_2O/K2O and SiO_2 vs. total alkalies. For comparison purposes, the geochemical data for Darreh-Zereshk granitoids were plotted using different symbols along with the averages of the other skarn districts (Fig.1). As illustrated in Fig.1 the mean MgO (1.19%), K_2O (2.98%), K_2O+Na_2O (5.2%) and FCN/K ($FeOt+CaO+Na_2O/K_2O$) values plot close to the Fe, Cu and Au-skarn granitoid averages. The K_2O/MgO ratio can also help discriminate between the skarn granitoids too. K_2O/MgO ratio of Darreh-Zereshk granitoids (2.5) is close to ratios for Fe- and Cu-skarn granitoids (1.8-2.9), suggesting a transition between Fe- and Cu-skarn granitoid signatures. Furthermore, individual Darreh-Zereshk granitoid samples mostly overlap the area occupied by McKenzie Cu-skarn, Millstream Cu-Fe skarn and Ertsberg Cu–Au-skarn granitoids. Therefore, it can be suggested that the Darreh-Zereshk granitoids could be associated with the Fe, Cu and Au skarns. In terms of alumina saturation, Al-saturation index of Fe-skarn granitoids ranges from 0.36 to 1.09 which interpreted as skarns derived from mantle granitoids with little or no crustal interaction. The Al-saturation index of the Darreh-Zereshk granitoids is between 0.9 to 1.1; therefore, unlike the average Fe-skarn granitoids, this suggests more crustal interaction.

Another approach in understanding the relationship between skarns and associated granitoids is to examine the trace element content. For the magmatic rocks, it is known that Rb should increase as crystallization and differentiation proceeds. Fe-skarn granitoids are characterized by lower Rb content (39 ppm) than Cu-skarn (103 ppm) and Au-skarn granitoids (69 ppm). The mean Rb content of the Darreh-Zereshk granitoids (54 ppm), which is high for Fe skarn granitoids but are close to Au skarn granitoids. This suggests that the Darreh-Zereshk granitoid associated with skarns have more crustal component compared to world skarn granitoids. This is probably due to mixing of an underplating mafic magma with felsic magma at shallower depths. Of the skarn plutons, V and Ni are highest in Fe-skarn granitoids

(Ni=35, V=152). The average Ni content of Darreh-Zereshk granitoid (15.36 ppm) is less than the average for Fe-skarn granitoids. The presence of high Ni contents in the presence of high Rb contents seems to be a result of mixing of a mantle-derived (or a mafic) magma with a highly differentiated crustal melt (crustal interaction), like most granitoids of the SBTB.

8. Conclusion

Intrusion of the calc-alkaline metaluminous to peraluminous I-type granitoids, formed in a typical syn-collisionall volcano-plutonic arc tectonic setting, into the Cretaceous Limestones has developed skarn mineralization. The geochemical characteristics of these granitoid are similar to some of the Cu-, Fe-, Cu-Au- and Fe–Cu-skarn granitoids in Romania, Canada and Spain. Although from ancient historical times, only iron has been mined from the Darreh-Zereshk skarns, the present study suggests that Cu-rich and Au-rich skarns may be present as well. Thus, a study of basic field relations and igneous petrology can indicate new avenues for exploration. This method can be established as an exploration strategy for various skarn deposits in Iran by defining petrogenetic and tectonic characteristics of known igneous rocks associated with well-known skarn mineralizations, and then predicting the types of skarn deposits that might be present in addition to those already known and explored.

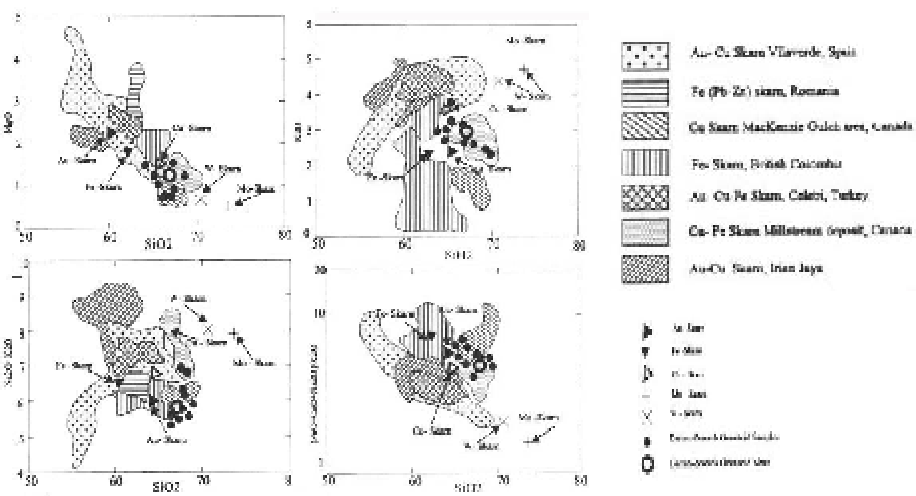

Fig. 1. Harker-type MgO vs. SiO_2; K_2O vs. SiO_2; total alkalies vs. SiO_2, and total iron+CaO+Na_2O/K_2O ratio vs. SiO_2 diagrams for the Darreh-Zereskh granitoids

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