Geochemistry and Petrography of the Meiduk porphyry copper deposit, Kerman, Iran

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Abstract: The porphyry copper deposit Meiduk is situated in Kerman province, 132 Km northwest of the Sarcheshmeh porphyry copper deposit, Iran, and intruded into Eocene volcanic rocks of andesite, andesitic-basalt and dacite and Eocene tuff and agglomerate of andesitic to dacite composition (Razak complex). Based on the petrography and geochemistry, it is suggested that the Meiduk porphyry stock consists mainly of granodiorite, quartz diorite and diorite rocks. It also contains a number of late porphyry dikes with a NS trend. Mineralogically, Meiduk porphyry rocks contain plagioclase, amphibole, biotite and quartz. Sericite, chlorite, epidote and magnetite are secondary phases. Meiduk porphyry rocks are petrochemically K-enriched and belong to high-calc-alkaline to shoshonitic series. They display enrichment of large ion lithophile elements (LILE) Rb, K, U, Th, Sr, Pb and depletion of high field strength elements (HFSE) Nb, Ta, Ti and the heavy rare earth elements (HREE) and Y without Eu anomalies. These characteristics demonstrate that subduction played a dominant role in their petrogenesis and residual garnet was left in the magma source. The results of these calculations indicate that the Meiduk porphyry copper deposit were formed within a tectonic framework of a volcanic arc, after the collision of the Arabian and Iranian plates, and the quartzdiorite and granodiorite intrusions (Meiduk porphyry) were emplaced during a late orogenic stage of the post-collisional tectonic setting and is related to subduction of the Neotethian oceanic crust beneath the central Iranian volcanic belt.

Key words: geochemistry, Meiduk porphyry copper deposit, post-collisional tectonic setting, central Iranian volcanic belt.

INTRODUCTION

The Meiduk porphyry copper deposit is one of the major copper deposits in the Kerman province and is associated with calc-alkaline intrusive rocks in the central Iranian volcanic belt (CIVB) or Urumieh-Dokhtar magmatic arc (UDMA). The southeast segment of the this belt in the Kerman province was named by Dimitrijevic (1973) Dehaj-Sarduieh belt. The CIVB belt which was first identified by Stockline and setudienia (1972), consist of alkaline and calc-alkaline volcanic rocks and related intrusive (I-type) and was formed by subduction of the Arabian plate beneath central Iran during Alpian orogeny (Stockline and Setudenia, 1972; Berberian, 1976, 1983; Berberian and King, 1981).

Porphyry copper mineralization occurs in close proximity to granitoid intrusive rocks of Miocene age in the Central Iranian volcanic belt (CIVB; Fig. 1). In addition to CIVB, two major tectonic elements including the Sanandaj - Sirjan metamorphic zone and the Zagros fold thrust belt are recognized in western and southwestern Iran (Alavi, 1994; Mohajjel et al., 2003). More than 50 porphyry-vein type deposits occur in this belt (Taghipour 2007). The length of the Dehaj-Sarduieh volcano-plutonic belt is approximately 450 km with an average width of 80 km. The Sar Cheshmeh porphyry copper deposit is the largest deposit in the area with 1200 Mt of ore at 0.69% Cu and 0.03% Mo (Shahabpour, 2000). The Meiduk porphyry copper deposit is located in the Shahr-Babak area in Kerman province, Iran. This deposit is located 135 km NW of the Sar Cheshmeh porphyry copper deposit (Fig. 1). Preliminary mineral exploration in this area was carried out in 1967-1970 by Parjam and Metallgesellschaft (Hassanzadeh, 1993). So far, more than 50 diamond drill holes with a maximum depth of 1013 m have proved the existence of the size-able and potential porphyry copper...
mineralization at the Meiduk deposit (Taghipour, 2007). The orebody contains 170 million tons of ore, with an average grade of 0.86% Cu, 0.007% Mo, and 1.8 ppm Ag. Supergene enrichment blankets average approximately 50 m thickness and comprise the primary source of Cu ore (Taghipour, 2007).

This paper presents petrography and new geochemical data, to better understand the origin, tectonic setting, and metallogenic of the Meiduk deposit.

Regional Geology:

The oldest units in the area (Fig. 2) are Cenomanian Turonian calcareous flysch (Saric et al., 1971) that are unconformably overlain by Paleocene Kerman conglomerate (Dimitrijevic, 1973) and subsequently covered by Eocene flysch (Saric et al., 1971; Dimitrijevic, 1973). All of these units are in turn covered by Paleogene volcanic complexes. Three volcanic complexes cross-cut these Cretaceous - Paleocene rocks in the Miduk area (Taghipour, 2007) (Fig. 2).

The oldest, Bahraseman volcanic complex formed in the Lower Eocene and began with an explosive phase of acidic pyroclastics, tuffs and volcanic breccias, separated mainly by rhyolite flows (Dimitrijevic, 1973). This complex is the earliest volcanic activity of Tertiary age in the southern part of the Iranian volcano-plutonic belt in Kerman province. The thickness of this complex is estimated to be approximately 7 km, but in the Meiduk area it is approximately 400-500 m (Taghipour, 2007). Razak volcanic complex is the main host rock to the Meiduk porphyry copper deposit and is subdivided into three units: a lower mainly basic subcomplex (trachybasalt, andesite and trachyandesite); a middle, acidic subcomplex (acidic tuff) (Dimitrijevic, 1973); and an upper, basic to acidic subcomplex (trachyandesite, andesite-basalt and dacite) (Fig 3).

Ar/Ar dating of albite from the lower unit of this complex yielded an age of 37.5±1.4 Ma for the volcanic rocks (Hassanzadeh, 1993). The youngest volcanic complex of Paleogene, Hezar, consists of appreciable amounts of acidic rocks (Taghipour, 2007). This complex covers large parts of the Miduk area and mainly consists of trachyandesite and trachybasalt. 40Ar/39Ar dating of analcime of this complex yielded an age of 32.7±6.3 Ma (Hassanzadeh, 1993) for the Hezar complex.
Younger porphyry intrusions in the Miduk area include three phases, ranging from Miocene to Pliocene age. Miocene plutonic bodies intruded the aforementioned Paleogene volcanogenic complexes. Based on structural level of exposure, they can be subdivided into two distinct groups (Dimitrijevic, 1973; Hassanzadeh, 1993). The first group is represented by a shallowly emplaced stock of granodiorite - tonalite that is partly covered by the late Miocene - Pliocene volcanic and subvolcanic rocks and located southeast of the Masahim (Abdar) stratovolcano (Fig. 2). The other groups of the Miocene intrusions occur as smaller bodies that represent even shallower parts of the subvolcanic system (Taghipour, 2007).

These are diorite and quartz-diorite porphyries, principally containing andesine, hornblende and biotite phenocrysts in a groundmass of plagioclase, quartz and K-feldspar. Porphyry copper mineralization at Meiduk is associated with the shallow intrusive rocks (Taghipour, 2007) (Fig. 4).
The youngest intrusions in this area are subvolcanic rocks formed in a caldera of Masahim (Abdar) that generated the Abdar Pb-Cu mineralization. $^{40}$Ar/$^{39}$Ar age dating of biotite and hornblende of the lava flows and flanks of Masahim (Abdar) stratovolcano and U/Pb dating of zircon intrusion yielded 6.8 ± 0.4 Ma, 6.4 ± 0.8 - 6.3 ± 0.9 Ma, and 7.5 ± 0.1 Ma, respectively (Hassanzadeh, 1993; McInnes et al., 2005). The youngest subvolcanic and volcanic phases that mainly occurred in the Meiduk area began in the Pliocene and consist of dacitic domes and lava plugs and Masahim stratovolcano (Taghipour, 2007)(Fig. 2).

**Method:**
A total of 120 samples have been collected from drill hole and outcrops for the study of the petrography, geochemistry. The location of the holes is shown in figure 4. On the basis of petrographic observation, forty six samples were prepared for major, trace and rare earth elements analysis. Major elements analyzed by Inductively-Coupled Plasma-Atomic Emission Spectrometer (ICP-AES) method with detection limit of 0.01% and trace elements analyzed by Inductively-Coupled Plasma-Mass Spectrometer (ICP-MS) method with detection limit of 0.01 ppm, following lithium meta-borate fusions HNO$_3$ total digestion, in the ALS Chemex Laboratory group Ltd, B.C., Canada (Table 1). Analytical error for most elements is less than 2%.
### Table 1: Major, trace and rare earth element analyses of the Meiduk porphyry granitoides. Average (Av) from 46 samples.

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<tr>
<th>Drill holes</th>
<th>Average No. 44 Av.15 samples</th>
<th>Average No. 55 Av. 8 samples</th>
<th>Average No. 56 Av.14 samples</th>
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<td>3.12143</td>
<td>2.085556</td>
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<td>(La/Yb)ₜ</td>
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<td>17.901</td>
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<td>5.31</td>
<td>5.44</td>
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<tr>
<td>Mg#</td>
<td>31.91</td>
<td>22.90</td>
<td>37.57</td>
<td>28.15</td>
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</table>

**Ore Deposit Geology:**

The Meiduk ore body is approximately circular in shape with diameter of about 700 m × 1Km. It is located at the bottom and slopes of a valley, which open to the north. The Meiduk intrusive deposit is intruded into andesite, anesitic-basaltic and dacite rocks and andesitic, dacite tuffs and Eocene agglomerates (Razak complex).

The stock consist of three different intrusive phases (Fig. 4). Almost all intrusive units contain the same assemblage of minerals: Plagioclase, K-feldspar, quartz, biotite and/or chlorite, apatite, magnetite and zircon. The intrusive rock at Meiduk are: 1. Fine grained porphyry; 2. granodiorite, quartz-diorite and diorite porphyry (Meiduk porphyry); and 3. Late dike porphyry.

Contact between Meiduk porphyry and andesite rocks are not always clear due to hydrothermal alteration. A contact rock type is called “fine grained porphyry” and it probably belong to andesitic cap rocks (Outomec 1992). It has a porphyry-aplitic texture and is gray and strongly altered. Currently, no fresh part has been found. The Meiduk porphyry is the dominating host rock of the copper ore.

It is light gray in colour, porphyritic in texture with plagioclase phenocrysts up to 5 mm in size. The chemical composition is typically granodiorite and quartz-diorite, diorite and quite homogenous considering effects of hydrothermal alteration. It is characterized by preserved plagioclase phenocrysts, biotite and quartz. The intrusion strongly stockworked veined, mineralized and altered to quartz, K-feldspar and secondary biotite.
Both fine-grained porphyry and Meiduk porphyry and the andesite, andesite-basalt and dacite volcanic rocks have been intruded by numerous late porphyry dikes with NS trend (Fig. 4). Petrographically, these dikes are very close to Meiduk porphyry. The only differences are slightly smaller fracturing and alteration. Shallowly emplaced tracy-andesite, andesite-basalt and dacite dikes without mineralization are also present in the Meiduk area and around it.

**Petrography:**
Fine-grained porphyry resembles porphyric dike and Meiduk porphyry samples and the only difference is slightly more homogeneous and massive texture in fine-grained porphyry. Mineral composition is the same as in Meiduk porphyry and contains about 30 vol% of phenocrysts.

The Meiduk porphyry contains 50-60 vol% plagioclase phenocrysts, K-feldspar up to 20 mm in diameter (10 vol%), quartz up to 2 mm in diameter (13-15 vol%), biotite up to 4 mm in diameter (4-8 vol%) and hornblende up to 5 mm in diameter (8 vol%).

The hornblende has been completely replaced by biotite and magnetite and is only recognizable from the characteristic amphibole morphology of pseudomorphs and in some cases rutile needles aligned in the direction of the principal cleavage.

Textural relationships show that plagioclase phenocrysts formed shortly after the amphibole and that quartz and biotite phenocrysts formed during the last stage of magmatic crystallization. Quartz phenocrysts contain biotite and muscovite inclusions. Most of the plagioclase phenocrysts are calcic, euhedral and have been altered to sericite, quartz and calcite. Based on petrography, two generations of plagioclase are distinguishable in terms of size, inclusions and texture: Large crystals (phenocrysts) with highly altered cores, and relatively small crystals with clear Carlsbad twinning, that are interpreted to have formed during a sodic alteration episode, this interpretation is based on the compositional similarity to the albite rims around K-feldspar, which were clearly developed during sodic alteration (Hezarkhani and Williams-Jones, 1998). The composition of plagioclase phenocrysts is oligoclase-andesine. K-feldspar phenocrysts are mainly anhedral, small in size (>3 mm) and perthitic. They commonly contain small inclusions of primary biotite, plagioclase, apatite, and zircon. Hydrothermal K-felspar can be distinguished from magmatic K-feldspar by the absence of perthitic intergrowths.

Biotite phenocrysts are brown up to 3 mm in diameter, Fe enriched and subhedral. Pale-brown to greenish-brown, Mg enriched, biotite forms small ragged crystal interpreted to be of hydrothermal origin. Petrographic observations also indicate the presence of two compositionally distinguishable types of biotite within this rock unit: 1. phenocrysts (magmatic biotite); and 2. hydrothermal biotite.

Quartz phenocrysts are commonly rounded suggesting that pressure fluctuated during crystallization (Whitney, 1975, 1989, Whitney and Stormer, 1985).

Accessory minerals are apatite, Zircon and magnetite. These minerals occur both in the silicate phases (i.e. biotite and plagioclase) and interstitial to them (in the groundmass). The sulphid minerals consist of pyrite, chalcopyrite and molybdenite, chalcosite and bornite. All these occur as inclusion in altered biotite or interstitial in the matrix of rock.

The groundmass of this intrusive phase consists mainly of fine-grained quartz, biotite, plagioclase and k-feldspare.

Two types of dike cut the Meiduk porphyry and the volcanic rocks around the stock.

1. The late dike porphyry that cut the Meiduk porphyry and is characterized by abundant plagioclase phenocrysts, relatively minor quartz and hornblende phenocrysts and euhedral and fresh phenocrysts of biotite. These phenocrysts contain more than 60 vol% of this dike. Hornblende and biotite phenocrysts are altered to chlorite and magnetite. The groundmass consists mainly of fine-grained quartz, plagioclase and apatite.

2. Shallowly emplaced unmineralized trachyandesite, andesite-basalt and dacite dikes up to 3 m thick are also present in the Meiduk area and around the stock, into the volcanic rocks (host rock). Petrographically this dike consists of phenocrysts of biotite, hornblende and 20 vol% Euhedral plagioclase.

**Geochemistry:**

**Major Element:**
Major and trace element results of whole-rock geochemical analysis of all samples are present in Table 1. The Meiduk porphyry granitoid samples display SiO₂ and MgO content ranging from 56.5 to 68.5 Wt% and from 0.31 to 2.67 Wt% respectively.

The R1-R2 diagram (Fig. 5) show that the Meiduk porphyry igneous rocks are mainly in the range of,
granodiorite to tonalite and quartz-monzonite. Plots of major element abundances against SiO₂ (Harker variation diagrams) as an index of fractionation shows that MgO, CaO, TiO₂, Fe₂O₃, P₂O₅, and Al₂O₃ decrease with increase SiO₂ (Fig. 6). These variation indicate that hornblende, biotite and magnetite have played important roles during the crystallization of the granitoid rocks. Trends of increasing alkalis (Na and K) with increasing SiO₂ are also consistent with such fraction (crystallization of progressively more sodic plagioclase and of k-feldspar), although the possibility that they also partly represent the effects of potassic and sodik alteration and silicification cannot be excluded. Similar trends have been reported for porphyry copper deposits elsewhere (Eastoe, 1978; Mason, 1978; Mason and McDonald, 1978; Dilles, 1987). Aluminum is highly immobile in porphyry copper deposits (Grant, 1986), and displays the same behaviour at Meiduk Porphyry deposit.

**Fig. 5:** R1-R2 diagram showing that chemical composition of the Meiduk Porphyry ranges from granodiorite to tonalite. 1- tonalite, 2- granodiorite, 3- granite, 4- quartz-monzonite

Fig.7a, b show that the Meiduk porphyry granitoid rocks are subalkaline and classified as high-K, calc-alkaline and shoshonite rocks, which are generated from partial melting of basalt in continental arc settings (Berberian, 1976, 1983). There is a clear petrochemical similarity between the Meiduk porphyry igneous rocks and calc-alkaline rock elsewhere in the central Iranian volcanic belt (Hassanzadeh, 1993).

Classification of these rocks by the aluminum saturation index (ASI, Zen, 1986) indicates that the Meiduk porphyry granitoid rocks reflect a change from metaluminous to peraluminous compositions (Fig. 8). The peraluminous nature of these rocks may be attributable to differentiation of hornblende (Zen, 1986) or heterogeneity of water content in the protolith (Waight et al., 1998). Overall, the mineralogy of the Meiduk porphyry granitoid rocks, which include biotite, hornblende, magnetite, apatite and zircon, strongly suggests a metaluminous source.

According to the modified alkali-lime index (Malli=Na₂O + K₂O - CaO) after Frost et al., (2001), the Meiduk porphyry granitoid rocks with high total alkalis (Na₂O+K₂O= 6.71-8.85 Wt%) content and lime concentration (CaO= 0.35-4.51 Wt%), plot in the alkaline and alkali calcic fields (Fig. 9). The Malli of the studied granitoides slightly increase with increase SiO₂ (Wt%).

**Trace Element:**

Fig. 10 presents N-MORB normalized trace element patterns of the Meiduk porphyry stock. This figure indicates that trace element concentration in this porphyry copper stock show regular variation. Their large ion lithophile elements (LILE) Rb, K, Sr, U, Th, and Pb are highly enriched, while the high field strength elements (HFSE) Nb, Ta, and Ti are strongly depleted. In addition, the fluid-mobile element Ba is also depleted relative to the fluid-nonmobile element Th. All these features clearly suggest the characteristics of magmatism typical of a subduction zone (Wilson, 1989). Moreover, the relative depletion of Ba indicates that this enrichment was not related to fluids released from the subducted-slab because Ba is the most mobile element in such fluids (e.g., Bedard, 1999; Seghedi et al., 2001). The strong depletion of the HREE Yb in Fig. 10 was evidently related to relict garnet in the magma sources (Sun and Stern, 2001).
Fig. 6: Chemical variation diagrams for major oxides of the Meiduk porphyry rocks. Oxides in wt%, symbols as in Fig. 5.

Fig. 7: Geochemical typology of the investigated Meiduk porphyry rocks. (a) alkali versus silica diagram (Irvine and Baragar. 1971), (b) Plot of K₂O vs. SiO₂ diagram showing the high-K Calc-alkaline & shoshonite nature of the Meiduk porphyry samples (divisions after Rickwood, 1989).
Fig. 8: Molecular A/NK versus A/CNK [A/NK = Al₂O₃/(Na₂O+K₂O) and A/CNK = Al₂O₃/(CaO-Na₂O+K₂O)] diagram: symbols as in Fig. 5.

Fig. 9: Modified alkali-lime index (Na₂O + K₂O - CaO) against SiO₂ (wt. %) diagram of Frost et al. (2001).

Fig. 10: N-MORB normalized trace element abundances for representative samples from Meiduk porphyry granitoid. The normalizing values are from Sun and McDonough (1989).
In Fig 11 the rare earth element patterns at Meiduk porphyry stock compared with Zaldivar and Chimboraza porphyry copper deposits (Richards et al., 2001) in the Chile. The REE patterns at Meiduk porphyry deposit samples such as depletion in Nb and Ti, and lack a negative Eu anomaly are similar with those of Zaldivar and Chimboraza porphyry copper deposits in Chile. The similarity reveals that they were all generated in a subduction-collision-orogenic environment.

Fig. 11: Primitive mantle-normalized trace element abundances for representative samples from Meiduk porphyry, and Zaldivar and Chimboraza porphyry copper deposits in Chile.

Considering these and also information of tectonic environment from Figs.13, it seems that the Meiduk porphyry copper deposit were formed within a tectonic framework of a volcanic arc related to interaction between the Arabian and Iranian plates during the middle Miocene and is likely similar to porphyry copper deposits of continental arc settings such as northern Chile.

Fig. 12: Chondrite-normalized REE diagram for the samples at the Meiduk porphyry deposit.
Fig. 13: Tectonic discriminant diagrams for the Meiduk porphyry deposit: (a) Rb versus Y+Nb diagram (after Pearce et al., 1984), (b) Rb/100-Tb-Ta diagram (Thieblemont and Cabanis, 1990) and (c) R1 versus R2 diagram (after de la Roche et al. 1980) displaying the geotectonic fields (Bachelor and Bowden, 1995) as well as their petrological equivalents (Lameyer and Bowden, 1982): group 1, tholeiitic; group 2, calc-alkaline and trondhjemitic; group 3, high-potassic calc-alkaline; group 4, sub-alkaline monzonitic; group 5, alkaline and peralkaline.
Rare Earth Element (REE):
Like trace element, the REE of the Meiduk porphyry granitoids also display very consistent variation, with $\sum$REE = 60-195 ppm and notable LREE and HREE fractionation. The samples show strong LREE/HREE fractionation ($\langle$La/Yb$\rangle = 8-33$) and lack a negative Eu anomaly. Their chondrite-normalized patterns (Fig. 12) slope smoothly down to the right, which is consistent with mantle magmatism and different from upper crustal magmatism (Wilson, 1989).

Tectonic Setting:
Trace element discrimination diagrams (Fig. 13) depict the probable tectonic setting intrusive rocks containing 56-80% SiO$_2$. The Nb+Y- Rb diagram (Fig. 13a) show that the Meiduk porphyry igneous rocks are plotted mainly in the volcanic arc fields. In the Rb/100-Tb-Ta diagram (Fig. 13b), the Meiduk porphyry granitoids share the common field of post-collisional and syn-subductional granites.

Furthermore in the R1-R2 diagram of Batechelor and Bowden (1985) that relates the entire orogenic cycle, the Meiduk porphyries mostly plot in the post-collisional field, with some located in the Late orogenic field (Fig. 13c). The subalkaline trend of the investigated granitoids is portrayed in this diagram where the Meiduk porphyry samples plot into the high-potassic calc-alkaline and sub-alkaline monzonitic fields. This distribution is consistent with the evolutionary history of the CIVB. As stated above, after the collision of the Arabian and Iranian plates, the quartzdiorite and granodiorite intrusions (Meiduk porphyry) were emplaced during a late orogenic stage of the post-collisional event characterized by crustal relaxation and porphyry emplacement at (U/Pb, 12.5±0.1 Ma, McInnes et al., 2005; Re-Os molybdenite, 12.23±0.07 Ma, Taghipour, et al., 2007).

Genetic:
In the $P$O$_2$ versus SiO$_2$ and Pb versus SiO$_2$ diagrams (Fig. 14a,b), $P$O$_2$ decrease with increasing SiO$_2$, while Pb scatter but roughly increases with SiO$_2$, both following the I-type granite trend proposed by Chappell and White (1992) and Chappell (1999).

Furthermore, the SiO$_2$ and Na$_2$O contents, molecular A/COK ratio, $K$O/Na$_2$O ratio, abundance of Cr and Ni, key modal minerals (such as hornblende, titanite, and zircon) all suggest that Meiduk porphyry granitoids show I-type characteristics on the basis of the Chappell and White, 1974.

The Emplacement Model for Meiduk Porphyry Copper Deposit:
Magmatic events in the Central Iranian volcanoplutonic belt are closely related to subduction of Neotethys oceanic lithosphere within Central Iranian volcanic belt. It is believed that the opening of Neotethys started in the Permian and that the collision of the Arabian and Iranian plates occurred during the end of the Miocene (Forster, 1978; Berberian and King, 1981; Berberian et al., 1982). The main volcanic activity began in the Lower Eocene with the Bahraseman complex, Middle-Upper Eocene Razak complex and Oligocene Hezar complex. These complexes comprise the main volcanic activity in the area, with thickness approximately 11-16 km in the Dehaj- Sarduieh belt. After the formation of the Razak complex, the Meiduk porphyry stock intruded into this complex.

The second episode consisted of fracturing in the cooling Meiduk porphyry and contact rocks. Due to the competence differences and cooling process itself, fracturing was dense in Meiduk porphyry, but sparse in the contact rocks.

The third phases, in time almost simultaneous to the second one, is the late porphyry dykes formation or mobilization of still molten porphyry magma. The dykes are quite linear around Meiduk porphyry (Fig. 4). The direction of dykes there is, either NS- directed tension dominating at that time, or a radial fracturing developed in the fracturing of Meiduk porphyry.

The fourth and latest major episode was hydrothermal alteration with copper mineralization. The intensity of copper mineralization depends mainly on fracturing. The most intensive fracturing occurred in the Meiduk porphyry, and here are found also the highest copper grades. The dykes formed after the main phase of fracturing. This would be a natural reason for their low copper grade.

The latest phase has been erosion and supergene processes, which are responsible for the formation of supergene ore. The climatic conditions during the main supergene processes have been moist or wet, because the water table was at a much higher elevation than now, even after allowing for erosion effects.

Conclusions:
The Meiduk porphyry copper deposit is located in the central Iranian volcanic belt (CIVB) and is associated with Calc-alkaline intrusive rocks of middle-Miocene age that intruded the Eocene Razak volcanic complex.
Fig. 14: Genetic classification of the Meiduk porphyry deposit, showing its dominating igneous source (I-type) associated with S-type: (a) P₂O₅ versus SiO₂ and (b) Pb versus SiO₂, variation diagrams with the evolution vectors of I- and S-type granites (Chappell and White, 1992; Chappell, 1999), symbols as in Fig. 5.

The Meiduk porphyry copper deposit were formed within a tectonic framework of a volcanic arc, after the collision of the Arabian and Iranian plates, and the quartzdiorite and granodiorite intrusions (Meiduk porphyry) were emplaced during a late orogenic stage of the post-collisional event characterized by crustal relaxation.

Geochemically, they belong to the calc-alkaline and high-K calc-alkaline series and are characterized by LILE enrichment and HFSE depletion, revealing that subduction played an important role in their generation. On comparing the Meiduk deposit with several porphyry copper ores from around the world, along with mineralogy and geochemistry, it is concluded that the Meiduk porphyry copper deposit is very similar to those of continental arc and post-collisional-ectonic setting.

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