Mineralization in the Taroum Mountains with Special Reference to the Barik-Ab Pb-Zn (Cu) Deposit, West Central Alborz, Iran

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Abstract: - The Alborz Mountain ranges in northern Iran are part of the collisional Alpine orogenic belt, resulting from subduction of the Paleo-Tethys oceanic crust under southern edge of Eurasia and subsequent collision of the Central Iran microplate and the Turan plate in the Late Triassic. This orogen system is bounded to the north with the Caspian depression block and to the south with the Central Iran depression. The east central Alborz includes zones of bentonite and zeolite mineralization and is occupied mostly with tuff and shale of the Karaj Formation (KF), while the Taroum mountains in west central Alborz are mostly composed of volcanic and pyroclastic rocks of the Karaj Formation (KF) and host the alunitic, kaolinitic and metallic zones in the northern, middle and southern parts, respectively. The alunitic zone is characterized by sericite-quartz-pyrite assemblage and close intimation between silisic and advanced argillic alterations with brecciated and mineralized centres. The kaolinitic zone overlies acidic tuffs, rhyolitic, dacitic and trachydacitic lavas together with ignimbrite of the KF and is marked by local hydrothermal kaolinitization. The Barik-Ab ore deposit, hosted by the Ea4 submember (rhyolite, dacite, trachyandesite and sandstone) of the Amand member in the KF occurs in the metallic zone. Mineralization occurs as veins and veinlets. The Tectonic activities and subsequent fracturing in the host rocks facilitated percolation of hydrothermal fluids and formation of ore minerals. The common ore minerals are galena and sphalerite with subordinate to rare amounts of chalcopyrite, argentite and bornite. The secondary oxidic minerals include hematite, goethite, limonite, cerussite, malachite and azurite. Mineralization in the study area share similar features of epithermal ore deposits, consisting of good correlation between kaolinite and alunite, development of alteration zones along structural elements, association with volcaniclastic rocks, lack of sedimentary strata and diaspore and boehmite minerals, good correlation between silica and alumina contents of the altered rocks with hydrothermal alteration types.

Key-Words: - Alborz, Tharoum Mountains, Barik-Ab, Eocene, Karaj Formation, Alunite, Kaolinite, Pb-Zn (Cu) deposite, Epithermal

1 Introduction

The Alborz Mountain ranges in northern Iran are part of the Alpine-Himalaya orogenic belt in the western Asia. This orogen system is limited to the north by the Caspian depression block which is a post arc extentional basin [28], while the southern boundary is marked by Central Iran depression [11]. The structural setting of the Alborz ranges has been evolved by orogen phases [3, 24]. The Alborz ranges with a crustal thickness of only 35-40km have been folded by the Alpine orogen [9, 11], which indicates that it has not been compensated by a lithospheric root [22, 23]. The Alborz ranges are part of the Eurasia metallogenic belt [16] and host ore deposits like Barik-Ab, particularly along the Taroum Mountains (Fig. 1). Contrary to the countless examples of the Pb-Zn ore deposits hosted by carbonate rocks worldwide, the study area includes exotic Pb-Zn ore deposit in the volcanic and pyroclastic hosts [6].

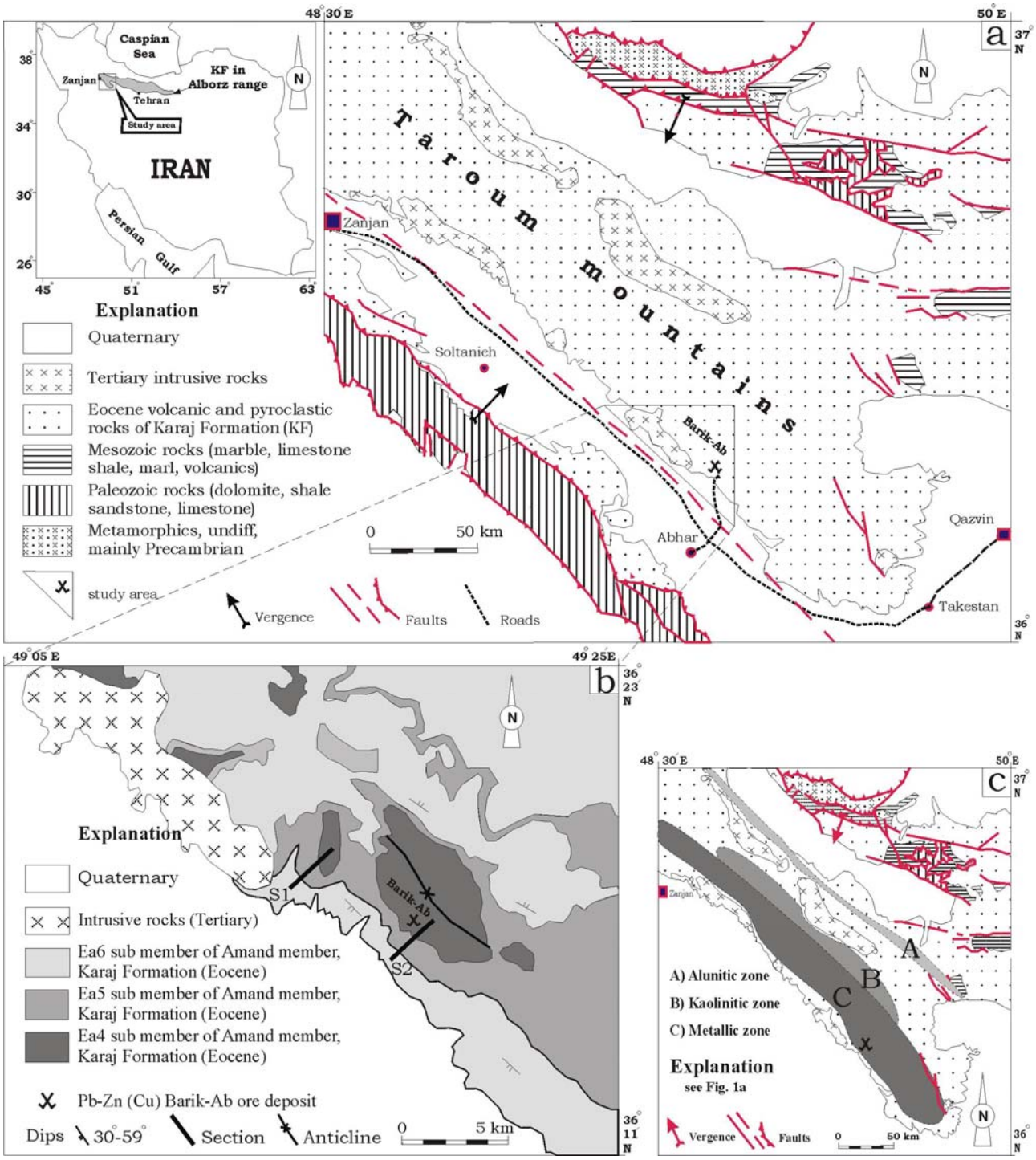

Fig.1 (a) Geological setting of the west central Alborz, (b) Regional geology of the Taroum Mountains illustrating the Karaj Formation, intrusive rocks and Barik-Ab ore deposit, (c) Mineral zones; A: alunite, B: kaolinite, C: Pb-Zn (Cu). Geological map modified from [25, 29, 30].

In the Central Alborz, there are three main groups of Pb-Zn deposits/occurrences, comprising a) Mississipi Valley Type Pb-Zn deposits in Mesozoic carbonate rocks, b) stratiform Pb-Zn deposits in Paleozoic carbonate rocks and c) Pb-Zn deposits in Cenozoic volcanic rocks and Tuffs [6]. In the west central Alborz and along the Taroum Mountains, the Pb-Zn (Cu) deposits like Barik-Ab occur solely in the volcanic and pyroclastic rocks.

Mineral deposits in the Taroum Mountains have been divided into 3 zones, consisting of A) alunitic zone in the north, B) kaolinitic zone in the middle

and C) Pb-Zn (Cu) zone in the southern parts (Fig. 1c).

The purpose of this paper is to intruduce three aforementioned mineralization zones and their relationships with particular emphasis on lithology, stratigraphy, geochemistry and mineralography of the exotic Pb-Zn (Cu) Barik-Ab ore deposit.

2 Methodology

The general geology of the Taroum Mountains area have been compiled from available geological and tectonic maps [14, 25, 29, 30], and field observations during several weeks of surveys in 2006 and 2007. Samples were obtain through the entire section exposed around Barik-Ab, including each of the mineralization zone described in this study. Polished blocks, polished and polished thin sections were prepared and studied by conventional petrography microscopes at Department of Geology of the University of Tehran, Iran. The XRD analysis was done using Cu Kα at Geological Survey of Iran. The major and trace elements were analyzed by ICP in ACME Laboratories, Vancouver, Canada.

3 Geological Setting

The Alborz ranges of northern Iran are a region of active deformation within the broad Arabia–Eurasia collision zone [3], whilst Hirayama et al. [14] believed the rift operation system. The Taroum Mountains in west Alborz ranges are composed of the Cenozoic volcanic and pyroclastic rocks (KF) which are bounded between two thrust faults in the northeast and southwest (Fig. 1a). These faults caused exposure of the Paleozoic and Mesozoic rocks. The KF was deformed by the Cretaceous orogen, termed Pyrenean phase [14, 20, 25]. Two main tectonic phases affected the Alborz ranges including Assinitic and Alpine in Precambrian and Cenozoic, respectively.

In general, three kinds of faults acted in the study area (Fig. 1). These include 1) NW-SE trend thrust faults with right and left-lateral movement in the Miocene and Pliocene-Quaternary, respectively [3], 2) NW-SE trend compressional faults [1] and 3) N-NE trend normal faults. The last type with tensional system, hosts predominately Pb-Zn (Cu) mineralization along strike.

4 Regional Geology and Mineralization

The Karaj Formation consists generally of volcanic and pyroclastic rocks which in the east central Alborz changes to tuff and shale in addition to much evaporate in the lower and specially in the upper sequences. These rocks host bentonite and zeolite zones [7]. In the west central Alborz (Taroum Mountains), the KF includes volcanic and pyroclastic rocks. Hirayama et al. [14] divided the KF into two members, comprising the lower Kordkand member and the upper Amand member (Fig. 2). The last member has been divided into six sub members, termed Ea1, Ea2, Ea3, Ea4, Ea5 and Ea6. In the study area, the Ea4, Ea5 and Ea6 sub members have exposure (Fig. 1b) and toward north coincide respectively to the metallic, kaolinitic and alunitic zones.

The Barik-Ab Pb-Zn (Cu) ore deposit is hosted by the Ea4 sub member of the Amand member (Figs. 1b, 3b).

The Ea4 sub member contains andesite, rhyolite and sandstone with 250m thickness. The Ea5 sub member encompasses 100m mudstone and tuff, whilst the Ea6 sub member is composed of 300m andesite, rhyolite lava and acidic tuff. Hirayama et al. [14] reported thickness of the KF in the Taroum Mountains as much as 3800m. Alavi [2] and Allen et al. [3] estimated thickness of the KF up to 5000m, while Bazargani-Guilani and Rabbani [7] proposed a thickness of about 2000m for the KF in the east of central Alborz.

The KF has pervasive hydrothermal alteration zones along the Taroum Mountains (Fig. 3b). Alteration is texturally destructive and the relationships between alteration assemblages in all three zones are complex.

In the alunitic zone, sericite, silica and subordinate clay minerals are present [5]. At a broad scale, intense silicic and advanced argillic alterations are associated with major breccia and mineralized centers. In the northern part of the alunite zone (A zone) silicic alteration is characterized by patchy vuggy silica, consisting of fine-grained secondary quartz and very rarely primary quartz phenocrysts. Local silicification is also evident as fine-grained quartz, occuring as veinlets and vugs-filling. This alteration zone becomes larger along structural elements, where alunite and silica are associated with pyrite. More detailed information about alunite mineralogy can be found in Bazargani-Guilani [5].

Quartz-alunite alterations of the Miocene volcanic rocks in the western part of the Virginia range are associated with significant precious metals [26]. Alunite in the Pascua-Lama and the El Idio-Pascua belt of Chile and Argentina contains also precious metals [10].

Sys.	Form.	Mem.	Hirayama et al., 1966		Stöcklin & Eftekhar-nezhad, 1969		Lithology of the study area
Eocene	Karaj Formation	Amand	Eai	Tuffaceous mudstone, sandstone, acidic tuff, andesite, rhyolitic lava on top (250m)	Ea6	Dacite, andesite, rhyolitic tuff (300m)	Red & grey tuffaceous, mudstone, sandstone, rhyolitic & andesitic lava, acidic tuff, ignimbrite
			Eah Eag	Mudstone, tuff (60m)	Ea5	Lapilli tuff, tuff (100m)	Purple & red mudstone, tuff
			Eaf	Complex of adesitic lava, rhyolite, breccia tuff, sandstone (300m)	Ea4	Trachyte, andesite, tuff, rhyolitic tuff, dacitic tuff, rhyodacite (250m)	Andesite& rhyodacitic lava, tuff breccia, tuff, tuffaceous sandstone, mudestone

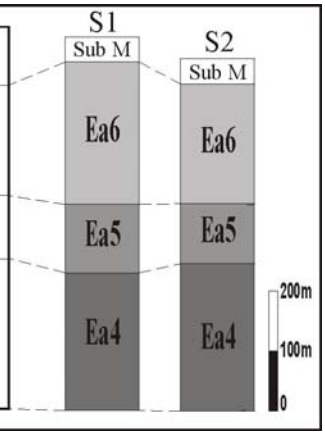

Fig.2 Stratigraphic sections of the Taroum Mountains (Barik-Ab ore deposit). For profiles (S1 and S2) locations see Fig. 1b.

The geological investigations show that acidic tuffs, rhyolitic, dacitic and trachydacitic lavas together with ignimbrite of the KF are basement rocks, above which the kaolinitic zone (B zone) has been formed. The fresh bedrocks consist of volcanic glass (ignimbrite) and rhyolitic breccia. Alteration of ignimbrite proceeds along the perlitic cracks. The fresh rhyolitic breccia contains lithic fragments and many rock forming minerals. The breccia texture, form and radial crystalline structure of the spherulites, have been preserved fully in kaolin. Local hydrothermal kaolinitization is also evident together with fine-grained quartz as veinlets, voids and vugs-filling.

In northern parts of the Taroum Mountains, hydrothermal fluids were rich in sulfate, causing development of the kaolinitic zone (B zone) and alunite. On the contrary, central Taroum which is very close to the metallic zone (C zone), is marked only by kaolinitic zone, indicating less sulfate ions in and much more acidity of the hydrothermal fluids. The metallic zone (C zone) is associated with Pb-Zn (Cu) mineralization (Barik-Ab ore deposit) which is explained in parts 5 and 6.

5 Petrology and Geochemistry

As mentioned before, three different mineralization zones have been appeared in the study area. These include from north to south 1) the laterally extended alunitic zone [5, 13] from Taroum Mountains to Azerbaijan [5], the elongated kaolinitic zone [4, 12, 20] (Fig. 1c) and the metallic zone which hosts Pb, Zn and Cu mineralization.

The lithological study on the profiles S1 and S2 (Fig. 2) revealed that the host rocks are composed mainly of altered rhyolitic and dacitic tuffs, plotted in calc-alkaline and subalkaline fields (Fig. 4). Plagioclase and K-feldspar have been converted to sericite and chlorite with subordinate calcite. These rocks host Pb-Zn (Cu) ore deposit as vein and veinlet (Figs. 3a, 3h). Minor Fe oxides and hydroxides occur in the fractures of the ore zones (Fig. 3c).

Peyrowan [19], reported the composition of intrusive rocks (Fig. 1b) quartzmonzonite and quartzsyenite and Alavi [2] believes that these rocks are post tectonic I-granitoid with alkaline and shoshonitic affinity.

6 Mineralogy and Paragenesis

In the Barik-Ab ore deposit, mineralization occurs mostly as several veins and veinlets. The biggest vein with 4m thickness and 500m long hosts the main part of Pb-Zn (Cu) mineralization. Detailed petrography and ore microscopy studies identified following minerals and ore minerals in the host rocks and veins:

1- Quartz, feldspar (Plg, K-feld), mica minerals (biotite, sercite), clay minerals (kaolinite, dickite) and calcite occur in the host rocks, veins and veinlets.

2- Sphalerite, galena, chalcopyrite, pyrite, covelite, bornite, and argentite are sulfidic minerals (Figs. 3e, 3f, 3g, 3h), of which sphalerite, galena and to a lesser extent chalcopyrite are the main sulfides. Chalcopyrite occurs also as inclusion in sphalerite (Fig. 3g) which has been interpreted by (Ramdohr, 1980) as an exsolution texture. Pyrites are mostly fine grained and surround sphalerite.

3- Hematite, goethite, limonite, cerussite, malachite and azurite are the secondary oxidic minerals.

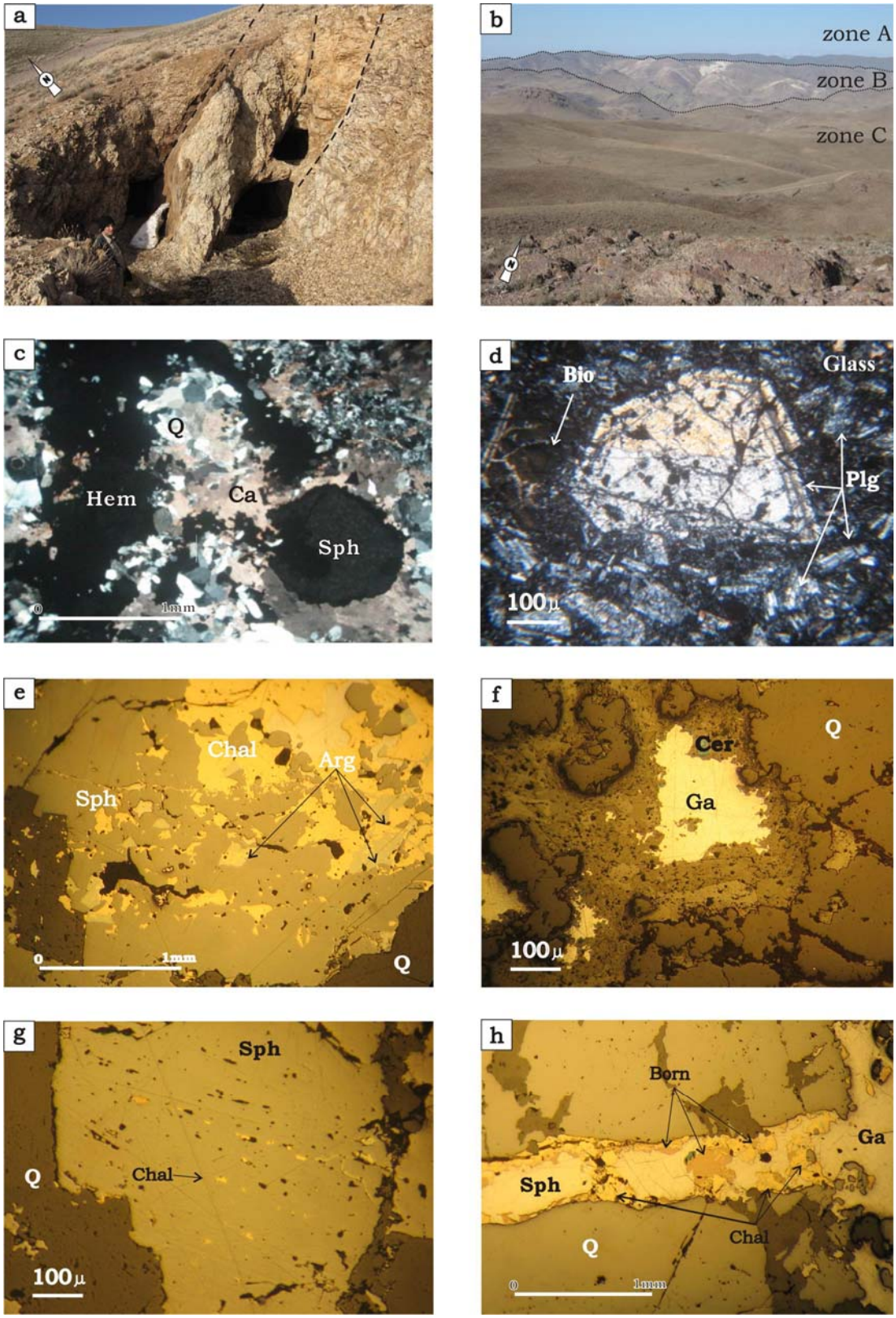

Fig.3 (a) The tunnels and faults with N45°E strike, (b) General view of the three mineral zones, (c) Tuff with sphalerite, calcite, quartz and FeO oxides in vein, (d) Zoning of Plg crystal in tuff, (e) Sphalerite (dark grey) with coarse-grained argentite, (f) Galena (white) altered to cerussite, (g) Sphalerite (grey) with fine unmixing chalcopyrite inclusions (white), (h) Sphalerite cut by vein of bornite and chalcopyrite. Hem = hematite; Sph = sphalerite; Q = quartz; Ca = calcite; Bio = biotite; Plg = plagioclase; Chal = chalcopyrite; Arg = argentite; Cer = cerussite; Born = bornite.

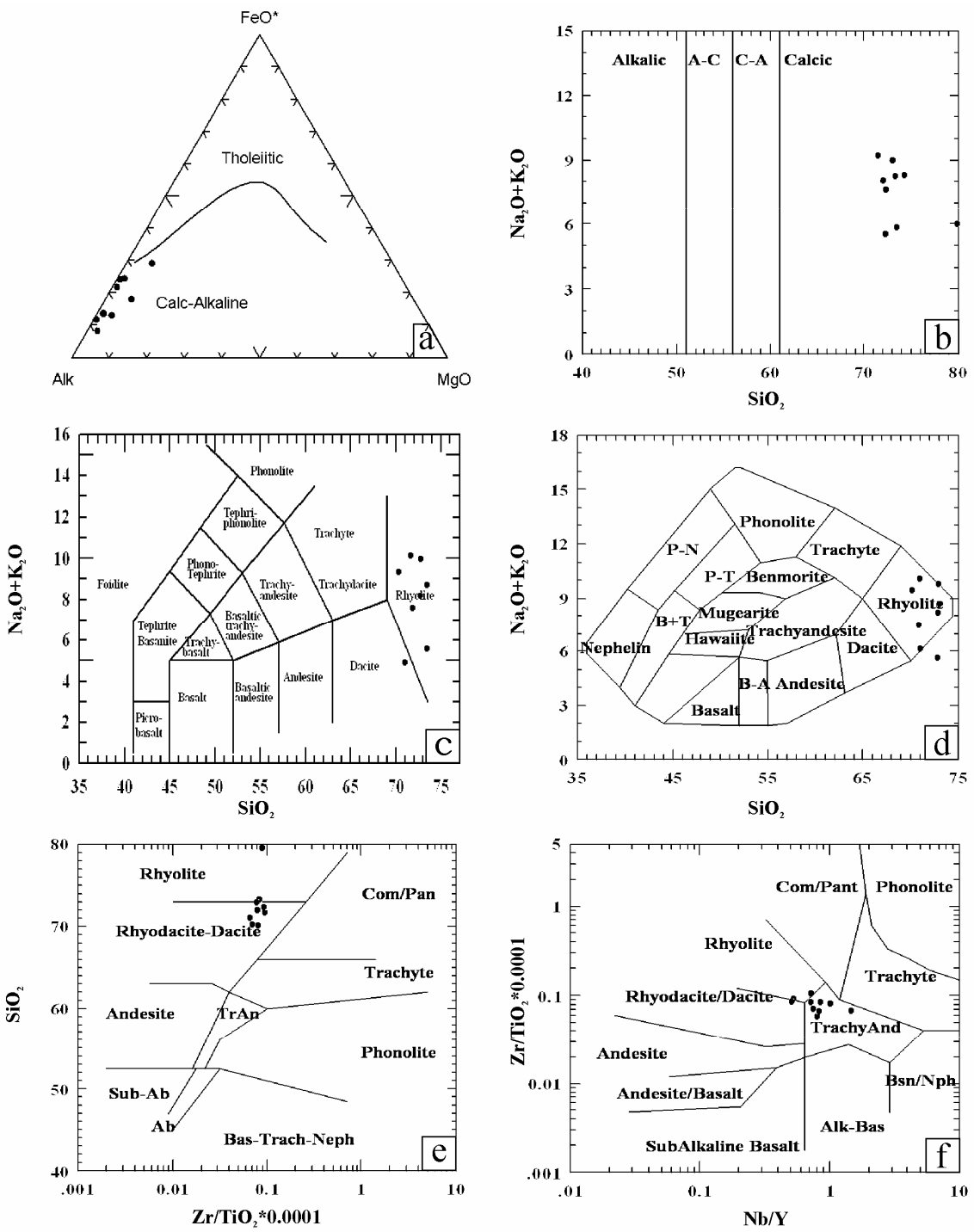

Fig.4 (a) Plot of 10 volcanic rock samples from the Barik-Ab ore deposit on AFM and alkalies % vs SiO_2 % diagrams of Irvine and Barger [15]. The rocks are plotted in the calc-alkaline and subalkaline fields, respectively. (b) Diagram of Peacock [18] illustrating position of 10 plotted Cenozoic volcanic and pyroclastic rocks from Barik-Ab ore deposit. The samples show calcic field. (c) Plot of 10 samples of the Cenozoic volcanic and pyroclastic rocks from Barik-Ab ore deposit, on diagram of Le Bas et al. [18], indicating that except one sample of dacitic composition, the rest ones are located in the rhyolite field. (d) Diagram of Cox et al. [8], illustrating position of 10 samples from the Barik-Ab ore deposit in the rhyolite field. One altered sample is plotted out of diagram. (e) Plot of 10 samples of the Barik-Ab ore deposit on SiO_2 % vs $Zr/TiO_2*0.0001$ % diagram of Winchester and Floyd [27]. The rocks coincide with rhyolite and rhyodacite/dacite fields. (f) Plot of 10 samples of the Barik-Ab ore deposit on $Zr/TiO_2*0.0001$ % vs Nb/Y % of Winchester and Floyd [27]. The composition of rocks are in accordance with rhyolite, rhyodacite/dacite and trachyandesite field.

There are several evidence which support an epithermal origin for the mineralization in the study area. These include close relationship between kaolinite and alunite, fault-controled alteration zones, association with volcaniclastic rocks and lack of sedimentary strata, lack of diaspore and boehmite minerals, good correlation between silica and alumina contents of the altered rocks with hydrothermal alteration [4, 12, 20].

7 Conclusion

The Eocene volcanic and pyroclastic rocks (Karaj Formation) along the Taroum Mountains in west central Alborz are composed of andesite, rhyolite, green tuff, tuff, sandstone and mudstone. The Ea4 sub member of the Amand member in the KF is composed of rhyolitic and dacitic rocks and hosts mineralization in general (Figs. 3a, 3b) and particularly the Barik-Ab Zn-Pb (Cu) ore deposit. This sub member coincides with metallic zone (C zone), as well. The quartzmonzonitic to quartzsyenitic intrusions with alkalic to shoshonitic afinity were intruded the KF. Faulting and emplacement of intrusions resulted in anticline structures and fractures which acted as suitable passages for hydrothermal solutions and subsequent mineralization. Mineralization in the Barik-Ab ore deposit occurs as vein and veinlet and resembles some features of epithermal ore deposits.

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