Aliabad-Morvarid iron-apatite deposit, a Kiruna type example in Iran

Maryam-Sadat Mazhari [1]*, Majid Ghaderi [1], Mohammad-Hassan Karimpour [2]

[1] Department of Geology, Tarbiat Modares University, Tehran, Iran

[2] Department of Geology, Ferdowsi University of Mashhad, Mashhad, Iran
* E-mail address: m.mazhari@modares.ac.ir

Abstract
Aliabad-Morvarid iron-apatite prospecting area is located in southeast of Zanjan, Tarom mountain range, northwest Iran. The exposed rocks are Eocene andesite, trachyandesite and basalt (both lava and pyroclastic). Oligo-Miocene quartz-syenite, quartz-monzonite, monzonite and monzogranite intrude the volcanic rocks. Trace and REE chemical composition of the intrusive rocks indicate that they were emplaced in a volcanic arc setting.
Mineralization is found mainly as vein, stockwork and hydrothermal breccias. The geometry of the faults controls the shape of the mineralization. Most of the veins are parallel. Paragenesis involves magnetite, apatite, pyrite, chalcopyrite and secondary ones are hematite, malachite, azurite and goethite. The size of apatite crystals is variable of some mm to more than 20 cm. Important alteration types are: argillic (illite, kaolinite and montmorillonite), sericitic, silicification, potassic, tourmalinization, epidotization, actinolitization and carbonate.
The REE distribution patterns of apatite and magnetite samples from the area are similar to those of subvolcanic rocks. Spatial distribution of intrusive rock; type and geometry of alteration; and style, location and mineral paragenesis all indicate that the intrusive rocks are the source of mineralization. The REE patterns of Aliabad-Morvarid mineralization show similarities with Kiruna type magnetite deposits; therefore, it can be classified as a magnetite-apatite Kiruna-type deposit.

Keywords: *Magnetite-apatite, Kiruna-type, alteration, Aliabad-Morvarid, Zanjan.*

Introduction
Major Iranian Fe oxide - apatite deposits were mainly found in Central Iran structural zone during the past decades. Recently, a number of researchers (e.g., Amini, 2002; Rahmani et al., 2004; Sahandi, 2006) have reported such deposits in the Tarom mountain range, Western Alborz-Azarbaijan structural zone, northwest Iran. The reported deposits include Aliabad-Morvarid, as well as Sorkheh Dizaj to the southeast and Zaker to the northwest. Geological studies on these deposits resulted in the introduction of promising areas for magnetite-apatite. The Aliabad-Morvarid iron-apatite prospecting area is located 33 km southeast of Zanjan in Tarom mountain range. Systematic studies on various aspects of the deposit such as its mineralogy, alteration, host rocks, tectonic setting and geochemistry could be the key for exploration of similar deposits in the region.

Generalized geology of the Aliabad-Morvarid deposit
The exposed rocks in the study area are Eocene andesite, trachyandesite and tuff (both crystal lithic tuff and vitric lithic tuff). Eocene-Oligocene quartz-syenite, quartz-monzonite, monzonite and monzo-granite intrude the Eocene volcanic rocks. Volcanic rocks are exposed in north and northeast of the area, east of the intrusive rocks (Fig. 1). Microscopic study

shows that the main minerals in the volcanic rocks are plagioclase, pyroxene. Alteration minerals are sericite, carbonate, chlorite and quartz in a microlithic matrix of plagioclase. Intrusive rocks mainly show granular, intergranular, mirmicitic and graphic textures.

Mineralization

Based on field studies, mineralization occurs as vein type in the subvolcanic rocks. The magnetite veins vary in thickness and length. The length of veins varies from 2 to 16 cm; their thickness ranging from 70 to 200 m. Strike of the veins is almost east-west and most of the veins are exposed along the fault system. In the veins, magnetite is accompanied by apatite. The size of the apatite crystals is variable of some mm to more than 20 cm.

The ores have disseminated, vein-veinlet, massive, banded and brecciated textures.

Disseminated texture: In this texture automorph-subautomorph magnetite crystals are intergrown with other rock-forming minerals.

Massive texture: Most of the ores in the study area have a massive texture in which apatite crystals are accompanied by magnetite.

Banded texture: Alternate bands of magnetite and apatite have produced this texture in all parts of the deposit.

Vein-veinlet texture: Magnetite veins and veinlets are observed in the deposit. Veins and veinlets display stockwork shape near the ore.

Brecciated texture: Breccias, sub-angular, altered clasts of host rocks and magnetite cement have formed a brecciated texture.

Mineralogy

The major primary minerals are magnetite, apatite, pyrite and chalcopyrite and the secondary ones are hematite, goethite, lepidocrosite, malachite and azurite. The gangue minerals are calcite, quartz, chlorite, epidote, actinolite and pyroxene.

Alteration types

At Aliabad-Morvarid prospecting area, the influence of subvolcanic rocks and the volume of hydrothermal fluids have caused intense alteration and mineralization in the subvolcanics and host rocks. Based on field and microscopic studies and XRD analysis, the important alteration types are: argillic (illite, kaolinite and montmorillonite), silicic, sericitic, silicification, potassic, tourmalinization, epidotization, actinolitization and carbonate. Among these alterations, the argillic and silicic alterations are extensive in the study area. In the advanced argillic alteration in the subvolcanics, the rocks have turned into a white powder. In the sericitic alteration, plagioclase has turned into sericite, tiny crystals of sericite being observed within the alkali-feldspar. Epidotization, chloritization and actinolitization are found near the ore, formed by alteration of clinopyroxene. In microscopic section, replacement of plagioclase with alkali-feldspar displays potassic alteration. Carbonate alteration in the subvolcanic rocks occurs as calcic vein and veinlet and in apatites caused the change to powder, vacant space of apatite remaining.

Tectonic setting

For determination of tectonic setting of intrusive rocks, Pearce et al. (1984) diagrams were used. The diagrams for the intrusive rocks indicate that they were emplaced in a volcanic arc setting (Fig. 2).

REE patterns

In order to investigate rare earth element behavior in the magnetites and apatites from the deposit, their chondrite-normalized REE patterns are presented. The important point in these diagrams is the enrichment in LREE together with negative Eu anomalies (Fig. 3). These diagrams have a good similarity with those of the samples from Kirrunavaara deposit in Sweden (Harlov et al., 2002). The similarity between apatite and magnetite REE patterns implies similar origin for both minerals.

Conclusion

The vein geometry of magnetite-apatite mineralization host rocks (including quartz-syenite, quartz-monzonite, monzonite and monzogranite), textures such as disseminated magnetite crystals in subvolcanic host rocks, accompaniment of apatite with magnetite, typical alteration types such as potassic, argillic, epidotization and actinolitization and formation of deposit in a fault zone show that the emplacement of subvolcanic rocks and the accompanying fluid resulted in the alteration and mineralization in the deposit. The similarity between apatite and magnetite REE patterns is indicative of a similar origin for both minerals. The REE patterns of Aliabad-Morvarid mineralization show similarities with Kiruna-type magnetite deposits (Kurmies, 2002). Therefore, Aliabad-Morvarid can be classified as a magnetite-apatite Kiruna-type deposit.

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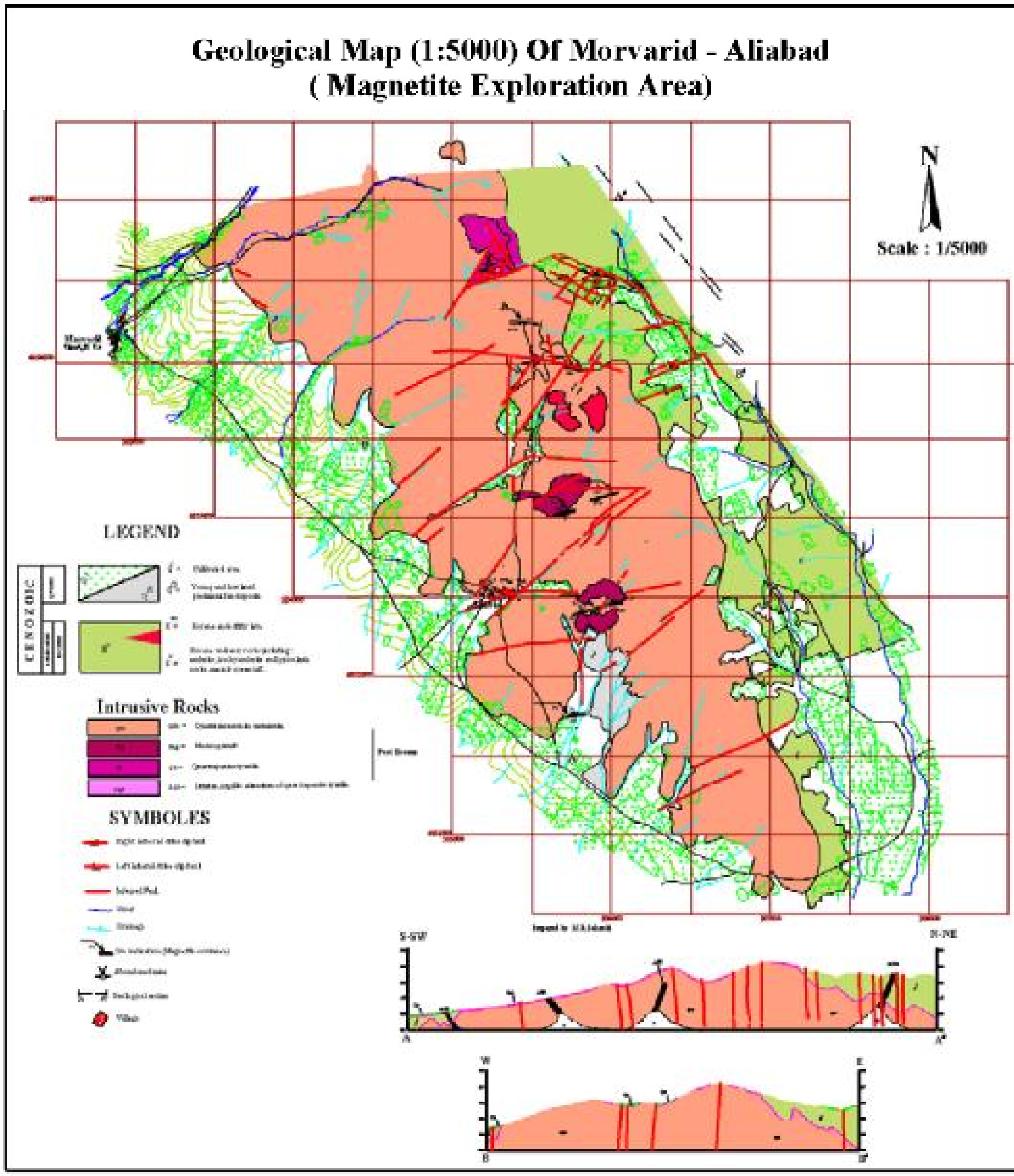

Figure 1. Geological map of Aliabad-Morvarid deposit (Sahandi, 2006)

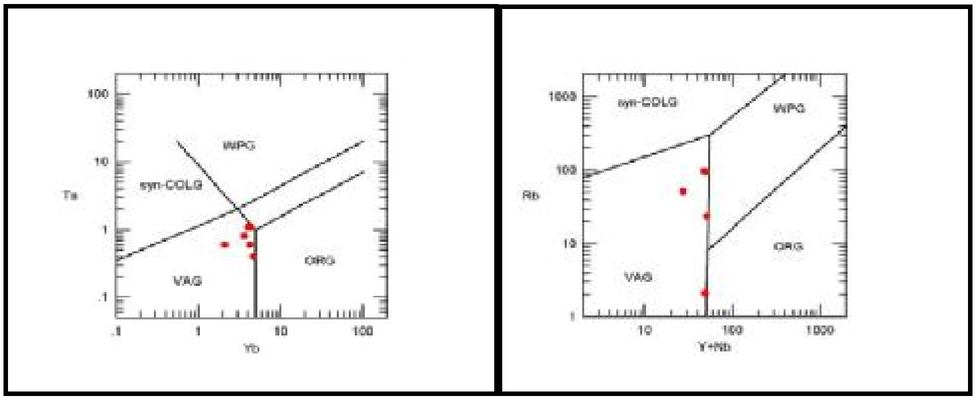

Figure 2. Ta/Yb and Rb/Y+Nb diagrams (Pearce et al., 1984) for intrusive rocks from Aliabad-Morvarid deposit.

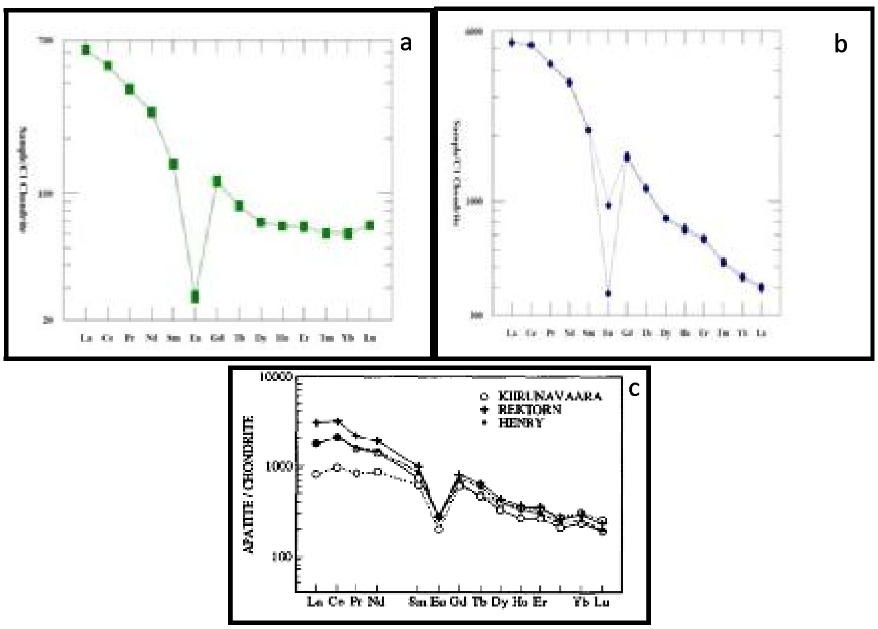

Figure 3. Chondrite-normalized patterns of a) Aliabad-Morvarid magnetite; b) Aliabad-Morvarid apatite; c) Kirunavaara apatite.