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# Mineralogical and geochemical studies on apatites and phosphate host rocks of Esfordi deposit, Yazd province, to determine the origin and geological setting of the apatite

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## Introduction

Iron-apatite ore deposits well known as Kiruna iron type formed in association with calc-alkaline volcanism from Proterozoic to Tertiary (Hitzman et al., 1992). Liquid immiscibility in an igneous system was proposed to explain the formation of the iron oxides accompanying apatite in mineralized zones (Förster and Jafarzadeh, 1994; Daliran, 1999). The mode of ore formation however, is a matter in debate. Bafq region in Central Iran is one of the greatest iron mining regions in Iran with 750 million tons of reservoir. The majority of the iron deposits contains apatite as minor mineral and underwent metamorphism-alteration in varying degrees. The mode of formation and geological setting of Esfordi iron-apatite deposit in this region with an average of 13.9 wt% apatite are discussed using geochemical and mineralogical data along with field description.

## Materials and methods

Fifty-three samples of mineralized zones and host rocks collected from 7 cross sections were studied by conventional microscopic methods. Seven representative samples were determined by XRD at Department of Physics, Shiraz University. Fifteen and six samples were also analyzed for major and trace elements using XRF at Binaloud Co. Iran, and ICP-MS at Labwest Minerals Analysis, Australia, respectively. Microprobe analyses were carried out on apatite in Geo Forschungs Zentrum Telegrafenberg at Potsdam University, Germany.

## Results

Field observation shows that igneous host rocks in Esfordi were intensively altered by hydrothermal fluids. The ores are surrounded by wide altered halos. Petrographic investigation indicated that the most important alterations are of potassic, carbonatitic and silicification types. Magnetite and apatite occur as major minerals, accompanied by minor hematite and goethite in the mineralized zones. Rare Earth Element (REE) minerals are present as minor phases in the ores. Three apatite mineralization types (vein, massive, and disseminated) were recognized. Petrographic data represent three apatite generations: stage 1 which is recognized in the massive and disseminated ore types, stage 2 occurred in brecciated zones and stage 3 which is formed by dissolution and redeposition of the 1 and 2 apatite types in vein-shaped bodies. The correlations among major elements and $SiO_2$ correspond to magmatic differentiation. Cerium is the most abundant REE in the studied samples. Similar REE distribution patterns were observed in the apatite, magnetite and host rhyolite. Electron Probe Micro Analysis (EPMA) shows that the apatites are of fluoroapatite type, enriched in LREE. Low content of Sr was detected in apatites of Esfordi. Low Cd and Na concentrations but high U and Th values were also detected in the studied ore samples.

## Discussion

Esfordi iron-apatite deposit is located NE of Bafq, Yazd Province, and in the Central Iran structural zone hosted by mainly Infracambrian rhyolites.

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Field evidence such as flow structure of ore and dendritic texture of some minerals, e.g., actinolite reveal the magmatic origin of iron-apatite deposit. The trends of major element concentrations in ores from different rocks are consistent with magmatic origin of the ores. The absence of sulfides shows an oxidized condition of magma at the time of ore formation. Low Sr in the apatite however, rejects any carbonatitic magma at Esfordi (Belousova et al., 2002). Similar REE distribution patterns in the apatite, magnetite and host rhyolite indicates the same origin for them. Cerium concentration in the ores from Esfordi is also consistent with magmatic ore types and negatively sloped REE distribution pattern and negative Eu anomaly resemble to the Kiruna type iron-apatite deposits (Hsieh et al., 2008). Low Cd and variable Th/U in the apatite along with low Na are contradicting with sedimentary environment (Jami, 2005; Alves, 2008). The Esfordi deposit probably formed in an extensional arc-related setting associated with syn-collision granitoids.

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