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Alteration-mineralization, and radiometric ages of the source pluton at the Sangan iron skarn deposit, northeastern Iran

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ABSTRACT

The world-class Sangan iron skarn deposit with a proven reserve of > 1000 Mt iron ore @ 53% Fe, is located in the Khaf-Kashmar-Bardaskan Volcano-Plutonic Metallogenic Belt (KKB-VPMB) of northeastern Iran along the E–W trending regional Doruneh Fault, north of the Lut Block. Skarn mineralization occurs at the contact of the 39.1 ± 0.6 Ma to 38.3 ± 0.5 Ma Middle Eocene syenite to syenogranite porphyry source pluton with Cretaceous carbonate rocks. The source pluton is part of an I-type, calcalkaline granitoid series with potassium to shoshonitic affinity, metaluminous to slightly peraluminous character. The granitoids are enriched in LILE (Cs, Rb, Ba, K, Th, and U) and LREE (La and Ce), are depleted in HFSE (Nb, Y, Ta, and Ti), HREE (Yb and Lu) and Eu, which together with the low Sr (96 to 362 ppm) and $(La/Yb)_N$ contents suggest a metasomatized, slab-derived mantel source within the Cenozoic volcanoplutonic continental arc of northeaster Iran. The location of the skarn orebodies is controlled by the regional E–W Doruneh Fault structure, and the spatial distribution and the two, calcic and magnesian, skarns is controlled by the composition of the carbonate protolith that consists of limestone in the west and dolomite in the east. The chemistry of the skarn minerals reflects the composition of the protoliths. The western skarn is dominated by ca-rich calcsilicates that consist of prograde Ca-rich garnet ($Adr_{50-97}Grs_{0-45}Sps\text{-}Alm_{2-7}$), Ca–Fe-rich pyroxene ($Hd_{75.6}Di_{20}$ $Jo_{4.5}$), K–Cl–F-bearing Fe–Ca-rich amphibole ferrohastingsite ($Fe_{4.4}Ca_2Mg_{0.5}K_{0.4}Na_{0.3}(Si_{6.5}Al_{1.8}O_{22})(Cl, F, OH)_2$ in endoskarns, and retrograde ferroactinolite ($Fe_{4.2}Ca_2MgMn_{0.04}Na_{0.1}K_{0.06}(Si_{7.8}Al_{0.2}O_{22})(F, Cl, OH)_2$ and Fe-rich chlorite ripidolite ($Fe_{4.3}Mg_{1.1}Ca_{0.06}Mn_{0.01})(Al_{2.8}Si_3O_{10})(OH)_8$ in the exoskarns. Wollasonite, plagioclase, and K-feldspar have been additionally formed together with ferrohastingsite in the endoskarns. The eastern magnesian skarn is typically phlogopite-rich ($K_{0.9}Mg_{2.7}Fe_{0.2}Na_{0.02})(Si_{2.9}Al_{1.2}O_{10})(OH, F)_2$, and consists of prograde forsterite ($Fo_{97.0}Fa_{2.7}$), diopsidic pyroxene ($Hd_{0.2}Di_{0.88}$), and retrograde Mg-rich actinolite, Mg-rich chlorite clinochlore ($Mg_{4.5}Fe_{0.1}K_{0.05})(Al_{1.8}Si_{2.7}O_{10})(OH)_8$, serpentine and talc. Iron mineralization overprints the calcsilicate skarns in both the western and the eastern skarns and is magnesian in the eastern orebodies (3.65 wt.% MgO). The iron ore consists of a number of high grade, replacement, and magnetite orebodies with minor amounts of pyrrhotite, chalcopyrite, and pyrite indicating a large scale metasomatic transfer of iron bearing fluids during Middle Eocene magmatic activity at the KKB-VPMB.

1. Introduction

The Sangan iron skarn deposit at the Khorassan Department in northeastern Iran is located at the eastern edge of the Khaf-Kashmar-Bardaskan Volcano-Plutonic-Metallogenic Belt—KKB-VPMB (Fig. 1) Having a proven reserve of over 1000 Mt iron ore @ 53 % Fe, Sangan represents a worldclass iron skarn deposit. The skarns and the iron orebodies, defined by surface mapping and diamond drilling, extend over an E–W trending zone of around 8 km, and occur at depths down to 600 m below the surface. The iron ore consists of seven orebodies or anomalies defined in the mine as (Á), (A), (B), (C-South or Cs), (C-North or Cn), Baghak, and Dardvay from the west to the east. Historic records of iron ore at Sangan are known since 600 years (Mostowfi Ghazvini, 1339), although significant mining activity only started after 1975. Extensive modern exploration began in 1983 by the National Iranian Steel Company (NISCO) and continued by Madankav and Kavoshgaran companies in 2004 that resulted in 240,000 m of bore cores and the definition of an iron ore reserve of more than 1000 Mt grading @ 53% Fe.

Previous studies were mainly limited to the alteration and mineralization characteristics of selected parts of the Sangan deposit (Boomeri, 1998; Karimpour, 1999; Karimpour and Malekzadeh Shafaroudi, 2006, 2008; Mazloomi et al., 2009; Yousefi et al., 2009). A number of questions such as the petrochemistry of the different intrusions, their relationship with the iron skarn ore and their relative ages, and the nature of the magmatism were still unclear. The present paper is the result of the PhD study of the first author and is based on extensive field works and the recognition of different intrusive bodies, their radiometric age determination and

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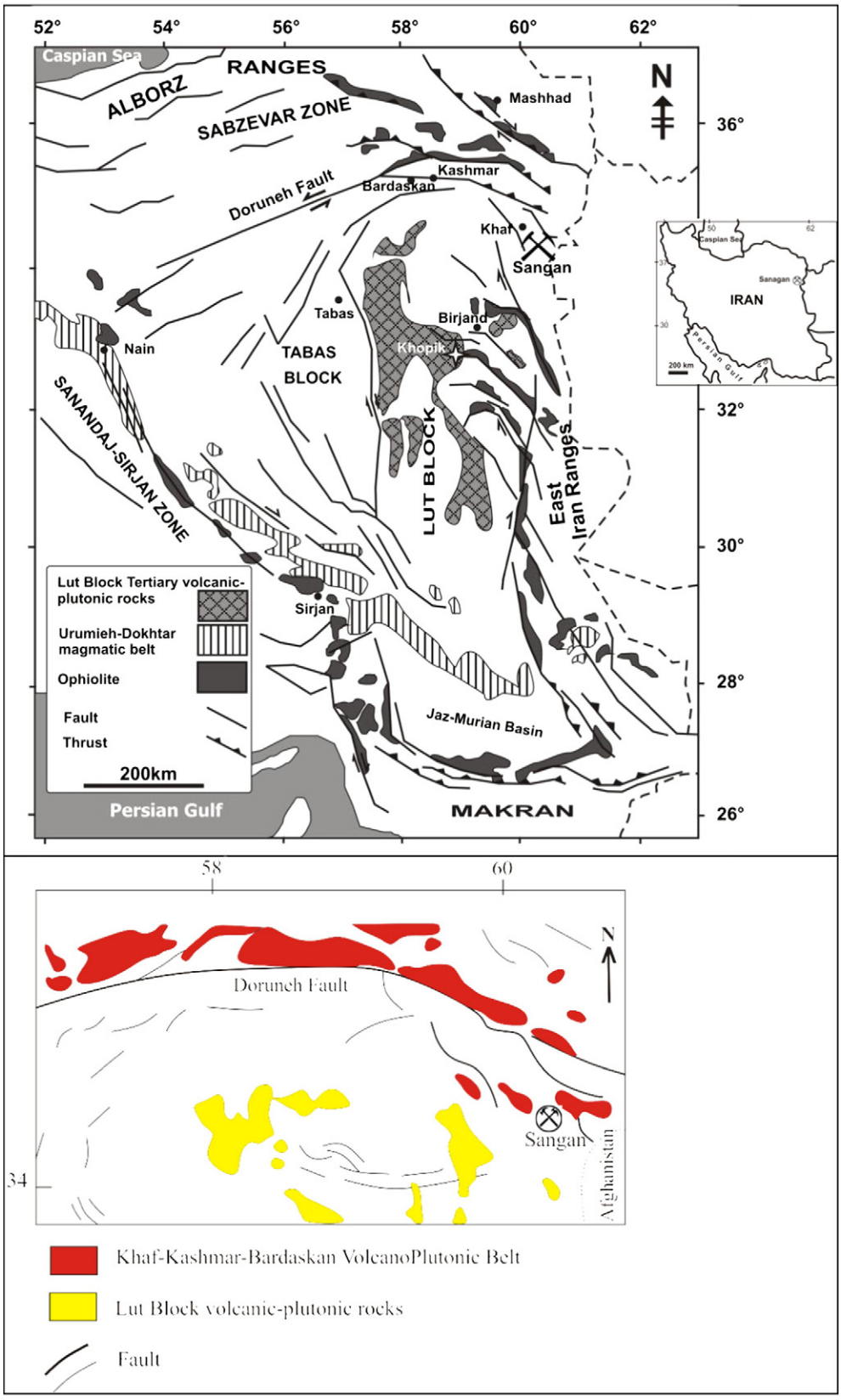

Fig. 1. Simplified structural map of eastern Iran showing the location of the Sangan deposit at the eastern edge of Doruneh Fault (modified from Malekzadeh et al., this volume), the Khaf-Kashmar-Bardaskan Volcanoplutonic Belt, and the southerly Cenozoic volcanoplutonic rocks of the Lut Block.

relationships with skarn mineralization, as well as the mineralogy and mineral chemistry of the skarns. An outcome of this study was the recognition of two distinct zones of calcic and magnesian skarns controlled by the composition of the metasomatized prototype carbonate host rocks. The results have been summarized in a schematic model for the skarn mineralization at Sangan.