Geological Investigation and Mineralization of the Dardway Iron deposit, Sangan Ore Field, Northeast Iran

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Abstract
The Sangan iron ore deposit is located approximately 300 Km southeast of Mashhad, in the Khorasan Razavi province. It is the biggest Iron mine in Eastern Iran. Sangan iron mine comprised of several ore body such as Dardway, Baghak, A, A', B, C, C North. Dardway ore body is located in the southern marginal of the Upper Eocene Sar Nowsar granite (biotite-amphibole granite) and occur in east-west trending sequence of Upper Mesozoic sedimentary rocks. Magnetite skarn, formed in black limestone and dolomite (Jurassic- Lower Cretaceous). They are massive and in some localities they have about 200 meter thickness. Mineral paragenesis are: magnetite ± hematite ± pyrite and some chalcopyrite ± garnet (andradite) ± actinolite ± chlorite ± phlogopite calcite ± dolomite. Dardway is Mg-skarn the Mg content of magnetite is about 1.22-1.26% . At least four stages of skarn formation and ore deposition have been recognized at area (stage I, II, III and IV a, b). Based on the satellite images and field observation, Dardway was displaced by strike slip fault more than one Km from Baghak deposit. Also exploration drill holes and ground magnetic surveys in the study area confirm this motion and dips of mineralization zone are declination towards in South (80°-85°). The recognition of fault system and structural feature are important because it may implication in assessment and exploration of other segment of hidden ore body.

Keywords: *Magnetite skarn; strike slip fault; Dardway Iron Ore; Sangan; Iran.*

Introduction-1
Sangan iron deposit consists of a number of ore bodies and the ore reserves is more than 600 Mt with grade of > 45% Fe (Karimpour, 1989). This mine is located at latitude of N 34° 25 and longitude of E60° 30 about 290 Km southeast of Mashhad, 40 Km southeast of Khaf city in Northeastern Iran (Fig.1a,b).

Evidences of old mining operations are seen in the area and is attributed to about 600 years ago (mention by Iranian historian, Hamdolah Mostofee), However the formal report and systematic exploration (include geological, geophysical and survey studies) have begun in the area since 1975 by Ghassemipour,1975; Ternet et al. 1980; Alavi Naini 1992; Boromandi 1981; Marjaei, 1989; Karimpour, 1990; Kermani & Forster, 1991; BHP Ltd (Ian Lipton, 1992), Boomeri, 1992; Ghavami, 1993; Karimpour, 1994; Mazaheri, 1995; and Karimpour, 2007. Academic studies on the genesis of the ore deposit more confirmed Metasomatic hydrothermal skarn model (Karimpour, 1990; Boomeri, 1998; Karimpour, 1994; Mazaheri, 1995).

The iron mineralization in Sangan are observed in more than a few part (namely Sangan group) , and most of them extend for more than 20 Km along south marginal granitoid rocks (Sar Now Sar Granite) and this ore deposit at geologically divided into Western (subdivided into A, A', B, C, C North), Central (subdivided into Dardway and Baghak) and Eastern anomaly (Fig.1c). This study is mainly focused on the Dardway ore deposit (Central anomaly).

2. Geological setting

The Sangan area is located at Centeral Iran Blocks and eastern segment of large scale old Doruneh fault passing near area (Fig. 1a). The geology of the region has been described by Ternet et al. (1980), Alavi Naini (1980) Fauvelet and Eftekhar Nezhad (1990). A brief account regarding the relevant geological features is summarized here. The oldest formation is composed of late Late Proterozoic (?) Low-grade metamorphic, volcanic and sedimentary rock. This basement is cover by a sequence of Palaeozoic, Mesozoic and Cenozoic rock.

Paleocene-Eocene formations are composed of sedimentary, volcanic and pyroclastic rocks, late Eocene plutonic rocks (of granitic to dioritic composition intruded into the older rocks. The region consists of few fault-bounded uplifted blocks, and rock formations strikes obey these fault strikes. The largest blocks constitutes the Main Range (Fauvelet and Eftekhar Nezhad, 1990). Thick series of Oligo-Miocene sediment and Neogene formation (conglomerate, sandstone, gypsiferous marls) occupy extensive depression lying between uplifted blocks of older rocks.

Fauvelet and Eftekhar Nezhad, (1990) distinguish One episode of pre-Jurassic regional metamorphic of the greenschist facies which have been subjected by early Cimmerian orogeny.

3. Geology of the Dardway deposit

The geology and distribution of iron ore in Dardway mine are shown in Fig.2a. The stratigraphic sequence cropping out in the study area (and other part of mine district) ranges from Jurassic to Quaternary in age. This sequence in Sangan mine is approximately more than 3000 m thick (Fig.2 b) and includes Jurassic shale, siltstone and sandstones (Shemshak Formation) in the Southern part of Western Dardway mine this shales contain plant index fossils belong to lower Jurassic (Boomeri, 1998).

Middle-Upper Jurassic and Cretaceous calcite and dolomite marbles which host the iron ore bodies and skarn minerals overlie the Lower Jurassic metamorphosed and metasomatized shale, siltstone and sandstone (Kermani and Forster, 1991; Boomeri, 1998).

The carbonate rock uncomfortably overlain by volcanic (rhyolite, dacite, andesite) and volcanoclastics rocks of Eocene age. Intrusive bodies (named Sar Nowsar granite) consisting ranging in composition form alkali granite, biotite-hornblende granite to quartz monzodiorite and microgranite According to a radiometric dating, the age of the granite is 38.4±1 Ma, belong late Eocene to Early Oligocene (Ternet et al., 1990). The magmatic series in area is calc-alkaline and generally granite bodies can be grouped I type and the most of granitic rock are of continental arc affinity granite (CAG) and tectonic setting associated with mostly subduction related processes (Ghavami, 1993; Karimpour, 1994). In the mine area Quaternary sediments consist of alluvium in creeks and colluviums along slopes.

4. Ore and skarn zone

The ore body at Dardway occurs as a discontinuous irregular zone located mostly between exoskarn and the pluton (Fig. 4). In this zone, ore (Magnetite) appears as massive lenses (length in outcrop ~200 m) in the in the vicinity of the pluton with the limestone. Most of the ore is hosted by intensely altered limestone (exoskarn), marble are strongly replaced by magnetite skarns. The ore bodies are columns with elliptical cross section and extending vertically down to considerable depth to 700 m (Kermani and Forster, 1991).

Magnetite ore in the marble forms topographically highest cliffs and the host rocks dip toward the south with an angle of approximately80-85 around ore body.

The iron mineralization (skarn zone) in this area is limited by fault zone WNW-oriented and forms the boundary with granitoids rocks in south also the general trends of the skarn zones parallel to fault zone. (Fig.2a). The regional faults developed in the out side of the study area extend over 10 km, With have use satellite image and control field observation, indicate occurrence motion right lateral strike slip fault system which may suggest that the ore body package offset near 1 Km from southeast (Baghak ore body) to north in present situation.

4. Skarn mineralogy and paragenesis

The skarn in the Dardway is mostly magnesian skarn and principal skarn minerals are magnetite (forms euhedral grains up to 2.5 cm in diameter), garnet (means of chemical composition; And_{70-79}-Gro_{26-17}), clinopyroxene (means of chemical composition; Hed_{48-41}-Dio_{48-56}), clinchlorite, and phlogopite together with, calcite, dolomite, quartz, hematite, chlorite, and pyrite, chalcopyrite as subordinate minerals. Chemical composition of typical ore shown low content of S, P and high amount in MgO (1.22%-1.26%) and MnO between 0.28 %-0.36 % (Table 1). Paragenetic studies based on macro- and micro-textures show that skarn formation at occurred in emplacement of plutonic rocks, two major early higher temperatures, prograde stages (Stages I &II); and two (Stage III&IV) later lower temperature, retrograde event (Mazaheri et al, 1995).

The prograde stage were characters by replacement of Mg-limestone by contact skarn containing predominantly andradite-garnet (stage I) and stage II recognized by abundant development of andradite-hedenbergite assemblages.

Retrogression (stage III) produced manly hydrosilicate minerals, whereas later are was generally characterized by the development of chlorite, magnetite, pyrite and chalcopyrite (stage IV_a), and growth of kaolinite and hematite (stage IV_b).

Fluid inclusion study (Tale Fazel et al., 2010) show temperature of emplacement granitic rocks in range 320-520 ºC and prograde stage developed within the temperature ranges of 310-490º C with average salinity of 33.6 equiv. wt % NaCl and retrograde stage (metasomatic mineralization) developed within temperature ranges of 190-310º C with average salinity of 13.6 equiv. wt% NaCl.

5.Conclusions

The Geological studies show that the ore body at Dardway occurs as a discontinuous irregular zone located mostly between exoskarn and the pluton. The iron mineralization (skarn zone) in this area is limited by fault zone WNW-oriented and forms the boundary with granitoids rocks in south also the general trends of the skarn zones parallel to fault zone. Most of the ore is hosted by intensely altered limestone (exoskarn), marble are strongly replaced by magnetite skarns.

The skarn in the Dardway is mostly magnesian skarn and principal minerals are magnetite ± garnet (And_{70-79}-Gro_{26-17}) ± clinopyroxene (Hed_{48-41}-Dio_{48-56}) ± clinchlorite, and phlogopite together with, calcite ± dolomite ± quartz ± hematite ± chlorite± pyrite± chalcopyrite and low content of S, P and rich amount in MgO (1.22%-1.26%) and MnO(0.28 %-0.36 %).

Skarn mineral assemblages at Dardway show that skarn evolution occurred in four stages. The Stage I and II (310-490º C with average salinity of 33.6 equiv. wt% NaCl) mineral assemblages are dominated by anhydrous minerals (garnet and clinopyroxene). These two stages are considered to represent prograde anhydrous skarn development, whereas Stage III, which is dominated by hydrosilicate and magnetite minerals. But the bulk of magnetite within the deposit formed during the later stag (temperature 190-310º C with average salinity of 13.6 equiv. wt% NaCl) of skarn evolution (Stage IV).

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Table 2.Chemical composition of magnetite of Dardway ore

Sample	Fe_2O_3	FeO	TiO_2	MgO	CaO	MnO	NiO	Cr_2O_3	*
D-1	68.1	28.1	0.03	1.22	-	0.36	-	-	92.8
D-2	79.5	28.7	0.01	1.26	0.01	0.28	0.01	0.02	92.8
K-3**	69.97	25.12	0.02	1.15	0.04	0.12	-	-	

***Fe+Mn/Fe+Mn+Mg;**

**** After Kermani& Forste(1991).**

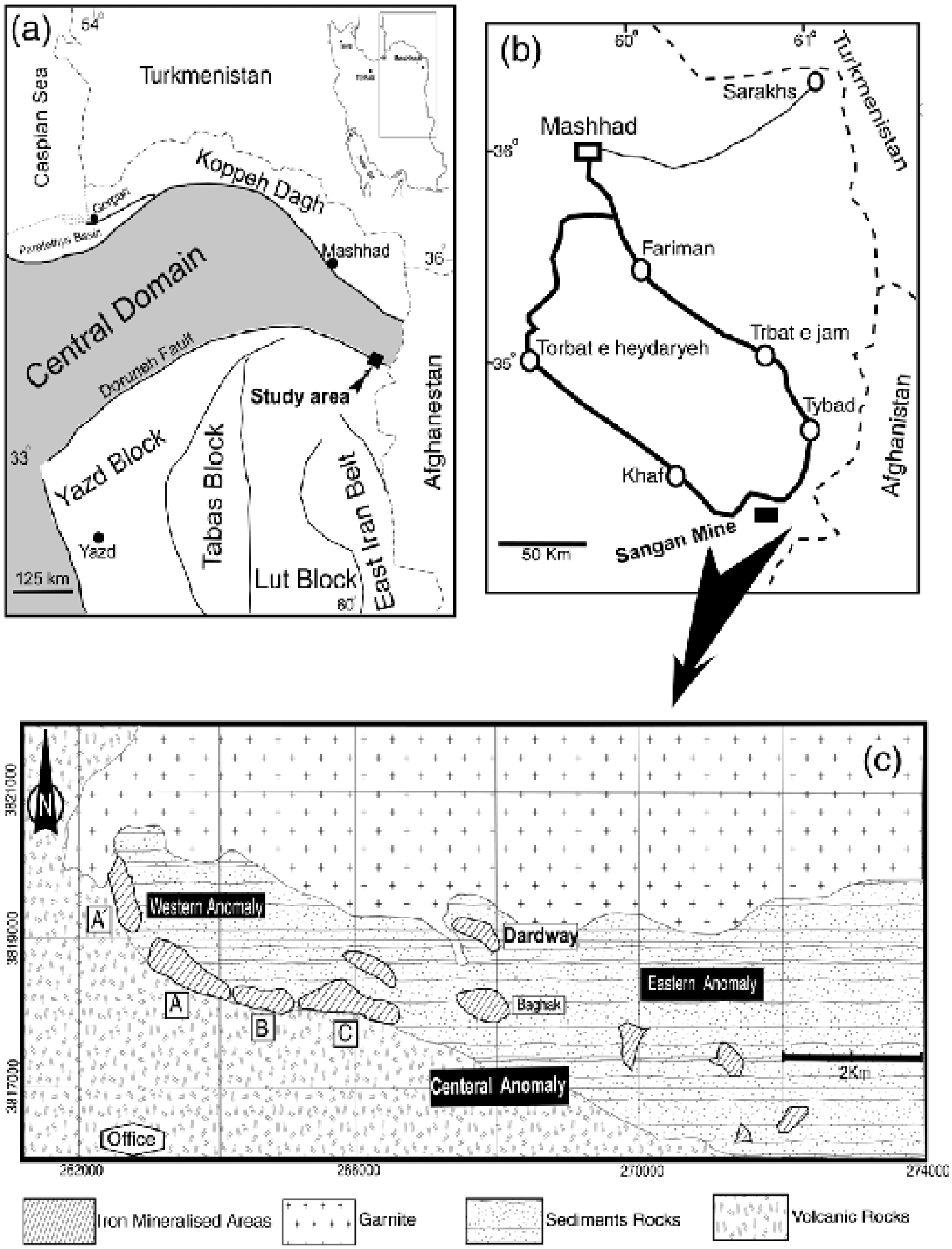

Fig.1. (a) Iranian structural major zones schematically and Localities Sangan area in the Northeast Iran (modified form Aghanabati ,2004). (b) location and access to the study area. (c) Sketch map showing the location of Sangan ore bodies, Include Dardway in Central anomaly (modified from www.simp.ir; Kermani & Forster, 1991).

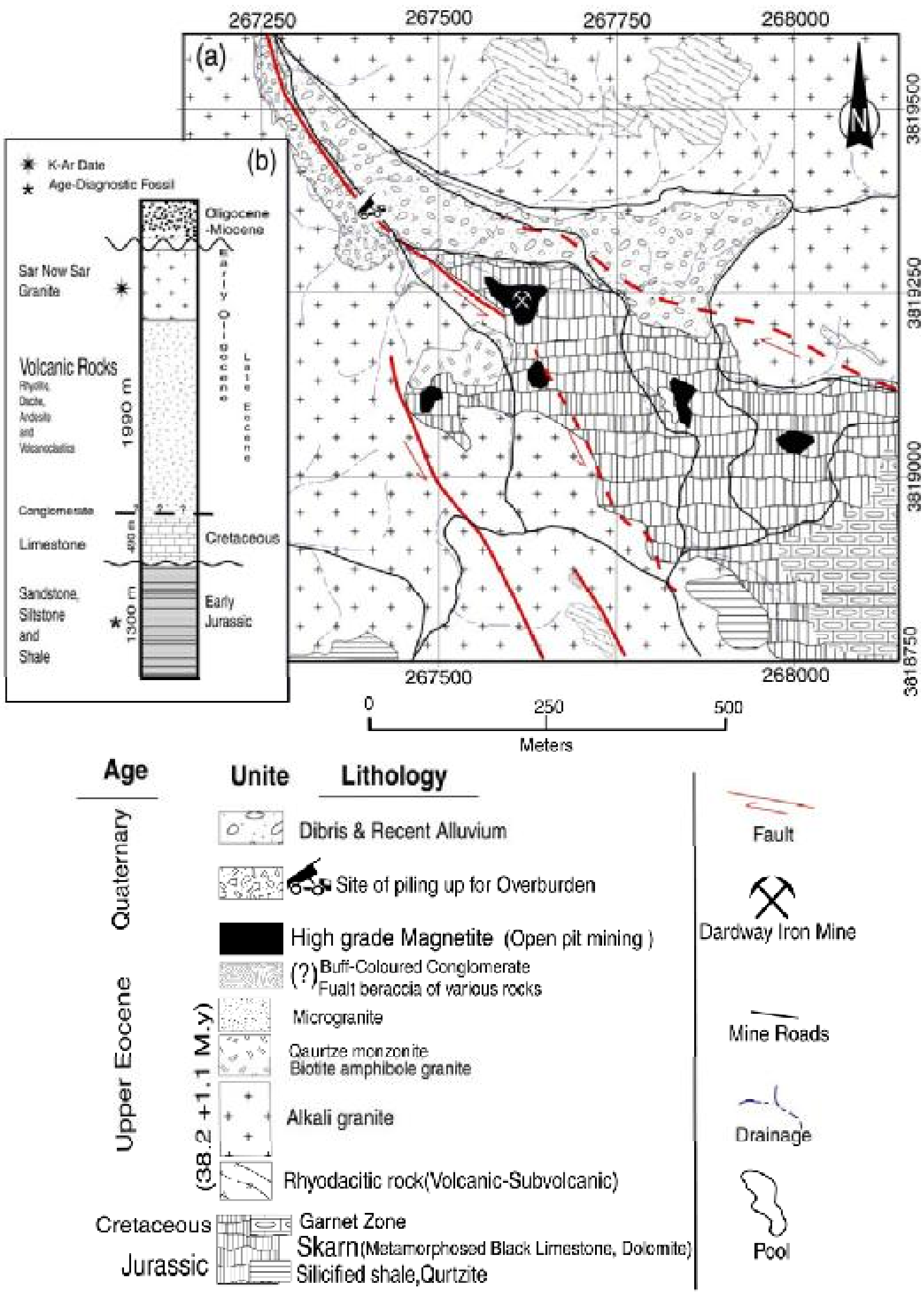

Fig. 2.(a) Geological map of the Dardway iron deposit. (b) Stratigraphic column for the Sangan are showing maximum thickness of the Early Jurassic and Early Oligocene unite (after as Mazaheri 1995).