



Fluid inclusion evidence for hydrothermal fluid evolution in the Darreh-Zar porphyry copper deposit, Iran



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ABSTRACT

The Darreh-Zar porphyry copper deposit is associated with a quartz monzonitic–granodioritic–porphyritic stock hosted by an Eocene volcanic sedimentary complex in which magmatic hydrothermal fluids were introduced and formed veins and alteration. Within the deepest quartz-rich and chalcopyrite-poor group A veins, LVHS2 inclusions trapped high salinity, high temperature aqueous fluids exsolved directly from a relatively shallow magma (0.5 kbar). These late fluids were enriched in NaCl and reached halite saturation as a result of the low pressure of magma crystallization and fluid exsolution. These fluids extracted Cu from the crystallizing melt and transported it to the hydrothermal system. As a result of ascent, the temperature and pressure of these fluids decreased from 600 to 415 °C, and approximately 500–315 bars. At these conditions, K-feldspar and biotite were stabilized. Type A veins were formed at a depth of ~1.2 km under conditions of lithostatic pressure and abrupt cooling. Upon cooling and decompressing, the fluid intersected with the liquid–vapor field resulting in separation of immiscible liquid and vapor. This stage was recorded by formation of LVHS1, LVHS3 and VL inclusions. These immiscible fluids formed chalcopyrite–pyrite–quartz veins with sericitic alteration envelopes (B veins) under the lithostatic–hydrostatic pressure regime at temperatures between 415 and 355 °C at 1.3 km below the paleowater table. As the fluids ascended, copper contents decreased and these fluids were diluted by mixing with the low salinity-external fluid. Therefore, pyrite-dominated quartz veins were formed in purely hydrostatic conditions in which pressure decreased from 125 bars to 54 bars and temperature decreased from 355 to 298 °C. During the magmatic-hydrothermal evolution, the composition and *P–T* regime changed drastically and caused various types of veins and alterations. The abundance of chalcopyrite precipitation in group B veins suggests that boiling and cooling were important factors in copper mineralization in Darreh-Zar.

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1. Introduction

The Darreh-Zar porphyry copper deposit is located in the Urumieh–Dokhtar arc, 8 km southeast of the giant Sar–Cheshmeh deposit (Fig. 1), Iran, and contains 67 Mt of sulfide reserves with copper grade of 0.37 wt.% (unpublished data from Iranian Copper Company). Previous investigations in Darreh-Zar (Derakhshani and Abdolzadeh, 2009; Grujic and Volickovic, 1991; Hemmati, 1995; Maanijou, 1993; Ranjbar, 1997; Ranjbar et al., 2001) revealed the lithological and alteration pattern in the area but did not provide adequate data for evaluating the formation history of the Darreh-Zar porphyry Cu deposit and physico-chemical conditions of the hydrothermal system responsible for alteration and mineralization in Darreh-Zar. The aim of this investigation is to evaluate the hydrothermal system which formed the porphyry

Cu deposit in Darreh-Zar on the basis of vein and alteration mineral assemblages, vein crosscutting relations and fluid inclusion evidence. Fluid evolution was derived from fluid compositions and *P–T* evaluation of this system, and a model was elaborated which clarified vein formation, wall-rock alteration and metal precipitation.

2. Geological setting

The porphyry copper deposit in Darreh-Zar, the southwestern part of Kerman, belongs to the Tertiary Urumieh–Dokhtar arc; this is the southeastern segment of the Kerman Cenozoic magmatic arc (KCMA; Shafiei et al., 2009), (Fig. 1) which was formed during the successive stages of Tethyan ocean closure during the Cretaceous–Oligocene subduction and late Paleogene continent–continent collision (Berberian and King, 1981). Related in origin, porphyry copper deposits of the Kerman arc show a close temporal and spatial association with the Miocene adakite-like porphyries which intruded Eocene volcanic rocks (Shafiei et al., 2009).

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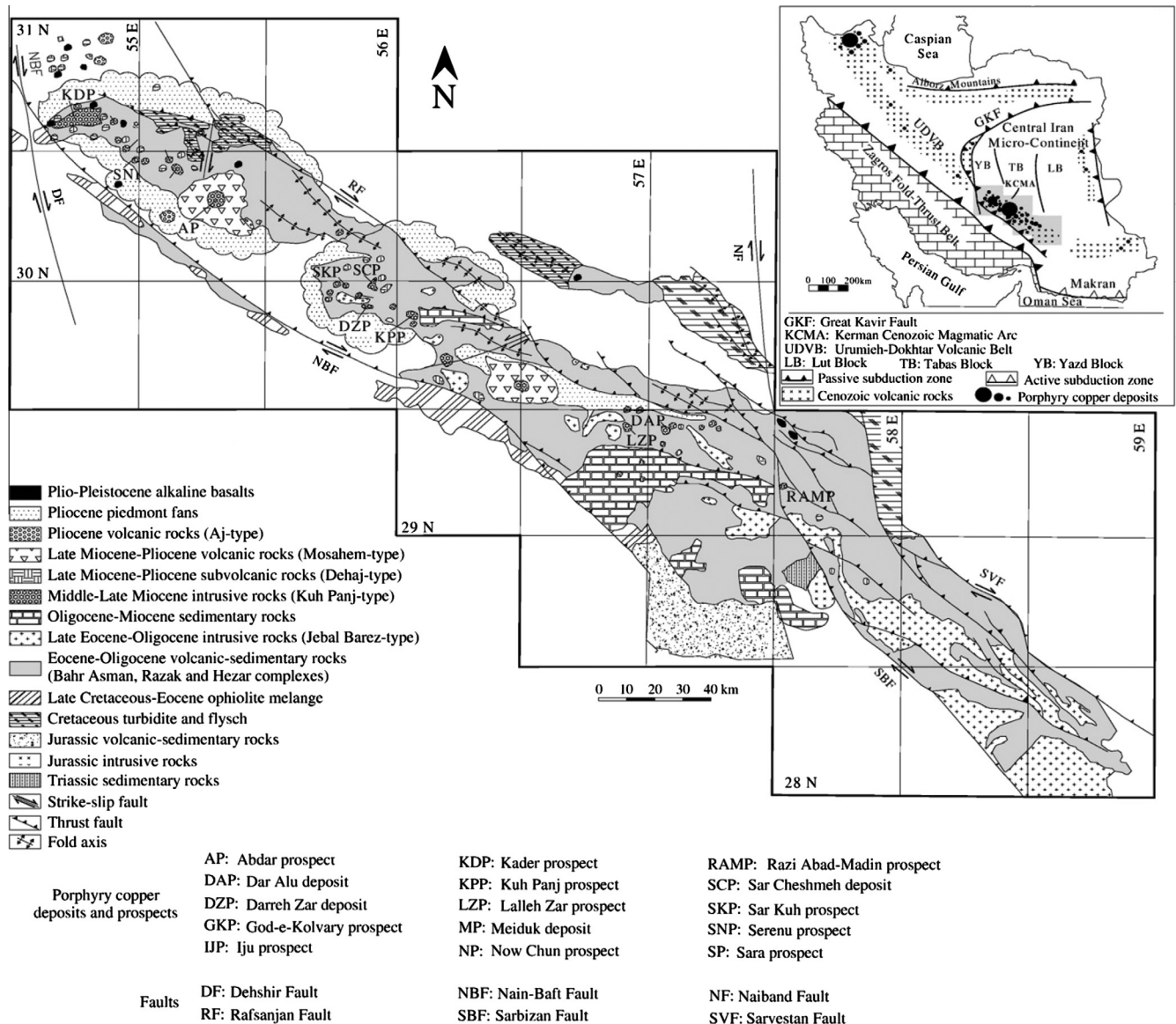


Fig. 1. Location of the Kerman Cenozoic magmatic arc in the Urumieh–Dokhtar volcanic belt and geologic map of KCMA with location of some porphyry copper deposits and prospects (from Shafiei, 2010).

General geology and petrography are summarized here from more detailed descriptions by Hemmati (1995) and Maanijou (1993). The Darreh-Zar porphyry copper deposit is associated with quartz monzonitic–granodioritic–porphyritic stock hosted by the Eocene volcanic sedimentary complex. The quartz monzonitic–granodioritic–porphyritic stock contains phenocrysts of Pl, Hbl, Qz and Bt (50–65 vol.%) and fine-grained groundmass of Qz, Pl, Kfs, Bt and Amp with minor to trace apatite, zircon, titanite and rutile (rock-forming minerals are abbreviated according to Whitney and Evans (2010)). After emplacement of the stock and development of the porphyry system, the stock was intruded by a swarm of unmineralized dioritic to microdioritic dikes containing phenocrysts of highly altered Pl, Amp, Bt, Qz and minor apatite. Within the central part of the stock, the youngest intrusive event is represented by unmineralized and weakly altered small granodioritic stocks and genetically related dikes. Most copper mineralization occurred during the stock formation (Fig. 2). Three main fault systems have been recognized in the Darreh-Zar porphyry copper deposit: An E–W striking premineralization fault, a NW–SE striking mineralized fault and a N–S striking postmineralization fault sys-

tem (Ranjbar, 1997). Based on the mode of occurrence and mineral associations, two main episodes of hydrothermal alteration have been recognized. The first episode contains two pervasive alteration types, namely potassic and propylitic, and represents the earlier stage of hydrothermal alteration. Potassic alteration is characterized by the conversion of mafic minerals to Bt, replacement of Pl by Kfs + anhydrite (Ranjbar, 1997). The earliest potassic alteration zone occurs at the deep, central part of quartz monzonitic–granodioritic–porphyritic stock and has relatively sharp boundary with propylitic alteration zone (Derakhshani and Abdol-zadeh, 2009). Propylitic alteration is represented by the replacement of Pl by epidote, conversion of Bt to chlorite and carbonate veins. Minor minerals associated with propylitic alteration are albite, sericite, anhydrite, and pyrite. The second episode of alteration comprises a phyllic alteration zone and argillic alteration zone. Phyllic alteration is characterized by conversion of Pl phenocrysts to sericite + Qz with up to 5 vol.% pyrite in veins and disseminations. The latest alteration stage is represented by an argillic assemblage of kaolinite and montmorillonite after Fsp (Ranjbar, 1997), and overprints the underlying phyllic and propylitic alter-

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