

Discrimination between mineralized and unmineralized alteration zones using primary geochemical haloes in the Darreh-Zar porphyry copper deposit in Kerman, southeastern Iran



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ABSTRACT

Primary geochemical haloes were studied at the Darreh-Zar porphyry Cu-deposit, southern Iran. In terms of geochemical signatures, high K_2O/Na_2O enrichment, HREEs and HFSE's depletion in the potassic alteration, high $(La/Sm)_{cn}$, $(La/Yb)_{cn}$ and $(Gd/Yb)_{cn}$ ratios in mineralized sericitic and potassic zones and notable depletion in the REEs content in argillic alteration is recognized. Further, Mg, Li, Sc, P enrichment and W depletion can serve to separate potassic alteration from the other altered zones, while $(Eu/Eu^*)_{cn}$ and $(Ce/Ce^*)_{cn}$ don't show pronounced changes in different alteration zones. The coupled positive Tl, Se, S, Rb, Co, Cs, Mo, K and negative Te, Ta, Ti, Sr, Rb, As, Bi, Ga, Hf, In, Mn, Zn and Zr anomalies can be adequately used in discriminating between the mineralized zones (potassic, chlorite-sericite and sericite alterations) and the barren (propylitic zone). The behavior of the trace elements on isocon diagrams reveal that HFSEs are depleted in mineralized altered zones and display variations in the amounts in the barren facies.

Zonality index in the axial direction from drill holes 146 to 124 estimates the zonality sequence as Pb-Zn-Ag-Cu-Pb-Zn in the surface horizons. The calculated zonality in five drill holes and six levels indicates that the level of 550 m at the DH 117 in the central part of the area has the highest value (0.76) for Cu. The zonality sequence from the surface to the depth is variable and can be demonstrated as follow: DH 146: Pb-Zn-Cu-Mo-Ag; DH 137: Zn-Cu-Mo-Pb-Ag; DH 117: Ag-Zn-Pb-Mo-Cu; DH 121: Cu-Mo-Zn-Ag-Pb; DH 136: Pb-Ag-Zn-Cu-Mo; DH 124: Zn-Mo-Cu-Pb-Ag. Available data of the enrichment factors shows different enrichment for copper and molybdenum (i.e. $EF > 10$), selenium and silver (i.e. $EF > 5$), tin and LREEs (i.e. $1 < EF < 5$).

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1. Introduction

Trace and rare earth elements (REEs) have been used over three decades as a tool for better understanding hydrothermal processes. Some workers (i.e. Chang-bock et al., 2002; Hass et al., 1995) believe that most REEs are mobilized in chlorine-rich hydrothermal solutions as carbonate, sulfate and fluorine complexes. Terakado and Fujitani (1998), and Parsapoor et al. (2009) came to the conclusion that these elements behave selectively in hydrothermal systems. Fulignati et al. (1999) emphasized on high mobility of REEs by acidic fluids and demonstrated that light rare earth elements (LREEs) are immobile while heavy rare earth elements (HREEs) are

depleted in advanced argillic zone. Takahashi et al. (2004) pointed out that HREEs, due to forming more stable complexes with some ligands, stay in solutions longer than LREEs. Thus, they generally tend to concentrate in latter products of hydrothermal systems. Buchl and Gier (2002) cited that in spite of old ideas, some elements including the REEs, Zr and Ti are to some extent mobile. They stressed on enrichment of U, Th, Ba, Cs, Rb and K and weak depletion of Ni and Mg. These lines of evidence suggest that geochemical behavior of REEs and other trace elements in an aqueous solution is complex and no single rules can be established for their mobility during hydrothermal processes.

Over the years, various methods of mineral exploration have been developed (cf. Deng et al., 2008, 2009, 2011; Filzmoser et al., 2009, 2012; Li et al., 1993, 1995, 1998; Rose et al., 1979; Wang et al., 2010) but among the methods, the analysis of primary geochemical haloes has become an authentic exploration tool for

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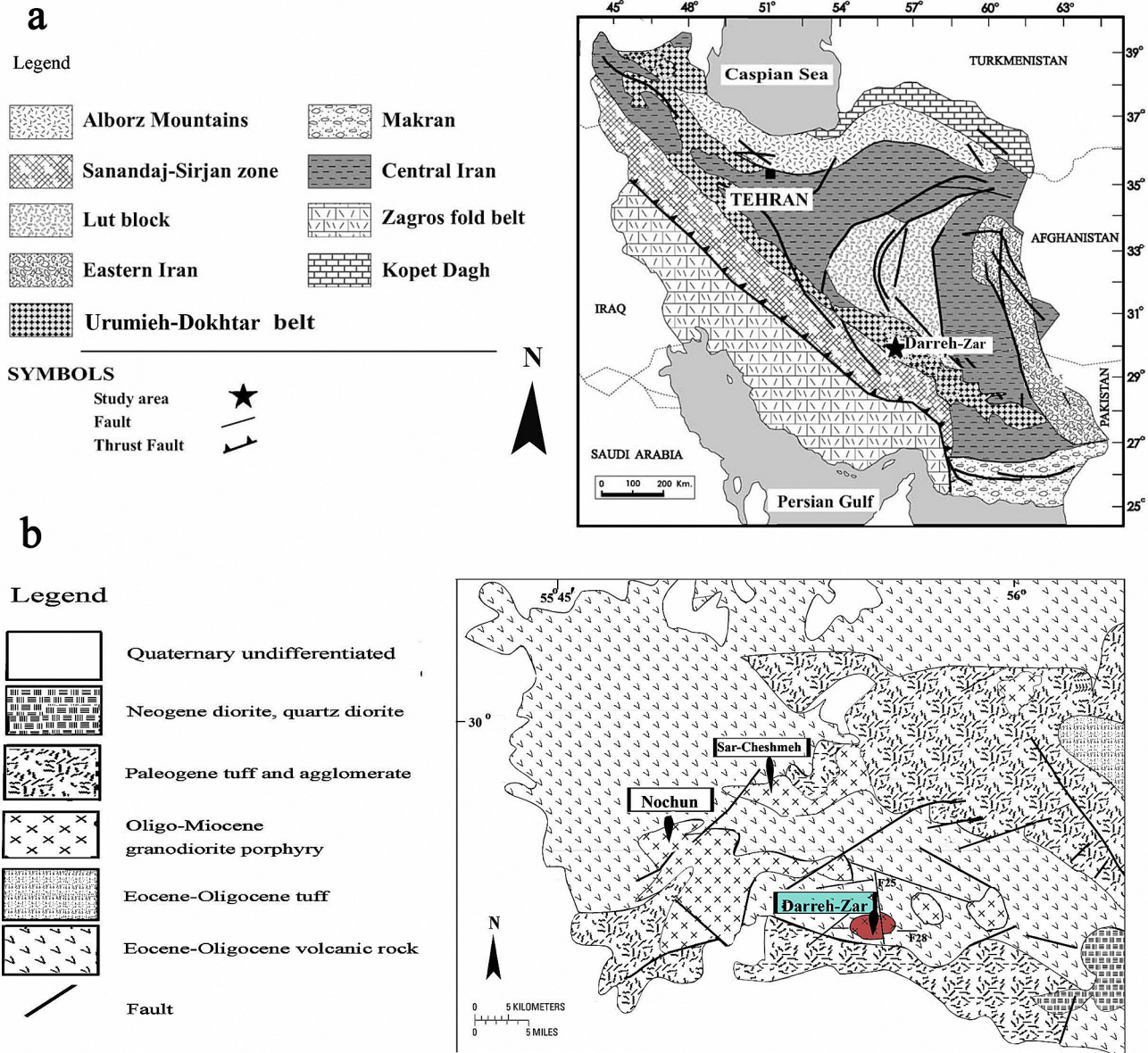


Fig. 1. a. Tectonic map of Iran illustrating various structural units and deformation belts. b. Geological map of Sar-Cheshmeh, Nochun and Darreh-Zar porphyry copper deposits (modified from Huber, 1969).

revealing the presence of hidden or non-outcropping deposits (Eilu and Groves, 2001; Goldberg et al., 2003; Li et al., 2006; Schmid and Taylor, 2009). The presence of trace elements in primary haloes in ore deposits have long been recognized by numerous workers (i.e. Beus and Grigorian, 1977; Solovov, 1987). Since the haloes are multi-component; therefore, it should be necessary to compare haloes of different elements to choose the appropriate pathfinder elements (Beus and Grigorian, 1977; Harris et al., 2000). Three essential types of zoning have been recognized in primary geochemical haloes of mineral deposits - axial, longitudinal and transversal but, research into 3-dimensional variations of primary geochemical haloes in mineral deposits has frequently focused mostly on axial zoning, which is connected to the flow direction of ore-bearing fluids (Beus and Grigorian, 1977; Chen and Zhao, 1998).

In particular, geochemical studies of primary haloes of mineral deposits can provide important insights to mineral systems as well as significant implications for mineral exploration (e.g., de Almeida

et al., 2010; Goldberg et al., 2003; Kekelia et al., 2008; Zhang et al., 2011). Primary haloes of mineral deposits, which are the results of interactions between country rocks and mineralizing fluids, are

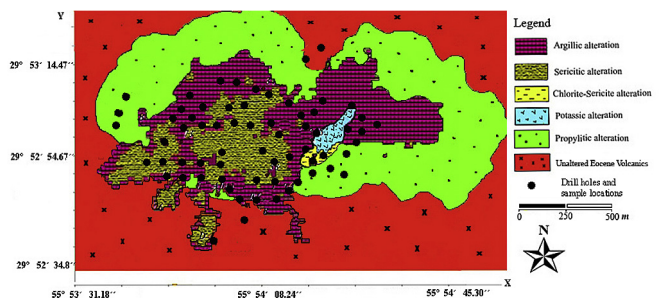


Fig. 2. Hydrothermal alteration map from the surface of the Darreh-Zar area provided by using Aster images.

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