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Mineral chemistry and isotopic composition of magmatic, re-equilibrated and hydrothermal biotites from Darreh-Zar porphyry copper deposit, Kerman (Southeast of Iran)

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ABSTRACT

The Darreh-Zar porphyry copper in the southeastern part of the Urumieh–Dokhtar magmatic belt developed as a consequence of hydrothermal alteration related to the Darreh-Zar granodioritc porphyry stock intruded into mafic volcanic rocks. Hydrothermal alteration and Cu–Mo mineralization are focused on the Darreh-Zar porphyry pluton belonging to Miocene time and the neighboring basaltic country rocks. A core zone of potassic alteration is enclosed by a peripheral zone of chlorite–sericite, sericitic, argillic and propylitic alteration. Judging by petrographic features as well as chemical composition, the biotites studied display variable size, color, and shape and occur as magmatic (M), re-equilibrated (R) and hydrothermal (H) types. The M and R-type biotites are found in the Darreh-Zar porphyry and the H-type formed during potassic alteration within the Darreh-Zar porphyry and the volcanic host rocks as well. The hydrothermal biotites are characterized by the highest amounts of Al_2O_3 and K_2O whereas the magmatic types are hosted by high level of TiO_2 (up to 4.38 wt.%). X_{Mg} values vary between 0.31 and 0.61 which is increased from M to R-biotites then decreased toward low temperature potassic alteration zone. Fluorine and chlorine contents from biotite types also vary between 0.07 to 0.56 wt.% and 0.14 to 0.38 wt.% respectively. These values change to 2.94 to 2.15 wt.% and −3.6 to −4.4 wt.% for IV(F) and IV(Cl) respectively. In all types of biotites, positive correlation is observed between X_{Mg}, Al_2O_3, $Na_2O + K_2O + BaO$ and F but with FeO and Cl it is negative. The TiO_2 content clearly decreases from the M to R and H-type (Average: 3.98, 2.9 and 2.4 wt.% respectively). A direct relation may be noted between Mg# and oxygen fugacity. Log (fH_2O/fHF) and log ($fH_2O/fHCl$) values range from 6.24 to 5.46 and 4.49 to 4.12 wt.% respectively. Oxygen fugacity increases during formation of re-equilibrated biotites but it decreases in the course of potassic alteration. Crystallization temperatures range from 600° to 650 °C, 550 to 600 °C and 450 to 550 °C for magmatic, re-equilibrated and hydrothermal biotites respectively. The M-biotites from Darreh-Zar have the δD values of −89 to −101‰ and the calculated δD values of the aqueous fluids (−66 to −78‰) in equilibrium with the biotites are consistent with a large component of magmatic fluid which shows similarities with the biotite originated from the primary mantle source. The $\delta^{18}O$ also varies between 7.4 to 8.2‰ for fluids in equilibrium with biotites. The obtained M-biotite data from Darreh-Zar porphyry indicates that there is no clear correlation between δD values, Fe and Mg contents but for δD values, Al and Fe^{3+}/Fe^{2+} some affinities were observed. The isotopic data indicate that M-biotites are formed at high temperature (620 ± 20 °C) from fluids with the highest $\delta^{18}O_{H2O}$ (7.8 ± 0.4‰) in comparison with the biotites from some other copper porphyries.

1. Introduction

Chemical variation of micas from magmatic and associated hydrothermal alteration has been subjected to numerous studies (Zhu and Sverjensky, 1991, 1992; Munoz, 1992; Jiang et al., 1994; Boudreau et al., 1995; Leger et al., 1996; Taran et al., 1997; Piccoli et al., 1999; Willmore et al., 2000). The chemical and petrologic features of hydroxyl-bearing minerals, such as micas can be used to estimate the fugacities of HCl and HF in coexisting fluids (Munoz, 1984; Finch et al., 1995; Coulson et al., 2001). Also, trioctahedral micas in igneous rocks have been applied to identify the nature of magma types (i.e. Nachit et al., 1985). Micas in different rock types are stable over wide range of temperature and pressure. Among micas, biotites are pervasively used to decipher physicochemical attributes of the hydrothermal systems (Bird and Helgeson, 1980; Munoz, 1984; Charles et al., 1988; Cho et al., 1988). Biotite is a ubiquitous and abundant phase in various geologic

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environments, which indicates its origin within wide range of temperatures, pressures, and acidity–alkalinity of mineral-forming media. In terms of chemical composition, biotites are complex trioctahedral micas with extensive isovalent and heterovalent isomorphic substitutions. Biotites occupy an intermediate position between the end members of the phlogopite–siderophyllite–annite solid solution series. The composition of biotite from igneous and metamorphic rocks reflects the chemical characteristics of the rocks and the P–T–$f\text{O}_2$ conditions of their formation.

Most previous studies on biotite chemical composition from porphyry Cu deposits focused on determination of F and Cl contents, with the objective of identifying mineralized and barren plutons (Stollery et al., 1971; Kesler et al., 1975; Parry and Jacobs, 1975). Munoz (1984) formulated some equations to estimate the chemistry of hydrothermal fluids and their evolution within porphyry Cu systems. In addition, micas, in particular biotite and phlogopite, owing to the presence of Fe^{2+}, Fe^{3+} and OH^{-} in their structure, can be used to evaluate magmatic conditions (i.e. T (°C), $f(\text{O}_2)$ and $f(\text{H}_2\text{O})$) (Yavuz, 2003a).

Multiple studies (i.e. Jacobs and Parry, 1979; Munoz, 1984, 1992; Van Middelaar and Keith, 1990; Ayati et al., 2008; Boomeri et al., 2010; Afshooni et al., 2013) on porphyry Cu deposits have documented the full elemental chemistry of biotites with focused on the methods of determining the relative fugacity of halogens in igneous and hydrothermal ore forming systems.

In 10,000 km-long Alpine–Himalayan orogenic and metallogenic belt, numerous porphyry copper deposits have been discovered. In Iran, porphyry Cu deposits are mainly widespread in Urumieh–Dokhtar magmatic belt (UDMA) (Bazin and Hubner, 1969). The belt is part of the Alpine–Himalayan mountain chain, extending parallel to the Zagros thrust zone and hosts an assemblage of significant porphyry Cu systems. Within this, magmatic and mineralization processes are related to subduction of Arabian plate beneath the central Iranian microcontinent (Shahabpour, 1982). Across this belt, numerous porphyry copper deposits including the Sar-Cheshmeh, the Sungun, the Nochun and the Darreh-Zar are the most worth mentioning (Fig. 1a,b).

The principal objective of this study is to document the chemical composition of biotites from Darreh-Zar porphyry copper deposit which has not been substantiated so far. The results contribute to our understanding of crystallization conditions such as oxygen and halogen fugacities of the biotites from the granodioritic rocks and the associated potassic alteration zone.

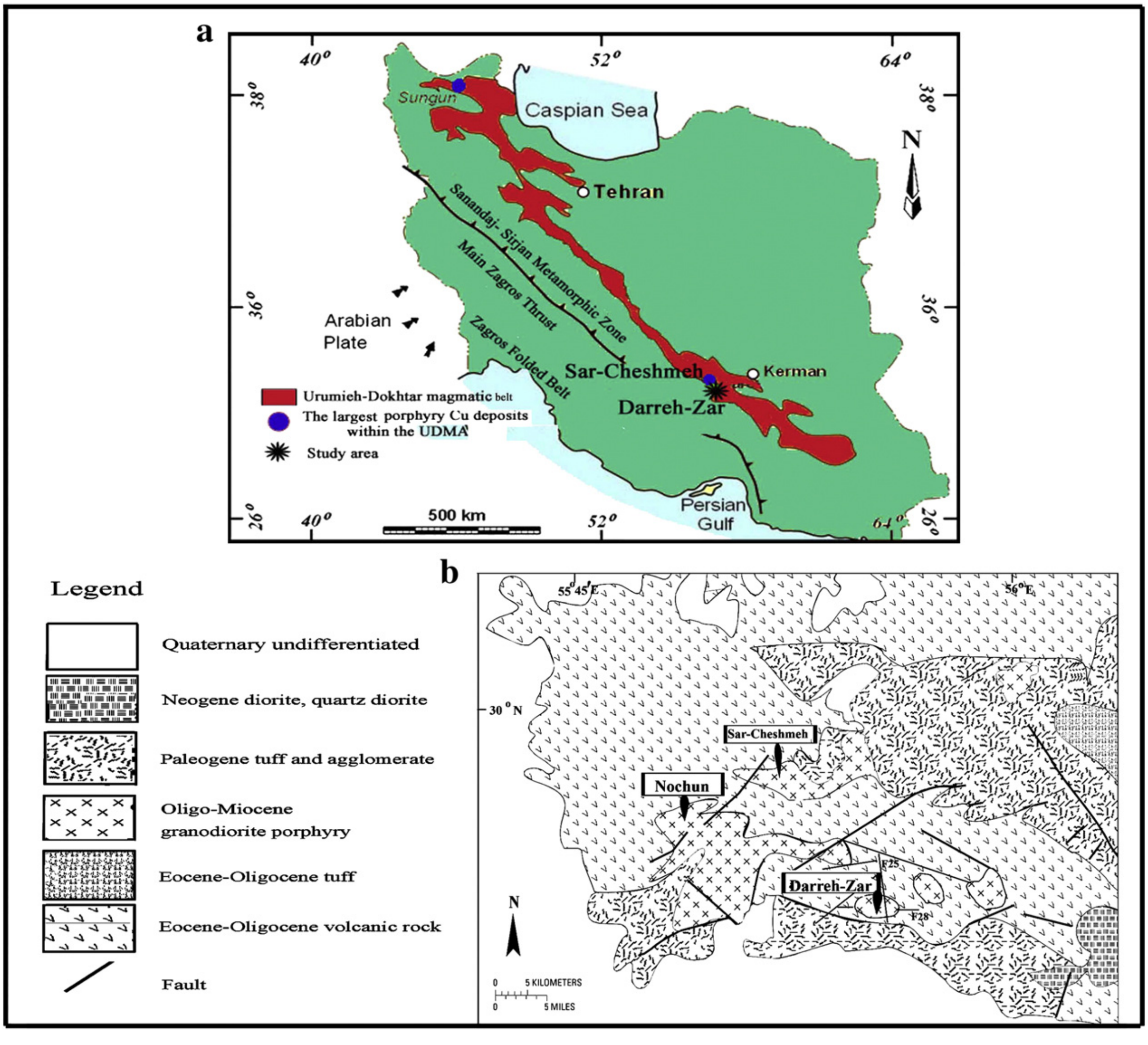

Fig. 1. a) Tectonic map of Iran illustrating various geological structures and fold belts. b) Geological map of the Sar-Cheshmeh, Nochun and Darreh-Zar. Modified from Huber (1969).