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The Khopik porphyry copper prospect, Lut Block, Eastern Iran: Geology, alteration and mineralization, fluid inclusion, and oxygen isotope studies

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ABSTRACT

The Khopik porphyry copper (Au, Mo) prospect in Eastern Iran is associated with a succession of Middle to Late Eocene I-type, high-K, calc-alkaline to shoshonite, monzonitic to dioritic subvolcanic porphyry stocks emplaced within cogenetic volcanic rocks. Laser-ablation U-Pb zircon ages indicate that the monzonite stocks crystallized over a short time span during the Middle Eocene (39.0 ± 0.8 Ma to 38.2 ± 0.8 Ma) as result of subduction of the Afghan block beneath the Lut block.

Porphyry copper mineralization is hosted by the monzonitic intrusions and is associated with a hydrothermal alteration that includes potassic, sericitic-potassic, quartz-sericite-carbonate-pyrite (QSCP), quartz-carbonate-pyrite (QCP), and propylitic zones. Mineralization occurs as disseminated to stockwork styles, and as minor hydrothermal breccias. Some mineralization occurs in fault zones as quartz-sulfide veins telescoped onto the porphyry system. The main ore minerals are chalcopyrite and bornite with minorpyrite and magnetite and the highest Cu (0.01–0.9 wt.%), Au (>2 ppm), and Mo (<80 ppm) grades are closely associated with potassic alteration zones.

Unidirectional, pre-ore stage solidification texture (UST) represented by comb-quartz layers within the potassic alteration zone formed from a hypersaline brine (57–73 wt.% NaCl equiv.), low density vapor-rich fluids (4–22 wt.% NaCl equiv.) at temperatures of 482 °C to over 600 °C. The isotopic composition of oxygen ($\delta^{18}O_{water} = 8.7$–$8.9$ ‰) suggests that the quartz layers crystallized from magmatic-hydrothermal fluids that exsolved in the upper part of the monzonitic intrusions. Potassic alteration formed from high salinity fluids (51–73 wt.%) at temperatures between 432–592 °C, and low salinity vapor-rich solutions with 11–19 wt.% NaCl equiv. Later veinlets in the QSCP zone formed from lower salinity fluids (<47 wt.% NaCl equiv.) at temperatures between 332°–400 °C. The oxygen isotopic data for the early alteration zones ($\delta^{18}O_{water} = 9$–9.3 ‰ for potassic and 7.3 ‰ for QSCP) also indicate a magmatic origin for the ore fluids.

The widespread presence of Middle Eocene to Lower Oligocene magmatism and mineralization in Eastern Iran suggests the presence of another important porphyry copper belt in addition to the northwest-southeast Urumieh-Dokhtar copper belt of Iran.

1. Introduction

World-class porphyry copper deposits have long been recognized along the Middle to Late Miocene Urumieh-Dokhtar Magmatic Belt (UDMB) of Iran, are being mined (e.g., Sar Cheshmeh, Meiduk, and Sungun), and have been the subject of research studies for over forty years (Ahmadian et al., 2009; Berberian et al., 1982; Boomeri et al., 2009; Dimitrijevic, 1973; Forster, 1978; Ghasemi and Talbot, 2006; Hassanpour, 2010; Hooper et al., 1994; Jamali et al., 2010; Jankovic, 1984; Jung et al., 1976; Mohajjel et al., 2003; Shahabpour, 2005, 2007 Shafiei et al., 2009; Waterman and Hamilton, 1975). In contrast, little is known about the ore metal potential of other parts of Iran. The Karimpour (2007) established a database for a portion of eastern Iran, including Aster mineral mapping, aeromagnetic data, geology, petrologic model, as well as stream sediment geochemical data, and a number of prospects with potential for porphyry copper were identified (Khopik, Maherabad, Dehsalm, Chahshaljami, Shiekhabad, etc.).

The Khopik and Maherabad prospects were the subject of a PhD study by the first author (Malekzadeh Shafaroudi, 2009). In this paper we present the results of this study with an emphasis on the alteration and mineralization at the Khopik prospect. Fluid inclusion and oxygen isotopic data obtained for quartz crystals in UST layers and for selected

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alteration zones have been elaborated to assess the nature of the hydrothermal fluids responsible for alteration and mineralization.

2. Regional geology

The Khopik prospect is located in the Lut Block of Eastern Iran approximately 80 km SW of the town Birjand (Fig. 1). The Lut Block is one of several microcontinental blocks interpreted to have drifted from the northern margin of Gondwanaland during the Permian opening of the Neo-Tethys, which was subsequently accreted to the Eurasian continent in the Late Triassic during the closure of the Paleo-Tethys (Golonka, 2004). The tectonic and magmatic evolution of the Lut Block has been interpreted within an extensional setting (Jung et al., 1983; Samani and Ashtari, 1992; Tarkian et al., 1983). The presence of ophiolitic complexes in Eastern Iran between the Lut and the Afghan Blocks, led Saccani et al. (2010) to consider the subduction of the oceanic lithosphere at this zone. Eftekharnejad (1981) proposed that magmatism in the northern Lut area resulted from the subduction of Afghan Block beneath the Lut Block, and Berberian (1983) showed that igneous rocks at Lut Block had a calc-alkaline arc signature. The accretionary prism-fore arc basin polarity, the structural vergence and younging of the accretionary prism to the southwest are consistent with a northeast-dipping subduction scenario (Tirrul et al., 1983). Recently, asymmetric subduction models have been discussed for situations similar to that of the Lut Block (Arjmandzadeh et al., 2011; Doglioni et al., 2009).

The Lut Block extends some 900 km from the Doruneh Fault in the north to the Jaz-Morian basin in the south and is ~ 200 km wide (Stocklin and Nabavi, 1973). The Lut Block consists of a pre-Jurassic metamorphic basement, Jurassic sedimentary rocks and several generations of Late Mesozoic and Cenozoic intrusive and/or volcanic rocks (Camp and Griffis, 1982; Tirrul et al., 1983). Radiometric age data indicate that the oldest magmatic activity in the central Lut Block took place in the Jurassic (Tarkian et al., 1983). Rb-Sr isotope data from the whole-rock and the biotite from the Sorkh Kuh granitoid yield Middle to Late Jurassic ages (164.8 ± 1.9 Ma and 170 ± 1.9 Ma, respectively; Tarkian et al., 1983). Intrusive rocks of a similar age are also recognized in the Deh-Salm metamorphic complex in the eastern Lut Block (Mahmoudi et al., 2010). Further to the north, magmatic activity started in Upper Cretaceous (75 Ma) and generated both volcanic and intrusive rocks (Tarkian et al., 1983). The Middle Eocene (47 Ma) was characterized by alkaline and shoshonitic volcanism with a peak at the end of the Eocene. In addition, calc-alkaline basalts and basaltic andesites erupted in the Eocene-Oligocene (40–31 Ma) (Tarkian et al., 1983).

Several sulfide deposits are known from Eastern Iran, in the vicinity of the Khopik prospect, including the Maherabad porphyry-type Cu-Au,

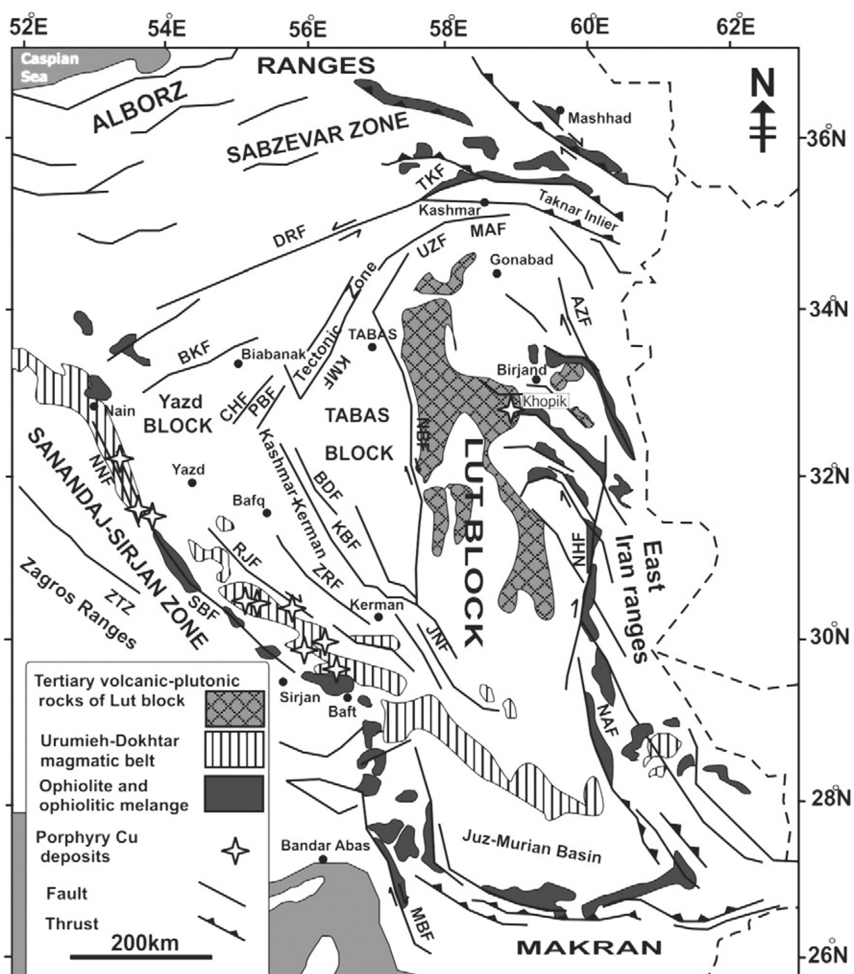

Fig. 1. The structural map of Central-East Iran and its crustal blocks (compiled and modified from Alavi, 1991; Berberian, 1981; Haghipour and Aghanabati, 1989; Jackson and McKenzie, 1984; Lindenberg et al., 1984). AZF = Abiz Fault; BDF = Behabad Fault, BKF = Biabanak Fault, CHF = Chapedony Fault, DRF = Doruneh Fault, KBF = Kuhbanan Fault, KMF = Kalmard Fault, MAF = Mehdiabad Fault, MBF = Minab Fault, NAF = Nostratabad Fault, NHF = Nehbandan Fault, NNF = Nain Fault, RJF = Rafsanjan Fault, SBF = Shahre-Babak Fault, TKF = Taknar Fault, UZF = Uzbak-Kuh Fault, ZRF = Zarand Fault, ZTZ = Zagros Thrust Zone.