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Mineral assemblages, fluid evolution, and genesis of polymetallic epithermal veins, Glojeh district, NW Iran

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ABSTRACT

The Glojeh district contains silver- and base metal-rich epithermal veins and is one of the most highly mineralized locations in the Tarom-Hashtjin metallogenic province, northwestern Iran. It consists of four major epithermal veins, which are located in the South Glojeh and North Glojeh areas. Alteration in the Glojeh district consists of propylitic, sericitic, and argillic assemblages, as well as extensive silicification. The ore-bearing veins comprise three paragenetic stages: (1) early Cu-Au-As-Sb-Fe-bearing minerals, (2) middle stage Pb-Zn-Cu-Cd-Ag-bearing minerals, and (3) late hematite-Ag-Bi-Au-Pb mineralogy. The veins are best classified as the product of an early high-sulfidation hydrothermal system, which was overprinted by an intermediate sulfidation system that was rich in Ag and base metals. Hematite is locally altered to goethite in zones of as much as 40 m in width during supergene alteration and the goethite is an important exploration tool. Fluid inclusions from the early, middle, and late stages, respectively, have salinities and homogenizations temperatures ranging from 5 to 11 wt.% NaCl eq. and 220 °C to 340 °C, to 1 to 8 wt.% NaCl eq. and 200 °C to 290 °C and finally to. 0.1 to 2 wt.% NaCl eq. and 150 °C to 200 °C. The oxygen isotope values in quartz range from 8.8 to 13.3‰ and most calculated fluid $\delta^{18}O$ values are between 4 and 8‰, suggesting a magmatic fluid with some meteoric water contamination. Sulfur isotope values for chalcopyrite, pyrite, sphalerite, and galena are mainly −7.3 to +1.3‰ and −0.3 to +8.4‰ for North Glojeh and South Glojeh, respectively. Sulfur isotope data suggest a magmatic origin. Boiling, isothermal mixing, and dilution are the main mechanisms for ore deposition in the Glojeh veins. Recent $^{40}Ar/^{39}Ar$ age measurements of 42.20 ± 0.34 Ma and 42.56 ± 1.47 Ma for the North Glojeh and South Glojeh veins, respectively, overlap with the 41.87 ± 1.58 Ma age of the Goljin intrusion in the northern part of the district, which we interpret as the main heat source controlling the hydrothermal systems.

1. Introduction

The east-west trending Alborz Magmatic Belt in northern Iran (Azizi and Moinevaziri, 2009; Azizi and Jahangiri, 2008) is divided into western and eastern parts by the north-south striking Rasht-Takestan Fault (Fig. 1). The eastern part consists of mafic and felsic tuff and lava with an alkaline to shoshonitic affinity (Nabatian and Ghaderi, 2013; Nabatian et al., 2014; Moayyed, 2001; Blourian, 1994), whereas the western part consists of andesitic to dacitic lava and many calc-alkaline to shoshonitic granitoid bodies. The western part, referred to here as the Alborz-Azarbayejan Magmatic Belt, is subdivided into two mineralized provinces, the Ahar-Arasbaran Belt in the north and the Tarom-Hashtjin metallogenic province in the south (Fig. 1).

The Glojeh district is situated approximately 30 km north of the town of Zanjan, within the Tarom-Hashtjin metallogenic province (Fig. 2). The district consists of a set of polymetallic (Pb-Zn-Cu-Ag-Au) sulfide-bearing veins, with also recoverable amounts of Cd and Bi. It can be subdivided into a northern area of silver and base metal-rich veins that trend east-west, and a southern area of gold-rich veins that are NW-and N-S-trending (Fig. 3). No modern-day mining has occurred in the Glojeh district, except for the Cu-Au Rasht Abad deposits that are located in 250 m east of the North Glojeh veins. However, historic mine workings can be seen as tunnels and wells in the North Glojeh area. Modern exploration in the Glojeh district has been conducted by the Iranian Mineral Research and Application Co. (IMRA) since 2003. In 2003, exploration drilling led to the discovery of the northern group of veins, which motivated an extensive exploration program in the area that resulted in the discovery of southern veins in 2005. In 2006, the IMRA estimated a combined reserve for the district of

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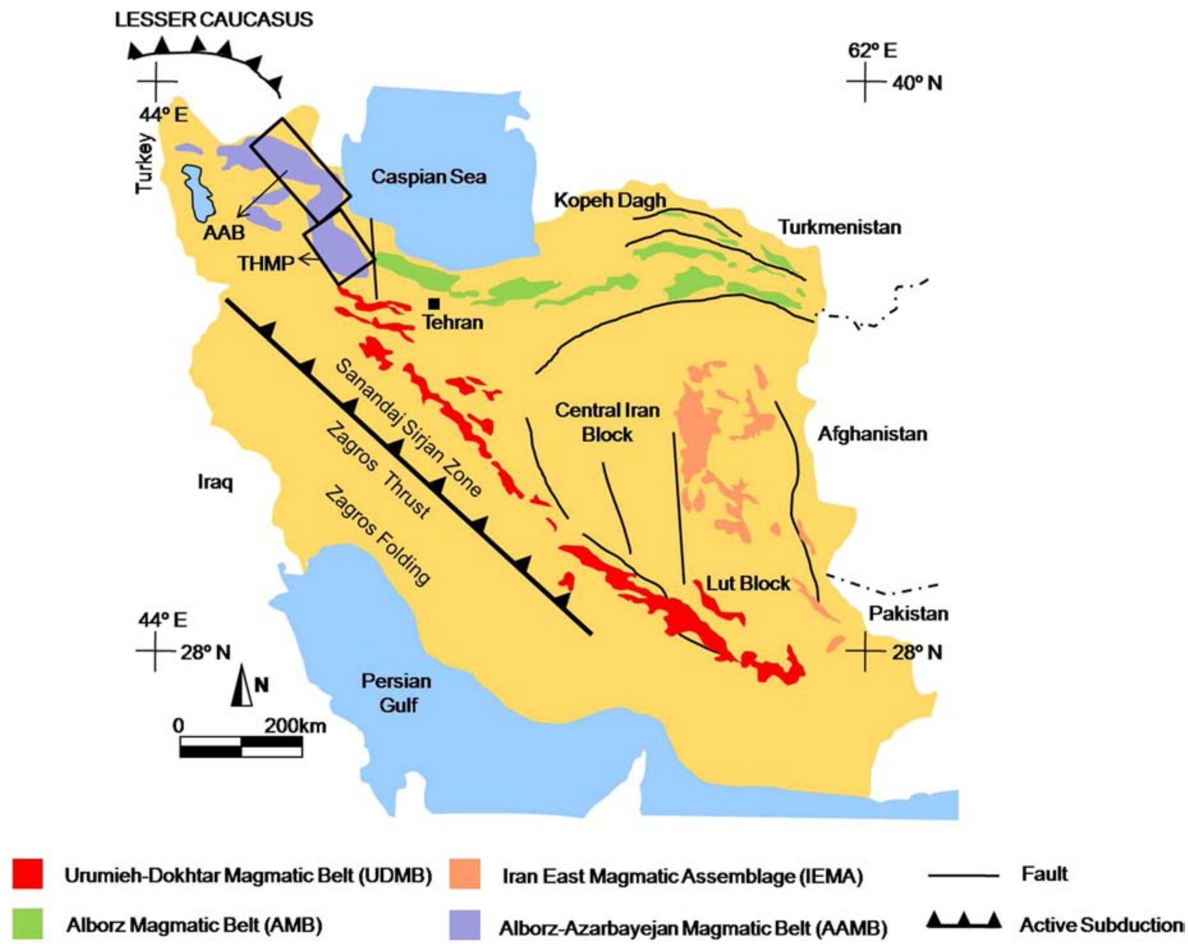

Fig. 1. Location of the Tarom-Hashtjin metallogenic province in the Alborz-Azarbayejan Magmatic Belt (NW Iran). The Alborz-Azarbayejan Magmatic Belt is subdivided into the Ahar-Arasbaran Belt in the north and Tarom-Hashtjin metallogenic province in the south.

2.27 million tonnes of ore containing an average grade of 3.0% Pb, 2.2% Zn, 1.5% Cu, 2.88 g/t Au, and 350 g/t Ag.

In this paper, we present a detailed study on the geology, paragenesis, hydrothermal alteration, fluid inclusion characteristics, and stable isotope geochemistry of the ore veins. The characteristics of the mineralized veins in both the northern and southern Glojeh areas are used to suggest an ore genesis model. This paper builds upon what was first published by Mehrabi et al. (2014), which introduced the North Glojeh veins as epithermal mineralization. In this paper, we have added new data on the hydrothermal alteration, fluid inclusion characteristics, geochronology, and stable isotope geochemistry of both the North Glojeh and South Glojeh veins for comparative purposes, and for development of a comprehensive regional ore formation model.

2. Regional geology

The Alborz magmatic belt is situated in northern Iran and has an E-W orientation, and is 600 km in length and 100-km-wide. The Alborz magmatic belt occurs in the hinterland of the Arabian-Eurasia collision zone in the broad Alpine-Himalayan orogenic belt. The Sanandaj-Sirjan zone formed as a result of the subduction of Neotethys ocean crust during the Mesozoic. Subsequently a back-arc basin developed behind the Sanandaj-Sirjan zone. This back-arc basin was subducted beneath the Central Iran block, and the Urmieh-Dokhtar magmatic belt formed along the continental margin of central Iran. High-angle subduction in the northwestern part of Iran (Azizi and Jahangiri, 2008) caused the development of an extensional tectonic regime in the Alborz-Azarbayejan micro-continent. Subduction of Neotethys beneath central Iran ended in the Late Cretaceous-early Paleocene with collision of the Sanandaj-Sirjan zone with the Central Iran block. During this period, the Khoy back-arc basin began subduction to the northeast beneath the Alborz-Azarbayejan micro-continent (Azizi and Jahangiri, 2008; Juteau, 2003; Ghazi et al., 2003; Khalatbari-Jafari et al., 2003). The result of this subduction was the formation of the Alborz-Azarbayejan magmatic belt. This subduction occurred during the early Eocene and, due to emplacement of several intrusive bodies near the end of subduction, resulted in widespread mineralization in the Alborz-Azarbayejan Magmatic Belt. In the Alborz magmatic belt, the bedrock consists of a Paleozoic-Mesozoic passive-margin sedimentary sequence with few volcanic rocks, overlain, in the south, by Cenozoic volcanic and sedimentary rocks (Mirnejad et al., 2010). Cenozoic successions in the Alborz magmatic belt are represented mainly by marine and subaerial, porphyritic and non-porphyritic, massive lava flows of andesite, basaltic andesite, and basalt (Aghazadeh et al., 2010, 2011). In addition, the Alborz-Azarbayejan magmatic belt can be subdivided into two metallogenic regions, termed the Ahar-Arasbaran metallogenic belt (AAB) in the north and the Tarom-Hashtjin metallogenic province (THMP) in the south (Fig. 1).

The Glojeh district is located approximately in the middle of the Tarom-Hashtjin metallogenic province (Fig. 2), where it abuts the NW-trending Urmieh-Dokhtar volcano-plutonic zone that parallels the Zagros thrust-fault system (Fig. 1). The NW-striking metallogenic province, 70- to 150-km-wide and 300-km-long, hosts numerous Ag-Au and polymetallic epithermal deposits associated with Eocene to Oligocene volcanic and plutonic events (Fig. 2). Regionally, the Tarom-Hashtjin metallogenic province is underlain by Precambrian metamorphic basement, Cambrian and Permian metamorphic rocks, Jurassic to