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# Geology, mineralization and sulfur isotopes geochemistry of the Mari Cu (Ag) Manto-type deposit, northern Zanjan, Iran

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ABSTRACT

The Eocene volcano-sedimentary sequence, northern Zanjan, consist of 1.5 km of shallow-marine sediments. These include sandstone, lapilli tuff, andesite, basalt and felsic volcanic rocks. The Mari deposit is strata-bound that hosted by the Eocene andesite rocks. The major copper sulfides are bornite, chalcocite, and chalcopyrite associated mainly with pyrite that show open-space filling, disseminated, vein-veinlet, and replacement textures. The abundances of Cu and Ag in the ore-bearing andesite are up to 40,000 and 70 ppm respectively. Wall rock alterations include carbonatization, chloritization, epidotization, and sericitization. Sulfur isotope compositions have a negative range from $\delta^{34}S = -2.7$ to $-3.4$‰, suggesting the presence of a reducing environment resulting from activation of sulfate reducing bacteria. Mineralization formed two stages: stage one include volcanic activity and eruption of andesitic lava, in this stage syngenetic disseminated pyrites formed. In the second stage, increasing of the thickness of sediments, basin subsidence, and burial diagenesis accompanied with the entry of metal-rich fluids into the reduced host rock, caused the replacement of the first stage pyrites by copper sulfides. The geology, ore mineralogy, alteration characteristics and sulfur isotopic compositions suggest the Mari deposit may be classified as a Manto-type deposit.



## 1. Introduction

In Iran, numerous volcanic-hosted strata-bound copper deposits often termed as "Manto-type" have been recognized in several places (Maghfouri and Movahednia, 2015; Boveiri et al., 2011, 2013; Samani, 2001; Abolipour et al., 2015, 2012; Alizadeh et al., 2013; Salehi and Rasa, 2016), forming an economically important Cu mineralization in Iran (Fig. 1). In Chile, the strata-bound Cu deposits are the second most after the Cu porphyry deposits; these Manto-type deposits tend to display relatively high grade (>8%) (Wilson and Zentilli, 1999). Campus (1980) has separated the Mesozoic Manto-type Cu deposits into the sedimentary-hosted deposits class (e.g., Cerro Negro), and the volcanic-hosted deposits class (e.g., Mantos Blancos and Buena Esperanza) (Wilson and Zentilli, 1999). Similar Proterozoic to Triassic deposits in North America (Kojima et al., 2009) are named "volcanic redbed" (Kirkham, 1996; Lefebure and Church, 1996; Cabral and Beaudoin, 2007), and are mainly distributed in the northwestern part of Canada and in the North Michigan district (e.g. White, 1968; Wilton and Sinclair, 1988). Most of the aforementioned deposits occur in volcano-sedimentary piles with andesitic to basaltic nature.

In Iran, the most important Manto-type Cu deposits include the Kesht Mahaki Cu (Ag) deposit in the Sanandaj-Sirjan zone (Boveiri et al., 2011, 2013), the Abbas Abad deposit in the Sabzevar zone (Maghfouri and Movahednia, 2015; Salehi and Rasa, 2016), the Kashkouieh and Veshnaveh in the Uromieh–Dokhtar Magmatic Assemblage (UDMA) (Abolipour et al., 2012, 2015), the Varzag in the Lut Block (Alizadeh et al., 2013), and the Qableh Bolagh and Mari deposits in the Alborz Magmatic Assemblage (AMA) (Fig. 1). Except for the Cretaceous Kesht Mahaki deposit, all others Manto-type deposits in Iran formed within the Eocene volcano-sedimentary sequence (Maghfouri and Movahednia, 2015).

The Mari Cu (Ag) deposit is located 40 km to the north of Zanjan city, in the central-western part of the AMA (Fig. 2). The deposit contains approximately 4% Cu, and up to 70 g/t Ag. It has been mined discontinuously from ancient times until to the present day. The Mari deposit is stratabound, and occurs within a volcano–sedimentary sequence (Fig. 3) (Maghfouri and Movahednia, 2015). Based on stratigraphic

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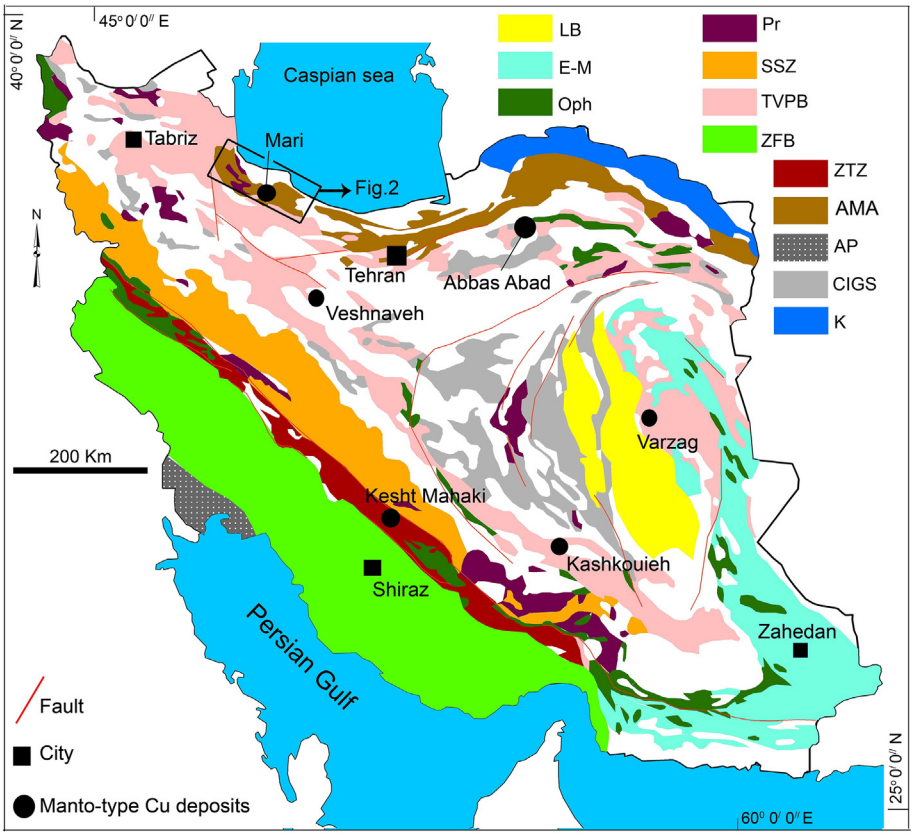


**Fig. 1.** Distribution map of Manto-type deposits in the main tectonic elements of Iran (Outlined rectangle is the area shown in Fig. 2); AMA, Alborz Magmatic Assemblage; AP, Arabian platform; CIGS, Central Iranian geological and structural gradual zone; E-M, East Iran-Makran; K, Kopeh-Dagh; LB, Tabas block; Oph, ophiolite belts; Pr, Precambrian basement; SSZ, Sanandaj-Sirjan zone; TVPB, Tertiary volcanic-plutonic belts; ZFB, Zagros folded belt; ZTZ, Zagros thrust zone.
(Tectonic and structural map of Iran modified after Stöcklin, 1968.)

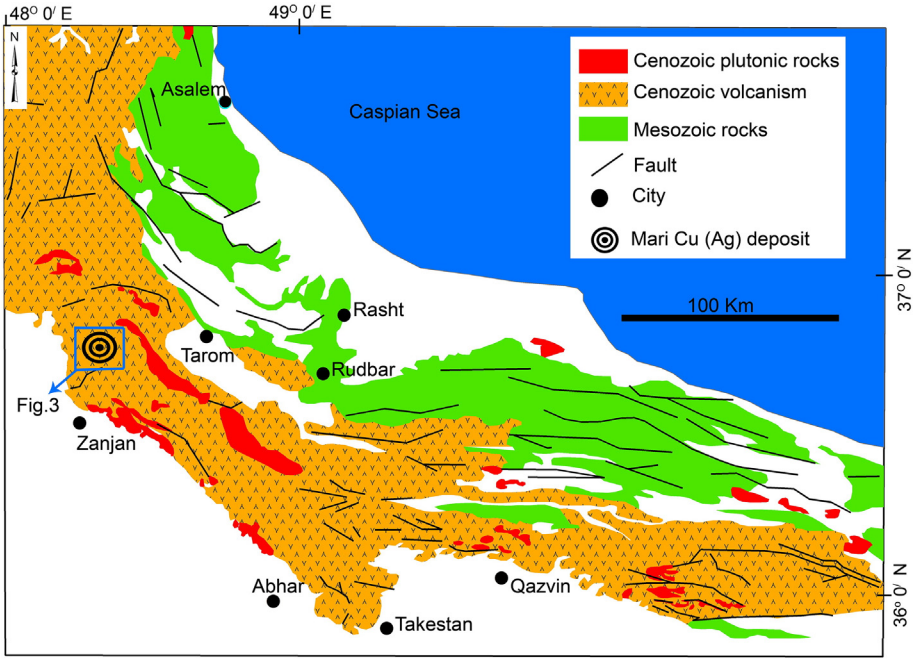


**Fig. 2.** Geological schematic map showing the western Alborz Magmatic Assemblage (AMA) and Mesozoic and Cenozoic rock units especially Cenozoic plutonic rocks of NW Iran. Small rectangle shows the location of study area in the Fig. 3.