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Chemical composition and evolution of the garnets in the Astamal Fe-LREE distal skarn deposit, Qara-Dagh–Sabalan metallogenic belt, Lesser Caucasus, NW Iran

Saeid Baghban [a,*], Mohammad Reza Hosseinzadeh [a], Mohsen Moayyed [a], Mir Ali Asghar Mokhtari [b], Daniel David Gregory [c], Hosein Mahmoudi Nia [a]

[a] Department of Earth Sciences, Faculty of Natural Sciences, University of Tabriz, 5166616471 Tabriz, Iran
[b] Department of Geology, Faculty of Science, University of Zanjan, 45371-38791 Zanjan, Iran
[c] ARC Centre of Excellence in Ore Deposits (CODES), School of Physical Sciences, University of Tasmania, Private Bag 79, Hobart, Tasmania 7001, Australia

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ABSTRACT

The chemistry of garnet can provide clues to the formation of skarn deposits. The chemical analyses of garnets from the Astamal Fe-LREE distal skarn deposit were completed using an electron probe micro-analyzer. The three types of garnet were identified in the Astamal skarn are: (I) euhedral coarse-grained isotropic garnets (10–30 mm across), which are strongly altered to epidote, calcite and quartz in their rim and core, with intense pervasive retrograde alteration and little variation in the overall composition ($Adr_{94.3–84.4}$ $Grs_{8.5–2.7}$ $Alm_{1.9–0.2}$) (garnet I); (II) anhedral to subhedral brecciated isotropic garnets (5–10 mm across) with minor alteration, a narrow compositional range along the growth lines ($Adr_{82–65.4}$ $Grs_{21.9–11.7}$ $Alm_{11.1–2.4}$) and relatively high Cu (up to 1997 ppm) and Ni (up to 1283 ppm) (garnet II); and (III) subhedral coarser grained garnets (>30 mm across) with moderate alteration, weak diffusion and irregular zoning of discrete grossular-almandine-rich domains ($Adr_{84.2–48.8}$ $Grs_{32.4–7.6}$ $Alm_{19.9–3.5}$) (garnet III). In the third type, the almandine content increases with increasing grossular/andradite ratio and increasing substitutions of Al for Fe^{3+}.

Almost all three garnet types have been replaced by fine-grained, dark-brown allanite that is typically disseminated and has the same relief as andradite. The Cu content increases while Ni content decreases slightly towards the rim of garnet II and garnet III. Copper in garnet II is positively correlated with increasing almandine content and decreasing andradite content, indicating that the almandine structure, containing relatively more Fe^{2+}, is more suitable than andradite and grossular to host divalent cations such as Cu^{2+}. Nickel in garnet II is positively correlated with increasing andradite content, total Fe, and decreasing almandine content. This is because Ni^{2+} substitutes for Fe^{3+} in the Y (octahedral) position. There are unusual discrete grossular-almandine rich domains within andraditic garnet III, indicating the low diffusivity of Ca compared to Fe at high temperatures.

1. Introduction

Garnet is a common rock-forming mineral in many skarn deposits, with a variety of compositions that allow it to be utilized in studying ore-forming processes and aid in ore deposit exploration (e.g., Jamtveit and Hervig, 1994; Whitney and Olmsted, 1998; Nicolescu et al., 1998; Karimzadeh Somarin, 2004, 2010; Smith et al., 2004; Gaspar et al., 2008; Ismail et al., 2014; Peng et al., 2015). The majority of skarn deposits are spatially related to the emplacement of intrusions, thus the minerals within a skarn can provide a record of the hydrothermal fluids present during ore formation (Meinert et al., 2005). In other words, the evolution of a fluid's composition may be recorded in the mineral growth zones of garnets, particularly in skarn bodies where the growth of garnet reflects the interplay between heat and fluid infiltration (e.g. Jamtveit, 1997). Meinert et al. (2005) described the compositional variation of garnet during the passage of an alteration front in which systematic zonation patterns differ with proximity to the fluid source. In more complex systems with evolving and cyclical fluid flow patterns that cannot be distinguished or separated, the interpretation of skarn zonation is more difficult (Meinert et al., 2005). In these systems, chemical zonation in garnets record the evolution of the deposit in terms of temperature variation, rate of fluid flow, compositional variation of mineralizing hydrothermal fluids, and the oxidation state of hydrothermal fluids.

The Astamal Fe-LREE skarn deposit is located approximately 85 km north of Tabriz, in the Qara-Dagh ore district of the Lesser Caucasus in the Alpine–Himalayan Orogen of northwestern Iran (Fig. 1). The

* Corresponding author at: Abrasan Street, Pezeshkan-Plaque 1.17, Postal Code: 5156845714, Tabriz, Iran.
E-mail addresses: Saeid.Baghban_geomine@yahoo.com, SaeidBaghban@gmail.com (S. Baghban).

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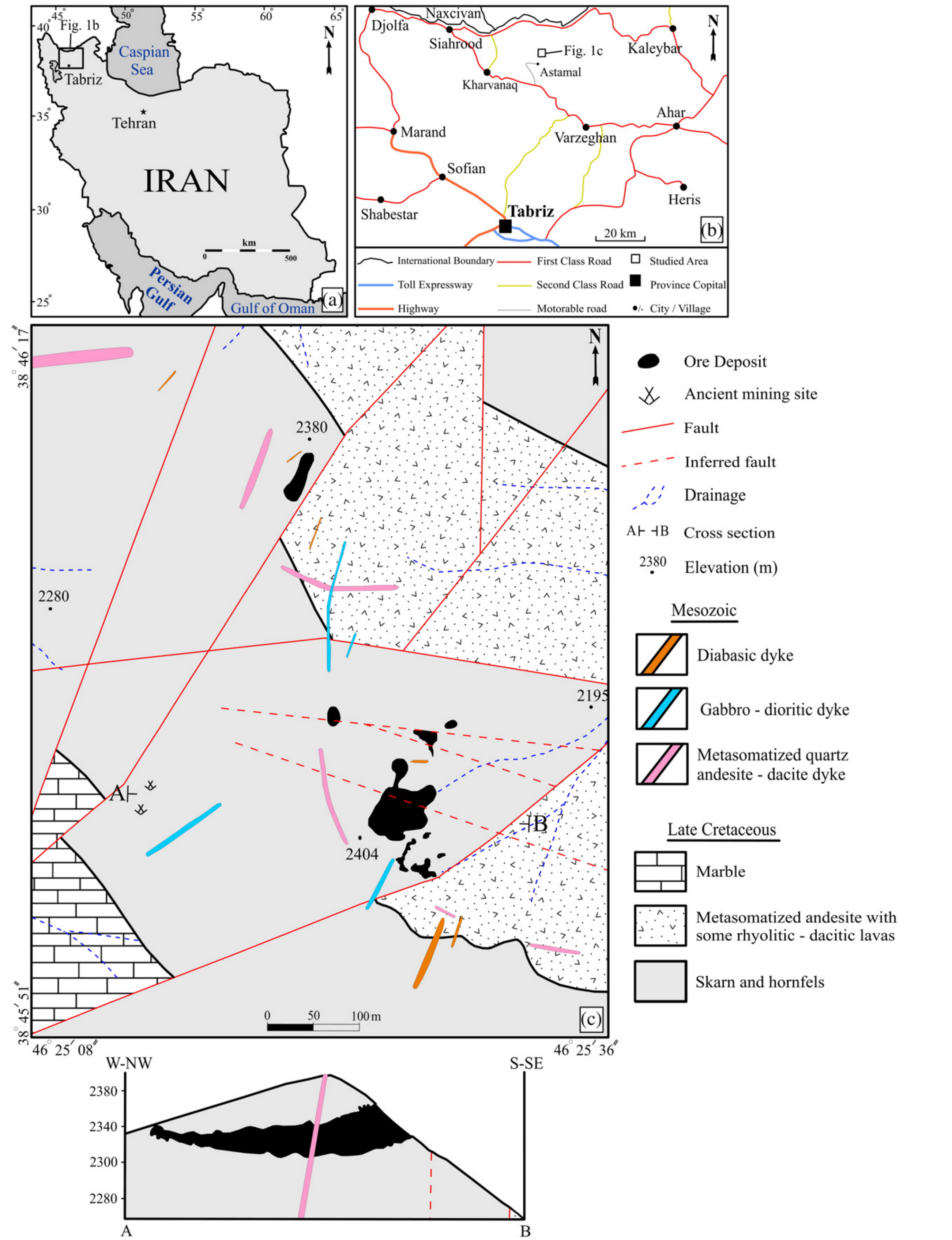

Fig 1. Detailed geological map of the Astamal skarn deposit (Baghban et al., 2015).

Geological Survey of Iran (GSI) recently discovered the mineralization in the area and Astamal is the largest and richest magnetite deposit with a resource of >10 Mt magnetite grading ~60% Fe (Mokhtari and Hosseinzadeh, 2013). Baghban et al. (2015) give detailed descriptions of the geological characteristics of the Fe ore and skarn bodies, the formation conditions of calc-silicate minerals, and descriptions of light