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The study of hidden and appear zoning in existed garnets in metamorphic rocks of Hamadan region

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Abstract

Understudied region is located in south and south east of Hamadan and is part of the metamorphic belt named Sanandaj-Sirjan zone. Metamorphic rocks of the region include slate, phyllite, schist, migmatites and hornfels. Garnet is one of the main minerals in schist, migmatits and hornfels and sometimes it is found in some of the granites and aplitic-pegmatite. Zoning is common in most of the gernets existing in region's metamorphic rocs. In some of the region's garnets zoning phenomenon is observable, and this is divided in to three groups of appear, hidden (inverted and normal) and mixed groups. Appear zoning is detectable under the microscope and mostly comes along with discontinuities in crystals' growth and in amphibole garnet; regions schist of this type of zoning are observable. Hidden zoning (chemical) are not observable by polarizing microscope, but it can be distinguished by quantitative analysis pictures. This type of zoning mostly is along with continuity in crystals' growth, and there are chemical compounds' changes in the environment during their growth. Hidden zoning (chemical) can be classified in to two groups of normal and inverted classes. In mixed zoning, part of the zoning relating to changes in elements' amount is observable under the microscope, and the other part only appears in quantitative analysis pictures. This type of zoning can be the indicator of change in dominant conditions in crystals growth during multi-changing events in the understudied region. Therefore garnets zoning of understudied region has lots of varieties that can be related to multi-changing event in understudied region.

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Introduction

Understudied region is part of the Hamadan province and is located between 48°24'51.6" to 48°45'29.6" of northern longitudes and 34°51'35.5" to 34°32'9.3" of eastern latitudes; it also is located in Sanandaj-Sirajan zone from geological aspect (Fig. 1). Alvand plutonic mass is one of the most important igneous phenomenon's in this region that is surrounded by contact and regional metamorphic rocks with low to high alteration degrees. Metamorphic rocks of Hamadan can be classified in to three groups of regional and contact metamorphic rocks and migmatites. Regional metamorphic rocks are formed of slate, phyllite, mica schist, garnet mica schist, Grant andalusite (±sillimanite,±Kyanite) schist, staurolite, garnet amphibolite schist and amphibolite. Contact metamorphic rocks include Hornfels mica, garnet hornfels, garnet-andalusite (±Fibrolites) hornfels, cordierite (±andalusite) hornfels, cordierite potassium feldspar and sillimanite hornfels, potassium feldspar hornfels. Region's migmatites can be classified in to two groups of sillimanite migmatite and cordierite migmatite. Garnet crystals are present in all of the region's metamorphic rocks except slate and phyllites. Region's main plutonic rocks include Granitoid, diorite and gabbroides that have been cut by Aplitic-pegmatites and silica veins, these crystals have been observed in Aplite, pegmatites and monzo granitics crystals.

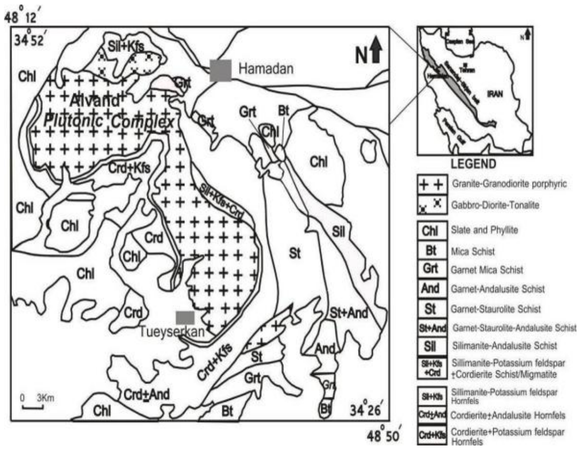

Fig. 1. The position of Sanandaj-Sirjan zone, along with petrology map of Hamadan region (Sepahi, 2008).

Zoning phenomenon happens in some of the minerals, mostly those that have solid solvent. Some minerals such as olivine, pyroxene, plagioclase and garnet have solid solvent and are as a result of zoning. When a mineral has solid solvent of anisotropy, the study of its mineral is easily possible by polarizing microscope, while when a mineral is isotropy (such as garnet) the study of its zoning is done hardly by optical mineralogy. To do so, present study uses X-ray diffraction to study this phenomenon more carefully on the garnets of Hamadan region.

The structure of garnet's crystal always is considered as an important chemical set. According to including rock, background compound, surrounded minerals, temperature ad pressure conditions various elements have involved in the compound of this mineral and have created various types of garnet mineral. The general formula of anhydrous garnet crystals is $R_3R'_2(SiO_4)_3$. R can be substituted by divans of Mg^{2+}, Fe^{2+}, Mn^{2+} and Ca^{2+} and R' can be substituted by trivalent cations such as Mn^{3+}, Fe^{3+} an Cr^{3+} (Locock, 2008 and Li Li *et al.*, 2001). Usually more than one cation is located at the positions of R and R', therefore, garnet crystals grow as isomorphous series (solide solvent). On this base, If Al^{3+} is located in R' site, the pyralspite group [(Fe^{2+},Mg^{2+},Mn^{2+})$_3$ $Al_2(SiO_4)_3$] with almandine [$(Fe^{2+})_3$ Al_2 $(SiO_4)_3$], pyrope [$(Mg^{2+})_3Al_2$ $(SiO_4)_3$] and spessartine [$(Mn^{2+})_3Al_2(SiO_4)_3$] end members will form. If Ca^{2+} is located in R site, the ugrandite group [$(Ca^{2+})_3(Al^{3+},Fe^{3+},Cr^{3+})_2(SiO_4)_3$] with grossularite [$Ca_3Al_2(SiO_4)_3$], andradite [$Ca_3(Fe^{3+})_2(SiO_4)_3$] and uvarovite [$Ca_3(Cr^{3+})_2(SiO_4)_3$] end members will form. Some other cations may also be emplaced in R and R' sites (Locock, 2008). The aim of this study is considered zoning and chemical compounds of these crystals carefully by field and laboratory studies.

Material and methods

Area under study

The study area is located in Sanandaj- Sirajan zone from geological aspect (Fig.1). Alvand plutonic mass is one of the most important igneous phenomenon's in this region that is surrounded by contact and regional metamorphic rocks with low to high alteration degrees. Metamorphic rocks of Hamadan can be classified in to three groups of regional and contact metamorphic rocks and migmatites.

Sampling and analysis method

To do petrography and morphology of garnet crystals existing in metamorphic and igneous rocks of the region, a thin segment of sample was cut after field studies and systematic sampling. After petrography, total sample of rock and garnet crystals were chemically analyzed in Kanpajoh lab in Tehran and Teif Kansaran Binalood lab in Mashhad by the method of XRF. In addition garnet crystals existing in proper samples were analyzed using a JEOL 8900 microprobe at the University of Minnesota, USA. The configuration used an acceleration voltage of 15 kV, 25 nA beam.

Structural formula of garnet was calculated by Russell *et al.* (1999) method with consumption of 8 cations and 12 oxygens. In present paper, minerals' abbreviation was done regarding Kertz (1983) and rocks naming was done on the basis of suggestion of International association of geological sciences (Schmid *et al.*, 2002).

Results and discussion

The study of zoning in Garnet crystals

Garnet zoning is one of the most important criteria for understanding the history of metamorphic rocks and growth of garnets (Whitney *et al.*, 2007 and Dziggel *et al.*, 2009); and by the help of this phenomenon important information can be achieved about changes in physical conditions, such as, temperature and pressure during metamorphic evolutions (Chakraborti, 2007 and Rabel *et al.*, 2007). Zoning phenomenon happens in some of the minerals that have solid solvents. Chemical zoning of garnet crystals in metamorphic rocks are created under the effect of growth processes during temperature enhancement, releasing and spilling liquefy (Hwang *et al.*, 2001). Zoning has been observed as following models in understudied garnet samples.

Classification of garnet zoning types

1. Appear zoning (physical)

This type of zoning is detectable under the polarizing microscope under polarize light (P.P.L). In quantitative analysis pictures of elements, changes in mineral compound are obvious. This type of zoning mostly comes along with discontinuity in crystals' growth and this type of zoning is observable in amphibole garnets of region's schists (Fig. 4).

2. Hidden zoning (chemical)

This type of zoning is mostly undetectable under polarizing microscope, but they are detectable in quantitative analysis pictures. This type of zoning is index type in metamorphic rocks (Kertz, 1994) and mostly comes along with continuity in crystals' growth; and there are changes in chemical compounds in the environment during their growth. Such environmental changes lead to changes in chemical compounds of garnet crystals. Hidden zoning (chemical) can be classified in to two sets of normal and inverted.

A- Normal zoning

In this type of zoning, garnet nuclear mostly is rich of spessartine and grossularite and the amount of pyrope an almandine increase near the crystal's edges (Tracy, 1982) (Fig. 2). Quantitative analysis pictures of Ca, Fe and Mg of a garnet crystal in Amph-sch$_1$ sample are shown in Fig. 3 (a, b, c). The distribution of these elements in garnet is under the effect of alteration degree, temperature, cooling rate, alteration fluid's nature and chemistry of host rock (Harangi *et al.*, 2002). spessartine and grossularite percentages in the center of this crystal were more than its edges and almandine and pyrope percentages were higher in the edges than in the central part. The reason of Mn concentration in garnets' nuclear can be explained by this fact that Mn is very consistent element and all of the Mn is concentrated in its structure during first stages of garnet crystallization.

As a result, the environment becomes empty of Mn and by proceeding of alteration garnet's edges become poorer than it's nuclear. It should be mentioned that reduction of Mn concentration in crystal edge can be the indicator of garnet crystals decomposition (Kohn *et al.*, 2000 and Wilbur and Ague, 2006).

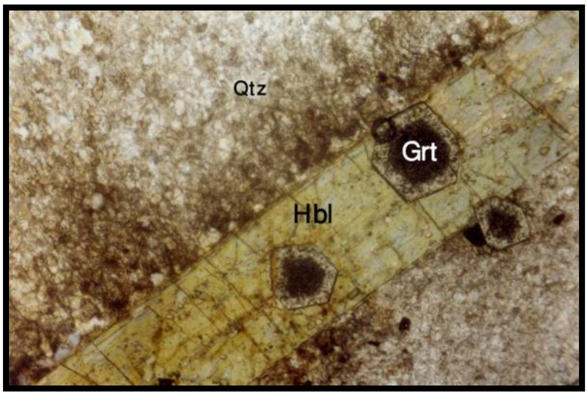

Fig. 2. Appear zoning in garnet crystals existing in a schist hornblende.

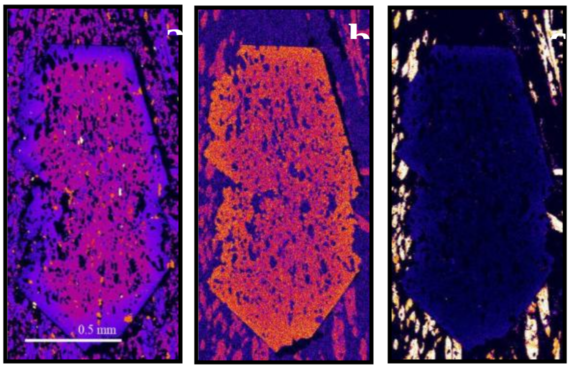

Fig. 3. Qualitative analysis pictures for Ca (a), Fe (b) and Mg (c) in a garnet crystal with normal zoning.

B- Inverted zoning

This type of zoning is the opposite type of normal form and was not observed in region's garnets.

3. Mixed zoning

In this type of zoning part of the zoning that is related to changes in the amount of elements is observable by microscope and the other part can be observed in quantitative analysis pictures. This type of zoning can be the indicator of changes in dominant conditions of crystals growth during multi-metamorphic events in understudied region (Fig. 4). Quantitative analysis picture of Ca, Fe and Mg of a garnet crystal of Amph-sch$_2$ are shown in Fig. 5. Because of growth of these crystals during several alteration stages, there are not regular distributions of elements. Almandine percentage in the central part was lower than edges of the crystal.

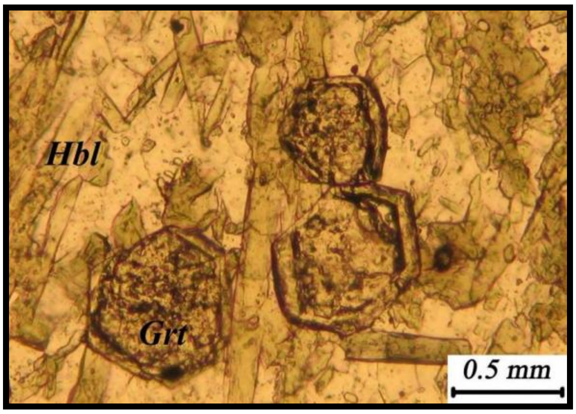

Fig. 4. Microscopic pictures of multi stages growth of garnet in garnet amphibole schist (P.P.L light).

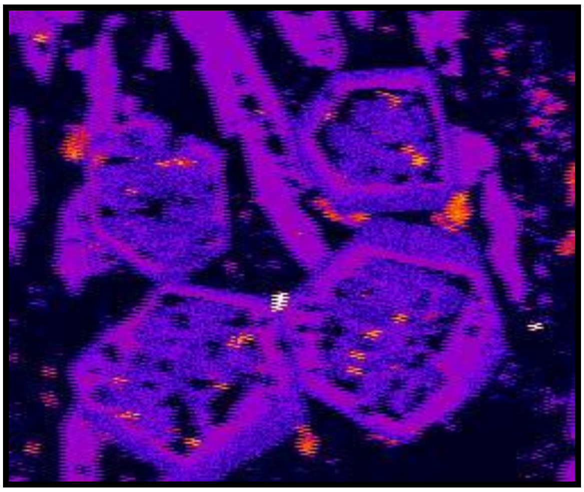

Fig. 5. Filtered X-ray picture that shows mixed zoning in garnet crystals.

The enhancement was not monotonic toward edges and was observed with multi stages of reduction and enhancement. Grassular percentages are the same in center and edges of the crystal, but from center to edges lots of fluctuations were observed. Spessartine percentage was higher in the central part, but change of this amount was monotonic toward edges. Pyrope percentage in the central part of the garnet was lower than edges, but its changes from center to edges were monotonic. The importance of discontinue and mixed zoning is that it indicates changes of thermodynamic conditions dominating on crystallization i.e. the environment that the rock exists on.

Conclusion

Region's garnets are rich of almandine and zoning phenomenon is observable as appear (physical), hidden (chemical) and mixed types. Appear zoning is created as a result of discontinuity in crystals' growth. In hidden zoning, which is classified in to normal and inverted forms, there is continuity in crystals' growth and changes in chemical compound lead to creation of such zoning. Mixed zoning is created as a result of changes in dominant conditions of crystals' growth during multi-metamorphic events.

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