Garnet composition from felsic pegmatitic rocks in North of Golpayegan (Ochestan), Iran

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Received: 19 December 2015 / Accepted: 06 March 2016 / Published online: 13 March 2016

Abstract

The felsic pegmatitic rocks are exposed in the north of Golpayegan. The dominate mineral assemblage is quartz, K-feldspar, plagioclase, muscovite, tourmaline and garnet. The elevated spessartine content of the garnets in the studied rocks along with their idiomorphic shape, the absence of resorption feature and garnet-free country rocks may point to their magmatic origin and crystallization at a fairly low pressure (less than 3 Kbar). A significant geochemical criteria is the absence of chemical zoning which suggest their crystallization at temperatures above ∼ 700 °C. Apparently at these temperatures, the Mn diffusion becomes sufficiently rapid to eliminate compositional zoning. The overall petrographical and geochemical data indicate that these phases generated from peraluminous S-type melts.

Keywords: Spessartine, Felsic pegmatite, Golpayegan, Iran.

1- Introduction

Garnet has been reported in wide variety of igneous rock types such as some peraluminous S-type granites (e.g., Jung *et al*., 2001; Villaros *et al*., 2009) and volcanic rocks (e.g., Harangi *et al*., 2001, Baharifar, 2011). This mineral is a common accessory and a minor mineral in peraluminous granitic pegmatites (e.g., London 2008). Garnet composition is also sensitive to P-T changes (Spear 1993, Menard & Spear 1993). A great majority of all reported plutonic garnets are Mn-rich, with greater than ten percent spessartine component, and occur in very felsic rocks, indicating that manganese enrichment in differentiated magmas may be the controlling factor in paragenesis of most granitoid garnets (Miller & Stoddard, 1981). Moreover, the compositional zoning of magmatic garnet is distinct from that of metamorphic garnet with high spessartine contents and typical spessartine-decreasing profiles from core to rim (e.g., Du Bray, 1988; Leake, 1967). Magmatic garnets in granitic rocks crystallized above ∼700 °C have “spessartine inverse bell-shaped profile” or are unzoned, whereas garnet exhibiting “spessartine bell-shaped profile” must be considered of metamorphic origin (i.e., xenocrystic) or formed in very felsic magmas crystallizing below ∼ 700 °C (Dahlquist *et al*., 2007).

Felsic pegmatitic rocks are outcropped in the north of Golpayegan (Ochestan) area in which garnet is one of the mafic accessory minerals. In the present study, magmatic garnet of peraluminous pegmatites from the Ochestan area was investigated by X-Ray Map and electron-probe microanalysis (EPMA).

2- Geologic setting

The study area is located in the northwest of the Isfahan province in central of Iran and Sanandaj-Sirjan structural Zone. The tectonic evolution of the Golpayegan region and exhumation of the old rocks are interpreted (Nadimi and Nadimi, 2008) as the product of three major sequential geotectonic events:

thrusting, extensional fractures and exhumation, and strike-slip movements. Metamorphic rocks in the study area consist of gneiss, granite gneiss, marble, amphibolite, mica schist, amphibole schist, garnet micaschist and quartzite (Thiele *et al*., 1968, Sheikholeslami and zamani, 2005). Some felsic pegmatitic rocks (Fig. 1a) occurred as lentoid (10m in wide and 30m in thickness) interlayering with garnet free mica-schists (Fig. 1b). Previous works indicate S-type, peraluminous nature and partial melting of metasedimentray rocks for magma generation of these felsic rocks (Sharifi, 2007; Movahedi, 2009; Mirlohi, 2014).

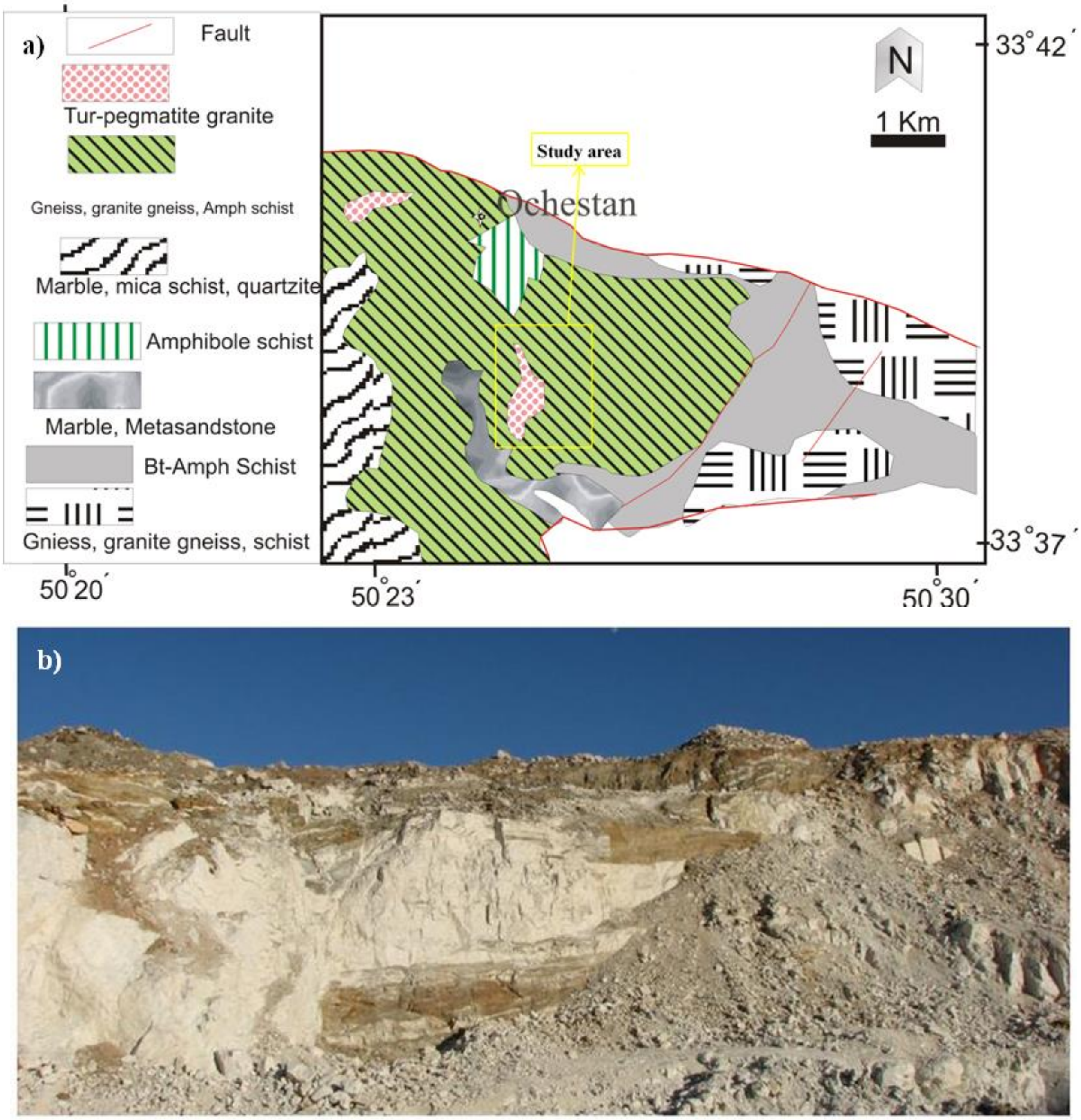

Figure 1a) A part of geological map from the north of Golpayegan (Ochestan). The pegmatitic rocks are presented by red color. b) Field photo showing central Feldspar mine from Ochestan which lentoid pegmatite cut the mica-schist.

3- Material and Methods

Some mineral analyses (more than 40 points from 5 garnets) were collected using Cameca SX100 electron microprobe at Institut Für Mineralogie und Kristallchemie, Universität Stuttgart (Germany). The quantitative analyses of selected minerals were performed with a

15keV accelerating voltage, a 15nA beam current. The counting time at each peak was 30s.

3.1- Petrography

The pegmatite mineral assemblage which are coarse (>2 cm) grain, consists of K-feldspar, plagioclase, quartz, muscovite, tourmaline (schorl-dravite), biotite and garnet (almandine-spessartine), in order of decreasing abundances. In thin sections the leucocrate matrix is dominated by K-feldspar which occurs in large anhedral grains with broad perthitic exsolution lamellae. Plagioclase forms twinned crystals which have commonly undergone sericitisation. Twinning is sometimes clearly curved, indicating a late tectonic overprint. Anhedral quartz shows intensive oscillatory extinction and sub-grain formation. Tourmaline is usually anhedral and shows optical zonation. Garnet (Fig. 2) forms euhedral, sometimes atoll-shaped grains; they do not contain any inclusions and devoid of reaction rims.

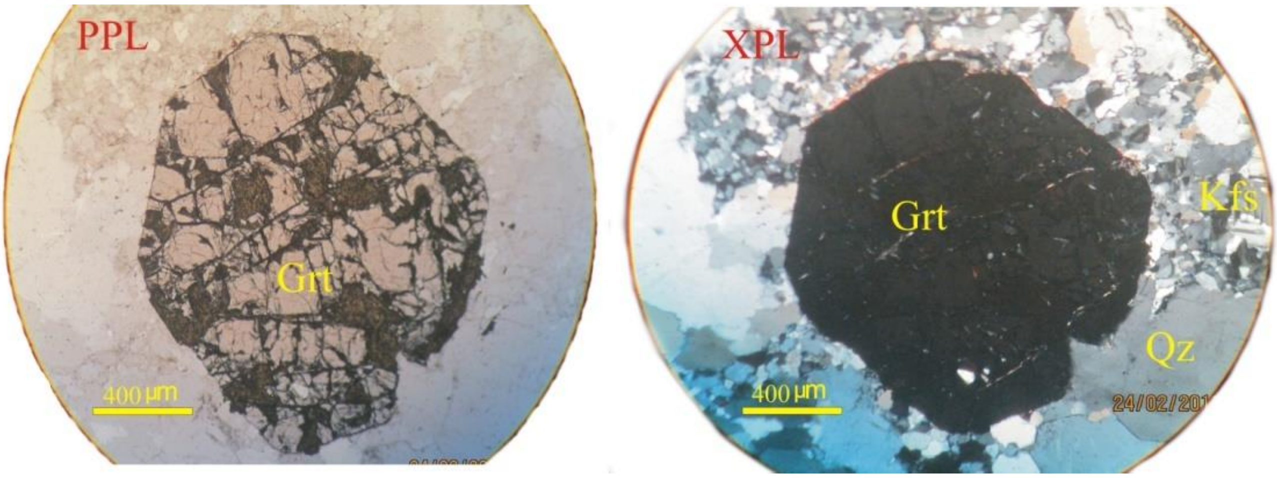

Figure 2) Photomicrographs of garnets in the felsic pegmatite rocks (mineral abbreviations from Whitney and Evans, 2010.

3.2- Geochemistry

The chemical composition of the garnets in discussion carried out by microprobe analyses reported in Table 1. Representative X-Ray Map images of garnet and its chemical composition and profile (R-C-R) is presented in figurers 3 and 4, respectively. No sensible chemical zonation is seen.

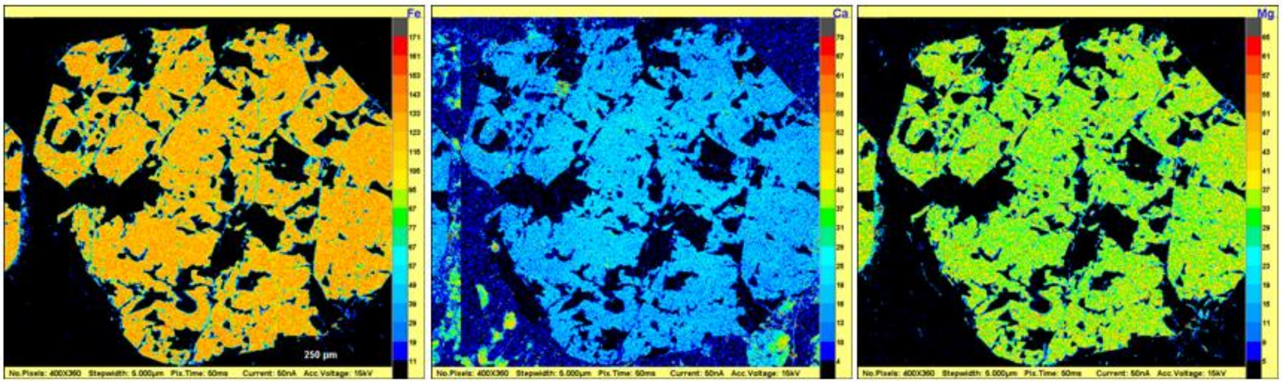

Figure 3) X-Ray Map images of garnets from the felsic pegmatitic rocks showing their homogeneous composition (the black parts are carves created during polishing the thin section).

The garnet from Ochestan has the predominant spessartine component with a subordinate almandine composition (Table 1, Fig. 4), which is typical of garnet in pegmatitic assemblages (e.g., London, 2008).

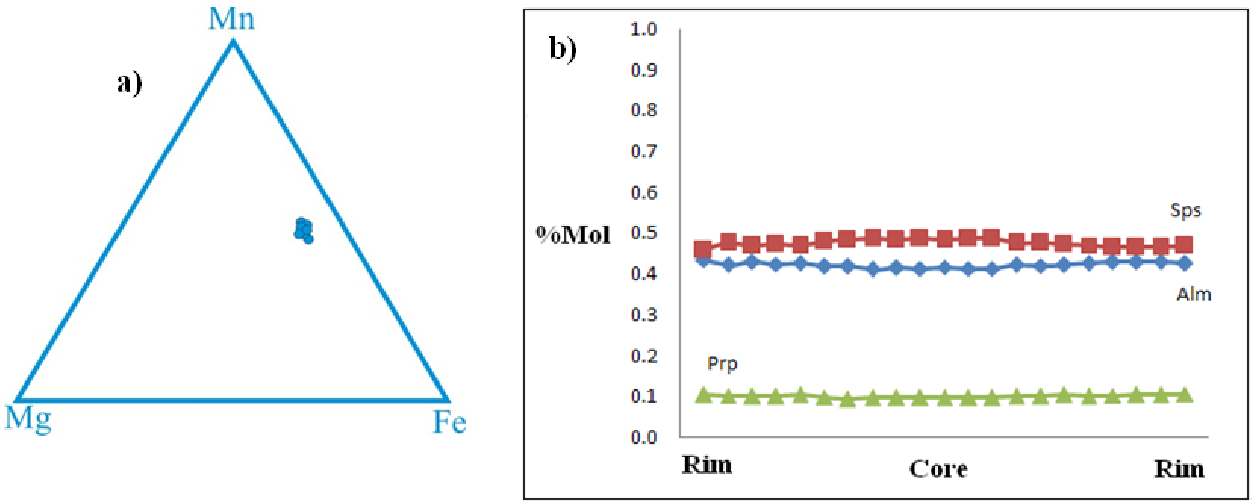

Figure 4a) Chemical composition of the studied garnets. b) Chemical zoning profiles of almandine-spessartine-pyrope.

4- Discussion

As Dahlquist *et al*. (2007) reported, the unzoned garnets in Peñón Rosado Granite (PRG3) involve crystallization at temperatures above ~ 700 °C and high Mn diffusion, and the absence of Mn enrichment in the rims suggests that crystallization ceased above ~700 °C. At magmatic temperatures above ~700 °C, the diffusion becomes sufficiently rapid to eliminate compositional zoning, typically producing spessartine-almandine garnets that are unzoned (Dahlquist *et al*., 2007).

Garnet from granitic aplites and pegmatites is mainly a solid solution between manganese-rich almandine and spessartine, and of magmatic origin (Manning, 1983). Experimental studies (Hsu, 1968; Green, 1978) show that high Mn enhances stability of garnet in magmas, allowing it to crystallize as a primary igneous mineral at pressures of 3 kb or less (Miller & Stoddard, 1981). In any case, the occurrence of spessartine-rich garnet in late differentiates is consistent with magmatic trends of Mn concentration. Experimental work (e.g., Green, 1978) showing such Mn-rich garnets are stable in magmas down to relatively low pressures (< 3 kb) that is consistent by Miller and Stoddard (1981).

Major controlling factors of the magmatic garnet composition are the melt composition (e.g., Černy *et al*., 1985) and coexisting minerals (e.g., Chernoff and Carlson, 1997). Where garnet crystallizes from a melt containing both of Mn^{2+} and Fe^{2+}, the Mn is preferentially incorporated in the garnet (e.g., Feenstra and Engi, 1998; London *et al*., 2001), as is the case for the studied garnet. Where garne*t al*one is responsible for the Fe and Mn contents of the melt, the melt becomes depleted in Mn relative to Fe, and the composition of garnet changes progressively from Mn-rich (core) to Fe-rich (rim).

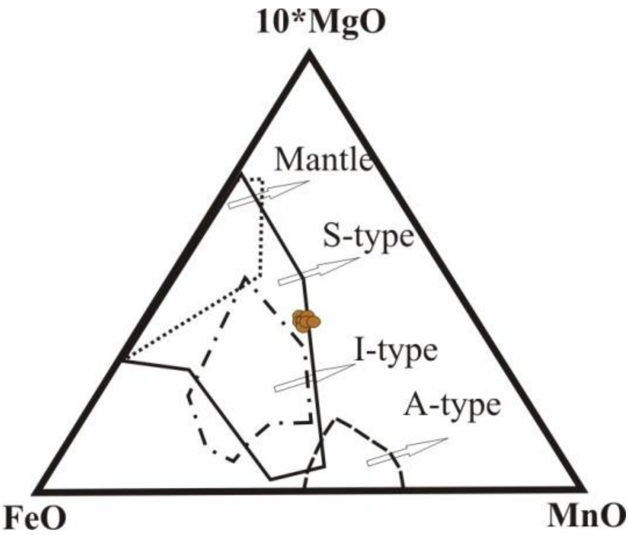

*Figure 5) Plot of garnets from the felsic pegmatites in the FeO-(10*MgO)-MnO triangular diagram (note the studied garnets are considered as S-type, Zhang et al., 2012).*

Table 1) Electron microprobe analyses of the garnets from the felsic pegmatites in the north of Golpayegan (Ochestan).

	#101	**#102**	**#103**	**#104**	**#105**	**#106**	**#107**	**#108**	**#109**	**#110**	**#111**	**#112**	**#113**	**#114**	**#115**	**#116**	**#117**	**#118**	**#119**	**#120**
SiO_2	36.08	36.21	36.32	35.92	36.27	36.01	35.57	35.77	35.77	36.08	35.90	35.60	36.06	36.09	35.88	35.96	36.47	35.83	35.97	36.27
TiO_2	0.00	0.02	0.02	0.01	0.00	0.02	0.05	0.03	0.03	0.02	0.04	0.05	0.03	0.02	0.02	0.02	0.02	0.00	0.00	0.00
Al_2O_3	20.38	20.24	20.22	20.21	20.23	19.79	19.83	19.58	19.70	19.90	20.24	19.70	20.01	20.48	20.12	20.16	20.39	19.93	20.18	20.30
FeO	19.90	19.17	19.51	19.28	19.45	19.05	19.22	18.92	19.16	19.12	19.03	18.90	18.99	19.13	19.12	19.51	19.53	19.76	19.70	19.67
MnO	20.78	21.38	21.10	21.27	21.23	21.57	21.92	22.24	22.10	22.29	21.83	22.00	22.08	21.36	21.40	21.61	21.34	21.10	21.12	20.99
MgO	2.64	2.58	2.56	2.56	2.62	2.50	2.40	2.50	2.51	2.46	2.43	2.48	2.51	2.55	2.55	2.67	2.59	2.62	2.69	2.65
CaO	0.25	0.18	0.19	0.24	0.25	0.28	0.26	0.33	0.27	0.26	0.29	0.29	0.29	0.24	0.26	0.26	0.22	0.23	0.20	0.21
Na_2O	0.02	0.02	0.03	0.09	0.07	0.02	0.04	0.03	0.10	0.06	0.00	0.07	0.04	0.01	0.02	0.03	0.06	0.01	0.04	0.04
K_2O	0.00	0.00	0.00	0.04	0.02	0.01	0.00	0.01	0.03	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.02	0.01	0.00	0.02
O^{12}																				
Si	2.95	2.97	2.97	2.95	2.97	2.97	2.95	2.96	2.95	2.96	2.95	2.95	2.96	2.95	2.96	2.95	2.97	2.96	2.95	2.96
Al	1.97	1.95	1.95	1.96	1.95	1.93	1.94	1.91	1.92	1.92	1.96	1.93	1.90	1.93	1.91	1.89	1.92	1.89	1.90	1.92
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe^{2+}	1.36	1.31	1.33	1.33	1.33	1.32	1.33	1.31	1.32	1.31	1.31	1.31	1.30	1.31	1.32	1.34	1.33	1.36	1.35	1.34
Mn	1.44	1.48	1.46	1.48	1.47	1.51	1.54	1.56	1.55	1.55	1.52	1.55	1.53	1.48	1.49	1.50	1.47	1.47	1.47	1.45
Mg	0.32	0.32	0.31	0.31	0.32	0.31	0.30	0.31	0.31	0.30	0.30	0.31	0.31	0.31	0.31	0.33	0.31	0.32	0.33	0.32
Ca	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Na	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.02	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
X_{Mg}	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
X_{Ca}	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Alm	0.43	0.42	0.43	0.42	0.42	0.42	0.42	0.41	0.41	0.41	0.42	0.41	0.41	0.42	0.42	0.42	0.42	0.43	0.43	0.43
Sps	0.46	0.47	0.47	0.47	0.47	0.48	0.48	0.49	0.48	0.49	0.48	0.48	0.48	0.47	0.47	0.47	0.47	0.46	0.46	0.46
Prp	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.10	0.10	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Grs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

The compositional zoning of magmatic garnet is distinct from that of metamorphic garnet with high spessartine contents and typical spessartine-decreasing profiles from core to rim (Leake, 1967; Du Bray, 1988).

Igneous garnets with distinct chemical composition can crystallize from either I-, M-, A- or S- type granites. Magmatic garnets may result in the classification of their host (Zhang *et al*., 2012). In the FeO-10*MgO-MnO ternary diagram (Fig. 5), the garnets in question are plotted within the S-type granites field confirming the peraluminous characters of the studied pegmatite which is in agreement with the presence of abundant muscovite.

5- Conclusion

At least in this location, several line of evidences including homogeneous composition of garnets, high spessartine content, lack of metamorphic inclusions in the garnets in discussion and lack of reaction rims, in accompany with whole rock composition, garnet free country-rocks indicate that garnets in the felsic pegmatitic rocks could be crystallized from an S-type peraluminous magma. Moreover, these phases are considered as magmatic types which have been crystallized at pressures of approximately 3 Kb, temperatures of above 700 °C and high Mn content.

Acknowledgments:

We wish to thank Mr. Rahnama and Theye Thomas for their help during the course of this work. Financial support provided by the University of Isfahan is acknowledged.

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