GEOCHEMISTRY OF GARNETS FROM A TONALITE AND GRANITIC APLITE–PEGMATITE VEINS FROM CIBORRO – ALDEIA DA SERRA, OSSA–MORENA ZONE, SOUTHERN PORTUGAL

S.S.M. Lima[1], A.M.R. Neiva[1] AND J.M.F.Ramos[2]

[1] Department of Earth Sciences and Geoscience Centre, University of Coimbra, 3000-272 Coimbra, Portugal (selmalima252@gmail.com; neiva@dct.uc.pt)
[2] INETI, S. Mamede de Infesta, Apartado 1089, 446-956, Portugal (farinha.ramos@ineti.pt)

ABSTRACT

Electron-microprobe analyses of garnets from a tonalite and aplite–pegmatite and pegmatite veins cutting different lithologies from an area located in the Ossa–Morena Zone, southern Portugal, show distinct compositions, mainly andradite with a subordinate grossular component in tonalite, and predominantly spessartine with a subordinate almandine component [and rarely, of mainly almandine with a subordinate spessartine component] in the veins. In general, single crystals of garnet are unzoned in tonalite, but commonly show a Mn-enriched core in veins, as the ratio Mn/(Mn + Fe) in the melt is controlled by garnet. However, reverse zoning also occurs owing to resorption of garnet at lower temperatures. A fractionation trend involving a decrease of Mn/(Mn + Fe) occurs in garnet from a complex aplite–pegmatite vein with 22 alternating layers cutting schists; values decrease toward the hanging wall because garnet is the sole host of Mn, which is depleted in the granitic magma.

Keywords: garnet; S. Geraldo tonalite; aplite-pegmatite veins.

INTRODUCTION

Manganese-rich grossular – spessartine occurs in granodiorites and monzodiorites (*e.g.*, Barth and Ehlig, 1988). Garnet from granitic aplites and pegmatites is mainly a solid solution between manganese-rich almandine and spessartine, and of magmatic origin (Manning, 1983). Single crystals of garnet are commonly unzoned, but normal and reverse zoning patterns have been also reported (*e.g.*, London, 2008).

Crystals of garnet from a tonalite and aplite–pegmatite veins from an area in southern Portugal were studied to get information on zoning patterns of garnet crystals and genesis and evolution of the granitic magmas.

GEOLOGICAL SETTING

The Ciborro – Aldeia da Serra area is located within the Ossa–Morena Zone, which is one of the major divisions of the Iberian Massif. This massif corresponds to the southwestern extension of the European Variscan Belt. Granitic rocks intruded the Ordovician–Silurian schists. Two bodies of biotite>amphibole tonalites, biotite trondhjemite, biotite>amphibole granodiorite, three biotite granodiorites, biotite granite and two biotite>muscovite granites crop out. Microgranite veins, rhyolite porphyries, granitic aplite–pegmatite and pegmatite veins intruded all the lithologies. Quartz veins cut the two biotite>muscovite granites.

Granitic aplite–pegmatite and pegmatite veins and masses trend NW–SE and range from a few meters to tens of kilometers long, 0.05–2.80 m thick and fractured. They are particularly well developed in the border of the Pavia Massif. In general, the veins consist of several alternating layers, up to 22, ranging between aplite and very coarse-grained pegmatite.

PETROGRAPHY

Garnet occurs in S. Geraldo tonalite and aplite–pegmatite and pegmatite veins. The biotite>amphibole tonalite contains quartz, oligoclase–andesine, K-rich feldspar, magnesiohornblende, ferrohornblende, edenite, magnesiohastingsite, ferroedenite, ferropargasite, epidote, titanite, biotite, garnet, apatite, ilmenite, magnetite and secondary epidote and chlorite.

Granitic aplite–pegmatite and pegmatite veins contain quartz, albite, K-rich feldspar, muscovite, garnet, magnetite and secondary hematite and goethite, but opaque minerals are rare. Veins cutting the S. Geraldo tonalite and medium-grained biotite>muscovite granite also contain oligoclase, biotite and monazite. The last two minerals also occur in veins cutting schists.

Garnet from tonalite is brown in colour and free of inclusions. It occurs in small anhedral grains up to 1.48 × 0.55 mm along biotite cleavages. In aplite–pegmatite and pegmatite veins, garnet is fine- to very fine-grained, generally >1 mm in diameter in aplites but from this size up to 3 × 2 mm in pegmatites, where it occurs in isolated grains. It is euhedral, light brown in colour, free of inclusions, and commonly is replaced by muscovite with undulose extinction along many fractures. Garnet is more abundant in aplite than in pegmatite.

METHODS

Chemical compositions of garnet were obtained using a Cameca SX 100 electron- microprobe at the Oviedo University, Spain, operating at 15 kV accelerating voltage and 15 nA beam current. FeO and Fe_2O_3 contents were estimated from FeO, obtained by electron-microprobe, using the method proposed by Droop (1987). A total of 131 analyses were obtained in garnet, 24 in garnet from the tonalite and 107 analyses in garnet from aplite–pegmatite and pegmatite veins. The garnet from the veins does not show any fractures.

GARNET COMPOSITIONS AND ZONINGS

Garnet from the metaluminous tonalite has a calcic composition and belongs to the ugrandite group. It consists mainly of andradite and grossular showing a significant compositional range between these two end-members (Figs. 1a, b). Very rare garnet crystals show chemical zoning (Fig. 2a) with a core ($Adr_{73.2}Grs_{23.0}Uv_{0.4}Alm_{2.6}Sps_{0.8}$) and a rim ($Adr_{60.7}Grs_{31.6}Uv_{4.7}Alm_{1.4}Sps_{1.1}Prp_{0.5}$).

Garnet from peraluminous granitic aplite–pegmatite and pegmatite veins containing 4–31 ppm of Li is aluminous, belonging to the pyralspite group. It contains mainly spessartine (44.8–75.7 mol.%) and almandine (22.1–48.1 mol.%), which is common in garnet from aplite–pegmatite and pegmatite veins with low Li content (*e.g.*, London, 2008). Most garnet crystals are zoned. In general, the Sps content decreases and

Alm content increases from core to rim (Fig. 2b). However, garnet crystals from an aplite–pegmatite vein cutting tonalite and a pegmatite cutting mixed biotite granodiorite and granite show a reverse zoning, either with a regular or an irregular pattern between core and rim (Figs. 2c, d). Within a granitic aplite–pegmatite vein consisting of 22 alternating layers and cutting schists, garnet shows a decrease in Sps content by up to 5.9 mol.% and an increase in Alm content by up to 4.6 mol.% from the 5th layer to the 19th layer. Garnet from the aplite–pegmatite vein cutting tonalite is the richest in Alm content and the poorest in Sps content (Figs. 1c, d) and has the lowest Mn/(Mn+Fe+Mg) value (Table 1), which is greater than that (0.01–0.04) in garnet from tonalite.

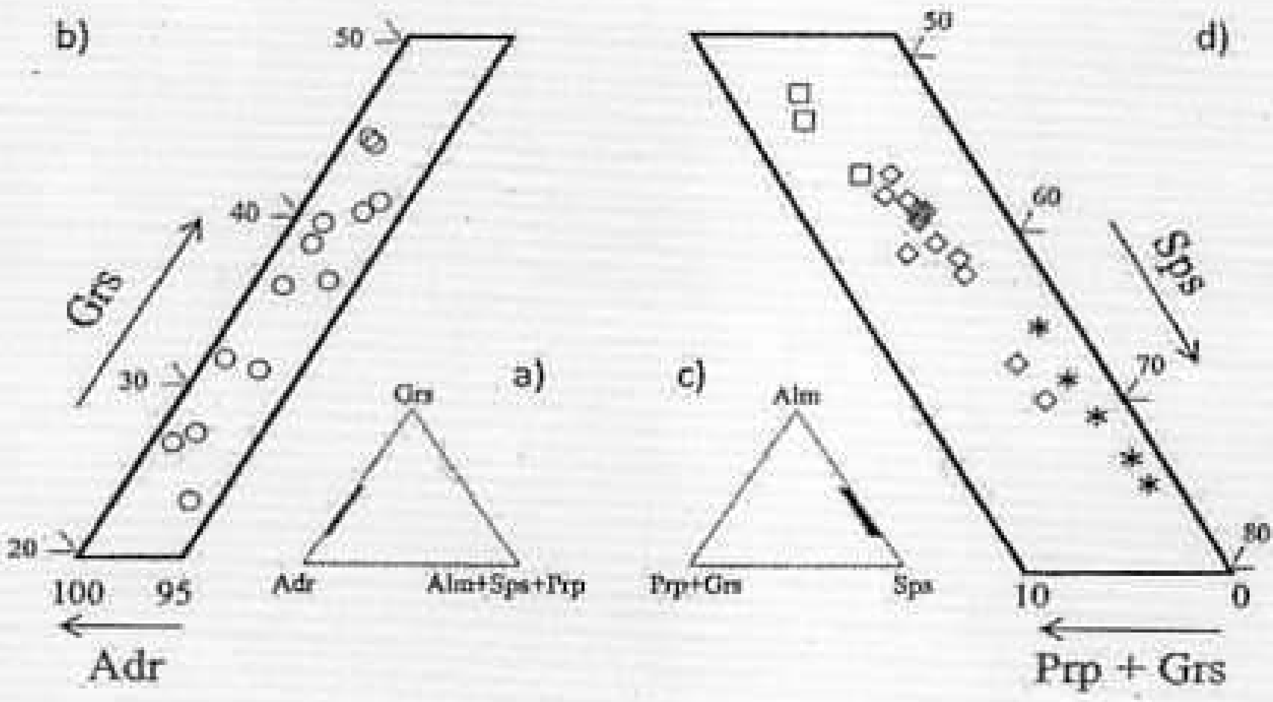

Figure 1 – Compositions of garnet from metaluminous tonalite and peraluminous granitic aplite-pegmatite and pegmatite veins from the Ciborro – Aldeia da Serra area, southern Portugal. Garnet compositions: a) and b) from S. Geraldo tonalite (μ); c) and d) from aplite-pegmatite and pegmatite veins cutting S. Geraldo tonalite (μ), medium-grained and coarse-grained biotite>muscovite granites and schists (μ) and mixed biotite granodiorite and biotite granite (μ).

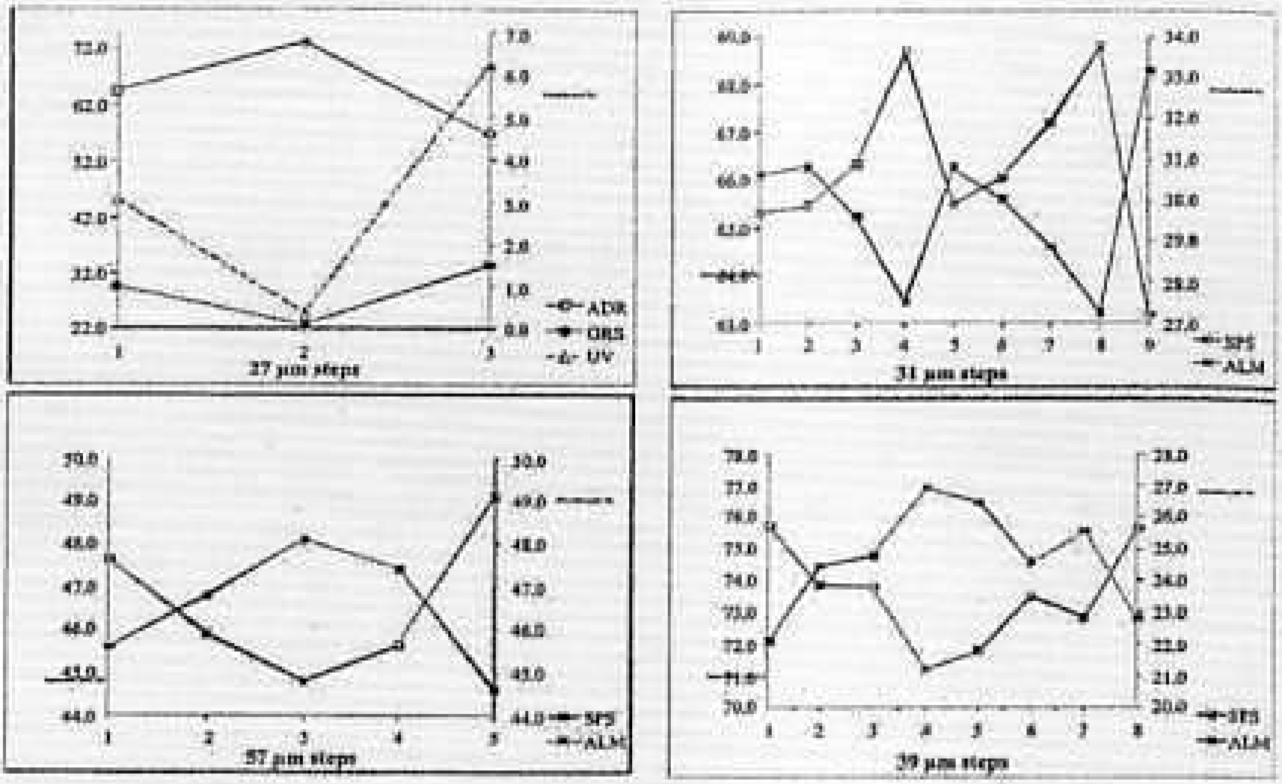

Figure 2 – Chemical zoning of single crystals of garnet (rim to rim) from the granitic rocks of Ciborro – Aldeia da Serra area, southern Portugal. a) Garnet from tonalite; b) garnet from pegmatite vein cutting coarse-grained biotite>muscovite granite; c) garnet from aplite-pegmatite vein cutting tonalite; d) garnet from pegmatite vein cutting mixed biotite granodiorite and granite. a) and b) Normal zoning; c) and d) reverse zoning.

Table 1 – Garnet composition from granitic aplite-pegmatite and pegmatite veins cutting different lithologies.

Garnet from aplite-pegmatite and pegmatite veins	Tonalite	Mixed biotite granodiorite and granite	Medium-grained biot>musc granite	Coarse-grained biot>musc granite	Schists
Mn/(Mn+Fe+Mg)	0.44 – 0.52	0.64 – 0.74	0.53	0.55 – 0.57	0.51 – 0.58

Garnet from the pegmatite vein cutting mixed biotite granodiorite and granite is the poorest in Prp + Grs content and the richest in Sps content and has the highest Mn/(Mn+Fe+Mg) value. This ratio has similar values in garnet crystals from aplite–pegmatite and pegmatite veins cutting medium-grained and coarse-grained biotite>muscovite granites and schists.

DISCUSSION

The garnet in tonalite from the study area is predominantly andradite with a subordinate grossular component, minor uvarovite and negligible almandine, spessartine and pyrope components (Figs. 1a, b). Late garnet penetrated along biotite cleavages, but it did not react with biotite, because this mica has a similar composition to that of biotite not associated with garnet. Individual crystals of garnet are commonly unzoned. Very rare single crystals are zoned, and show that the andradite component decreases and grossular and uvarovite components increase from core to rim (Fig. 2a).

Garnet from granitic aplite–pegmatite and pegmatite veins contains mainly spessartine with a subordinate almandine component (London, 2008); a few garnet compositions have predominantly an almandine component with a subordinate spessartine component (Figs. 1c, d). Other components containing Mg, Ca and Ti are negligible. The traverses show that most individual crystals are zoned with a core richer in Mn than the rim (Fig. 2b), because the Mn/(Mn + Fe) ratio in the melt is controlled by garnet, which captures Mn. However, reverse zoning occurs in a few crystals (Figs. 2c, d), which is attributed to resorption at temperatures low enough that diffusion rates within the crystals are low (Manning, 1983). The decrease in spessartine content and increase in almandine content of garnet toward the hanging wall of a granitic aplite–pegmatite vein consisting of 22 alternating layers indicates that garnet is a sink for Mn, which became depleted in the granitic magma owing to fractionation of garnet and the generation of the vein from a single batch of magma.

REFERENCES

Barth, A.P. & Ehlig, P.L. 1988. Geochemistry and petrogenesis of the marginal zone of the Mount Lowe Intrusion, central San Gabriel Mountains, California. *Contributions to Mineralogy and Petrology*, 100: 192-204.

Droop, G. 1987. A general equation for estimating Fe^{3+} concentrations in ferromagnesian silicates and oxides from microprobe analysis, using stoichiometric criteria. *Mineralogical Magazine*, 51: 431-435.

London, D. 2008. Pegmatites. *Canadian Mineralogist Special Publication*, 10, 347 p.

Manning, D.A.C. 1983. Chemical variations in garnets from aplites and pegmatites, peninsular Thailand. *Mineralogical Magazine*, 47: 353-358.