High temperature hydrothermal fibrolite in «El Payo Granite», Cadalso-Casillas de Flores granitic complex (Salamanca-Caceres, Spain)

Fibrolita hidrotermal de alta temperatura en el 'Granito de El Payo', complejo granítico de Cadalso-Casillas de Flores (Salamanca-Cáceres, España)

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ABSTRACT

Subsolidus replacements of fibrolite after biotite, muscovite, andalusite and feldspars have been recognized in El Payo granite near the contact with the more evolved Casillas granite. Both granites form part of the late-Variscan Cadalso-Casillas de Flores plutonic massif. Replacements follow microfractures and grain boundaries and are associated with fibrolite-quartz and less commonly fibrolite-tourmaline intergrowths. The limits of the altered zone are imprecise but the latter seems to be a thin band normal to the contact between the two granites. Base-cation leaching caused by the action of high temperature acidic hydrothermal residual fluids expelled from Casillas granite is thought to be responsible for the formation of fibrolite. Fibrolite repalcement after andalusite might probaly be indicative of metastable formation of the former within the andalusite stability field.

RESUMEN

En el granito de El Payo, junto al contacto con el garnito de Casillas, que es más evolucionado, se han observado reemplazamientos subsolidus de fibrolita a partir de biotita, moscovita, andalucita y feldespatos. Los dos granitos pertenecen al complejo plutónico tardi-Variscico de Cadalso-Casillas de Flores. Los reemplazamientos siguen microfracturas y bordes de granos y estan asociados con intercrecimientos de fibrolita-cuarzo y con menos frecuencia de fibrolita-turmalina. La zona afectada, aunque de limits imprecisos, parece ser una delgada lámina perpendicular al contacto entre los dos granitos. La fibrolitización es probablemente el resultado de un lixiviado acido de la roca producido por un fluido hidrotermal de alta temperatura procedente del granito de Casillas. El reemplazamiento de andalucita por fibrolita podría ser indicativo de la formación metastable de esta ultima, dentro del campo de estabilidad de la primera.

***Key words:** fibrolite, hydrothermal alteration, granite*

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Introduction

Fibrolite included in muscovite with textural relationships similar to those described by Carmichael (1969), is very common in the Cadalso-Casillas de Flores granitic complex (Hassan, 1996). However, a second variety of secondary fibrolite is distinguished in the contact zone between the El Payo granite (G2) and the more evolved Casillas granite (G3). This type of fibrolite is generally observed along grain boundaries and healed microfractures, or replacing biotite and andalusite and to a lesser extent muscovite and feldspars. It is also found as quartz-fibrolite and tourmaline-fibrolite intergrowths or as inclusions in the latter minerals.

Late-stage fibrolite has been addressed in both contact and regional metamorphic regimes, though its presence as an equilibrium phase has often been questioned (Pitcher and Berger, 1972; Vernon, 1979; Spear, 1982; Kerrick, 1987 and Kerrick, 1992). In contrast, little is known about fibrolite as a subsolidus mineral in low Ca peraluminous granites. Very few authors cited the presence of such type of fibrolite in granites and its formation has been attributed either to a thermal metamorphism induced by a later intrusion (Klein, 1965 and Barrera and Bellido, 1986) or to base cation leaching caused by the action of acidic volatiles emanating from an adjacent intrusion (Kerrick, 1987).

This paper describes this locally restricted, contact related subsolidus fibrolite in the El Payo granite.

Cadalso-Casillas de Flores granitic complex. Petrological features

The Cadalso-Casillas de Flores is a late Variscan, peraluminous and perphosphoric granitic complex. It is located in the western end of the Spanish Central System and is an eastern extension of the Guarda-Viseu complex in Portugal (Fig. 1). This massif is composed of six major units pertaining to two temporally diffe-

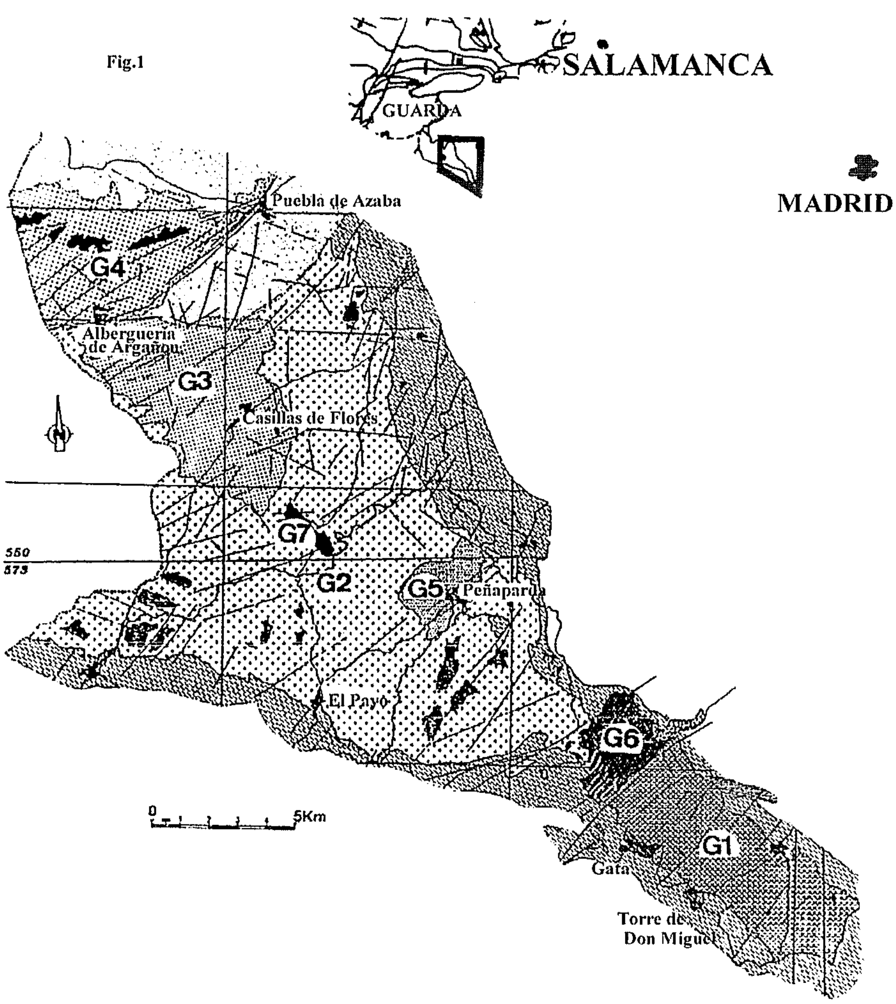

Fig. 1.- Geological map of the Cadalso-Casillas de Flores granitic complex.

Fig. 1.- Mapa geológico del complejo granítico de Cadalso-Casillas de Flores

rent events of granitic intrusions. The units of the first intrusive event (G1 through G4), are generally porphyritic medium-coarse grained granites. They range in composition from biotite rich granites (G1 and G2), to two mica or muscovite dominant leucogranites (G3 and G4). These units have been interpretad as resulting from an almost "in-situ" fractional crystallization of early biotite, plagioclase and accessory minerals such as zircon, monazite, ilmenite and xenotime. The second event consists of medium to fine grained minor granitic units (G5 and G6). In contrast to the first, the units of the second intrusive event, though cosanguineous, seem vaguely related by fractional crystallization (Hassan, 1996). High phosphorus content is the most outstanding chemical characteristic common to all the granites, whilst relatively low SiO_2 and CaO characterizes the units of the second event (Hassan, 1996) & Hassan et al. (1998).

The granitic complex intruded into a sequence of low grade metasedimentary rocks of late Proterozoic, Cambrian and early paleozoic age regionally known as the Schist Graywacke Complex.

El Payo and Casillas granites: Mineralogy and geochemical features

The El Payo granite (G2), is a biotite-rich porphyritic coarse grained granite. The essential minerals, besides quartz and in order of increasing abundance are: muscovite, biotite, k-feldspar and plagioclase, The former two minerals host accessory minerals such as zircon, monazite, apatite, xenotime, ilmenite and primary sulphides, whereas the latter mainly include biotite, ilmenite, apatite and quartz. Magmatic andalusite is a characteristic accessory mineral in El Payo granite. Plagioclase (An 26-8%) and K-feldespar phenocrystas 1 to 8 cm long are responsible for the porphyritic texture of this granite.

In the Casillas de Flores granite, the major distinguishing features are the non porphyritic texture, equal proportions of biotite and muscovite, accidental presence of andalusite the composition of plagioclase (An14-An2%). The main petrographic features of both granites are summarized in Table. 1.

Whole-rock chemical analyses of thirty seven samples belonging to both granites, gave an average SiO_2 content of 72.4 in G2 and 73.48 wt. % in G3. All samples have high normative corundum (2.65-5%), and A/CNK ratios higher than

Granite	Texture	Essential minerals	Accessory minerals	Secondary minerals	Enclaves	Associat kes & ve
G2	*Coarsely Porphyritic Coarse grained biotite granite*	*K-feldspar, Plagioclase, Biotite, Muscovite, (Bi>>Mu) Quartz*	*Zircon, Ilmanite, Monazite, Apatite, Arsenopyrite, Xenotime, Loellingite, Uraninite, Andalusite, Sphalerite, Rutile, Pyrite, Chalcopyrite & Tourmaline*	*Muscovite, Chlorite, Allanite, Barite, Calcite, Rutile, Tourmaline, Fibrolite, Fluorite, Kf, Albite, Apatite, Sphalerite, Arsenopyrite, Th-complexes, Hydrated Fe-phosphates*	*Metamorphic and granitic*	*Aplite, Pegmatite, Tourmalin veinlets & quartz*
G3	*Non porphyritic Medium-coarse grained two mica granite*	*K-feldspar, Plagioclase, Biotite, Muscovite, (Bi ≤ Mu), Quartz*	*Zircon, Ilmanite, Monazite, Apatite, Pyrite, Andalusite (very scarce), Arsenopyrite and uraninite*	*Muscovite, Chlorite, Allanite, Barite, Calcite, Rutile, Tourmaline, Fibrolite, Fluorite, Kf, Albite, Apatite, Th-silicate, Hydrated Fe-phosphates, REE-phosphosilicates*	*Metamorphic and granitic*	*Aplite, Pegmatite Tourmalin veinlets & quartz*

Table I.- Main petrographic characteristics of G2 and G3

Tabla I.- Características principales de G2 y G3

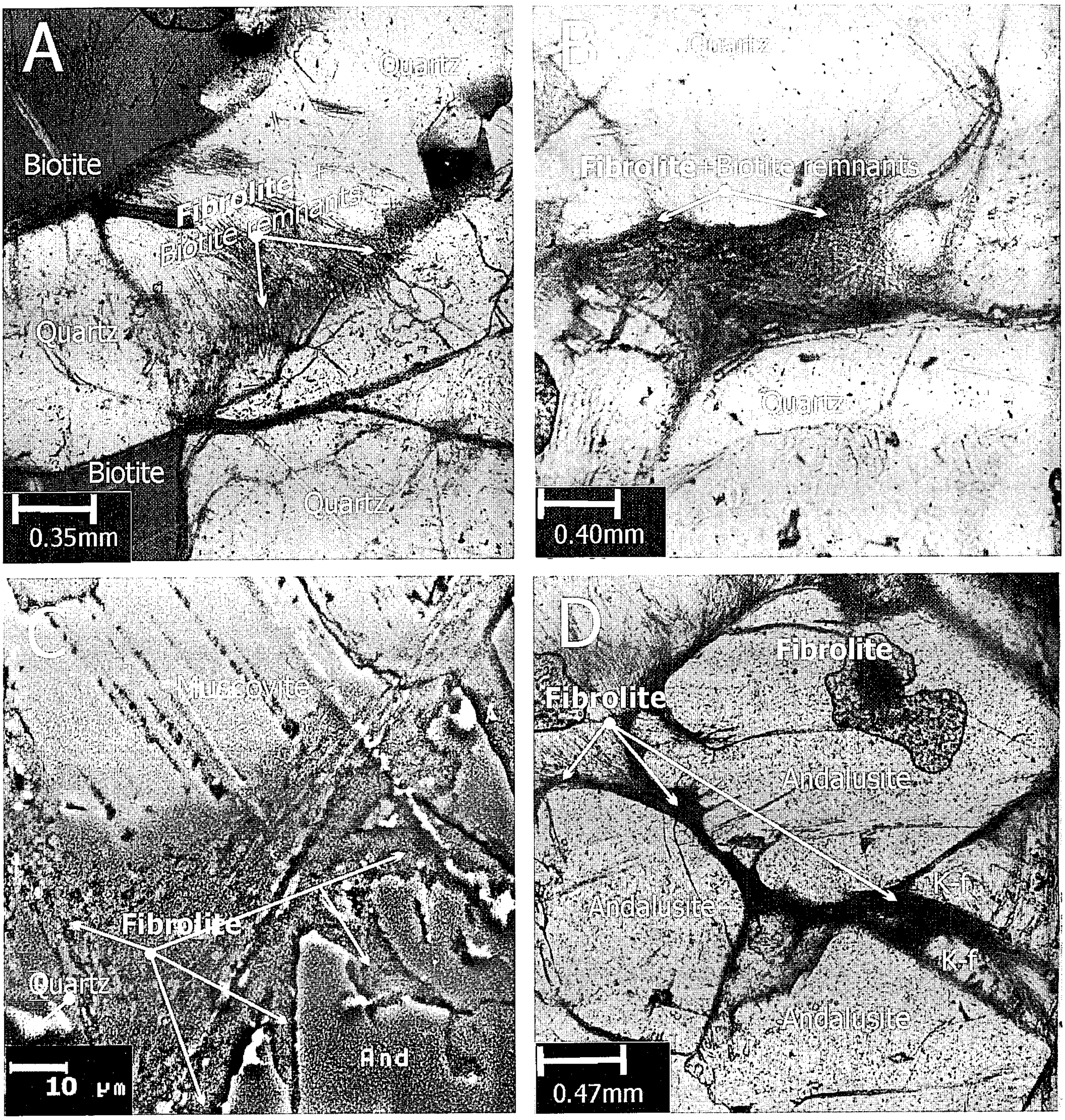

Fig. 2.- (a) Marginal replacement of biotite crystals (left top and bottom) and complete replacement of biotite (centre) by fibrolite, plane polarized light. (b) Complete pseudomorphous replacement of biotite by fibrolite (centre), plane polarized light. Relics of the original biotite are preserved within the dense mat of fibrolite fibres. Note the presence of fibrolite needles within the quartz grains. (c) BSE image showing a dense mat of fibrolite replacing both andalusite (And) and muscovite. Note the resulting embayed form of the andalusite crystal (lower right). (d) Subhedral to euhedral andalusite crystals (gray) surrounded by mats of fibrolite fibres (dark), plane polarized light. Fibrolite also replaces the outermost edges of K-feldspar (K-f) and is included in the quartz crystals in contact with andalusite (upper left).

Fig. 2.- (a) Reemplazamiento marginal de cristales de biotita (arriba y abajo a la izquierda) y reemplazamiento casi completo de biotita (centro) por fibrolita, luz polarizada plana. (b) Reemplazamiento pseudomorfo casi completo de biotita por fibrolita (centro), luz polarizada plana. Relictos de la biotita original se han preservado entre las fibras de la densa madeja de fibrolita. Nótese la presencia de agujas de fibrolita en el interior de los granos de cuarzo. (c) Imagen de BSE, mostrando una densa madeja de fibrolita remplazando a andalucita (And) y moscovita. Nótese la forma festoneada del cristal de andalucita (abajo derecha). (d) Cristales subhedrales a euhedrales de andalucita (gris) rodeados por madejas de fibras de fibrolita (oscuro), luz polarizada plana. La fibrolita también reemplaza los bordes del feldespato potásico (K-f) y se encuentra también incluida en los cristales de cuarzo en contacto con la andalucita (arriba izquierda).

1.5 (A/CNK= molar Al_2O_3/ $CaO+Na_2O+K_2O$) after adjusting CaO for apatite due to the excess of phosphorus of these rocks especially in the more evolved Casillas granite (Hassan, 1996).

Textural description of fibrolite and related minerals

Near the contact between the El Payo and Casillas granites a narrow band of imprecise limits is found within the former granite where secondary fibrolite is abundant. This type of fibrolite is arranged following arrays of microfractures and grain boundaries. In fact, well aligned fibrolite mats are well displayed in rock-sections cut perpendicular to the contact.

In contrast to the muscovite hosted fibrolite which is always found as random arrays or dispersed needles included into muscovite, the fibres of this second variety of fibrolite are mainly related to biotite and andalusite though muscovite and feldspars are also affected. Biotite is either rimmed or replaced partially or totally by fibrolite (Figs. 2a & b). Remnants of biotite, Fe-Ti oxides and radioactive accessories (zircon & monazite) formerly included in the original biotite are preserved within the fibrolitic mats. Igneous muscovite is also partially replaced by fibrolite (Fig. 2c). Fibrolite is also found replacing, or surrounding subhedral-euhedral magmatic crystals of andalusite and ocassionally radiating outward from them (Fig. 2c and d). Fibrolite-quartz intergrowths and less commonly fibrolite-tourmaline were observed in the vicinity and around fibrolite-rich microfractures.

Discussion

Secondary fibrolite after pre-existing silicates, especially biotite, has been described by many authors (Tozer, 1955; Loomis, 1972; Vernon, 1979; Vernon et al., 1987 ; Kerrick, 1987 and Hassan, 1996). The formation of such type of fibrolite was interpreted principally to be due to base cation leaching of the primary minerals by an external acidic fluid phase.

Vernon, (1979) proposed the following H^+ consuming and base cation liberating reactions (H-metasomatism) for the formation of fibrolite which is of application to our case:

(1) $CaAl2Si_2O_8 + 2H^+ = Al_2SiO_5 + Ca^{2+} + H_2O + SiO_2$

(2) $2KAlSi_3O_8 + 2H^+ = Al_2SiO_5 + 2K^+ + H_2O + 5SiO_2$

(3) $2K(Mg, Fe)_3AlSi_3O_{10}(OH)_2 + 14H^+ = Al_2SiO_5 + 2K^+ + 6(Mg, Fe) + 9H_2O + 5SiO_2$

(4) $2KAl_3Si_3O_{10}(OH)_2 + 2H^+ = 3Al_2SiO_5 + 2K^+ + 3H_2O + 3SiO_2$

Kerrick (1987) in a thorough study of the contact aureoles of the Main Donegal and Ardara plutons in Donegal (Ireland), suggested that secondary fibrolite was formed by the replacement of biotite by the influx of acidic hydrogen chloride-rich fluid of magmatic origin. The following reaction was inferred:

(5) $2K(Mg_x Fe_{1-x})_3AlSi_3O_{10}(OH)_2 + 14HCl = Al_2SiO_5 + 2KCl + 6(Mg_x Fe_{1-x})Cl_2 + 9H_2O + 5SiO_2$The intervention of a high-temperature hydrothermal fluid in the formation of secondary fibrolite in the El Payo granite is strongly suggested by the petrographic evidence. In this case the most probable source of the fluid was the Casillas de Flores granite as inferred by Hassan, (1996). The hypothesis of magma-derived fluid is supported by experimental studies (Rainer et al., 1998 and Webester et al., 1998), which have shown that crystal fractionation of peraluminous and perphosphoric magmas such as that of Cadalso-Casillas granitic complex may lead to strong enrichment of the residual fluids in disolved volatiles and fluxing components (e.g., H_2O, F, B and P). These components in turn will lower the viscosity of the residual volatile-enriched magmas strongly enhancing their capability to move easily through microfractures and grain boundaries.

Whether fibrolite grew metastably in the P-T field of andalusite or is a true stable phase is uncertain as the temperatue of the fluid is unknown. Nevertheless, we argue that the solidus temperatue of the Casillas granite was lower than that of the El Payo granite because of the higher silica, P and B content of the former. Thus, if the fluid was exolved very late, as expected in this case, we can especulate that its temperature might well have been within the andalusite stability field.

Conclusions

Fibrolite in the El Payo granite formed locally by the replacement of igneous minerals along microfractures and grain boundaries. An acidic high temperature late-magmatic hydrothermal fluid exolved from the nearby Casillas de Flores granite was probably responsible for the alteration.

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