Cordierite in the Cabeza de Araya granite: An exo-peritectic phase from wall-rock local assimilation?

Cordierita en el granito de Cabeza de Araya: ¿Una fase exo-peritéctica procedente de la asimilación local del encajante?

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Resumen: Una característica relevante del granito de Cabeza de Araya, una de las mayores intrusiones graníticas de la Zona Centro Ibérica (Macizo Ibérico), es la presencia de grandes cristales de tamaño centimétrico de cordierita. Estos aparecen especialmente concentrados en las facies más externas y más máficas del Plutón. A pesar de que se han propuesto varias hipótesis para explicar el origen de la cordierita en estos granitos, no se ha puesto mucha atención a las relaciones texturales, como apoyo a las inferencias procedentes de los estudios experimentales. En este trabajo se muestran relaciones texturales recientemente encontradas en los granitos de Cabeza de Araya que son decisivas en cuanto que indican la existencia de complejos procesos en el origen de los grandes cristales de cordierita que caracterizan estos granitos. Se concluye que la cordierita es xenógena pero crecida mediante reacciones peritécticas en xenolitos asimilados y a la vez en equilibrio local con el fundido residual del magma granítico.

Palabras clave: Cordierita, granito, Macizo Ibérico, asimilación.

Abstract: *A prominent feature of the Cabeza de Araya granite, one of the large granite intrusions of the Central Iberian zone (Iberian massif), is the presence of large, several cm length cordierite crystals. These are particularly concentrated in the outer, more mafic facies of the pluton. Although several hypotheses have been proposed to explain the origin of cordierite in these granites, scarce attention has been paid to textures as supporting inferences from experimental studies. We show here new textural relations recently found in the granites of Cabeza de Araya that are relevant in supporting the complex processes involved in the generation of the large cordierite crystals that characterize these granites. We conclude that cordierite is xenogenous but growing in the magma at expenses of peritectic reactions in assimilated xenoliths and in equilibrium with an interstitial melt of the host granite.*

Key words: *Cordierite, granite, Iberian massif, assimilation.*

INTRODUCTION

The presence of large and prismatic crystals of cordierite (Crd), of several cm length, in the marginal facies (facies A) of the Cabeza de Araya granite batholith has attracted the attention of Iberian granitologists for decades. These were described for the first time by L. G. Corretgé in his Doctoral Thesis (Corretgé, 1971), opening a fertile line of research on the meaning of mineral assemblages in granite petrogenesis.

The presence of cordierite -a characteristic Al-rich mineral phase of low-pressure metamorphic assemblages- in granites is quite common in anatectic domains of the Iberian massif, were granites are directly related in the field to the metasedimentary migmatitic source. However, in the case of Cabeza de Araya, cordierite is present in monzogranites that show, in part characteristic features of evolved calc-alkaline granitic intrusions, and in part, features of up-rooted peraluminous granites of anatectic origin. For this reason, these granites of Cabeza de Araya were classified as "granites avec caractères mixtes" in the seminal work of R. Capdevila, L.G. Corretgé and P. Floor (Capdevila *et al.*, 1973). Granites with similar features have been recognized along the Iberian belt and in other parts of the Variscan belt of Europe as Britany (Huelgoat granite, (Capdevila, 2010)). The composition of these "mixed features granites" departs in terms of major elements and isotopic relations from the composition of leucosomes and true anatectic granites. The main difference relates to the CaO content (>1.0 wt%) and the low $^{87}Sr/^{86}Sr$ initial ratios. The presence of intermediate (mesocratic) microgranular enclaves, possibly autolithic in origin, is another relevant feature, mostly typical of I-type calc-alkaline granites. All this makes the Crd-bearing monzogranites of the so-called "mixed features granites" a problem within the context of the "granite problem" that merits the attention of petrologists.

Furthermore, these Crd-bearing monzogranites host important ore deposits of U, W and Sn, making then of interest in metalogeny. Form this study we can infer that a close genetic relation exists between the processes of Crd generation and the formation of ore deposits of the type mentioned above.

THE CABEZA DE ARAYA GRANITE

The Cabeza de Araya batholith is the largest intrusion of the Central Extremadura batholith (Fig. 1). This is a concentrically zoned and elongated pluton with a centripetal arrangement of granitic facies. These are the facies named as A, B and C (Corretgé, 1971). The external facies A is relatively more mafic than the others. This is a very coarse-grained, Crd-rich monzogranite. The facies B and C are more leucocratic and classify as alkali feldspar granites, being C of aplitic appearance. A characteristic geochemical feature of these granites is the high content in P_2O_5 for low values of Ca; they are classified as per-phosphoric granites (Bea *et al.*, 1992).

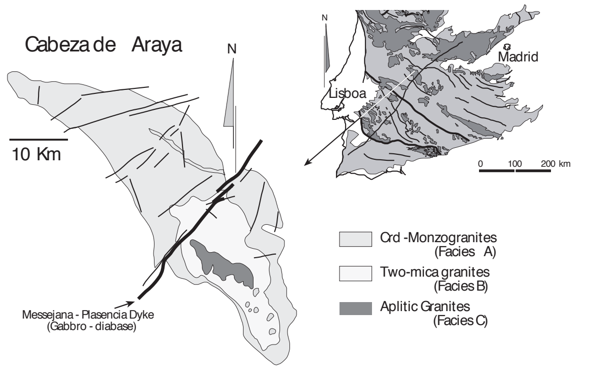

FIGURE 1. *Cabeza de Araya map (modified adter Corretgé, 1971)*

THE ORIGIN OF CORDIERITE: INFERENCES, TEXTURES AND PARADOXES

Geochemical relations and phase equilibrium experiments carried out by our team (Diaz-Alvarado *et al.*, 2011, García-Moreno *et al.*, 2007), strongly support that cordierite is formed in local domains of the granite magma by bulk-assimilation of pelitic xenoliths that were dragged from the walls in the way to a final emplacement reservoir. The first inferences were made on the basis of the incompatible bulk composition (too calcic) of Crd-bearing monzogranites (op. cit.) and the significant departure of mayor-element compositional trends from cotectic lines in appropriate phase diagrams (Castro, 2013).

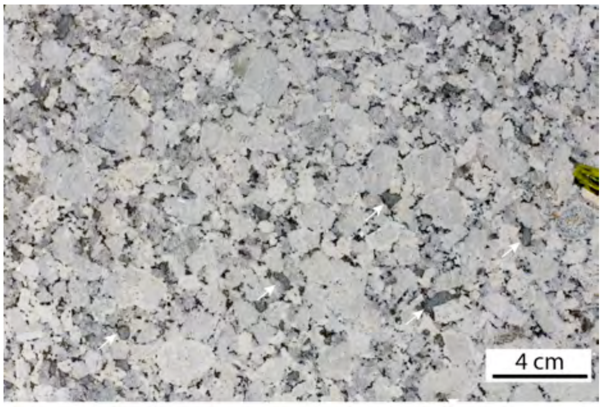

FIGURE 2. *Mesoscopic aspect of the Cabeza de Araya monzogranite (Facies A) showing the large Crd crystals with euhedral prismatic shape, occupying the interstices between the large K-feldspar crystals (arrows). These Crd prisms are pinnitized (dark green color) and surrounded by biotite remnant from xenolith assimilation.*

The new data on the textures of wall-rock xenoliths reveals that Crd is formed by a local peritectic reaction, preferentially at the edges of pelitic xenoliths. Figure 2 shows textural relations of Crd in xenoliths of the Cabeza de Araya granite. Prismatic crystals of Crd are growing from the xenolith outwards showing euhedral shapes within the granite mass. These observations points to a magmatic origin as Crd crystals grew freely in the liquid but were rooted at the xenolith-magma interphase. Poikilitic crystals of Crd are also found within the xenolith. In some cases, several cm-sized Crd crystals are close together in synneusis, showing a prismatic external shape and hosting relics of the xenolith foliation by parallel orientation of small biotite aggregates and inclusions (Fig. 3). The Crd-forming exo-peritectic reaction occurred after the formation of the large K-feldspar megacrysts that characterize the facies A of Cabeza de Araya (Fig. 2). These facies are mostly crystal cumulates from which an interstitial melt was lost by flow-induced deformation and filter-pressing. Consequently, it is possible to observe a texture of very coarse (>3 cm) minerals dominated by K-fedspar and Crd (Fig. 2).

Adopting this assimilation hypothesis solves some paradoxical observations. First, the facies richer in Crd are the more mafic and calcic facies of the pluton. This contrasts with the pure leucogranitic compositions (low Ca, Fe and Mg) of leucosomes of migmatites and experimental melts formed in equilibrium with peritectic Crd in the course of Bt breakdown. In Cabeza de Araya Crd is concentrated in the more mafic facies because these represent the more marginal part of the pluton in contact with the wall-rocks. Upon being peritectic ultimately, Crd is not an early mineral phase in the granite, occupying interstices between large K-feldspar crystals. The reason for this paradox is that Crd is peritectic in the xenolith but the granite was already formed and crystallizing at the time of assimilation. We adopt the term exo-peritectic for this particular phenomenon, possibly not very uncommon in other Crd-bearing monzogranites.

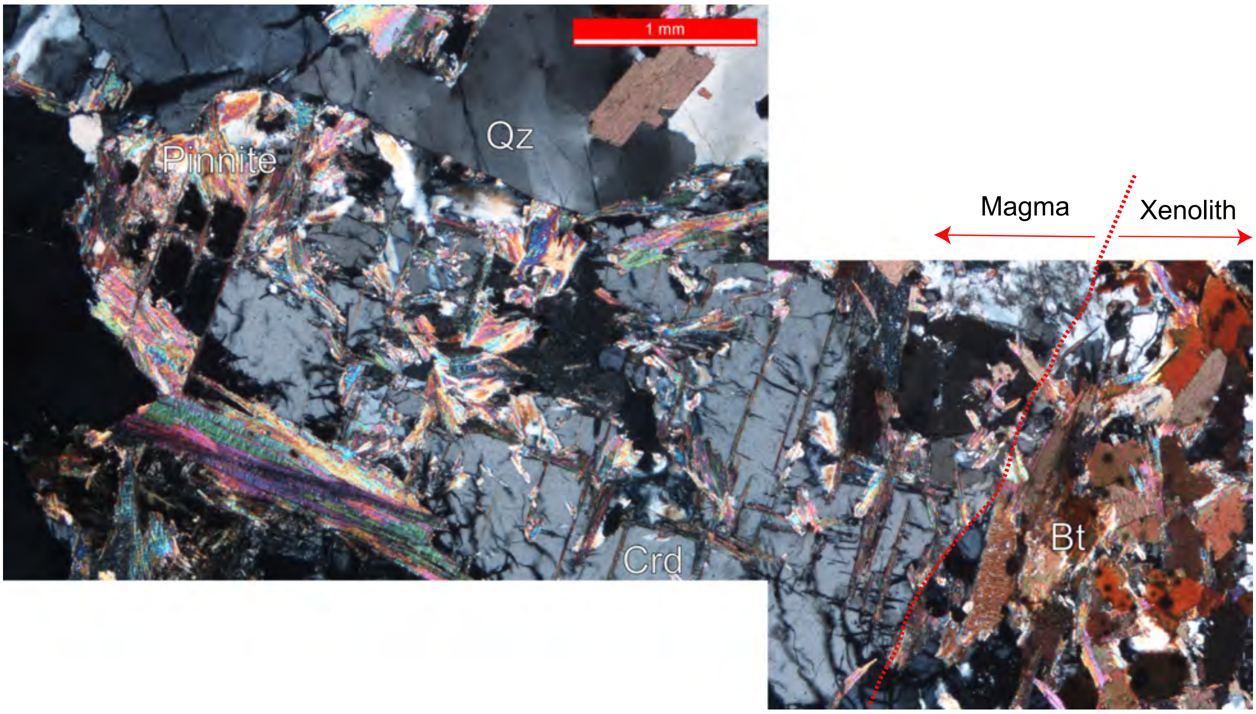

FIGURE 3. Photomicrograph showing the Crd growth starting from the xenolith. The red dashed line indicates the magma-xenolith boundary.

IMPLICATIONS

Origin of ore metals (Sn, W, U) in these granitoids comes from the country rocks. A mechanism to incorporate these metals to the magmas was not previously identified with support from geological and petrological observations. The most important metals forming ore deposits in these Crd-bearing monzogranites are U, W and Sn. It is well known that these elements are enriched in the Neoproterozoic pelites and greywackes of the CXG formation (Complexo de Xistos e Grauvacas) that dominate large regions of the upper Variscan continental crust in Iberia, and particularly in the Central Iberian zone, where the Cabeza de Araya batholith was emplaced. It is envisaged here that these ore metals were incorporated to the granite magma by assimilation and lately redistributed by late-magmatic fluids to form veins. Calc-silicate nodules, common within the CXG, supply with W and Sn metals by wall-rock assimilation. The processes can be inoperative in the case of granodiorites and tonalites, as the high temperature of magma intrusion will favor the formation of chilled margins (represented by autoliths), which prevent magma from local reaction with the host. Fine-grained autoliths are very scarce in the Cabeza de Araya intrusion, as well as in other similar intrusion in the region as Trujillo and Alcuéscar.

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