The mafic dikes from the Panticosa pluton (Pyrenean Axial Zone): petrology and mineral chemistry

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ABSTRACT

The Panticosa pluton is one of multiple granitic plutons cropping out in the Pyrenean Axial Zone, which corresponds to the Palaeozoic core of the Pyrenees. Mafic dikes cut both the Panticosa pluton and its Devonian metasedimentary country rocks. According to their mineralogy and mineral composition, these dikes can be classified into two different groups, with little textural variations: a calc-alkaline group and an alkaline group. The calc-alkaline rocks (spessartites and calc-alkaline diabases) include calcic to sodic Pl, slightly Ti-rich Amp and substantial Qz. In contrast, the alkaline rocks (camptonites and alkaline diabases) are composed of calcic Pl, Ti-rich Cpx, Ol pseudomorphs and inherited constituents (megacrysts and enclaves). The composition of Pl and the main ferromagnesian phase (Amp in calc-alkaline group and Cpx in alkaline group) is coherent with the geochemical affinity assigned to both groups. The megacrysts in the alkaline group are predominantly Krs and Ts, with a deep-origin according to thermobarometric calculations. A detailed mineral chemistry study of the phases observed inside the enclaves is necessary to better comprehend the petrogenesis of the magmas which generated these alkaline rocks.

Key-words: Dike, alkaline, calc-alkaline, Pyrenees, Variscan.

Introduction

The Panticosa pluton is a granitic intrusion located in the Pyrenean Axial Zone. It is the southernmost pluton of the Cauterets-Panticosa granitoid complex (Fig. 1). Its emplacement age is not well defined up to present. This emplacement could be subsequent (Debon, 1980) or coincident (Gleizes et al., 1998) with the main deformational phase of the Variscan Orogeny (Pennsylvanian in age). Several intermediate and mafic dike swarms can be recognized cutting both the pluton and its metasedimentary Devonian country rocks (Debon and Zimmermann, 1993). These dikes have been classified as lamprophyres (Lago et al., 2004; Galé, 2005) even though they have been also cited as doleritic dikes (Santana et al., 2006) or simply as mafic dikes (Debon and Zimmermann, 1993). The assumed dike age is Permian (Debon and Zimmermann, 1993; Galé, 2005). In this work, we combine previous data with new petrological and chemical data for the main mineral phases of the dikes.

Petrology

The dikes from the Panticosa pluton are melanocratic igneous tabular intrusions, up to 7 m thick. They intrude both the pluton and the Devonian country rock. Contacts between the dikes and the host rocks are sharp and quite straight. Chilled margins and deformation structures (Riedel fractures caused by shear) have sometimes been observed in the contacts.

To the naked eye, some of these dikes are porphyritic, with large crystals of Pl and/or Amp or less frequently Cpx (mineral abbreviations in this work follow recommendations by Whitney and Evans, 2010), whereas many of them correspond to fine grained equigranular rocks.
According to their mineralogy and geochemistry (Le Maitre, 2002), two main groups of dikes can be defined: a calc-alkaline group (CA) and an alkaline group (ALK). When cutting situations occur, the ALK dikes always cut the CA dikes, indicating that CA dikes were emplaced first. The CA dikes show a microporphyritic to intergranular texture, composed of Pl microcrysts (50-75%) and Amp micro-phenocrysts (25-40%), intergranular and xenocrystic Qz (3-10%), Opq (0-3%), Bt (0-5%) and acicular Ap (2%). Alteration phases, as Chl (3-15%), Opx (3-10%), Amp (1%), Bt (1%) and Ttn (1%), are common (0-12%). Moreover, macrocrysts (< 1 cm) of Amp, Ap, Pl and Opq are common in some of these alkaline rocks, thus making them appear porphyritic to the naked eye. Under the microscope, Amp megacrysts are anhedral, displaying oval or ameboid morphologies. They usually have reaction rims and also permeated zones, filled by the rock groundmass. Enclaves are also frequent in these alkaline rocks. Several enclave types can be defined, according to their mineral assemblages (Pl+Bt megacrysts, Pl+Ap macrocrysts, Pl+Amp macrocrysts and others) and size (up to decimetric).

These ALK rocks are classified either as camptonite (microporphyritic texture, macro and megacrysts) or alkaline diabase (doleritic texture).

According to the crystallization sequences, in both the CA and ALK rocks, the ferromagnesian minerals are the first phases to crystallize (Amp in CA and Cpx in ALK). The sequences continue with the crystallization of Pl, in competence with Amp or Cpx. The crystallization of Pl ends after that of the main ferromagnesian phase. The crystallization of Opq takes place throughout the whole crystallization process.

Mineral chemistry

The main mineral phases (Pl, Cpx and Amp) were analysed in 12 samples of the Panticosa dikes using a JEOL JZA-8900M electron microprobe at the Centro Nacional de Microscopía electrónica of the Universidad Complutense de Madrid.

Plagioclase

According to their composition, four principal Pl types have been discriminated (Fig. 2):

1. Microcrysts in CA rocks: this group shows a wide compositional range (An_{65} – An_{95}).

2. Microcrysts in ALK rocks, with a limited compositional variation (An_{65} – An_{95}) and some Ab compositions, probably related with subsolidus recrystallization.
3. Phenocrysts in ALK rocks: this group includes unzoned phenocrysts and phenocryst rims in some samples. Their compositions cover a wider range (An$_{61}$ – An$_{97}$) than the microcrysts in the same samples.

4. Inherited Pl in ALK rocks (this group includes Pl macrocrysts, Pl inside enclaves and antecrystic cores in some type-3 phenocrysts). Their compositions define a common trend from An$_{61}$ (less calcic than the micro- and phenocrysts in the same rocks) to An$_{52}$ (more sodic than the phenocryst rims).

Clinopyroxene

This mineral is only present in the alkaline rocks. According to the obtained results, 2 main types of Cpx can be differentiated. The most common Cpx type is formed by microcrysts of Ti-rich augite and diopside. The second type of Cpx consists of zoned phenocrysts with augite cores and Ti-rich augite and diopside rims.

In a Ti vs Ca+Na (per formula unit) plot, the whole of the data define a Ti-increase trend, coincident with the typical alkaline trend defined by Leterrier et al. (1982) (Fig. 3).

The compositional evolution is different for the Pl crystals of the two dike types (Fig. 2). The increase of the proportion of Ab molecule in Pl in the alkaline dikes is correlated with a slight increase in the K content (Or molecule). This evolution path is a common feature of Pl in alkaline magmas. This feature is absent, in contrast, in the Pl compositions in CA rocks, supporting their subalkaline affinity.

Amphibole

This mineral is found in both groups (CA and ALK). Four types of Amp have been chemically discriminated, namely: 1. Microphenocrysts in the CA rocks, 2. Green Amp in some type-1 phenocryst marginal zones, 3. Isolated macro/megacrysts of Ti-rich Amp in some ALK rocks, and 4. Crystals of Ti-rich Amp inside enclaves within some ALK rocks.

All the obtained analyses are calcic amphiboles, according to the nomenclature proposed by Leake et al. (1997). The first group is mainly classified as Mg-hastingsite with moderate TiO$_2$ contents (up to 3.36%), which are representative of sub-alkaline Amp. Their differentiation range is relatively large, according to the Mg# values (from 0.5 to 0.7).

The second group is composed of Mg-hornblende. Its composition is very different from that of type-1 Amp, as it is observed in diverse elements like titanium (lower Ti contents than Mg-hastingsite). Given their textural position (around type-1 Amp phenocrysts) and the fact that their composition differs from the proposed ranges for igneous Amp (Czamanske and Wones, 1993), this type of Amp can correspond to a late-magmatic phase.

The third group is exclusively formed by kaersutite (TiO$_2$ up to 6.13%). The Mg# values are clustered between 0.78 and 0.71. The alkaline affinity of these Krs is clear, although taking into account their resorption features, big size and different composition, they must be interpreted, at least, as an early mineral phase (probably antecrystalline).

Finally, the fourth Amp type is very similar in texture and optical features to type 3 Amp. They are classified as tschermakite, according to their (Na+K)$_4$ contents (minor to 0.5 pfu). They are also interpreted as antecrystalline and chemically related to type-3 Amp.

The pressure (Hammarstrom and Zen, 1986) and temperature (Otten, 1984) estimated for the Amp compositions suggest a deep origin for the Amp antecrysts found in the ALK group (about 8 kbar -25 km depth and 1100°C).

Discussion and conclusions

The Panticosa mafic dikes can be divided, according to their mineral parageneses and the chemical composition of their mineral phases, into two groups: one group with calc-alkaline affinity and another group with alkaline affinity. The calc-alkaline dikes are classified either as spessartites or calc-alkaline diabases, attending to their textures. Using the same criterion, the alkaline dikes are classified either as camp-tonites or alkaline diabases.

The calc-alkaline dikes contain Pl defining a sub-alkaline geochemical trend (Fig. 2) and Amp with contents in Ti (and other elements) similar to those described in other...
spessartites from the Pyrenees (Arranz, 1997). In contrast, the alkaline dikes present PI with a typically alkaline evolution, characterized by a relative K-enrichment as the differentiation advances (Fig. 2). Moreover, the Cpx compositions in this group are equivalent to those typical of Cpx in alkaline rocks (Leterrier et al., 1982) (Fig. 3).

The CA dikes are intermediate rocks, according to their mineralogy (substantial Qz -up to 10%- and very abundant PI, from calcic to relatively sodic members -An15-). On the contrary, the ALK dikes are basic rocks with Ol pseudomorphs, Ti-rich Cpx and predominantly calcic Pl (labradorite).

Apart from some examples of xenocrystalline Qz, the CA dikes do not show other xenocrystic phases. The wide range of differentiation displayed both by the calc-alkaline Pl (Fig. 2) and the calc-alkaline Amp (according to the Mg# index), suggests an extended crystallization process.

However, in the ALK dikes, antecrysts (e.g. Krs megacrysts) and/or enclaves have been recognized. They do not represent the crystallization of the alkaline melt, which is mainly represented by the Cpx and PI groundmass microcrysts.

The Cpx phenocryst cores formed during the early stages of the alkaline magma crystallization. Their low Ti and high Mg contents can be linked to the Cpx microcryst compositions by a normal differentiation trend in alkaline magmas (Fig. 3). Cpx phenocryst cores probably crystallized before the emplacement of the magma. In contrast, phenocryst overgrowths and groundmass microcrysts crystallized at the emplacement level.

The Krs megacrysts are diagnostic of alkaline rocks; in the Panticosa alkaline dikes they are interpreted as antecrysts transported by the alkaline magmas during their ascent to the emplacement level. This interpretation is supported by their rounded, anhedral morphologies, reaction rims, permeated zones and chemical composition. Furthermore, geobarometric calculations indicate higher depths for the crystallization of these antecrysts (ca. 7-8 kbar, that is, a 23-26 km depth). This implies that their host magma was likely stagnated and fractionated at lower crustal levels.

Finally, the enclaves show diverse mineralogies and represent rock fragments incorporated by the alkaline magma during its ascent. A detailed chemical study of the mineral phases forming these enclaves would be necessary to acquire better comprehension of the deep magmatic system related to the generation and ascent of the alkaline magmas.

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