Composition of the Aiguablava Camptonite Sill (Costa Brava Batholith)

/ TERESA UBIDE, CARLOS GALÉ, ENRIQUE ARRANZ, MARCELIANO LAGO

Departamento de Ciencias de la Tierra. Ciudad Universitaria. Universidad de Zaragoza. C/ Pedro Cerbuna 12. 50009, Zaragoza (España)

INTRODUCTION.

Several lamprophyric intrusions have been recognized crosscutting the Costa Brava Variscan batholith. Most of them are part of a well developed family of lamprophyric subvertical dykes, considered to be of Permian age. However, some other intrusions, both dykes and sills, clearly alkaline in composition cut the former. The age of this second group is Late Cretaceous (Solé *et al*., 2003).

We have carried out a detailed study of one of the Cretaceous intrusions, a sill, cropping out discontinuously along Aiguablava beach area (Fig. 1).

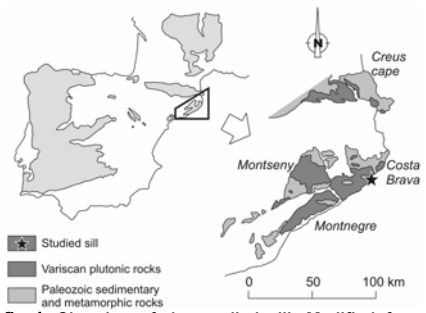

fig 1. *Situation of the studied sill. Modified from Enrique (1990).*

PETROLOGY OF THE SILL.

The studied sill crops out in three close locations: the southern area (Punta d´es Mut; outcrop 1) is 600m away from the next one (2), which is 100m away from the northern outcrop (Platja Fonda; outcrop 3).

It is a gently dipping sill (145, 15NE) which decreases in thickness from south (2m in outcrop 1) to north (1-0m in outcrop 3). The three outcrops are at the same height but, considering the northeast dip of the sill, they probably represent slightly different emplacement levels, being outcrop 3 the highest.

The sill has sharp contacts with aphyric chilled margins, sometimes displaying vesicle alignments (mainly near the upper rim) and lamination (more common in the lower margin) (Fig. 2). The rock in the central parts of the sill is almost aphanitic, except for the millimetric mafic minerals, frequently concentrated at the bottom. Country-rock xenoliths are rare, and without evidence of assimilation.

The rock, according to its mineral assemblage is a camptonite. It has a microporphyritic hypocristaline texture and the crystal size of the microcrystals varies among outcrops, being bigger in outcrop 1 (400µ) than in outcrop 3 (200µ).

The mineral assemblage is composed of clinopyroxene, amphibole (Kaersutite), plagioclase, opaque minerals (oxides and sulphides) and apatite. From these, only Cpx and Krs are present as big crystals, visible to the naked eye. When studied in detail, they display features typical of xenocrystaline phases: they have a rounded nucleus and are overgrown in optical continuity by a rim of the same composition as that of the equivalent phases in the groundmass. Both Cpx and Am nuclei include sulfide micro-inclusions, typical of mantle xenocrysts.

In the groundmass of the rock, textural criteria indicate that Krs started crystallizing only after the end of Cpx and oxides crystallization. Small sulfide crystals formed during Krs growth, followed by crystallization of apatite and plagioclase.

COMPOSITIONAL VARIATIONS.

Mineral compositions, analysed with electron microprobe (JEOL JXA-8900M, UCM, Madrid), confirm the homogeneity of the sill and its alkaline affinity: Cpx compositions show a vertical pattern situated in the alkaline field when plotted in the Ti *vs* Ca+Na (Leterrier *et al* 1982) diagram; Am is Ti-rich (Krs) and the less calcic Pl is also enriched in the Or molecule.

The mineral composition of the three outcrops is quite similar, but two differences must be noted. Ti p.f.u. in Krs (and thus, the temperature; Otten, 1984) increases from the southern (1:

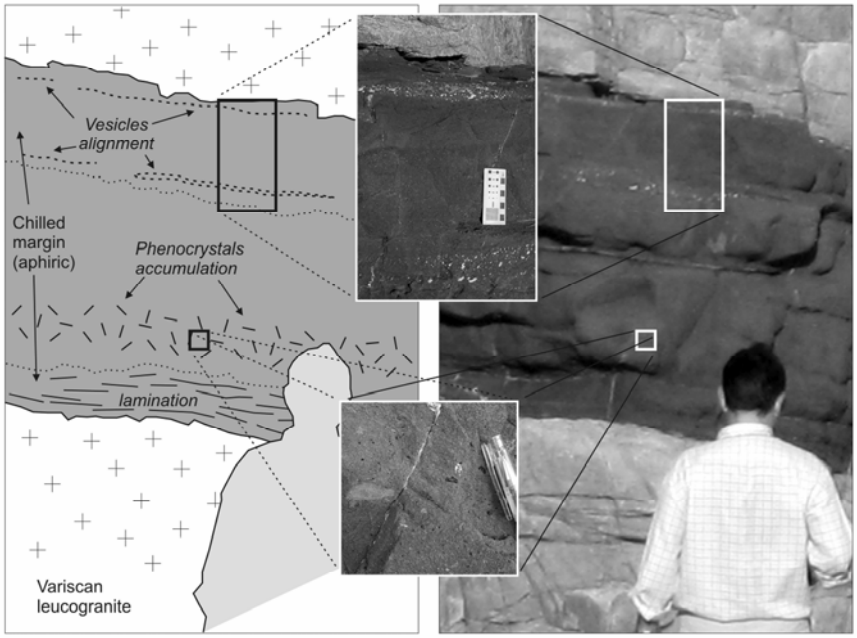

fig 2. *Outcrop scheme of the studied sill.*

palabras clave: camptonita, composición, Cretácico, Costa Brava

key words: camptonite, composition, Cretaceous, Costa Brava

* corresponding author: **tubide@unizar.es**

0.47-0.71) to the northern (3: 0.57-0.86) outcrops. The only other remarkable difference is that Cpx from outcrop 2 is slightly more differentiated, as it contains higher Fe^{2+} and Al VI, and lower Mg.

Apart from this, centre-rim patterns show interesting compositional variations, especially in early xenocrysts (Krs and Cpx). The compositional variation patterns for each mineral phase are very similar in the three outcrops.

Kaersutite centre-rim patterns.

Xenocrystic Krs nuclei are unzoned, although the mg* value (ratio $100*Mg/(Mg+Fe^{2+}+Fe^{3+}+Mn)$ in cations p.f.u.) in the different cores is variable (from about 65 to about 73). In contrast, the overgrowths have higher Ti contents, and mg* (72 on average) and lower K when compared to the nucleus.
The groundmass Krs shows the normal patterns of mg* depletion from the centre to the crystal rims, with an initial value of 69 on average.

Clinopyroxene centre-rim patterns.

Xenocrystic Cpx nuclei show marked zoning patterns, varying from Fs_{11} to Fs_{16}. The overgrown rim has a quite constant Fs_{12} value and, as in the Krs rims, is richer in Ti.

The Cpx microcrystals in the groundmass show the normal pattern of Fs enrichment to the crystal rims, with an initial content of about 11.

Plagioclase centre-rim patterns.

Pl is only present in the matrix, and displays normal zoning patterns (depletion in An and enrichment in K p.f.u.from centre to rim).

DISCUSSION.

The proximity, similar directions and characteristics of the studied outcrops indicate that all of them belong to the same sill. The sill is likely to have a staircase morphology, as indicated by the height, strike and dip relations among the different outcrops.

The sharp contacts with the wall rocks, together with the well developed chilled margins (Fig. 2), indicate that the wall rock was completely cooled when the camptonite intruded, in accordance with their differences in age. The concentration of mafic minerals to the lower parts and the well developed vesicle alignments (Fig. 2), suggest a slow and complex cooling process for the camptonite.

The thickness, groundmass grain size and Krs temperature decreases from outcrop 1 to 3; this could be related to the position in the sill: the thicker the sill, the slower the crystallization. However, the differences are not very significant and there are no more chemical parameters supporting this hypothesis, so the crystallization rate must have been rather similar.

Xenocrystic Cpx cores show an irregular compositional pattern, whilst Am cores are rather homogeneous. This difference suggests that they were crystallized under different conditions.

Both xenocrystic phases show a compositionally distinct rim. This rim grew probably in equilibrium with the melt, as it shows similar compositions in all analyzed crystals. Moreover, these compositions agree with those of the groundmass Cpx and Krs cores.

When compared to the xenocrysts, groundmass and rim Cpx and Am have higher Ti contents and mg*, and in the case of Krs, have lower K contents. Therefore, it seems that the melt in contact with the xenocrysts was less differentiated and alkaline (less potassic) than the melt (or melts) from which they originated.

The high Ti contents of the Krs microcrystals indicate high temperatures for the melt, pointing out that the ascension of the magma was rapid. This is also compatible with the crystallization of Krs after the end of the crystallization of Fe-Ti oxides (probably favoured by a reduction in the fO_2 of the magma).

CONCLUSIONS.

The petrological and mineralogical study of the Aiguablava camptonite sill supports the following conclusions:

- The three camptonite outcrops of the studied area belong to the same staircase shaped camptonite sill.
- The camptonite melt rose rapidly, intruding already cooled wall rocks. The sill cooled slowly, its thicker parts slightly slower than the thin parts.
- The camptonite melt included Krs and Cpx xenocrysts. Cpx nuclei have complex compositional zoning.
- Krs xenocrysts suffered resorption during transport; in contrast, Cpx xenocrysts suffered little or no resorption. Both minerals were overgrown in optical continuity, with compositions in equilibrium with the melt.
- The melt carrying the xenocrysts was slightly less differenciated and probably less alkaline than the melt(s) from which the xenocrysts originated.

ACKNOWLEDGEMENTS.

This work is part of the project CGL-2004-04481. It is included in the objectives of the pre-doctoral grant BF106.189, Mod. AE, Gobierno Vasco (Teresa Ubide Garralda).

REFERENCES.

Enrique, P. (1990): The Hercynian intrusive rocks of the Catalonian Coastal Ranges (NE Spain). Acta Geológica Hispánica, ***25*** *(1-2): 39-64.*

Leterrier, J., Maury, R., Thonon, P., Girard, D., Marchal, M. (1982): Clinopyroxene composition as a method of identification of the magmatic affinities of paleo-volcanic series. Earth and Planetary Science Letters, ***59****: 139-154.*

Otten, M. T. (1984): The origin of brown hornblende in the art fallet gabbro and dolerites. Contributions to Mineralogy and Petrology, ***86****: 189-199.*

Solé, J., Pi, T., Enrique, P. (2003): New geochronological data on the Late Cretaceous alkaline magmatism of the northeast Iberian Peninsula. Cretaceous Research, ***24****: 135-140.*