# Megacrystals and Related Xenoliths in Basaltic Lavas from the Sant Corneli Volcano (Girona, NE Spain)

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## INTRODUCTION

Megacrystals of mafic minerals along with mantle and pyroxenite xenoliths are frequent in alkaline basaltic lavas. They provide key information on the magma source, transfer, dynamics, storage and differentiation.

Megacrystals in volcanic rocks can be classified according to their origin (Jerram and Martin, 2008) as: (i) phenocrystals that nucleate and grow from the liquid represented by the groundmass or glass, ie., from the magma of the current eruption; (ii) xenocrystals physically incorporated into the magma system, but not related to it; and (iii), antecrystals formed from a progenitor of the final magma and therefore, directly associated with the active magmatic system, but incorporated later on during the final stages of eruption

Basaltic rocks from the Sant Corneli volcano are a case study because they include megacrystals and mantle and pyroxenite xenoliths. This volcano is located in La Selva graben (Girona), one of the three sub-zones of the Catalan Volcanic Zone (CVZ), which is part of the Neogene-Quaternary within-plate volcanism of the Iberian Peninsula. Only part of the neck and of the pyroclastic cone of the original volcano, are preserved due to erosion and intense working of stone quarries. The neck is formed of columnar structured basanites (López Ruiz and Rodríguez Badiola, 1985) with an estimated age of 8-2Ma (K-Ar method by Donvile, 1973).

### *Materials, objectives and methods*

Mantle xenoliths from Sant Corneli are mostly spinel lherzolites and were studied recently by Fernández-Roig and Galán (2015) and Fernández- Roig et al. (2017), but there is no studies on megacrystals and pyroxenite xenoliths. The former are of clinopyroxene, olivine and less common of plagioclase,

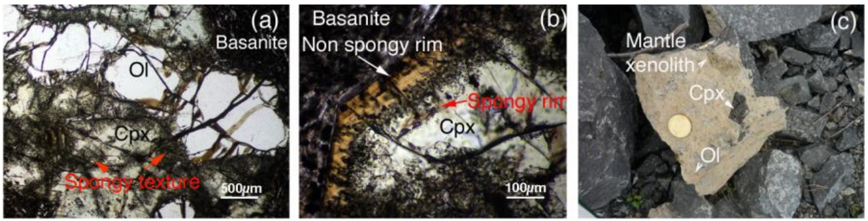

*fig. 1. (a) olivine clinopyroxenite xenolith with spongy-textured clinopyroxene. (b) Darker outer clinopyroxene rim developed on earlier spongy rim. (c) Sant Corneli basanite including mantle xenoliths, clinopyroxene and olivine megacrystals.*

This study is focused on the mineral chemistry and origin of the clinopyroxene, olivine megacrystals and the pyroxenite xenoliths formed mainly of these two phases. For such a purpose and for studying the host lava, we used, other than the petrographic microscope, backscattered electronic images obtained with an EVO Zeiss scanning electronic microscope, provided with an energy dispersive spectrometer, at the Microscopy Service of the UAB. Moreover, quantitative mineral analyses were determined with a CAMECA SX 50 microprobe, at the Scientific-technique Services of the Universitat de Barcelona. Finally, contrasting compositions with similar phases in mantle xenoliths, in other xenoliths of cumulative origin from neighbouring volcanoes and in the host basanite serve to assess the origin of these megacrystals and related pyroxenite xenoliths.

## RESULTS

### *Petrography*

Four xenoliths were examined. They are ±olivine clinopyroxenites (up to 3cm in size), angular or rounded shaped and with protogranular or porphyroclastic microstructure. Clinopyroxene is the main mineral in colourless crystals from 2cm to <1mm in size. These crystals show spongy rims, which are not preferentially developed at the contact with the host lava and penetrate to the crystal core (Fig. 1a). Moreover, spongy-textured clinopyroxene shows glass-filled dendrites and zeolite-filled amigdales. At the contact with the host lava, both spongy and non spongy-textured clinopyroxene developed a thin darker rim (Fig. 1b), similar in colour to the basanite clinopyroxene. Olivine forms rounded anhedral inclusions in clinopyroxene (Fig. 1a) or porphydoclasts and neocrystals in one xenolith.

Clinopyroxene megacrystals (0.5-4cm in size) were observed in seven thin sections. They show either angular or rounded edges and black colour in hand specimen (Fig. 1c), but they are colourless under the microscope. Spongy rims and spongy-tetured zones are associated with tiny crystals of spinel and with zeolite amigdales. As in the xenoliths, spongy and non-spongy textured clinopyroxene developed a thin darker rim at the contact with the host lava.

Olivine megacrystals are smaller than the clinopyrone ones (0.5-1cm), green or brownish green in colour (Fig. 1c) and anhedral.

The host basanite shows aphanitic

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porphyritic microstructure, with intergranular- or trachytic-textured groundmass, formed of olivine, brownish clinopyroxene, plagioclase ($An_{52-67}$) and interstitial nefeline or analcime, apatite and ilmenite.

### *Mineral chemistry*

The forsterite component (Fo) in olivine of xenoliths ranges from 76.6 to 85.4%. The lowest values were found in neocrystals. The Fo range in olivine megacrystals is similar (79.6-86.7), whereas it is lower in the basanite olivine (73.6-75.3). In contrast, the CaO content of olivine increases from xenoliths and megacrystals (0.19-0.27%) towards the basanite (0-28-0.39%).

Clinopyroxene is aluminian diopside, augite or wollastonite close to diopside with Mg# ($Mg\# = 100 * Mg/Fe_T + Mg$) from 86.4 to 69.6 and Cr# ($Cr\# = 100 * Cr/Cr + Al$) from 10.6 to 0.0, all in atoms per formula unit. Although there is large overlapping, Mg# in clinopyroxene decreases from the xenoliths to the basanite through megacrystals (Fig. 2a). Ti abundance also discriminates between the three types of clinopyroxene: it increases gradually (0.00-3.68) from xenoliths towards the basanite (Fig. 2a). Compositions of spongy rims differ by lower $Al_{total}$ and Na and by higher Ca and Al(T)/Al(M1) ratio (ie., by lower jadeite component) than in non spongy-textured clinopyroxene. The darker rims are Ti-enriched, with similar compositions to the basanite clinopyroxene (Fig. 2a).

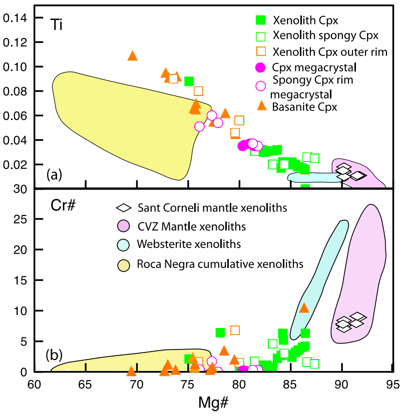

***fig. 2. (a) Ti vs. Mg# diagram for clinopyroxene of lherzolites, olivine clinopyroxenites, megacrystals and basanite from Sant Corneli. (b) Idem for Cr# vs. Mg# diagram. Comparison references are mantle peridotites, websterites and cumulative xenoliths from other volcanoes in the Catalan Volcanic Zone.***

Glass in the dendrites of the spongy-textured clinopyroxene is equivalent to basaltic trachyandesite, basaltic andesite and phonolite, with $Na_2O/K_2O > 1$.

## *DISCUSSION*

Anhedral olivine and clinopyroxene megacrystals along with overgrowth microstructures in the latter exclude their origin as phenocrystals in equilibrium with a melt represented by the basanite groundmass. An origin as xenocrystals from the fragmentation of mantle peridotites and websterites is also excluded: (1) Fo in olivine from lherzolite xenoliths in Sant Corneli basanite is higher (89.0-89.9%) than in the clinopyroxenites and megacrystals, as it is the case of olivine in other mantle peridotites from younger volcanoes of La Garrotxa (Fo: 88.4-91.8%; (Galán & Oliveras, 2014), another sub-zone of the CVZ; (2) clinopyroxene of the mantle peridotites have higher Mg# and Cr# and lower Ti (Fig. 2) than clinopyroxene in the studied megacrystals and xenoliths; and (3), there is no orthopyroxene in the pyroxenites from Sant Corneli and Mg# and Cr# of clinopyroxene are lower than in most websterite xenoliths (Fig. 2b; Galán et al., 2008). Therefore, the megacrystals are most likely recycled antecrystals resulting from the fragmentation of the clinopyroxenites by the host lava. However, it is worth noting that clinopyroxene compositions in Sant Corneli clinopyroxenites also differ from those in cumulative xenoliths (clinopyroxenites, hornblendites and gabbros) from the younger Roca Negra volcano in La Garrotxa (Neumann et al., 1999). The clinopyroxene of the Roca Negra xenoliths is more similar to the basanite clinopyroxene from Sant Corneli, but with less Ti (Fig. 2a-b). In other words, the clinopyroxenites and derived megacrystals are characteristic of the Sant Corneli magma-plumbing system.

Spongy-textured rims and zones in clinopyroxene of xenoliths and megacrystals (Fig. 1a) would be the result of earlier partial melting of this phase during decompression, since the jadeite component is lower than in non spongy-textured clinopyroxene. This partial melting would have occurred before the fragmentation and recycling by the host lava since spongy microstructures are not preferentially developed at the contact with it. In contrast, thinner and discontinuous clinopyroxene darker rims at the contact with the basanite (Fig. 1b) would be due to short time re-equilibration with the lava, most likely during its ascent to the surface.

## *CONCLUSIONS*

Megacrystals from Sant Corneli are thought to be antecrystals. They were formed by fragmentation and recycling of earlier olivine clinopyroxenites, interpreted as the fractional crystallization products at depth of an earlier, less differentiated alkaline basic magma than the host lava.

Spongy-textured clinopyroxene is due to decompression-induced partial melting taken place before the clinopyroxenite fragmentation, whereas outer and darker rims are due to short-time re-equilibration with the host lava,

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