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Magma differentiation and recharge processes: evidence from clinopyroxene compositions (Catalonian Coastal Ranges, northeast Spain)

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We have studied a late-Cretaceous alkaline lamprophyre (camptonite) cropping out in the Catalonian Coastal Ranges, near Calella de Palafrugell village (NE Spain). It is a gently dipping sill, 15-40 cm thick, emplaced within late-Variscan granodiorites. It has a hypocrystalline texture, porphyritic due to the presence of mm-sized mafic megacrysts, visible to the naked eye, which constitute up to 30% of the rock. The megacrysts are Cpx and Amp and, to a lesser extent, Mag and Ol (transformed to Chl-rich secondary assemblages). Occasional Qz xenocrysts are also recognised. The rock groundmass is composed of Pl, Amp, Cpx, Mag, accessory Ap and hydrated glass.

Cpx megacrysts are pale-pink crystals with idiomorphic to hypidiomorphic cores showing complex compositional zoning and, in some cases, aligned sulphide inclusions in the inner zones. This type of inclusions has been interpreted as droplets of immiscible sulphide liquids adhering to the surfaces of rapidly growing silicate crystals. A pale-green Cpx core has also been detected. It is unzoned and presents resorption features (it is corroded and displays an irregular contour). Both pale-pink and pale-green Cpx cores develop pink overgrowth rims, petrographically equivalent to the Cpx microcrysts embedded in the rock groundmass.

All Cpx crystals (megacrysts and microcrysts) are classified as diopside. According to their Mg# (Mg/(Mg+Fe2++Fe3++Mn) per formula unit, p.f.u.) values and the variation of Mg# vs. other geochemically-meaningful elements, most compositions can be arranged in two differentiation trends with contrasting Mg#. Groundmass microcrysts and the overgrowth rims of the megacrysts define a Mg#-rich trend, while pale-pink megacryst cores compose a Mg#-poor trend; this fact suggests that the pale-pink megacryst cores have a more evolved composition. On the other hand, the pale-green megacryst composition does not fit in either of the differentiation trends, but shows a more evolved composition.

Cpx trace element concentrations are ca. 10 times enriched over primitive mantle. Primitive mantle-normalised REE patterns are convex-upwards for the pale-pink megacrysts and for the groundmass microcrysts, whereas they are convex-downwards for the pale-green megacryst.

Given that the pale-pink megacryst cores have a more evolved composition than the groundmass microcrysts, the former seem to have crystallised from a slightly more evolved magma or, at least, under different conditions, instead of being phenocrysts of the host magma. Indeed, their higher AlVI/AlIV ratios and higher Na p.f.u. values indicate they probably crystallised under higher pressure and temperature conditions. In contrast, megacryst rims did crystallise in equilibrium with the host magma, as their composition agrees with that of the groundmass microcrysts. Hence, pale-pink megacryst cores probably formed slightly below the emplacement level, in a shallow magma chamber or magma conduit, and were afterwards incorporated in an ascending more primitive magma batch, which carried the megacrysts up to the emplacement level.

Regarding the pale-green megacryst, its resorption features, extreme composition and different normalised-REE pattern may primarily point to a xenocrystic origin. However, a melt similar in composition to that in equilibrium with the pale-green megacryst, although more REE enriched, can be produced by extreme fractionation (ca. 90% of crystallisation of Cpx and Amp) of a melt in equilibrium with the pale-pink megacrysts. The pale-green megacryst could be better explained as a crystallisation product of an early, highly fractionated melt, which was eventually included in the later camptonitic magma which reached the emplacement level. Therefore, the different Cpx megacrysts found in the studied sill might record several differentiation and recharge processes affecting the same magma system at depth.