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Unravelling the influence of antecryst settling on the composition of a lamprophyre sill: results from geochemical modelling and principal component analysis

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Small igneous intrusions can be regarded as scale models of the behaviour of large magma chambers. We have carried out a detailed petrological and geochemical study across a thin (< 0.5 m) mafic sill located in the Catalonian Coastal Ranges, in the vicinity of Calella de Palafrugell (NE Spain). It is a late-Cretaceous sub-horizontal alkaline lamprophyre, classified as a camptonite. The sill is visibly zoned, showing well developed chilled margins, several levels of vesicles and accumulation of large mafic crystals towards the bottom. According to their composition, these crystals are inherited antecrysts.

The whole-rock composition varies across the sill, indicating that the sill is compositionally zoned. However, the mineral compositions are constant, suggesting that the magma emplaced in a single pulse. The whole-rock compositional variations reveal that the chilled margins are more evolved than the centre of the sill; this is especially clear for the lower chilled margin, which defines a marginal reversal. Therefore, the compositional zoning of the sill does not correlate with a normal fractionation trend inwards. Instead, it agrees with the variable proportions of antecrysts across the sill: the higher the proportion of antecrysts, the more primitive the whole-rock composition.

In order to verify that the presence of antecrysts controls the whole-rock variations, a trace element model has been developed. Given that the sill displays a porphyritic texture defined by large antecrysts set in a fine-grained groundmass, the geochemical model quantifies the relative contributions of the antecrysts and the groundmass to the whole-rock compositions. Because the antecryst and whole-rock compositions were analysed for the different samples collected across the sill, the groundmass composition could be calculated for each sample. The obtained groundmass compositions are constant and more evolved than whole-rock compositions, supporting that the whole-rock variations are solely produced by the different proportions of antecrysts across the sill. The mean groundmass composition can be therefore considered representative of the homogeneous groundmass of the sill. It represents the host magma which carried the antecrysts up to the emplacement level.

The results of the model have been statistically tested by means of a principal component analysis (PCA). The distribution of the antecryst, whole-rock and groundmass compositions in a PC2 vs. PC1 plot shows that the whole-rock compositions define a linear trend between the groundmass and the antecryst compositions, where whole-rocks plot closer to the antecrysts as the proportion of antecrysts in the rock increases.

The obtained results prove that antecrysts affect whole-rock compositions. The accumulation of the antecrysts towards the bottom of the sill, together with the calculation of settling velocities for the antecrysts and cooling velocities for the magma, indicate that the gravitational settling of antecrysts during cooling is responsible for the varying proportions of antecrysts and therefore for the whole rock compositional zoning. This study reveals that crystal settling is a significant process in triggering compositional zoning of igneous intrusions even at the cm-scale, provided that the magma carries large crystals upon emplacement.