

Snapshots of primitive arc magma evolution recorded by clinopyroxene textural and compositional variations: The case of hybrid crystal-rich enclaves from Capo Marargiu Volcanic District (Sardinia, Italy)

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ABSTRACT

Capo Marargiu Volcanic District (CMVD) is an Oligo-Miocene calc-alkaline complex located in northwestern Sardinia (Italy) and characterized by the widespread occurrence of basaltic to andesitic domes. One of these domes hosts abundant crystal-rich enclaves with millimeter-to-centimeter sized clinopyroxenes showing intriguing textural features as a result of complex magma dynamics. To better understand the mechanisms governing the early evolution of the CMVD magmatic system, such clinopyroxene phenocrysts have been investigated in terms of their major, trace element, and isotopic compositions. Three distinct clinopyroxene populations have been identified, i.e., Type 1, Type 2, and Type 3. Type 1 appears as the sub-rounded cores of diopsidic clinopyroxenes with overgrowth textures corresponding to Type 2 and Type 3. These latter populations may also occur as single isolated crystals. Type 2 diopsidic pyroxene exhibits oscillatory zoning and spongy cellular textures with Type 3 overgrowths, whereas Type 3 are polycrystalline augitic glomerocrysts with occasional Type 2 overgrowths. The crystal overgrowths are striking evidence of magma recharge dynamics. Type 1 ($^{Cpx}Mg\#_{83-92}$), Type 2 ($^{Cpx}Mg\#_{75-82}$), and Type 3 ($^{Cpx}Mg\#_{72-79}$) are, respectively, in equilibrium with Sardinian mantle-derived high-Mg basalts (HMB with $^{melt}Mg\#_{56-73}$), least differentiated basaltic andesites (BA with $^{melt}Mg\#_{45-56}$) and evolved basaltic andesites (EBA with $^{melt}Mg\#_{41-50}$). Type 1 and Type 2 are diopsidic phenocrysts that have evolved along a similar geochemical path (i.e., linear increase of Al, Ti, La, and Hf contents, as well as negligible Eu-anomaly) controlled by olivine + clinopyroxene + amphibole fractionation. This differentiation path is related to phenocryst crystallization from hydrous HMB and BA magmas stalling at moderate crustal pressures. The occurrence of globular sulfides within Type 1 suggests saturation of the HMB magma with a sulfide liquid under relatively low redox conditions. Moreover, Type 1 clinopyroxenes show variable $^{87}Sr/^{86}Sr$ ratios ascribable either to assimilation of crustal material by HMB magma or a mantle source variably contaminated by crustal components. In contrast, Type 3 augitic phenocrysts recorded the effect of plagioclase and titanomagnetite fractionation (i.e., low Al and Ti contents associated with high La and Hf concentrations, as well as important Eu-anomaly) from more degassed EBA magmas ponding at shallow depths. Rare titanite associated to Type 3 and titanomagnetite crystals point to high oxidizing conditions for EBA magmas. The $^{87}Sr/^{86}Sr$ ratios of both Type 2 and Type 3 are almost constant, suggesting a limited interaction of BA and EBA magmas with the country rock. The overall textural and compositional features of Type 1, Type 2, and Type 3 clinopyroxene phenocrysts lead to the conclusion that CMVD was characterized by a polybaric plumbing system where geochemically distinct magmas crystallized and mixed under variable environmental conditions.

Keywords: Clinopyroxene phenocrysts, overgrowth textures, Sr-isotopes, trace elements, high-Mg basalts, Sardinian magmatism; Dynamics of Magmatic Processes