TORNARE Evelyne (2017) : Vertically layered mafic cumulates in the root zone of an ocean island volcano (Fuerteventura, Canary Islands); implications for magma differentiation

Abstract

The study of the internal structure of basaltic oceanic intraplate volcanoes is essential to better understand how volcanic systems work, as well as to define and locate magmatic processes occurring between magma generation in the mantle and eruption. In Fuerteventura, Canary Islands, a Miocene dismembered volcano provides an excellent opportunity to study the magmatic processes which occurred in the volcanic conduit. It enables us to link the cumulate formation in vertical channels in the root zone of the volcano with contemporaneous lava flows.

The mafic – ultramafic intrusion, named PX1, consists of a complex network of amalgamated centimetric to plurimetric feeder dikes. These are mostly constituted of cumulative rocks represented by wehrlites, clinopyroxenites and gabbros. The genetic link between plutonic lithologies and lavas was established based on compositional and textural similarities between plutonic clinopyroxene and phenocrysts in lava. Semiquantitative modeling shows that fractional crystallization can explain the evolution of the lavas from basalts to basaltic trachyandesites. This model reproduces the progressive fractionation of mineral assemblages corresponding to the crystallization sequence deduced from the plutonic rocks. However, complex core-rim chemical zoning observed in PX1 clinopyroxene suggest more complicated differentiation processes than simple crystal segregation and accumulation in vertical conduits. Primitive and resorbed cores suggest that they represent preexisting crystals entrained from deeper levels or crystallized during early stages of magma evolution. Reverse zoning and external resorption features in clinopyroxene mantles suggest progressive crystal coarsening by interaction with successive mafic to moderately differentiated melt pulses. Asymmetry in chemical zoning suggests crystallization in a confined environment. These observations support the hypothesis of magma differentiation by fractional crystallization. But unlike the traditional representation which implies a period of magma stagnation in a reservoir, this process could take place dynamically during vertical transport of magma in feeder conduits.

The plutonic lithological variability is controlled by three main factors: the efficiency of crystal-melt segregation; the degree of differentiation and modal proportions of the magmas at time of intrusion and the extraction efficiency of residual melts from the mineral cumulates, distinguishing typically a clinopyroxenite from a gabbro. It is assumed that cumulate formation in a dike requires the preservation of high temperatures in the conduit keeping it partially molten until a subsequent dike may cause the residual melt extraction by compaction. Based on this assumption, a thermal model was developed simulating incremental pluton growth by random magma channel emplacement in a confined area. The model reproduces petrological observations of long-lasting crystal-melt interaction by simulating magma flow inside the channels for a certain amount of time. The addition of a prolonged magma flow (1 to 3 months) combined with short intervals between dike injections (< 25 years) allows to reproduce the thermal constraints required for the PX1 cumulate formation, and also for the development of a broad migmatitic aureole surrounding the intrusion. The timescales predicted by the model are in agreement with data of historical eruptive frequencies and durations recorded for some oceanic island volcanoes, supposed comparable to the Miocene volcanoes of Fuerteventura.