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Complex interplay between geochemistry and magma dynamics in the petrogenesis of the Sithonia Plutonic Complex (NE Greece)

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Orogenic granitoids often display mineralogical and geochemical features suggesting that open-system magmatic processes played a key role in their evolution. This is testified by the presence of enclaves of more mafic magmas dispersed into the granitoid mass, the occurrence of strong disequilibrium textures in mineralogical phases, and/or extreme geochemical and isotopic variability. In this contribution, intrusive rocks constituting the Sithonia Plutonic Complex (Northern Greece) are studied on the basis of mineral chemistry, major, trace and isotope geochemistry, and methods of Chaos Theory and Fractal Geometry, in order to develop an integrated model on source control and evolution of a complex magma chamber system.

Sithonia rocks can be divided into two groups: a basic group bearing macroscopic (Mafic Microgranular Enclaves, MME), microscopic (disequilibrium textures), geochemical, and isotopic evidence of magma interaction, and an acid group in which most geochemical and isotopic features are consistent with a magma mixing process, but macroscopic and microscopic features are lacking.

Geochemical features and size of enclaves show the presence of two groups: a mafic and large-size MME group and an intermediate and small-size MME group. Quantitative textural analysis has been also carried out in order to decipher the crystallization history of enclaves once they have been entrained in the more acid and cooler host magma. Mineralogical and textural analyses show that, as the magmatic interaction process proceeded, the crystallization of enclaves involved the nucleation of apatite and epidote (first stage of crystallization) followed by biotite, hornblende, plagioclase, and titanite (second stage of crystallization); the last minerals that nucleate were quartz and K-feldspar. Size analysis of enclaves indicates that the smaller ones suffered higher degrees of geochemical interaction compared to the larger ones. We interpret this evidence as being strictly related to the kinematics of the mixing process governed by chaotic dynamics. In order to constrain this feature, fractal dimension of enclaves were estimated by using X-ray distribution maps of chemical elements inside enclaves. Results indicate that a clear correlation between fractal dimension of enclaves and geochemical evidence of interaction exists, and hence the two groups of enclaves reflect different degrees of interaction. MME are considered as portions of the basic magma that did not mix completely with the acid host magma and survived the mixing process. Host rocks are considered as volumes of the magmatic system where the more efficient mixing dynamics produced different, generally higher, degrees of hybridisation.

Geochemical modelling indicates that a two-step Mixing plus Fractional Crystallization (MFC) process is responsible for the evolution of the basic group. The first step explains the chemical variation in the mafic enclave group: a basic magma, represented by the least evolved enclaves, interacted with an acid magma, represented by the most evolved granitoid rocks, to give the most evolved enclaves. The second step explains the geochemical variations of the remaining rocks of the basic group: most evolved enclaves interacted with the same acid magma to give the spectrum of rock compositions with intermediate geochemical signatures. Regarding acid group a convection–diffusion process is envisaged to explain the geochemical and isotopic variability and the lack of macroscopic and petrographic evidence.

The mafic rocks of the Sithonia Plutonic Complex show characteristics of pre-plate collisional setting indicating subduction-related magma genesis, and are presumably the result of melting of a mantle, repeatedly metasomatized and enriched in LILE due to subduction events. The acid magma is considered the product of partial melting of lower crustal rocks of intermediate to basaltic composition. It is shown that Sithonia Plutonic Complex offers the opportunity to investigate in detail the complex interplay between geochemistry and magma dynamics during magma interaction processes between mantle and crustal derived magmas, and to make insights of the interplay between source control and evolution of magma chambers.