

Advances in Igneous Petrology: Coupled chemical maps & thermodynamic models to tackle mushes crystallization dynamics

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The assemblage and evolution in time through various differentiation processes of igneous reservoirs shapes magmatism expressions at depth and at surface. Our knowledge of those systems largely relies on theoretical or applied thermomechanical and kinetic models, on geophysical data from active systems, and on structural and petrological data from active and fossil systems. Petrological approaches commonly use textures, thermodynamic models, chemical compositions of major and trace elements to decipher on the dynamics of complex igneous processes. Although chemical maps are more and more common, the overwhelming of the published data reposes on punctual measurements. Also, although it is well known that partition coefficients are temperature and composition dependent, the overwhelming of the published data use fixed values for those key parameters.

Here by using the example of a basalt crystallizing from liquidus to solidus, we present a new petrological approach that couples chemical maps to thermodynamic models to provide the first maps of thermodynamic parameters with a value attributed to each pixel (e.g., temperature or melt fraction maps in plutonic rocks). If the cooling rate is quantified by other means (e.g., diffusion chronometry), then the first of its kind movies of the crystallization evolution can be built from the first crystal to form to the last melt drop crystallization. We will present such results, allowing the igneous petrologist to explore her/his data in a new perspective. As an example the studied samples could be observed at various stages of the crystallization path, and heterogeneous interstitial melt spatial distribution could be explored with potential implications on melt segregation, or the melt-crystal spatial distribution at the magma/mush transition could help us to better understand the crystal locking at this critical stage.

Further utilization of this new approach leads us to build composition and temperature dependent partition coefficient maps for REE. Corresponding results highlight that it is essential to consider those variables as partition coefficients could varies by a factor of 5 at the scale of a single thin section, with potential to strongly distort our interpretations.

Overall, this new approach will eventually help to make progress in our understanding of igneous systems.

