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Thermo-chemical evolution of magmatic systems at mid-crustal level: the role of chaotic advection

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Unravelling the dynamics occurring during the thermo-chemical evolution of igneous bodies is of crucial importance in both petrology and volcanology. This is particularly true in subduction related systems where large amounts of magma start, and sometimes end, their differentiation histories at mid and lower crust levels. These magmas play a fundamental role in the evolution of both plutonic and volcanic systems but several key questions are still open about their thermal and chemical evolution: 1) what are the dynamics governing the development of these magmatic systems, 2) what are the timescales of cooling, crystallization and chemical differentiation; 4) how these systems contribute to the evolution of shallower magmatic systems? Recent woks shed light on the mechanisms acting during the growing of new magmatic bodies and it is now accepted that large crustal igneous bodies result from the accretion and/or amalgamation of smaller ones. What is lacking now is how fluid dynamics of magma bodies can influence the evolution of these igneous systems.

In this contribution we focus on the thermo-chemical evolution of a subduction related magmatic system at pressure conditions corresponding to mid-crustal levels (0.7 GPa, 20–25 km). In order to develop a robust model and address the Non-Newtonian behavior of crystal bearing magmas, we link the numerical formulation of the problem to experimental results and rheological modeling. We define quantitatively the thermo-chemical evolution of the system and address the timing required to reach the maximum packing fraction.

We will show that the development of chaotic dynamics significantly speed up the crystallization process decreasing the time needed to reach the maximum packing fraction. Our results have important implications for both the rheological history of the magmatic body and the refilling of shallower magmatic systems.