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Cooling of a magmatic system under thermal chaotic mixing

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The cooling of a melt undergoing chaotic advection is studied numerically for a magma with a temperature-dependent viscosity in a 2D cavity with moving boundary. Different statistical mixing and energy indicators are used to characterize the efficiency of cooling by thermal chaotic mixing. We show that different cooling rates can be obtained during the thermal mixing even of a single basaltic magmatic batch undergoing chaotic advection. This process can induce complex temperature patterns inside the magma chamber. The emergence of chaotic dynamics strongly affects the temperature field during time and greatly increases the cooling rates. This mechanism has implications for the lifetime of a magmatic body and may favor the appearance of chemical heterogeneities in igneous systems as a result of different crystallization rates. Results from this study also highlight that even a single magma batch can develop, under chaotic thermal advection, complex thermal and therefore compositional patterns resulting from different cooling rates, which can account for some natural features that, to date, have received unsatisfactory explanations. Among them, the production of magmatic enclaves showing completely different cooling histories compared with the host magma, compositional zoning in mineral phases, and the generation of large-scale compositionally zoning observed in many plutons worldwide.