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The Magma Chamber Simulator Version 2.0: Computational Modeling of Open Magmatic Systems During Magma Storage, Transport, and Eruption

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Over a century of research has produced a treasure trove of analytical and geophysical data elucidating the complex open-system processes that influence magma evolution and transport. Over the past few decades, the routine application of computational tools has yielded many new insights. Data-driven computational modeling, in which best-fit models are informed by multidisciplinary micro- to macro-scale constraints, will yield profound new insights into translithospheric magma systems, thereby enabling more accurate estimates of the mass and energy exchange that has occurred between crust and mantle through geologic time.

The Magma Chamber Simulator (MCS) version 2.0 computes the open-system, polybaric evolution of magma storage regions and their connecting conduits by incorporating crystallization (fractional, equilibrium, or concurrent, which allows some crystals to be removed and others to remain in equilibrium with melt), stoping, assimilation of crustal melts, mixing of magmas, and mush entrainment and rejuvenation. Thermodynamic paths, including Gibbs minimization and isenthalpic/isentropic constraints, are implemented self-consistently for complex combinations of evolutionary processes. Output includes major and trace elements, isotopes, and the mass and thermal evolution of magma, wallrock, and recharge/mush reservoirs. MCS models provide insights into how complex petrological processes influence melt/mineral compositions and afford estimates of magma temperature, viscosity, and density, as well as the pressure(s) of magma storage. MCS v2.0 also allows tracking of magma changes during isentropic and quasi-isentropic transport between storage zones and during eruption. These modeling capabilities illuminate, for example, the pressure and extent of magmatic vesiculation, and the impact decompression has on (e.g.) crystal rims and microlites.

Best-fit computational modeling results are informed by comparisons with whole-rock and *in situ* data from rocks, glasses, melt/fluid inclusions, and minerals. Quantitative estimates of magma temperature, density, and viscosity facilitate robust petrogenetic and magma-dynamical interpretations, which are critically evaluated by assessing data and model uncertainties. An effective modeling approach employs sensitivity testing that refines a broad range of input variables (e.g., pressure, parent magma composition, initial volatile content) through iterative modeling. MCS represents the state-of-the-art in modeling open magmatic systems; it is a user-friendly tool that should be routinely used to investigate the evolution of translithospheric magma systems.