Quantifying open system magma body evolution

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Influential papers by O'Hara and colleagues (e.g., 1977, 1981, 1998) that quantify episodic open-system processes (recharge/mixing, crustal assimilation, crystal-melt separation (RAFC)) and eruption were among the first to highlight the critical role computational models play in modern igneous petrology. Energy-Constrained Recharge, Assimilation, Fractional Crystallization (EC, Spera & Bohrson 2001) computes trace element, isotope, and mass consequences of simultaneous RAFC. The Magma Chamber Simulator (MCS, Bohrson et al. 2014) employs mass and enthalpy balance in a thermodynamic framework to calculate thermal, mass, major/trace element, and isotope changes to melt + crystals ± fluid in a magma + recharge magma + wallrock composite system during RAFC, given reasonable assumptions about the rheology of partially molten systems at isobaric conditions. EC and MCS models illustrate thermal, petrological, and geochemical responses to RAFC that defy conventional wisdom. (1) Thermal: Assimilation of colder wallrock melt does not necessarily cause a pulse of magma crystallization; instead, assimilation typically suppresses crystallization by modifying the topology of GX-phase saturation surfaces. Calculations support observations that recharge/mixing yield mixed magma temperatures (T) that are greater than host magma T. But modelling also suggests that mixed magma T can be *lower* than T of both host and recharge because thermodynamic constraints require mineral resorption; disequilibrium mineral textures are thus evidence of *cooling* during recharge/mixing. (2) Petrologic: MCS results show that minerals in the magma body appear and disappear in response to mass and enthalpy exchange. Thus, petrogenetic reconstructions and inferences about magma timescales based on mineral records may be incomplete. (3) Geochemical: During RAFC, element concentrations, element-element and element-isotope trajectories are not simple, monotonic functions of degree of contamination and/or recharge. As O'Hara concluded forty years ago, diagnosis of RAFC requires computational modelling. We argue that mass- and energy-constrained thermodynamic modelling should routinely be applied to all petrologic studies to decipher crust vs. mantle contribution to geochemical diversity.