Perfect mixing in rhyolites based on numerical experiments and observations

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An increasing body of petrologic observations demonstrates a high level of isotopic and often compositional mixing and homogeneity of melts in voluminous deposits of low and high silica rhyolites. This melt homogeneity characterizes large ~10^3 km^3 volumes of crystal-poor rhyolites derived from, or emplaced into, isotopically-diverse, often low-$\delta^{18}O$ source rocks. Isotopically-diverse zircons [1] [3] and other crystals retain memory of segregation of diverse magma batches and suggests that these large volumes of magma are generated in ~10^3 years, within IDTIMS geochronologic uncertainty [1] and mineral-diffusive timescales. Highly efficient mixing of diverse magmas across caldera at the large horizontal distances of many km requires convection and exceptionally effective mixing mechanism. Thermal convection in cooling and crystallizing magma layers is sluggish [2] and tends to separate layers into isolated spatially stacked cells. We present new results of numerical modeling of mixing by compositional convection during melting of silicic rocks by superheated rhyolite, in addition to ref. 3. We use simple FEM code implementing bilinear elements for velocity and a penalty method for pressure elimination. Mass transfer is modeled with a dense Lagrange markers grid. Correctness of the calculations is provided by the proper resolution of up to 2 cm for the composition field in expense of the total computation magma domain size (typical thickness 7-10 m). We observe high effectiveness of mixing by many orders of magnitude more intensive convection which is not limited by the slow conductive heat loss through the surrounding rocks. Mixing occurs via stochastic trajectories of numerical magma particles in the set of convective cells of several meters size rotating in the opposite directions. We characterize mixing by mapping the horizontal shift of the material particles from the initial position and Lyapunov exponent. Convective melting was compared numerically with mixing in the cylindrical (2D) cell with a rotating smooth rod lacking spotty vorticity distribution. Pure shear Poiselle flow transforms inclusions into highly-sheared, thread-like structures as in an obsidian flow. The computed 3-10 cm average particle size distribution is similar to melted enclaves in mixed rocks observed in the field. Further homogenization on the smaller scales proceeds via molecular diffusion on cooling timescales, while residual elemental heterogeneities are due to late stage melting and crystallization of minerals.

[1] Wotzlaw et al., *Geology*, 2014, **42**: 807. [2] Brandies and Marsh, 1989, *Nature*, **339**:613. [3] Bindeman and Simakin, *Geosphere*, 2014, **10**: 930.