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Ductile compaction in volcanic conduits

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Silicic magmas typically outgas through connected pore and crack networks with a high gas permeability without the need for decoupled movement of pores in the melt. It is the efficiency with which this process can occur which governs the pressure in the pore network. However, such a connected coupled network is generally mechanically unstable and will relax until volume equilibrium when the pores become smaller and isolated. Consequently, gas permeability can be reduced during densification. Cycles of outgassing events recorded in gas monitoring data show that permeable flow of volatiles is often transient, which is interpreted to reflect magma densification and the closing of pore-networks. Understanding the timescale over which this densification process occurs is critical to refining conduit models that seek to predict the pressure evolution in a pore-network leading to eruptions. We conduct uniaxial compaction experiments to parameterize non-linear creep and relaxation processes that occur in magmas with total pore fractions 0.2-0.85. We analyze our results by applying both viscous sintering and viscoelastic deformation theory to test the applicability of currently accepted models to flow dynamics in the uppermost conduit involving highly porous magmas. We show that purely ductile compaction can occur rapidly and that pore networks can close over timescales analogous to the inter-eruptive periods observed during classic cyclic eruptions such as those at Soufriere Hills volcano, Montserrat, in 1997. At upper-conduit axial stresses (0.1-5 MPa) and magmatic temperatures (830-900 oC), we show that magmas can evolve to porosities analogous to dome lavas erupted at the same volcano. Such dramatic densification events over relatively short timescales and in the absence of brittle deformation show that permeable flow will be inhibited at upper conduit levels. We therefore propose that outgassing is a key feature at many silicic volcanoes and should be incorporated into conduit flow models.