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Solid-state sintering drives rapid permeability loss in the volcanic conduit

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We present results from a series of high temperature (T), high pressure (P) hot isostatic pressing (HIP) experiments in which solid-state sintering causes densification of crushed crystalline dacitic on the timescales of hours. The solid-state sintering and densification results from atomic diffusion between adjacent crystalline particles; in these powders there is virtually no glass nor opportunity for viscous annealing of particles. The samples of unconsolidated crystalline dacite powders (porosity values of ∼0.40) were subjected to T-P conditions (T = 700-900°C; P = 40, 70 MPa) expected within volcanic conduits and were transformed into dense, low porosity, composite solids within 60 hours. The HIP products have measured values of connected porosity between 0.30 and 0.13; permeability values decrease by more than an order of magnitude with decreasing porosity (1.4 × 10-14 to 9.9 × 10-16 m2). The experimental products share many attributes (e.g., microstructure and physical properties) with the variably lithified fault gouge that encases lava domes, described by Cashman et al. (2008), Kendrick et al. (2012) and Ryan et al. (2018). These HIP experiments show that solid-state sintering operates on relatively short time-scales at the conditions found in volcanic conduits and provides a means for post-faulting lithification of the glass-free fault gouge enveloping the 2004-2008 Mount St. Helens lava spines. The rapid (hours to days) conversion of unconsolidated cataclastic dacite material into dense, low porosity, low permeability rock makes solid-state sintering processes relevant to eruptive behavior. Destruction of permeability pathways by solid-state sintering suppresses outgassing, resulting in the development of an overpressure within the volcanic conduit and an increased potential for explosive eruptive behavior. Our experiments provide the first constraints of the solid-state sintering window (P-T-t) for volcanic systems and highlights its potential as an alternate, as yet unrecognized, mechanism for permeability loss in conduits, allowing for gas repressurization, and supporting cyclical explosive events.

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