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Hot pressing and lithification of gouge during the Mount St. Helens 2004-2008 eruption: insights from high temperature deformation experiments

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We present results from an experimental program designed to investigate the timescales, conditions and mechanisms responsible for the densification and lithification of volcanic gouge at Mount St. Helens (MSH). From 2004-2008, MSH produced a series of lava domes/spines that were mantled by thick layers of gouge resulting from fracturing and cataclasis at the conduit-wall rock interface. The gouge comprises fine crystal-rich rock powder containing little to no glass. The erupted gouge carapace is texturally diverse, and varies from loose granular material to moderately indurated coherent rock to fine-grained cataclasite within tens of centimeters. The spatial association of these materials suggests that the originally unconsolidated conduit-fault gouge is densified and lithified during ascent to the surface. At present the conditions, timescales and mechanisms for lithification of the glass-poor materials are unknown. Here, we present results from a series of high-temperature (T) uniaxial deformation experiments performed on natural gouge collected from MSH (spine 5). The experiments are intended to (1) establish the feasibility of experimentally densifying/lithifying natural gouge materials at laboratory conditions approximating those within the MSH conduit, and to (2) constrain the effects of T, load and time on the extents, rates and mechanisms of densification. Our experimental conditions include T up to 800°C (T<T¬melting), axial differential stresses up to 25 MPa and experimental times up to 90 hours. Experimental results will be compared to the physical properties (density, porosity, permeability, compressive strength and particle size distribution) of variably densified gouge samples from spines 4, 5 and 7 at MSH, tying the results from the lab to the natural system. Initial results show an increase in the amount and rate of densification with increasing experimental T, with an increase in sample shortening (axial strain) between experiments completed at 650 and 850°C. This change in axial strain-time curves with increasing T suggests the inclusion of a second densification process, aside from mechanical compaction, at elevated T. It is our hypothesis that solid-state sintering, a process wherein crystalline particles are fused together as a result of atomic diffusion across grain boundaries (i.e. the process occurring during the industrial production of ceramics by hot (isostatic) pressing), is the dominant mechanism operating at high T and under pressure. While viscous sintering (i.e. welding) operates in many "melt-glass-rich" volcanic systems, solid-state sintering has yet to be explored as a densification mechanism operating on fine granular crystalline volcanic materials at conditions and timescales relevant to volcanic processes.