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Origins of Mount St. Helens cataclasites: Experimental insights

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ABSTRACT

The 2004–2006 eruption of Mount St. Helens produced a sequence of lava domes characterized by a 1–3 m thick outer carapace of highly brecciated and comminuted dacite fault rocks. This outer layer of fault rocks is proposed to be a physical manifestation of the "drumbeat" microseismicity, such that magma extrusion occurred via integration of rapid, co-seismic slip along small displacement (<5 mm) faults.

A suite of deformation experiments performed on samples of Mount St. Helens (MSH) dacite under confining pressures of 0, 25, 50, and 75 MPa, at room temperature, and an average displacement rate of ~10^{-4}/s were run to reproduce fault textures found in nature. The MSH dacite starting material has low porosity (7–8%), and a microcrystalline groundmass with little glass. A subsidiary set of deformation experiments on dacite samples from the 2006 Augustine eruption was run under identical experimental conditions to evaluate the effect of increased porosity ($\phi \sim$ 20–24%) on failure mechanisms.

The MSH dacite samples show a progressive increase in peak strength with increasing confining pressure, are strong (peak stress at 75 MPa is 700 MPa) and failed by localized, brittle behavior, characterized by macroscopic fractures and rapid stress drops. In contrast, Augustine dacite deformed by distributed cataclastic flow and is much weaker (peak stress at 75 MPa is 220 MPa). We propose that the generation of low-porosity dacite was an important variable in promoting wholesale localized faulting and the attendant drumbeat microseismicity at Mount St. Helens.

Microstructures of gouge developed experimentally at room temperature are remarkably similar to those developed at ~730 °C at MSH. Mode I microcracking, shear fracture of grains, and grain size comminution occurred in both natural and experimental fault rocks. Laser grain size particle analyses show peaks at 1.5 μm for experimental run products vs. peaks at 1.9 and 4 μm for natural MSH gouge. We conclude that because the MSH lava had solidified prior to faulting, temperature is secondary in importance in the formation of the gouge material. Based on the amount of fault displacement per microseismic event, the number of "drumbeats," and the aggregate radial thickness (1–3 m) of the gouge, we calculate that the 3–6 m/day eruption rate allows for gouge-filled slip surfaces having thicknesses of 0.8–5 mm and strike lengths of 98–190 m per seismic event.

Keywords: Mount St. Helens, microseismicity, experimental rock deformation, fault rocks