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The 2004-2008 Mount St Helens Lava Dome: An experimental study of the influence of time and temperature on mechanical behaviour and earthquakes

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The 2004 to 2008 lava dome eruption of Mount St Helens was preceded and accompanied by thousands of small earthquakes. Extrusion and deformation localised along gouge covered shear fracture planes within the lava dome. Laboratory measurements of the high temperature deformation and fracture of dacite from this lava dome can be used to understand what controls the deformation, growth and gas escape of this lava dome and lava domes in general. Acoustic emissions (AE) recorded during deformation of these dacite samples under different controlled experimental conditions can be compared to earthquakes recorded at Mount St Helens to deduce the conditions under which they were generated.

Here we present results of triaxial deformation of dacite lava dome samples extruded at different times during the 2004 to 2008 eruption of Mount St Helens. The samples were deformed in triaxial compression (10 MPa confining pressure) at temperatures up to 900ºC, and strain rates from 10^{-4} s^{-1} to 10^{-6} s^{-1}. These conditions are typical of lava dome systems at Mount St Helens ,and elsewhere. Samples extruded at the middle of this eruption (mid 2005 to late 2006) had a compressive strength of 150 to 200 MPa and exhibited brittle failure behaviour in dry conditions from 25ºC to 900ºC. They became stronger at higher strain rates, and weaker at lower strain rates, though this strain rate dependence was more evident at higher temperatures. Samples extruded in the first few months of the eruption were considerably weaker and more ductile at room temperature (60 to 140 MPa compressive strength). They also became significantly weaker and more ductile when the temperature was increased to 850 $^{\circ}$C, with completely ductile behaviour for the sample extruded in the first two months of the eruption. The amount of AE recorded dropped as the behaviour of samples became more ductile. Comparison of the particle size distribution of fault gouge formed during experiments conducted under different conditions and gouge formed during the eruption help to constrain the conditions under which the eruption gouge could have been formed.

These results show that lavas erupted after the first few months of the 2004 to 2008 eruption have brittle behaviour up to very high temperatures, meaning that brittle earthquakes within and at the margins of the lava conduit and dome may be indistinguishable from those generated in the surrounding rocks. However, samples from the first few months of the eruption were considerably more ductile, especially when the temperature or confining pressure was increased. This indicates that extrusion dynamics were more ductile and that earthquakes were less likely to be generated within the magma conduit and lava dome themselves in the first few months of the eruption.