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Volcanic dome stability; Permeability and fluid pressurisation of the Mount St Helens 2004-2008 lava dome complex

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Dacitic volcanoes such as Mount St Helens are commonly associated with plinian eruptions. They can also erupt magma as lava domes that, in addition to simple effusion, frequently pass through episodes of major collapse and, under suitable increases in gas pressure, can also explode in vulcanian eruptions. Both dome collapse and vulcanian events can propagate pyroclastic flows and so extend the hazardous range of a dome far beyond the radius of the dome itself. Fluid circulation and the development of fracture networks are key factors in determining the stability of a dome and its potential to collapse or to explode. Understanding the interaction between fluid circulation, rock weakening and the development of fractures is thus crucial to increasing the possibility of forecasting dome collapses and explosions.

To investigate the fluid flow within lava domes, we have measured how permeability changed progressively over time on samples from the Mount St Helens lava dome emplaced between 2004 and 2008. The primary experimental block was an intact sample of massive dacite, collected in September 2010 from the interior of Spine 4, which grew between January and April 2005. Permeability was measured on cylindrical samples, 25 mm across, at confining pressures to 80 MPa in a hydrostatic permeameter and, also, at temperatures to 900^{o}C, confining pressures to 12 MPa and pore fluid pressures to 4 MPa in a high-temperature triaxial-deformation apparatus.

Our results showed a decrease in permeability by four orders of magnitude, from 10^{-12} to 10^{-16} m^2, when the effective pressure was increased in 10 MPa increments from 5 to 80 MPa (c. equivalent depths of 250 to 4,000 m). Applied to the growth of Spine 4, the data indicate a progressive decrease in the permeability of extruded lava by two orders of magnitude, from $10^{-12}$to 10^{-14} m^2. Such a decrease in permeability would significantly reduce the ability of gas and fluids to escape, thus favouring an increase in fluid pressure and the potential for an explosion. The reliability of forecasts of dome explosions may therefore be limited by the natural variation in permeability of lava through a dome and in the feeding conduit immediately beneath.