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The high temperature fracture mechanics of silicic magma: a comparison of crystalline andesite and rhyolitic obsidian

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The fracture mechanics of magma at high temperatures exert a fundamental control over the behaviour of silicic eruptions. How magma responds to the stress field in shallow conduits and lava domes determines the patterns of conduit flow and dome growth and the generation of geophysical signals such as shallow hybrid seismicity. A key question is to what extent the fracture mechanical properties of magma, such as its shear strength, are influenced by its texture and composition.

In order to investigate this we have carried out a series of high-temperature fracture mechanics experiments on two types of silicic magma at University College London: a crystalline andesite from Mount Shasta (California) and a crystal-free obsidian from Krafla (Iceland). Samples were subjected to triaxial and uniaxial compression at temperatures from 20˚C to 900˚C and constant strain rates between 10^{-5} s^{-1} and 10^{-3} s^{-1}. The stress, strain and acoustic emissions were all recorded and elastic wave velocities were measured before and after experiments.

We found that the compressive strength of crystalline andesite is considerably lower than that of the obsidian (100 MPa vs >450 MPa), elastic wave velocities decrease markedly post-failure in the andesite but not in the obsidian, and acoustic emissions in the andesite samples are more dominated by smaller events. These results emphasise the important role played by stress intensifiers such as crystals and pre-existing cracks in controlling the mechanics of fracture and the response of magma to applied stresses. The brittle-ductile transition in obsidian appeared to span a narrow range of temperatures and strain rates. For both rock types, acoustic emission hit rates and amplitudes

were comparable to those at room temperature when they were deformed at temperature and strain rate conditions within the brittle-ductile transition. This demonstrates that seismogenic rupture can occur in erupting magmas and magma conduit margins.

As a long-term research goal is to use geophysical signals such as seismicity to deduce the physical characteristics and state of stress of magma within volcanoes, our results provide useful insight into how strongly the texture and temperature of magma controls its behaviour under stress and the accompanying geophysical signals.