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Laboratory simulations of fluid-induced seismicity in shallow volcanic faults

Marco Fazio (1), Philip Benson (1), Sergio Vinciguerra (2,3), and Philip Meredith (4)

(1) Rock Mechanics Laboratory, University of Portsmouth, Portsmouth, UK, (2) Department of geology, university of Leicester, University Road, Leicester, LE1 7RH, United Kingdom, (3) British Geological Survey, Environmental Science Centre, Nicker Hill, Keyworth, Nottingham, NG12 5GG, UK, (4) Rock and Ice Physics Laboratory, Department of Earth Sciences, University College London, London, UK

Seismicity is a key tool used for monitoring fracturing and faulting in around volcanoes, with a particular emphasis placed on the frequency (Long period or Low Frequency, LF events) thought to be due to fluid movement, as compared to Volcano-Tectonic activity driven by pure fracture. To better understand these fundamental processes this research presents new rock deformation experiments designed to simulate shallow volcano-tectonic pressure/temperature conditions, linking pore fluid flow to the induced seismicity. A particular emphasis is placed on the conditions of pressure and temperature required to stimulate LF activity. Our setup imposes a rapid pore pressure release or “venting” via a small pre-drilled axial conduit to stimulate rapid fluid movement through an established fracture damage zone via a two stage process. Firstly experiments are conducted to generate a through-going shear fracture, with pore fluid connectivity to this fracture enhanced via the axial conduit. The shear failure is imaged via AE location with ∼mm scale accuracy. The second stage vents pore fluid pressure via an electrical solenoid valve.

We find that this second stage is accompanied by a swarm of LF activity akin to Long Period (LP) activity on active volcanoes. We find that a significant change in the dominant frequency of LF events is recorded as pore fluid pressure decrease through, and beyond, the water boiling point and the transition between LF and VLF occurred at the pressure at which the superheated water turn to vapour. In addition, we observe a significant dependence of the recorded LF upon the fluid flow rate. Finally, we present new data using low frequency (200 kHz) AE sensors, in conjunction with our standard 1 MHz-central-frequency sensors, which permit us to better constraint LF and VLF events with lower attenuation, and hence an improved characterization of these LF seismic signals. Data are used to forecast the final time of failure via the fracture forecast methods of Kilburn (2004), showing a good correlation between measured sample failure time and the forecast time based on AE event rate. Our data showed little change in forecast accuracy when using LF data compared to regular HF data, illustrating the importance of newly fracturing surfaces in the application of such models.