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Dyke propagation and tensile fracturing at high temperature and pressure, insights from experimental rock mechanics.

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It is well known that magma ascends trough the crust by the process of dyking. To enable dyke emplacement, basement rocks typically fail in a mode 1 fracture, which acts as conduits for magma transport. An overpressure of the ascending magma will further open/widen the fracture and permit the fracture to propagate. In order to further understand the emplacement and arrest of dykes in the subsurface, analogue and numerical studies have been conducted. However, a number of assumptions regarding rock mechanical behaviour frequently has to be made as such data are very hard to directly measure at the pressure/temperature conditions of interest: high temperatures at relatively shallow depths. Such data are key to simulating the magma intrusion dynamics through the lithologies that underlie the volcanic edifice. Here we present a new laboratory setup, which allows us to investigate the tensile fracturing properties under both temperature and confining pressure, and the emplacement of molten material within the newly formed fracture.

We have modified a traditional tri-axial test assembly setup to be able to use a Paterson type High Pressure, High Temperature deformation apparatus. Sample setup consists of cylindrical rock samples with a 22 mm diameter and a 8 mm bore at their centre, filled with a material chosen as such that it's in a liquid state at the experimental temperature and solid at room temperature to enable post-experiment analysis. The top and lower parts of the rock sample are fitted with plugs, sealing in the melt. The assembly is then placed between ceramic pistons to ensure there are no thermal gradients across the sample. The assembly is jacketed to ensure the confining medium (Ar) cannot enter the assembly.

A piston is driven into the sample such that the inner conduit materials pressure is slowly increased. At some point a sufficient pressure difference between the inner and outer surfaces causes the sample to deform and fail in the tensile regime. Tensile fractures can occur when the hoop stress exerted on the outer shell exceeds its tensile strength. The molten conduit material is then likely to flow into the newly formed fracture, depending on its viscosity and the fracture dimensions, allowing comparisons to be made between the temperature and intrusions dynamics of the simulated dyke process.

As a starting point, we are now testing an analogue material to replace the magma to avoid complex multi-phase rheology (bubbles, crystals) and the need for high experimental temperatures, relying of maintaining similar temperature/viscosity ratios between magma/country rock in the laboratory and the field. We chose PMMA (commonly known as plexiglass) for this task as it displays a large range in viscosities (log(visc)range = 10 –1) with temperatures between 100 and 300 ˚C, making it an excellent analogue material. In the future experiments at higher temperatures will be conducted with NIST-glasses and field collected glasses.

2D and 3D imaging of post-deformation samples show no preferential location of the fractures. Fractures are formed both around and trough crystals. Some evidence suggests the formation of microcracks and linking up as predicted by Griffith's theory. Correcting for apparatus distortion and friction of o-rings and the filler material we can calculate the conduit stress and arrive at a tensile strength values for different basement rock types in the order of 1-15 MPa.