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Fracture and healing cycles in glass

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The repeated occurrence of fracture and healing occurs in a variety of geological, biological, metallurgical and engineering processes. In geology, it is most common in active tectonic regions, earthquake settings and volcanic conduits, where healing is thought to be intrinsically related to diffusional processes, aided by catalytic fluids.

In this study, cycles of compression, healing by contact and tension are performed on standard soda-lime silicate liquids at high temperatures (500 to 700 ˚C; i.e., in the diffusive regime of the viscoelastic body). The flat ends of two cylinders are brought in contact at relatively low strain rates (10^{-3} s^{-1}) until a target normal stress is reached (1, 2.5, 5 and 10 MPa). The specimens are then held in contact whilst the normal stress is left to viscously dissipate for a different portion of Maxwell's relaxation timescale for the liquid (0.25, 0.5, 1, 2.5, 5, 10, 20, 40, 80, 160, 320) in order to achieve different degrees of fracture healing. Strength recovery is assessed by subjecting the healed sample to a rapid tension event at 10^{-1} s^{-1} (to ensure a purely brittle response). We note that healing becomes efficient when allowed to operate for at least 5 times the relaxation timescale of the material. From this point onward, we observe an exponential increase in strength as a function of healing time. A small component of heat is generated during failure, monitored using a high-speed infrared thermographic camera.

We find that fracture-healing dynamics has similarities with sintering, whereby the kinetics of the process is viscosity and diffusion dependent. Here we aim to expand this definition with normal applied stress constraints and link fracture and healing cycles to seismic swarms. Seismicity is perceived as a first order constraint on the mechanics of magma ascent and facilitates assessment of the real-time rheological state of magma in conduits. The processes presented here may be equally applicable to the strength recovery of tectonic fractures/ faults harbouring frictional melt (i.e., pseudotachylytes).