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The dynamics of magma ascent in the crust: Characterising fluid flow and host-rock deformation using scaled analogue experiments

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We present the results from a series of analogue experiments that use gelatine injected by water to study magma ascent dynamics in the crust. Gelatine is a viscoelastic material that displays predominantly elastic deformation when used at low temperatures (5-10 ºC) and mid-to-low concentrations (2-5 wt%). To study dyke propagation we have used a combination of Particle Image Velocimentry (PIV) and Digital Image Correlation (DIC) to characterise the dynamics of fluid flow within the intrusion and contemporaneous deformation of the host gelatine. Experiments are prepared by filling a 40 cm x 40 cm x 30 cm clear-Perspex tank with a gelatine mixture that has been seeded with neutrally buoyant fluorescent particles. Water, also seeded with tracer particles, is then injected into the solid gelatine from below under a constant flux or constant head pressure. This causes a vertical penny-shaped crack (dyke) to propagate through the gelatine and erupt at the surface. During the experiment, a vertical high-power laser sheet positioned along the centre of the tank is triggered to illuminate the seeding particles with short intense pulses, and two Dantec CCD cameras record successive images. Using PIV and DIC, vector fields of fluid flow within the intrusion and strain within the gelatine host is calculated by cross-correlation between successive images at a defined time interval. The experiments indicate that, prior to eruption, dyke propagation is characterised by rapid centralised and upwards fluid flow with accompanying downwards motion at the intrusion margin. Deformation of the gelatine solid is focused at a small head region, with the tail remaining relatively static as the dyke grows. Upon eruption, rapid centralised fluid evacuation occurs with contemporaneous contraction of the dyke and relaxation of the host gelatine. Models that can couple fluid dynamics and host deformation during magma ascent and eruption will make an important step towards improving our understanding of the dynamics of magma transport through the crust, and may help to constrain the tendency for eruption.