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The propagation of magma-filled cracks in an extensional tectonic setting

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The propagation of magma-filled cracks, or dykes, is a fundamental method of transport of magma through the Earth's lithosphere. Dykes are widespread and are evidently important in feeding the supply of magma to volcanoes. The physics of crack propagation is thus important for a sound understanding of the supply of magma in volcanic regions. Dyke injection is also crucial at rift margins where the repeated injections of magma, both in time and space, help in accommodating strain and in assisting crustal rifting, as revealed by the recent activity in the Afar rift. Scaled analogue experiments can provide a key insight into the mechanisms and dynamics of this process.

The results of a set of scaled experiments using a gelatine solid and a vegetable oil as the crustal and magma analogues respectively are presented. The experiments were designed to investigate the effect of the repeated injection of fluid into an extensionally-stressed solid, simulating the injection of dykes at rift margins. To replicate conditions of crustal extension, a gelatine solid was prepared in an acrylic tank and a lateral extension was applied to the gelatine prior to running the experiments. The vegetable oil was chosen for its well-known thermal and rheological properties, with the advantage of allowing the solidification of the fluid after the injection. The parameters varied were the lateral distance between the injection sites, the volume of oil injected repeatedly and the amount of applied extensional stress. The resultant injections dimensions and their spatial arrangement were measured, along with the propagation velocity of the crack tips measured in three dimensions. In addition, photoelastic plates were used to measure the stress field around the propagating crack tip.

A relationship between the injection spacing, the amount of extension, the final positions and orientation of the emplaced dykes is established. This has implications for the prediction of the location of secondary dykes intruded in a swarm as well as sequences of repetitive dykes intruded at rift margins.