Stress and strain distribution in the shallow crust during dyke and sill emplacement

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The mechanics of sill formation are important for understanding magma distribution within the shallow crust and the tendency for these magmas to intrude or erupt. We present a series of layered gelatine analogue experiments monitored with a Particle Image Velocimetry (PIV) system to document the small-scale deformation processes in the host material during dyke and sill emplacement. Experiments are prepared comprising multiple layers, with small strength contrasts (comparable to those between crustal strata) created by varying the gelatine concentration and allowing sufficient time for it to reach its Young's modulus plateau. Injection of dyed water (the magma analogue) into the solid gelatine from below causes a vertically propagating penny-shaped experimental dyke to form. A horizontal sill then forms along a weak contact beneath a more rigid layer. To monitor displacements within the gelatine using the PIV technique, neutrally buoyant fluorescing particles are added to the gelatine during experiment preparation. Two high-speed cameras are positioned outside the tank in a plane perpendicular to the strike of the experimental feeder dyke, and parallel to a vertical high-power laser sheet that fluoresces the particles in the gelatine with short intense pulses. The cameras and laser sheet are triggered so that images are recorded at known time intervals. Incremental displacement vectors are calculated by cross-correlation between successive images. Spatial derivatives of the velocity field yield map the gelatine's 2-D strain components within the laser sheet. As the gelatine deforms elastically, the calculated strain correlates with the stress distribution. PIV provides new insights into the dynamics of sill formation by allowing small-scale stress and strain perturbations within the host gelatine layers to be measured for the first time at the time of sill inception. These experiments highlight the stress and strain partitioning that occurs between layers of contrasting elastic properties during intrusion, and the important role this plays in sill initiation.