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Clarifying the role of rigidity contrasts and rock interface strength in sill formation processes

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Field observations, numerical and analogue models suggest rigidity contrasts may play an important role in sill formation processes. We present results from analogue experiments and rock strength tests which explore the additional role that rock interface strength could have on the geometry and propagation dynamics of magmatic intrusions. Dyed water (a magma analogue) was injected into layers of solidified gelatine (a crustal analogue) to form experimental dykes and sills. The intrusions were pressure-driven and injected under initially hydrostatic conditions. From 4 to $\sim$15 °C gelatine deforms elastically, and under these conditions the tensile strength of the gelatine (Youngs Modulus) evolves following a power-law relationship that plateaus with time. Varying the concentration of the gelatine allows layer strength contrasts as low as 1% to be created. Our results show that in a two-layered system the upper layer needs to be at least 10% more rigid than the lower layer to cause dyke arrest. An experimental sill then forms if the interface between the layers is weak; otherwise a lateral dyke forms.

To test rock interface strength variation in nature we used a 1 kN servo hydraulic test machine to test 5 mm thick cuboidal specimens of sandstone-siltstone rock core where the interface between the strata is preserved. By measuring the load required to grow a starter crack running along the lithological contact between the layers we can calculate its fracture toughness (a measure of the material resistance to the growth of a crack). The results show the rock interfaces have intermediate fracture toughness to their parent units.

These results bring into question the relative roles of magma viscosity versus rock fracturing in controlling the nature and propagation dynamics of magmatic intrusions.