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Saucer-shaped sill geometry as an indicator of the parameters governing emplacement

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A series of laboratory experiments have been performed in order to examine the parameters that control curving of circular fluid-driven fractures that grow near a free surface. It was found that these fractures, which were driven by injection of Newtonian fluids into Polymethylmethacrylate (PMMA) and borosilicate glass, curve towards the surface to form concave-upward saucer-shaped fractures that are thought to be analogous to saucer-shaped magmatic sills such as those observed in the Karoo Basin, South Africa.

It was found that the shape of the saucer is controlled by a dimensionless parameter $\chi = \sigma_r \sqrt{H}/K_{Ic}$ which compares the magnitude of the in-situ normal stress acting parallel to the free surface (σ_r) with a characteristic fracture-induced stress that may be estimated by the fracture toughness (K_{Ic}) divided by the square-root of the initial depth (H). In particular, the larger the value of χ the flatter the saucer-shaped fracture will be and furthermore, two fractures will have approximately the same shape up to a re-scaling by H provided that χ is the same for the two cases. This dependence of the geometry on χ suggests it may be possible to constrain the in-situ parameters at the time of emplacement by estimating χ from the observed fracture geometry. Furthermore, although further work is in order to determine the effect of biaxial stress on the fracture shape, one may hypothesize that the orientation of the least steeply dipping flanks of saucer-shaped sills may give indication of the direction of greatest compressive stress at the time of emplacement.