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Effect of rheology on the equilibrium shape and thickness of dykes: a numerical modelling perspective.

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The size and thickness of dykes is of fundamental importance for volcano dynamics because dykes are the primary path for magma transport, and because large numbers of dykes often comprise a large portion of the volcanic edifice and of the underlying crust.
Standard elastic models predict dyke geometry to be elliptic in cross-section, whereas observations show that dyke thickness is typically more nearly constant with a sharp taper at the ends. Moreover, the predicted overpressures required to inflate dykes in a purely elastic medium is much higher (>650 Mpa) than those estimated by other means (about 20-50 Mpa).
In this study, we use 2-D finite element models to test whether other host-rock rheologies lead to more realistic dyke shapes and overpressures. We examine 3 different rheologies, each of which is affected by the presence of the dyke itself: (1) elasticity with reduced moduli in regions of overall tension; (2) elasto-plasticity with plastic failure near the dyke tips; (3) visco-elasticity with a viscosity decrease due to the heat from the dyke.
We use realistic rheological parameters whenever possible, and assume static conditions for the final dyke shape. We thus neglect the dynamic effects of magma flow, an assumption that is probably justified because flow ceases well before the dyke solidifies.
We find that all 3 rheologies tend to make the dyke more rectangular relative to the ellipse resulting from the linearly elastic models. The change in shape is due to enhanced deformation in the high-stress zone surrounding the dyke tip. We also find that the overpressure required to inflate an initially thin dyke to a given thickness is reduced for all 3 rheologies.
The greatest decrease in overpressure is observed for the elasto-plastic model. We discuss our results with respect to dyke observations from the Rum Island (Scotland) and use these as a guide to evaluate our models.