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Analytical solution for 3D surface uplift above flat-lying magma intrusions: Implications for sill emplacement and geodesy

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We will present a new analytical solution for the surface uplift associated with the emplacement of axisymmetric sills and laccoliths. Our solution is based on the formulation of a thin bending plate lying on an elastic foundation. In contrast to the classical models of sill and laccolith emplacement based on a clamped bending plate, our model accounts for 3D uplift, both upon and outside the intrusion.

We will show that the model's behaviour is controlled by an elastic length l, which is a function of the elastic properties of both the bending plate and the elastic foundation. When a/l>5, with a the radius of the intrusion, the uplift is mostly restricted upon the intrusion, and the model converges towards that of a clamped plate for a/l> >5. In contrast, when a/l<5, there is substantial uplift outside the sill.

We will apply the model to two cases. First, we will introduce a propagation criterion to describe sill propagation and predict the sill radius, maximum uplift and uplifted volume. Second, we will introduce a bending strength to compute the critical size of saucer-shaped sills and discuss the occurrence of inclined sheets as a function of the stiffness of the elastic foundation. In both cases, we will show that the model provides results that are consistent with experimental and geological data.

We propose that our model can be used to analyze ground deformation resulting from sill intrusions in active volcanoes, offering a simple and practical alternative to complex existing numerical models.