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Forced-folding by laccolith and saucer-shaped sill intrusions on the Earth, planets and icy satellites

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Horizontal intrusions probably initially start as cracks, with negligible surface deformation. Once their horizontal extents become large enough compared to their depths, they make room for themselves by lifting up their overlying roofs, creating characteristic surface deformations that can be observed at the surface of planets.

We present a model where magma flows below a thin elastic overlying layer characterized by a flexural wavelength Λ and study the dynamics and morphology of such a magmatic intrusion. Our results show that, depending on its size, the intrusion present different shapes and thickness-to-radius relationships. During a first phase, elastic bending of the overlying layer is the main source of driving pressure in the flow; the pressure decreases as the flow radius increases, the intrusion is bell-shaped and its thickness is close to being proportional to its radius. When the intrusion radius becomes larger than 4 times Λ, the flow enters a gravity current regime and progressively develops a pancake shape with a flat top.

We study the effect of topography on flow spreading in particular in the case where the flow is constrained by a lithostatic barrier within a depression, such as an impact crater on planets or a caldera on Earth. We show that the resulting shape for the flow depends on the ratio between the flexural wavelength of the layer overlying the intrusion and the depression radius.

The model is tested against terrestrial data and is shown to well explain the size and morphology of laccoliths and saucer-shaped sills on Earth. We use our results to detect and characterize shallow solidified magma reservoirs in the crust of terrestrial planets and potential shallow water reservoirs in the ice shell of icy satellites.