Viscoelastic finite element models of an active magmatic intrusion at Uturuncu Volcano, Bolivia: Insights into vertical ascent through stratified continental crust

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Uturuncu is a dacitic stratovolcano in southwest Bolivia, located at the center of a 3,800 km^2 region currently uplifting at up to 1 cm/yr. Although the youngest lava flows from Uturuncu have been dated at 270 ka, the summit has active fumaroles, it is positioned in an area of intense silicic Miocene volcanism (the Altiplano Puna Volcanic Complex), and InSAR data shows that uplift has been occurring steadily since at least 1992. Combining two decades of InSAR data also shows evidence for a 'moat' of subsidence, up to 4 mm/yr over a 13,000 km^2 area. The unique combination of concentric surface uplift and subsidence could result from vertical ascent of magma from the lower crust (70 km) to the upper crust (20 km), or may result from the initiation of diapiric rise in the hot upper crust. Both mechanisms suggest magma migration at approximately 20 km depth, which coincides with a geophysically imaged zone of partial melt known as the Altiplano Puna Magma Body (APMB). Whether the current deformation is primarily due to the lateral migration of partial melt within the APMB toward a central diapir, due to the underplating of a recent intrusion, or due to an entirely different process, is an open question.

Surface deformation at Uturuncu can be replicated by vertically stacked finite pressure sources in a viscoelastic medium. However, rheological constraints imposed by compositional gradients, temperature gradients, and a layer of partial melt such as the APMB play a fundamental role in the transmission of shear and normal stresses from pressurization at depth. We therefore explore a range of realistic subsurface conditions with 3D finite element forward models using PyLith software. Combing over 750 Envisat and ERS interferograms from two descending (t282, t10) and two ascending tracks (t3, t89) we calculate representative profiles of vertical and radial surface displacement to validate model output. Models are constrained by regional and local geophysical and petrological datasets including: seismic tomography, gravimetry, heat flow, and compositional analyses of surface deposits. Results are therefore tuned to the unique conditions at Uturuncu, but give general insight into volcanic deformation resulting from pressurization below the brittle-ductile transition.