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What's causing the world's largest deformation anomaly in southern Bolivia? Insights from Finite Element Analysis

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This study focuses on a Finite Element Analysis of the world's largest recorded ground deformation anomaly in the Altiplano-Puna region of southern Bolivia. We present a series of forward models to construe the 70 km wide ground displacement field identified by satellite geodesy between 1996 and 2000, with a mean inflation rate of ~1.5 cm/yr, centered at Uturuncu volcano. The causative pressure sources simulated in the models have spherical, prolate and oblate shapes and the resulting stresses are solved numerically, accounting for both homogeneous and heterogeneous mechanical rock properties, as well as elastic and time-dependent rheologies and source multiplicity. Crustal heterogeneity is constrained by published seismic velocity profiles that indicate the presence of a large low-velocity region, the Altiplano-Puna Magma Body (APMB), at depths less than roughly 17 km below the surface. For the case of crustal elasticity, we find that the observed uplift is best explained by a single prolate source, in a mechanically heterogeneous medium, centered between 16.1 and 18.9 km below local elevation, with a semi-major axis of 5.2 - 9.8 km, semi-minor axes of 2.9 - 5.5 km and a uniform pressure change of between 5.6 and 29.1 MPa, as determined by bootstrapping of the best-fitting models at 90% confidence. We then further explore the sensitivity of the model fits by first-order approximations of varying Poisson ratio with depth, crustal viscoelasticity and source multiplicity, to account for a wider range of conditions at upper crustal levels in the Altiplano-Puna region. We find that such mechanisms play a primary role in explaining the observed deformation at Uturuncu. Both crustal viscoelasticity and source multiplicity reduce the pressure requirement of a source while maintaining the same amplitude of deformation. But in particular, the presence of a mechanically soft layer at source depths, such as the APMB, significantly alters surface displacement patterns.