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Aseismic magma supply inferred from geodetic Finite Element inversions: the case of the 2001-2002 non-eruptive unrest at Cotopaxi volcano

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The complex interplay between magma supply, storage and transportation, and how these processes interact with the host rock dictate the unrest signals we observe at the surface. Mechanical modelling allows us to link our recorded geophysical signals to subsurface processes and constrain a causative mechanism. We carry out this analysis for the 2001-2002 non-eruptive unrest episode at Cotopaxi volcano, Ecuador. During this period the volcano underwent a general inflation of its iconic edifice, recorded by an Electronic Distance Meter (EDM) network, and was accompanied by increased seismicity beneath the north-east flank. To solve for the optimum deformation source parameters we use an inverse Finite Element method accounting for subsurface material heterogeneity and surface topography. The model solutions favour a shallow source beneath the south-west flank, in contradiction to the seismicity locations in the north-east. The best-fit deformation model is a small, oblate shaped source approximately 1 km above sea level with a 20 x 106 m3 volume increase. To reconcile the deformation and seismicity simultaneously further Finite Element models were employed, incorporating an additional temperature-dependent rheology. These were used to assess the viscosity of the host rock surrounding the source. By comparing the elastic and viscous timescales associated with a small magma intrusion (implied by the best-fit deformation source in the south-west), we can infer this process occurred aseismically. To explain the recorded seismicity in the north-east we propose a mechanism of fluid migration from the south-west to the north-east along fault systems. Our analysis further shows that if future unrest crises are accompanied by measurable seismicity around the deformation source, this could indicate a higher magma supply rate and a critical level of unrest with increased likelihood of a forthcoming eruption. This research received funding through the EC FP7 “VUELCO” (#282759) project.