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Understanding the Yellowstone magmatic system using 3D geodynamic simulations

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The Yellowstone magmatic system is one of the largest magmatic systems on Earth. Therefore, it is an ideal location to understand the underlying processes that drive the magmatic system on a scale from the mantle plume to the shallow upper crustal magma chamber in the upper crust. Recent geophysical results suggest that two distinct magma chambers exist: a shallow, presumably felsic chamber and a deeper and much larger partially molten chamber above the Moho. To which extend the material parameters influence the rise of magma, the formation of shear zones in such systems and the magnitude of uplift remains puzzling. Therefore, we here employ lithospheric-scale massively parallel 2D and 3D geodynamic models to test the influence of different model parameters, and address questions such as: Are 3D effects are actually relevant or is 2D sufficient? How does the geometry control uplift? What is the effective viscosity and density of the magma chambers? What is the relative influence of magma inflation at different levels on the observable surface signal? The rock densities in our models are obtained by consistent thermodynamic modelling of whole rock data of the Yellowstone stratigraphy. In order to create a geodynamic model that is consistent with observations, we invert for the gravity anomaly data by varying the effective densities of the chambers and their distribution. We present derivations in the stress field around the Yellowstone plume and differences in the surface uplift signal, depending on how the chambers are connected and on which rheologies are active. Our model predictions are further coupled with available uplift data, through an adjoint-based inversion approach which tunes to material parameters to minimize the misfit between models and observations. We also show how short term magma pulses result in an localized inflation that can induce an additional surface signal, next to the longer-term geodynamic uplift signal.