The Influence of Lithosphere Strength, Thickness and Rheology on Topography above an Upwelling Mantle Plume

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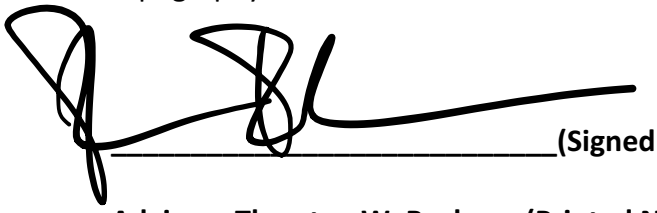
ABSTRACT

Dynamic topography is one of the surface expressions of mantle convection and includes the topographic responses to upwelling buoyant plumes and sinking subducted slabs, for example. While it is clear that dynamic topography may affect tectonics and solid Earth-hydrosphere interactions, the magnitude and wavelength of such effects remains debated. Here, we investigate the impact of different lithospheric conditions on the topographic response to upwelling mantle plumes through numerical and analytical approaches. The results are compared to analogue experiments. We also examine numerical models that explore the effects of viscoelastic rheology. Moreover, rather than using the free-slip boundary condition used in traditional numerical models, we apply a more realistic, stress-free condition on the surface. We find that this approach avoids overestimation of topography generated by a free-slip approximation. This effect is particularly important for thick, high-viscosity lithosphere. For free-surface models, we also find that a stiffer and thicker lithosphere generates a longer wavelength and smaller amplitude dynamic surface topography. For a viscoelastic lithosphere rheology, the effects of viscoelasticity are negligible in long-term lithospheric deformation but important over timescales less than the time taken to dissipate elastic stresses in a viscoelastic medium (Maxwell relaxation time), as expected. For a stratified lithosphere with a weak lower crust constituting a decoupling layer, the predicted topography is higher than for the case of a homogeneous lithosphere. This result can be reproduced by approximating the stratified lithosphere as a homogeneous lithosphere with an appropriately reduced, average viscosity. We also explore implications of variations in lithospheric viscosity, thickness and rheology on actual dynamic topography.



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