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Controls of the lower crust on upper crustal style of deformation in an intraplate setting: Insights from scaled physical analogue models

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Investigating the brittle ductile transition between the upper crust and the lower crust is important to understand how stresses are transferred from the deep lithosphere to the brittle upper crust. To study this geodynamic process in time and space we use physical scaled analogue modeling techniques. Our 3D models consist of a brittle upper crust (granular Si sand), viscous lower crust (Polydimethylsiloxane (PDMS) and putty) and viscous mantle lithosphere (PDMS and Si sand). The multilayer lithosphere overlying a viscous asthenosphere (glucose syrup) is deformed in a convergent setting. Deformation of the models is recorded using high spatial and temporal resolution cameras and the resulting data are analyzed using Particle Image Velocimetry (PIV) methods. These data are then compared to lateral cross-sections showing the finite internal structures of the deformed layered model. To understand the role of the lower crust, we test the effects of lithospheric strength by varying the strength of the lower crust including testing the absence of a lower crust. Recent research investigating intraplate deformation, has revealed that deep structures in the lithospheric mantle play a significant role in controlling surface tectonics. Therefore, in addition we include a structural plane of weakness in the mantle lithosphere and observe the transfer of deformation from the mantle lithosphere to the upper crust. Models with a weak lower crust result in zones of lower crust thickening which leads to the formation of faults in the upper crust. The rate of thickening of the lower crust determines how strain is distributed in the upper crust resulting in either localized or diffused deformation. Furthermore, a stronger lower crust and absence of the lower crust leads to a higher number of faults forming in the upper crust. Lastly, a structural heterogeneity in the mantle lithosphere controls the style of deformation of the upper crust. We observe brittle faulting and localized deformation above the plane of weakness vs. viscous folding in a completely homogenous mantle lithosphere. Results from our study might explain lower crustal exhumation in the European Alps, deep seismic activity such as below Southern Tibet, and even plateau formation due to the distribution of deformation. These cases further illustrate the importance of understanding the rheological heterogeneity of the lithosphere particularly for understanding surface tectonic processes on all temporal and spatial scales.