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A thin viscous sheet model for continental deformation

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Summary. For the purposes of describing its large-scale and long-term deformation, the continental lithosphere is regarded as a continuum, obeying a Newtonian or a power law rheology. The flow of a thin sheet of power law material overlying an inviscid substrate is studied under the assumption that vertical gradients of the horizontal velocity are negligible. A numerical model is used to investigate the deformation of such a sheet under conditions approximating those of continent–continent collision. The material flows in response to forces applied to its boundaries (for example, the indenting of one continent by another) and to forces in its interior arising from gradients in crustal thickness. The horizontal divergence of the flow produces changes in the crustal thickness and hence a time-dependent form to the flow itself. For a given set of boundary conditions, the flow depends on the stress exponent in the power law rheology, n, and on the Argand number Ar, which is a measure of the ratio between the stress arising from crustal thickness contrasts and the stress required to deform the material at the ambient strain rates. When the effective viscosity of the medium is very high ($Ar \rightarrow 0$), crustal thickness variations do not influence the flow. If the material is Newtonian ($n = 1$), the deformation associated with an influx of material (approximating an indenter) is of much greater lateral dimension than the width of the indenter, whereas when material has a power law rheology ($n = 3$, 5 are used), the deformation is confined to a region of lateral extent comparable to that of the indenter. As Ar increases, the forces arising from crustal thickness contrasts exert more influence on the flow, and the maximum crustal thickness that can be sustained by a given influx of material is related by a simple expression to the effective viscosity of the medium at the ambient strain rates. In the limit of a very weak medium ($Ar > 10$) the lithosphere is unable to sustain appreciable crustal elevation contrasts. The results of these numerical experiments show that systems in which the effective viscosities are such that the maximum deviatoric stresses are between 1 kbar

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