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An analog material for ductile non-linear lithosphere rheology: application to lithospheric tearing

Taco Broerse (1), Ben Norder (2), Rob Govers (1), Dimitrios Sokoutis (1), and Ernst Willingshofer (1)
(1) Utrecht University, Utrecht, Netherlands (d.b.t.broerse@uu.nl), (2) Delft University of Technology, Delft, Netherlands

Stress-dependent non-linear upper mantle rheology has a firm base in rock mechanical tests, where this non-linearity results from dislocation creep of minerals. Furthermore, many numerical geophysical models invoke the power-law viscosity reduction at increasing stress, as observed for dislocation creep in olivine aggregates, to explain localized deformation in the ductile parts of the lithosphere. In the last few decades there has been some attention to non-linear, power law, materials for application in analogue, laboratory models of geophysical problems. However, literature describing the rheology of analogue materials with the same non-linear dependency on stress as observed for lithospheric mantle materials at relevant stress levels, is still lacking.

We have developed and rheologically tested materials based on combinations of silicone polymers and plasticine, with the aim of obtaining a material that can serve as a laboratory analog to the power-law rheology of olivine aggregates at lithospheric mantle conditions. From our steady-state creep tests we find that it is possible to obtain such a power-law material, with effective viscosities over relevant model stress ranges [5-4000 Pa] that allow for deformation at laboratory time scales.

We apply the developed material to settings where localized deformation of the lithosphere can be expected: slab break-off and STEP tears. We study these processes using analogue models, where we apply the developed non-linear material to the lithospheric mantle domains, while we use Newtonian glucose to represent the low viscous asthenosphere. From these models we observe that lithospheric tearing occurs in a localized mode.