Geophysical Research Abstracts
Vol. 18, EGU2016-3220, 2016
EGU General Assembly 2016

Viscoelastic silicone oils in analog modeling - a rheological benchmark

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Tectonic analog models frequently use silicone oils to simulate viscous flow in the lower crust and mantle. Precise knowledge of the model rheology is required to ensure dynamic similarity with the prototype. We assessed the rheological properties of various silicone oils using rotational and oscillatory tests. Resulting viscosities are in the range of 2 - 3 $\times 10^4$ Pa s with a transition from Newtonian viscous to power-law, shear-thinning, around shear rates of 10^{-2} to 10^{-1} s^{-1}. Maxwell relaxation times are in the range of 10^{-1} s. Comparing the rheological properties of chemically similar silicone oils from different laboratories shows that they differ from laboratory to laboratory. Furthermore, we characterized the temperature dependency of viscosity and aging effects. The samples show a reduction in zero-shear viscosity over time. This stabilizes at a certain value over several months. The dynamic moduli decrease as well, but other viscoelastic constants, such as the Maxwell relaxation time, are not affected by aging. We conclude that the aging is mainly controlled by the storage conditions and that a silicone shows no further aging when it has equilibrated with the ambient laboratory conditions. We consider all these differences as minor compared to the much larger uncertainties for estimating the lithosphere rheology. Nevertheless, it is important that the rheological properties of the experimental materials are monitored during an experimental series that spans over several weeks to months.

Additionally, the viscoelastic properties may be scaled using dimensionless parameters (Deborah number) and show a dynamically similar change from Newtonian to power-law flow, like the natural prototype. In consequence, the viscoelasticity of these silicone oils is able to mimic the change in deformation mechanism from diffusion to dislocation creep.