Title: Non-uniqueness in flow law parameters for olivine polycrystalline aggregates for composite rheology.

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Deformation maps for olivine suggest that laboratory conditions favor the simultaneous operation of diffusion and dislocation creep. Hence, experimental data must be inverted for diffusion and dislocation creep flow laws simultaneously, a fact often overlooked by previous studies. Most of these studies estimated the grain-size exponent of diffusion creep (or stress exponent of dislocation creep) assuming the operation of only diffusion (or dislocation) creep mechanism for a given data set. Korenaga and Karato (2008) was the first study to implement a fully nonlinear inversion of rock-deformation data utilizing a Markov Chain Monte Carlo sampling. It can also account for errors in all experimental quantities (i.e., measurements of stress, temperature etc.). Mullet et al. (2015) improved this inversion scheme by correcting for its potential propensity to favor a higher value of model parameters. In this work, we used this improved code to invert deformation data of olivine polycrystalline aggregates, assuming the parallel operation of diffusion and dislocation creep. The flow law parameters for both mechanisms obtained were significantly different from the parameters obtained by linear least squares inversion of the same data by the original experimental studies. Our results indicated that diffusion creep was virtually insensitive to grain-size in the given data sets. Since the theory for diffusion creep suggests otherwise, we suspect that our results strongly indicate the presence of non-uniqueness in the model equation, particularly a trade-off between the diffusion creep grain-size exponent and dislocation stress exponent.

This issue of non-uniqueness has not been explored previously and could have important consequences in the field of geodynamical modeling. The contribution of diffusion creep to the total deformation in the mantle can vary markedly with different values of the grain-size exponent. If diffusion creep is indeed less sensitive to grain size, as our inversion suggests, it could potentially invalidate the hypothesis that shear localization may cause lithospheric weakening. In this study, we investigate the issue of non-uniqueness in the values of grain-size exponent and stress exponent and attempt to define the ideal range of experimental conditions under which the two exponents may be resolved more uniquely. This study underscores the necessity for a thorough error analysis of experimental data and the importance of assessing the uncertainty in predictions made from the inverted model parameters.