Which rheologies do we use and which do we want for the CRM?

1. What are you using right now as rheologies and what would you like the CRM to provide to improve them?

1. Upper crust is elastic/plastic with Drucker-Prager yield criterion. Ductile Lithosphere uses Hirth et al 2003 flow laws for olivine, feldspar...

2. Uses a vertical avg of properties and then partitions estimates of stresses, velocities etc. with depth using 1D rheological profiles. Typical profiles are elastoplastic in upper crust and viscoelastic at depth with various feldspar and olivine rheologies.

3. Uses layered structure usually, transient and power-law viscoelastic materials, is interested in CRM products and wants transient rheology (Burgers parameters) to be part of the CRM

4. Uses a range of viscoelastic and plastic rheologies, depending on quality of available data and target problem.

5. 3D Maxwell VE, could also incorporate transient (e.g. Burgers) rheology. Want the preliminary CRM (including the CTM)

6. Current focus is elastic (making Greens functions). In past, linear and nonlinear viscoelastic, some elastoplastic modeling.

7. Interested in the heat flow map and lithosphere thickness estimates that are part of the CTM, but he prefers to compute his own geotherms.

8. Suggests to contact Brad Aagaard, he might be able to write Python code to automatically link CVM and gridded version of CRM directly to PyLith.
First Order Rheologic Models

- Springs (linear elastic)
- Dash pots (linear viscous)
- Sliders (plastic)
- And various combinations thereof
First Order Rheologic Models

Figure 10. Phenomenological models for (a) elasticity, (b) plasticity, (c) viscosity, (d) elastoplasticity, (e) viscoelasticity, (f) two-layer elastoviscoplasticity, and (g) coupled elastoviscoplasticity.

Figure 11. Yield surfaces for Von Mises and Drucker-Prager plasticity in principal stress space (tension positive).

Nevitt, Warren and Pollard, 2017 JGR
Steady State Creep Rheology Depends Temperature, Strain Rate, Grain Size and Water Content

\[ \dot{\varepsilon} = A\sigma^n d^{-m} f_{H_2O}^r e^{-\frac{(Q+pV)}{RT}} \]

where \( A \) is a material constant, \( \sigma \) is differential stress \((\sigma_1 - \sigma_3)\), \( n \) is the (power-law) stress exponent, \( Q \) is activation energy, \( p \) is pressure, \( V \) is activation volume, \( T \) is absolute temperature, \( R \) is the molar gas constant, \( d \) is grain size, \( m \) is the grain size exponent, \( f_{H_2O} \) is the water fugacity, and \( r \) is the fugacity exponent.
Deformation Mechanisms

- Low stresses, small grain sizes, low T: Diffusion creep \( (n \approx 1) \)
- Moderate stress, larger grain sizes: Power law creep \( (n \approx 3-5) \)
- Deformation mechanisms can vary over short distance scales (inside versus outside of a shear zone) and timescales (earthquake-cycle).

Assuming strain rate of \(10^{-12} \text{ s}^{-1}\)

Bürgmann & Dresen, 2008 AnnRev

Fossen and Covalcante, 2017
Borrego Springs Mylonite Zone

Low Strain: Feldspar dominated
high strain: quartz dominated
Which rheologies do we use and which do we want for the CRM?
Continental Lithosphere Rheology

Bürgmann & Dresen, 2008
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