Toward a SCEC Community Rheology Model: TAG Kickoff and Workshop
SCEC Workshop Proposal 17206
Final Report

A one-day Community Rheology Model workshop was held at the Palm Springs Hilton on the Saturday before the 2017 SCEC annual meeting (September 9, 2017). The purposes of this workshop were:

> (1) Initiate the CRM Technical Activity Group (TAG) and provide a forum for presenting a preliminary Geological Framework (GF) and a preliminary Community Thermal Model (CTM).
>
> (2) To present a draft "straw man" CRM for the Mojave GF lithotectonic province, and use it as a basis for focused discussions on designing, evaluating and delivering the CRM.

Both of these goals were realized, and following productive discussions and breakouts, attendees produced a prioritized list of research tasks to move the CRM toward a draft product by 2019.

Pre-Workshop Activities and Attendee Summary. Over the summer of 2017, the CRM workshop PI's went through a compressed invitation process, in an effort to insure geographic and career-stage diversity while keeping the workshop budget below $10,000. Challenges arose, mainly because the invitation process started late due to federal funding roadblocks. In the end, thirty-six people attended, seven of whom happened to be in Palm Springs the weekend before the annual meeting. This skewed our attendance toward senior scientists: eight attendees were early-career scientists (graduate students, postdoctoral fellows or pre-tenure faculty). In spite of the rocky planning and invitation stage, we held what was by all accounts an exciting and productive meeting.

Meeting Summary. The workshop (agenda attached) began with progress reports from collaborators working on the southern California geologic framework (Michael Oskin, UC Davis), the Community Thermal Model (Wayne Thatcher, USGS), and differential stress constraints and flow laws (Whitney Behr, UT Austin). Figure 1 summarizes contributions from Michael Oskin and Whitney Behr, showing a preliminary, southern California-wide geologic framework and posited strength profiles for the Mojave lithotectonic block. Guest presentations on Mojave regional tectonics, seismicity depths as a constraint for rheology, and inferring rheology from seismic velocities were made by Alan Chapman (Macalester), Egill Hauksson (Caltech) and Billy Shinevar (Brown).

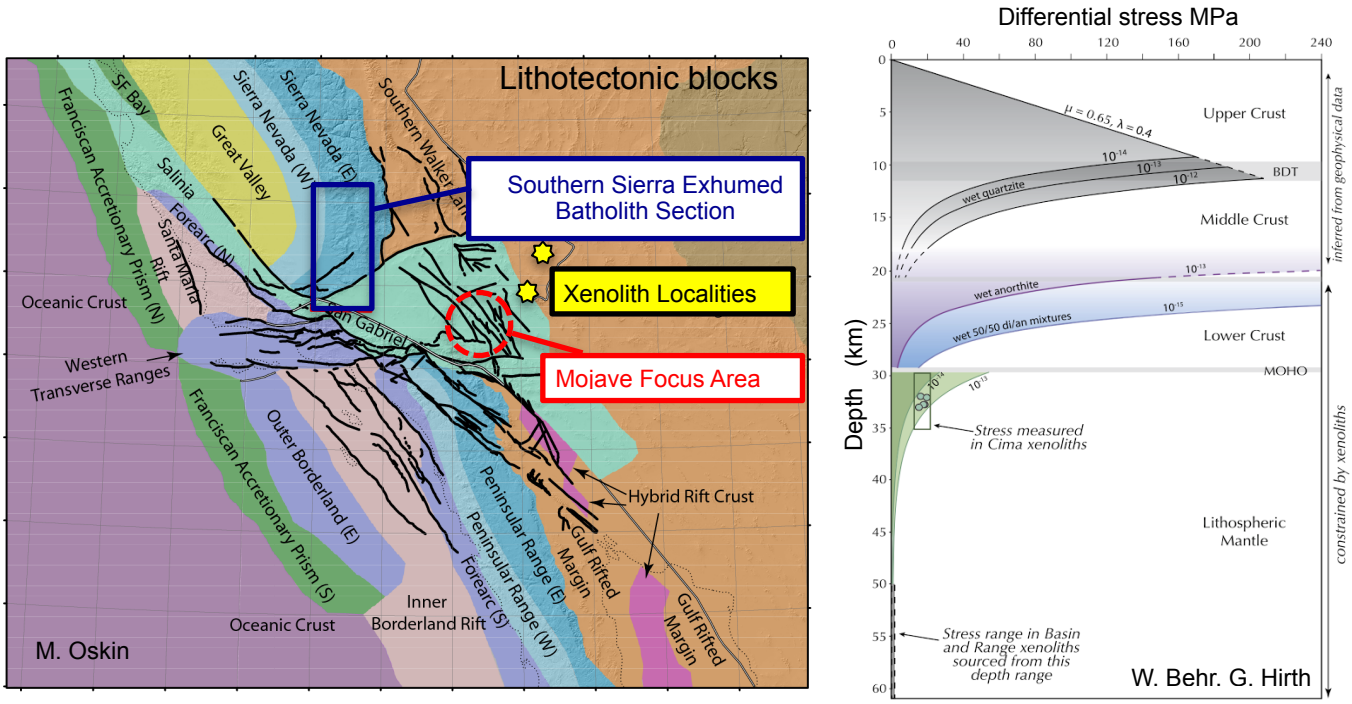
Liz Hearn (Capstone Geophysics) presented Mojave effective viscosity profiles for a suite of strain rates, based on the Geologic Framework Mojave rock types, a preliminary Mojave CTM geotherm, flow laws provided by Greg Hirth and Billy Shinevar, and water fugacity guidance from Whitney Behr and Greg Hirth. The flow laws were also incorporated directly into a finite element model of the Hector Mine earthquake to forward model postseismic deformation model (a range of initial stresses were assumed). Both exercises showed that our first-cut Mojave CRM is incorrect or at least incomplete. Because of the low temperatures obtained for the Mojave

CTM (constrained mainly by surface heat flow and the assumed distribution of radiogenic elements in the crust) effective viscosities for a range of reasonable strain rates were high. Effective viscosities in the lower crust and mantle asthenosphere at 60-100 km depth fell below 10^{20} Pa s only when a very hot geotherm (consistent with a temperature of 800°C at the Moho, rather than 650°C for the CTM) and a high strain rate (>> 10^{-15} /s) were assumed. For the upper mantle, assuming hot mantle with a saturated rather than "damp" water content was also an admissible explanation, though this is inconsistent with petrologic information. Predictably, when put into the Hector Mine earthquake postseismic deformation model, the posited Mojave CRM rheologies did not produce significant postseismic deformation. This result spurred discussions of explanations and possible next steps, both for the Mojave and the entire southern California region. One topic that immediately emerged as a high priority was localization of strain and lithosphere-scale shear zones.

The afternoon's schedule deviated from our planned agenda. We began with an hour-long continuation of our plenary discussion of next steps for the CRM, then held disciplinary breakout sessions, followed by breakout session reports and closing comments. The afternoon's work produced a draft, prioritized list of research tasks to advance the CRM toward the goal of completing a southern California-wide draft CRM in 2019 (per CRM workshop and TAG proposal [SCEC ID 17206, Figure 1]).

<u>Post-workshop activities and SCEC5 research priorities.</u> The preliminary list of CRM research priorities was sent out to all participants for a comment period. Subsequently, the PI's and attendees iterated via emails on what to add to the list, as well as wording and prioritization. The resulting list (attached) guided Hearn's updates to the SCEC RFP for 2018, which was issued in mid October of 2017.

Figure 1. Summary slide from the 2017 CRM workshop. Preliminary geologic framework is on the left, and posited strength profiles (based on assumed geotherms) for the Mojave lithotectonic block are on the right. Strength profiles generated using the preliminary Mojave CTM indicate much higher differential stresses.



<u>SCEC Community Rheology Model Workshop Agenda</u>
<u>9 September 2017, Palm Springs Hilton</u>

9:00-9:15 <u>Welcome, Motivation, Workshop Outline and Goals</u> (Hearn)

9:15-10:45 <u>Geologic Framework and Community Thermal Model (CTM)</u> (Oskin and Thatcher)

9:15-9:30 AM Michael Oskin: Overview of the geologic framework, with emphasis on constraining the lithospheric architecture of the Mojave region

9:30-9:45 AM Alan Chapman: Tectonic modification of the Mojave Desert region during Laramide shallow-angle subduction

9:45-10:00 AM Egill Hauksson: Applying the Depth Distribution of Seismicity to Probe the Rheology of the Seismogenic Crust in Southern California

10:00-10:15 AM Discussion: How should geologic and tectonic inference of lithosphere composition guide the CRM?

10:15-10:30 AM Wayne Thatcher: Preliminary CTM, with an emphasis on the Mojave region

10:10-10:45 Discussion: How important thermal versus compositional differences?

10:45-11:00 BREAK

11:00-12:30 Inferring Rheology, preliminary Mojave CRM (Hirth and Behr)

11:00 - 11:15 AM Whitney Behr: Overview of rheologies for Mojave rock volumes and shear zones, guidance on differential stress, volatile content and other parameters for these flow laws

11:15 - 11:30 AM William Shinevar: Inversion of seismic velocity for rheology

11:30-11:45 AM Discussion: Geologic vs. seismic inference of rheology.

11:45 AM - 12:15 PM Hearn: Preliminary Mojave CRM effective viscosities and their consistency (or not) with Hector Mine Earthquake postseismic deformation

12:15 PM Discussion: Assessing the CRM with deformation data and models

12:30-1:30 LUNCH

1:30-2:30 Disciplinary Breakout Session (I)

What can each scientific discipline contribute to the CRM over the next year and by the end of SCEC5, for the Mojave and southern California?

2:30-2:45 Breakout Session I Summaries

2:45-3:00 BREAK

3:00-4:00 Interdisciplinary Breakout Session (II)

Identify important scientific questions than can be addressed with a CRM (and other existing resources) by the end of SCEC5 - particularly, problems that relate to the five SCEC5 science questions

4:00-4:15 Breakout Session II Summaries

4:15-5:00 Next steps for 2018 and beyond: Our TAG (all conveners)

Other GF provinces, shear zones, delivery and sharing, future workshops and closing comments

CRM Research Priorities from the 2017 workshop plenary and breakouts, finalized following a post-workshop email comment and reply period open to all registrants, September-October 2017

Short term (at least begin in next 1-2 years)

Develop geologic framework for remaining domains (based on geological consensus), identify reasonable ductile flow laws. Compare predicted seismic velocities with SCEC CVM.

Characterize sensitivity of rock rheology to composition, water content, strain rate and temperature for the Mojave region.

Compare brittle-ductile transition and crustal strength distribution inferred from the CRM with the distribution of seismicity with depth.

Evaluate candidate/provisional CRM's against postseismic deformation models, with focus on the Mojave and Salton Trough regions.

Add provisional shear zone models (rheology and width) to the CRM based on simulations and natural examples at all available exposure levels, and test these for consistency with depth of rupture propagation, post-seismic deformation, and geodetic and seismically inferred locking depth.

Assess the relative importance of basal tractions, and appropriate boundary conditions for plate-boundary scale deformation models.

Investigate the importance of rheological anisotropy (from distributed fabric or localized shear zones) to the dynamics of the regional deformation

Longer term (most activity after 2 years)

Add rheology of upper crust, brittle-elastic regime to the CRM

Assess complete CRM using models of plate boundary-scale deformation and regional-scale geophysical observations (such as seismic velocities, attenuation, and anisotropy).

Other potentially important inputs (timing undetermined)

A lithosphere-scale water model

Magnetotelluric constraints on rheology

Workshop topic ideas

Shear zones, brittle/plastic rheology, BDT, Salton Trough