The SCEC Community Rheology Model: A modular resource for investigating the effective viscosity structure of southern California

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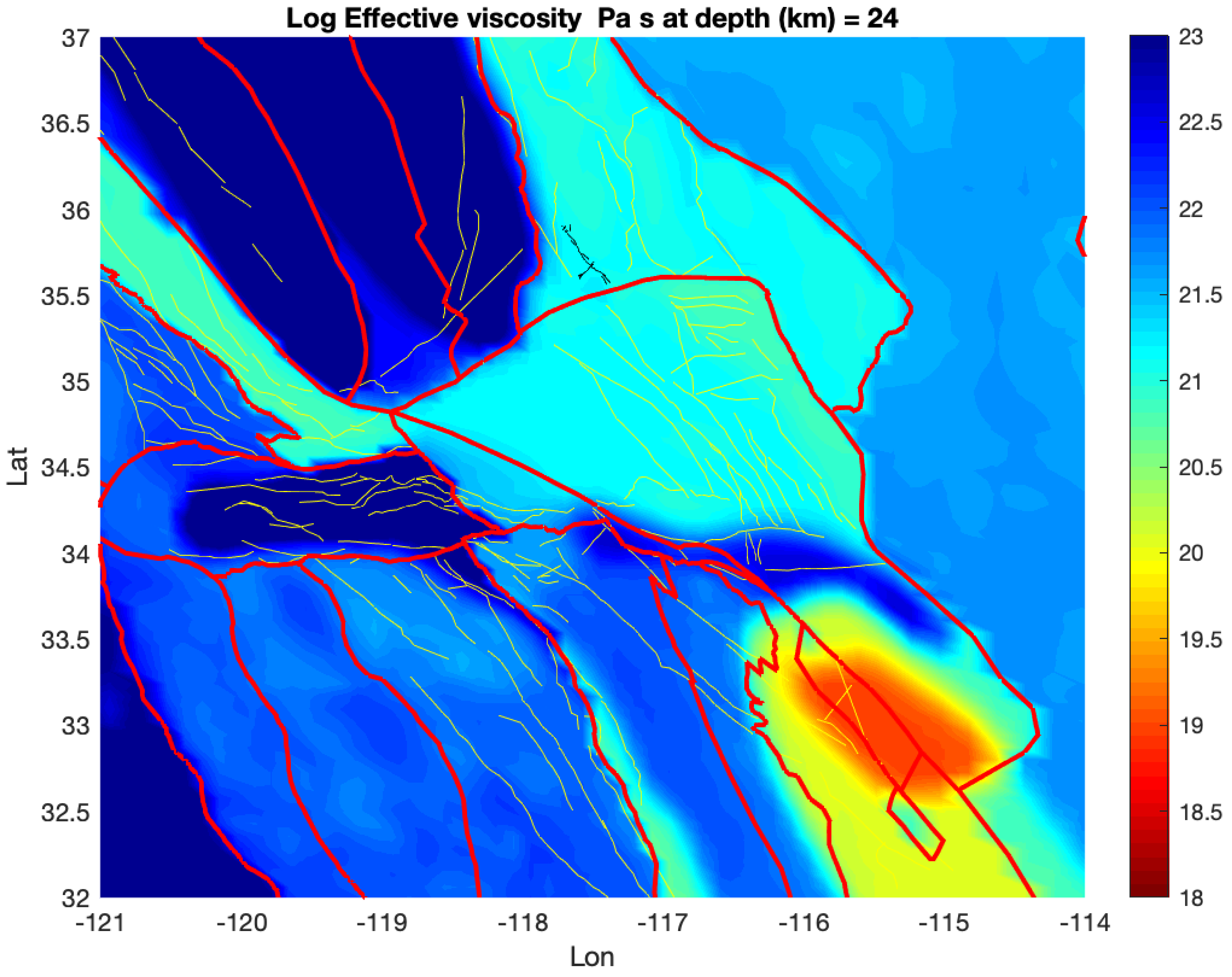

- CRM components
- examples of calculated viscosities
- comparison with independent estimates
- plans for the bridge period

The current CRM is a set of “tools and rules” for calculating effective viscosities for the southern California lithosphere

- **Geologic framework**: 3D distribution of major rock types and their mineral composition
- **Ductile flow laws**: for GF lithologies; also mineral flow laws and a tool for calculating ductile flow laws for other rocks

https://www.scec.org/research/crm

DATA PRODUCTS

SCEC Community Rheology Model, including the Geological Framework and ductile flow law details.

Download CRM, Version 20.9

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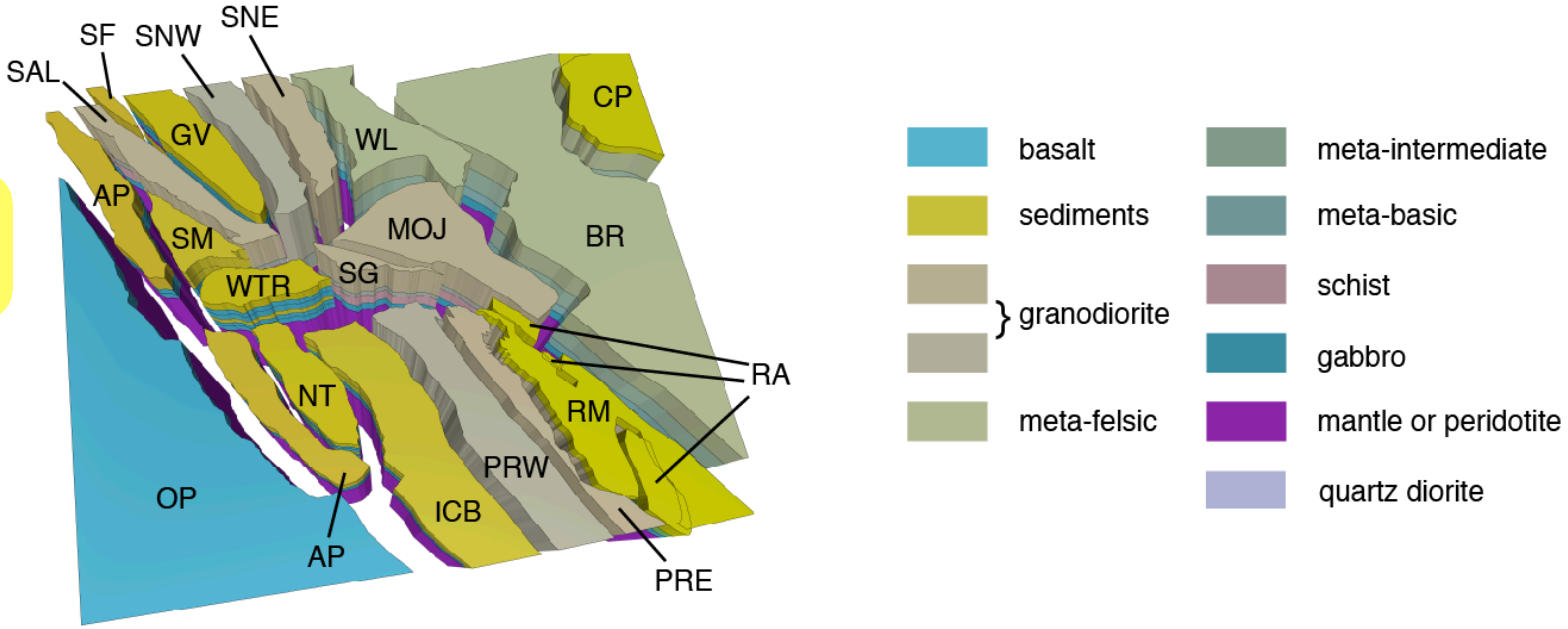
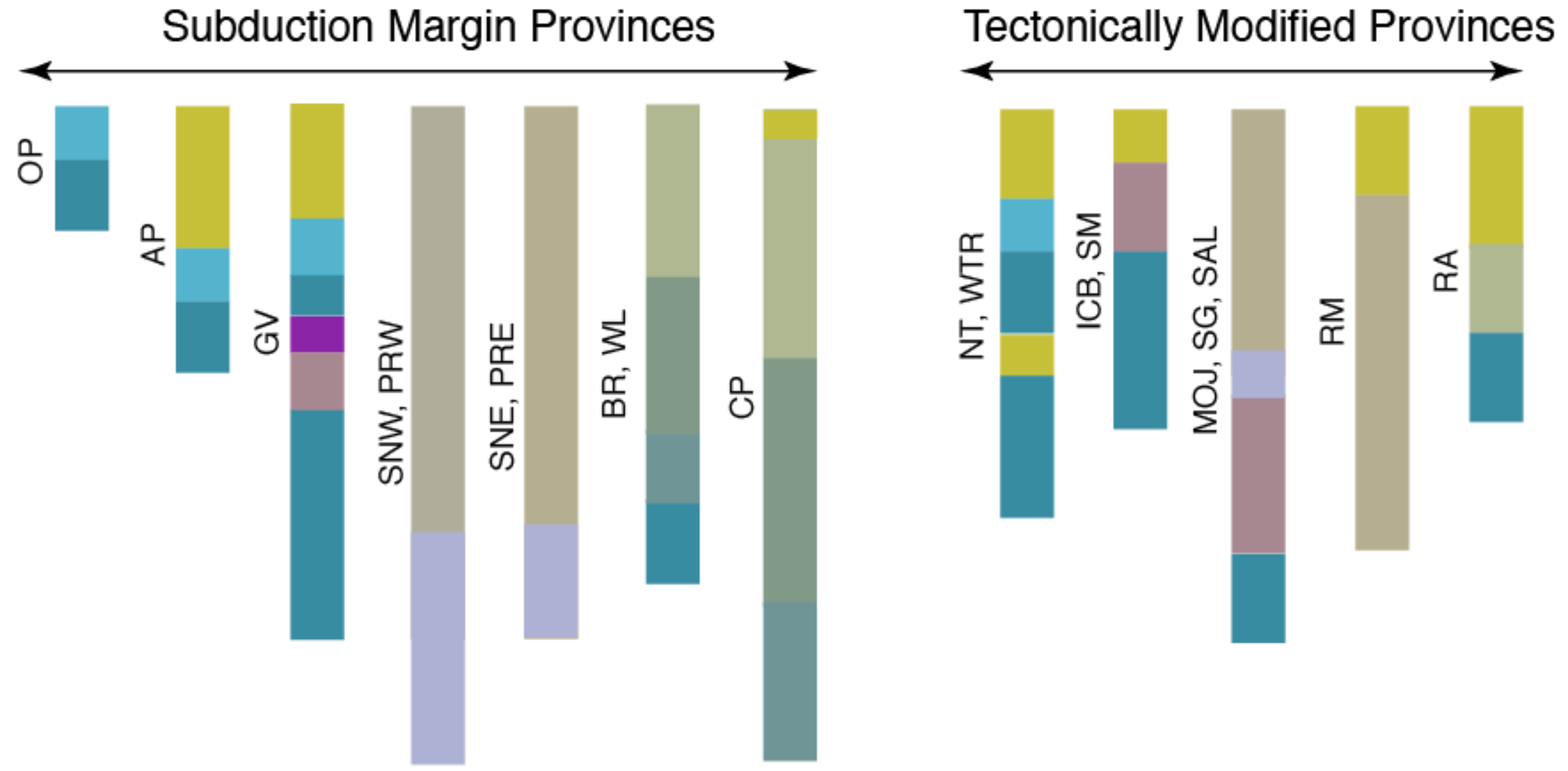
Geologic Framework

provinces



Hearn et al., 2021, based on Oskin et al., 2018, 2019



lithology columns

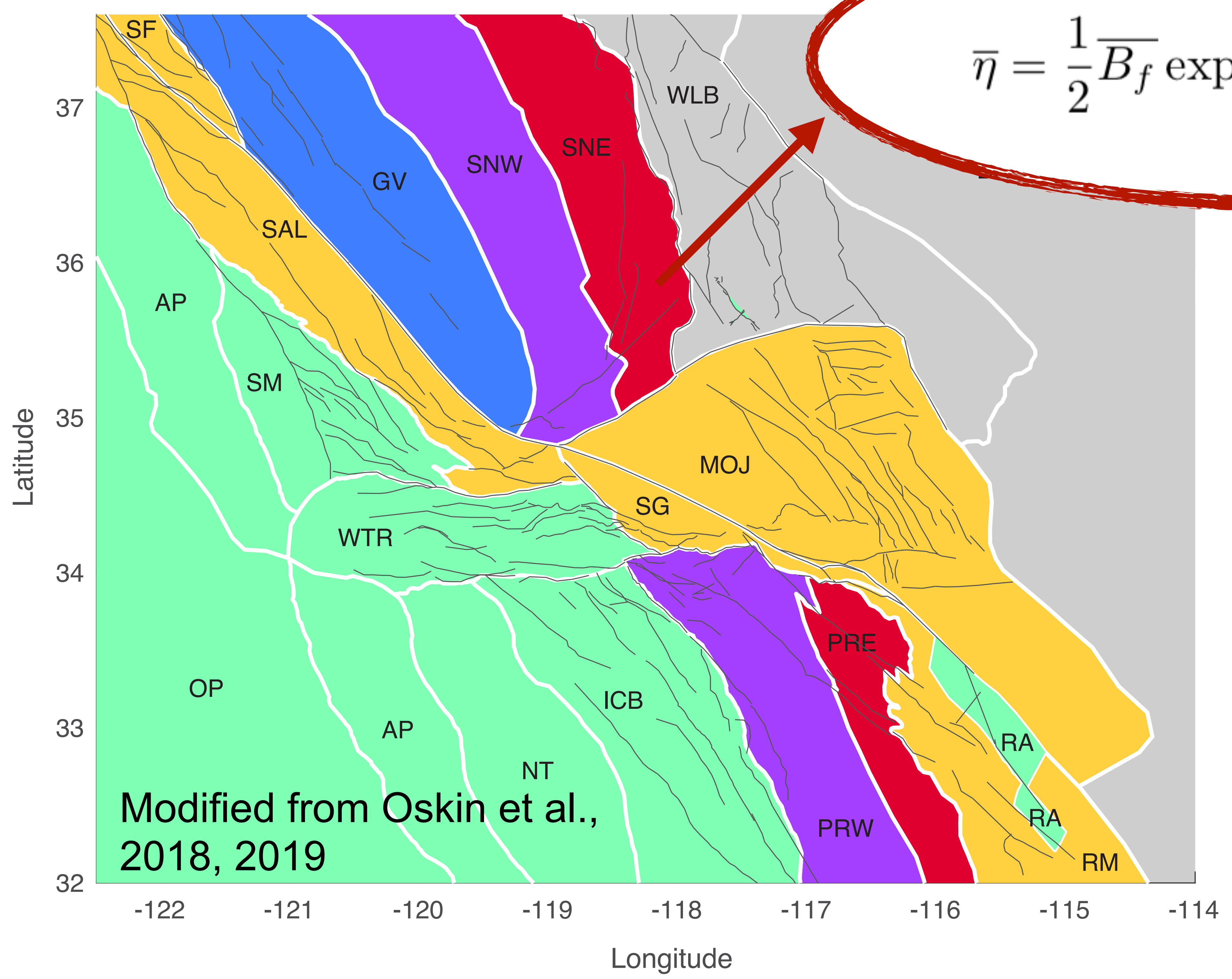
Data products

- Boundaries of 23 lithotectonic **provinces** (various formats)
- Tables with **lithology columns** for each lithotectonic province
- Tables with **mineral composition** (%) for each GF lithology

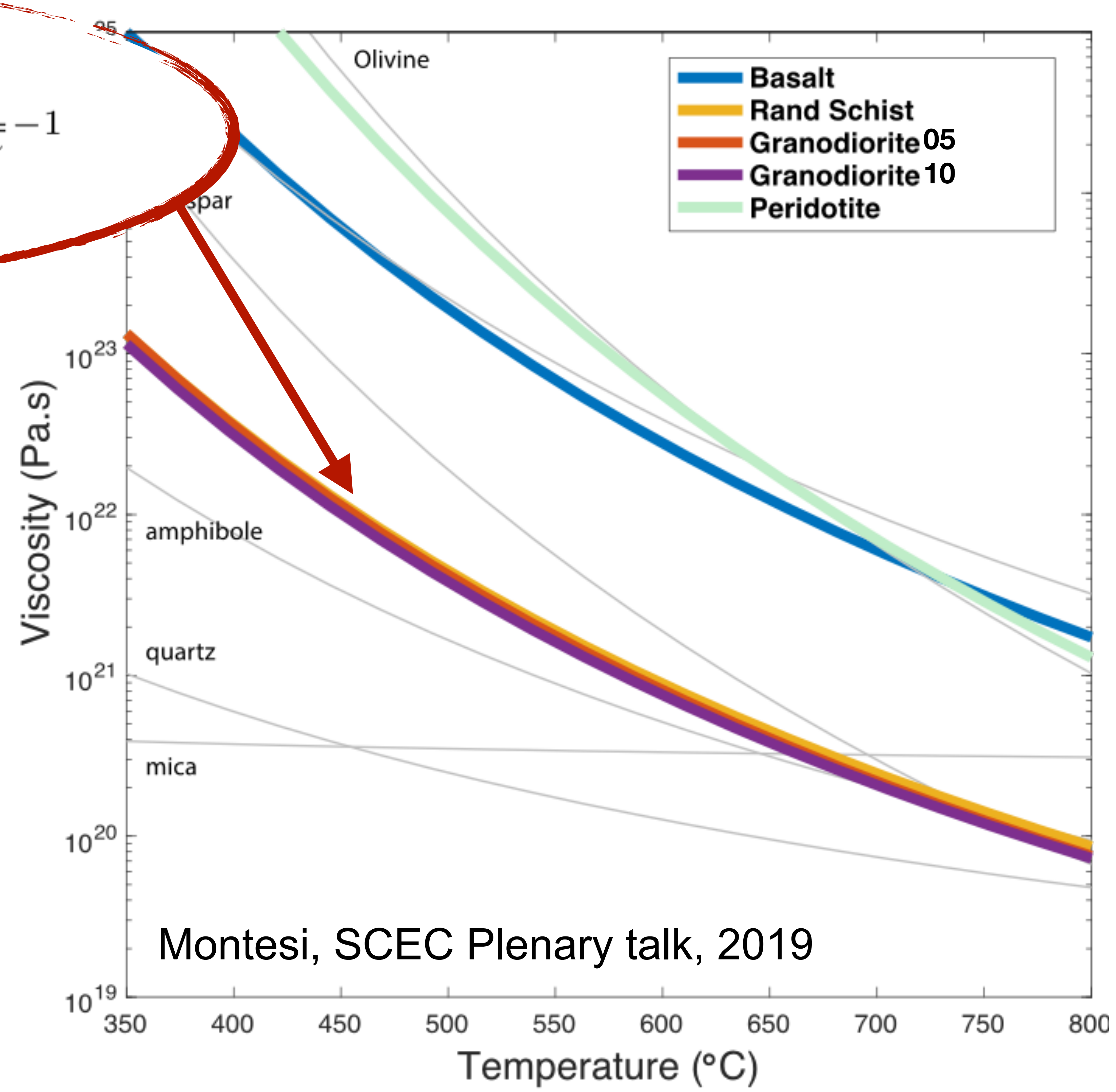
Ductile Flow Laws and Tools

Closed-form equations and parameters for each GF lithology based on mineral composition, mixing laws, and vetted mineral flow laws

$$\overline{\eta} = \frac{1}{2}\overline{B_f}\exp\left(\frac{\overline{Q_f}+P\overline{V_f}}{\overline{n}RT}\right)\dot{\varepsilon}^{\frac{1}{\overline{n}}-1}$$



Modified from Oskin et al., 2018, 2019

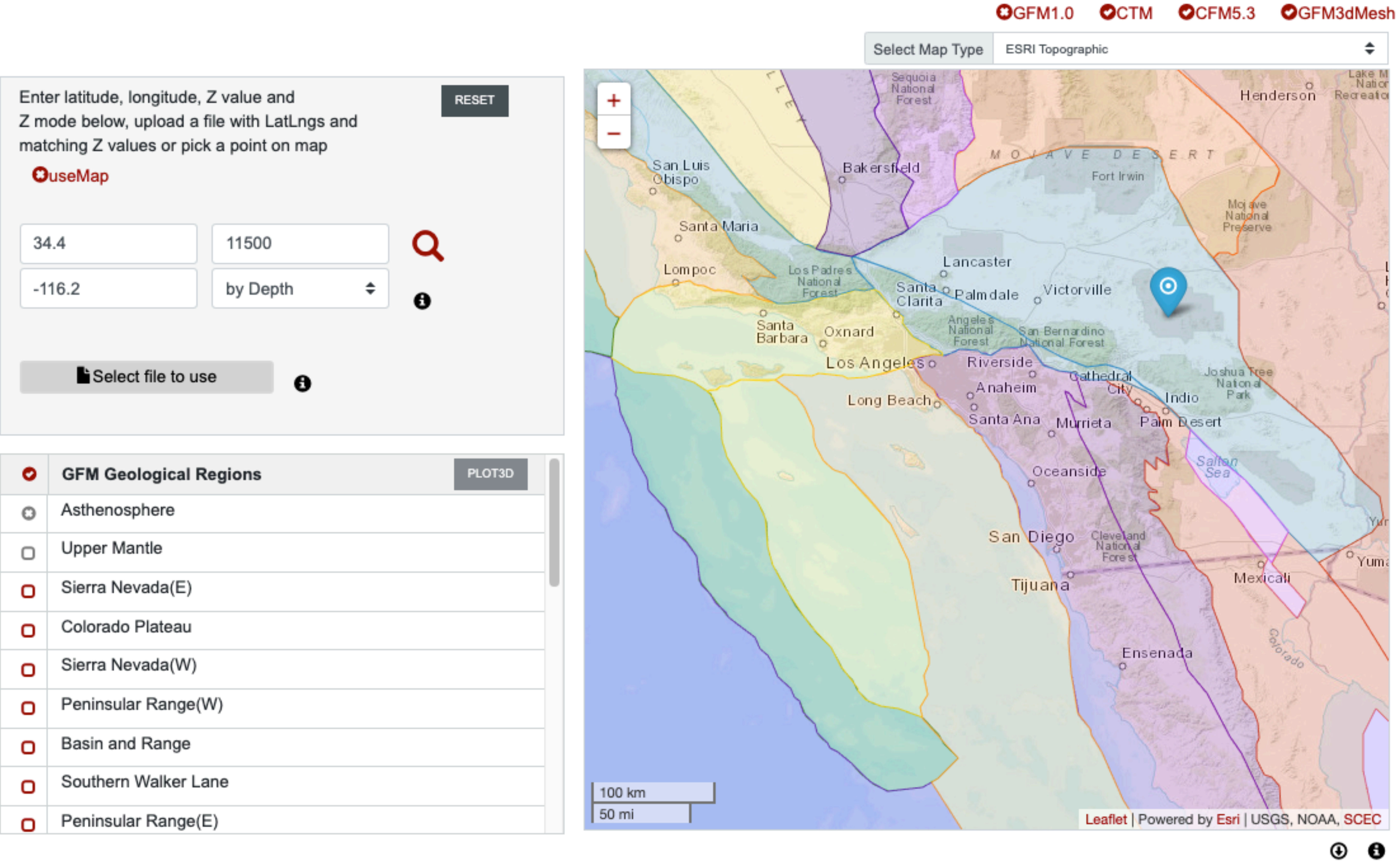


Montesi, SCEC Plenary talk, 2019

Data products

- Steady-state, low strain, dislocation creep flow law coefficients for GF lithologies (saturated and unsaturated - crust default is saturated)
- Mineral flow laws, code to apply mixing law to generate custom flow laws
- Guidance document (detailed instructions!)

Query Tool: GFM Web Viewer



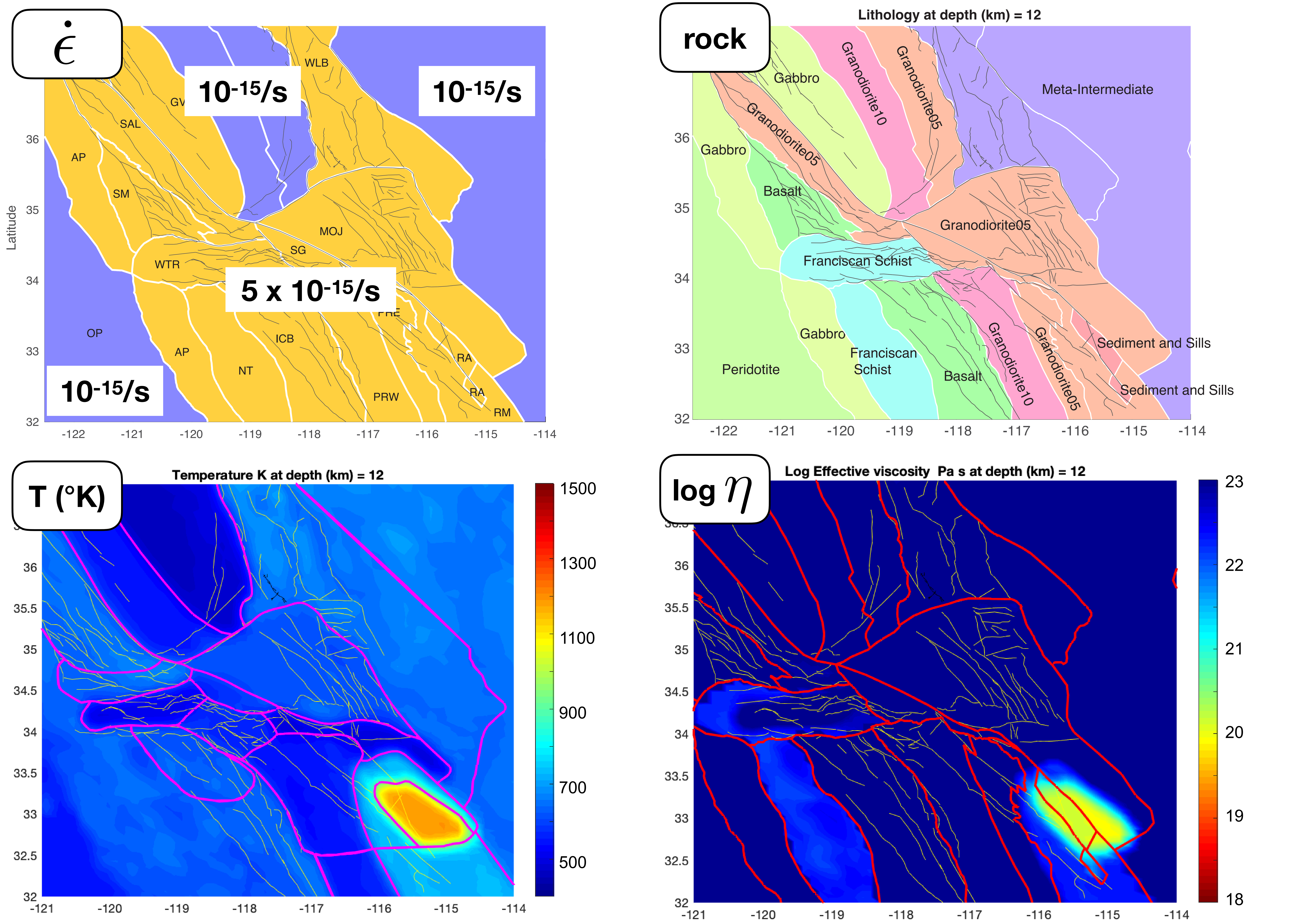
	Lon	Lat	Z	Elevation(m)	Vp(m/s)	Vs(m/s)	rho(kg/m3)	GFM Region	Lithology Type	Heat Flow Region	Smoothed CTM(degC)
	-116.2	34.4	11500 (by depth)	799.89	6020.26	3554.62	2721.02	Mojavia	Granodiorite05	MD	312.4

Query lat, lon, and depth for GFM province and lithology, CTM heat flow region and smoothed CTM temperature, and other information

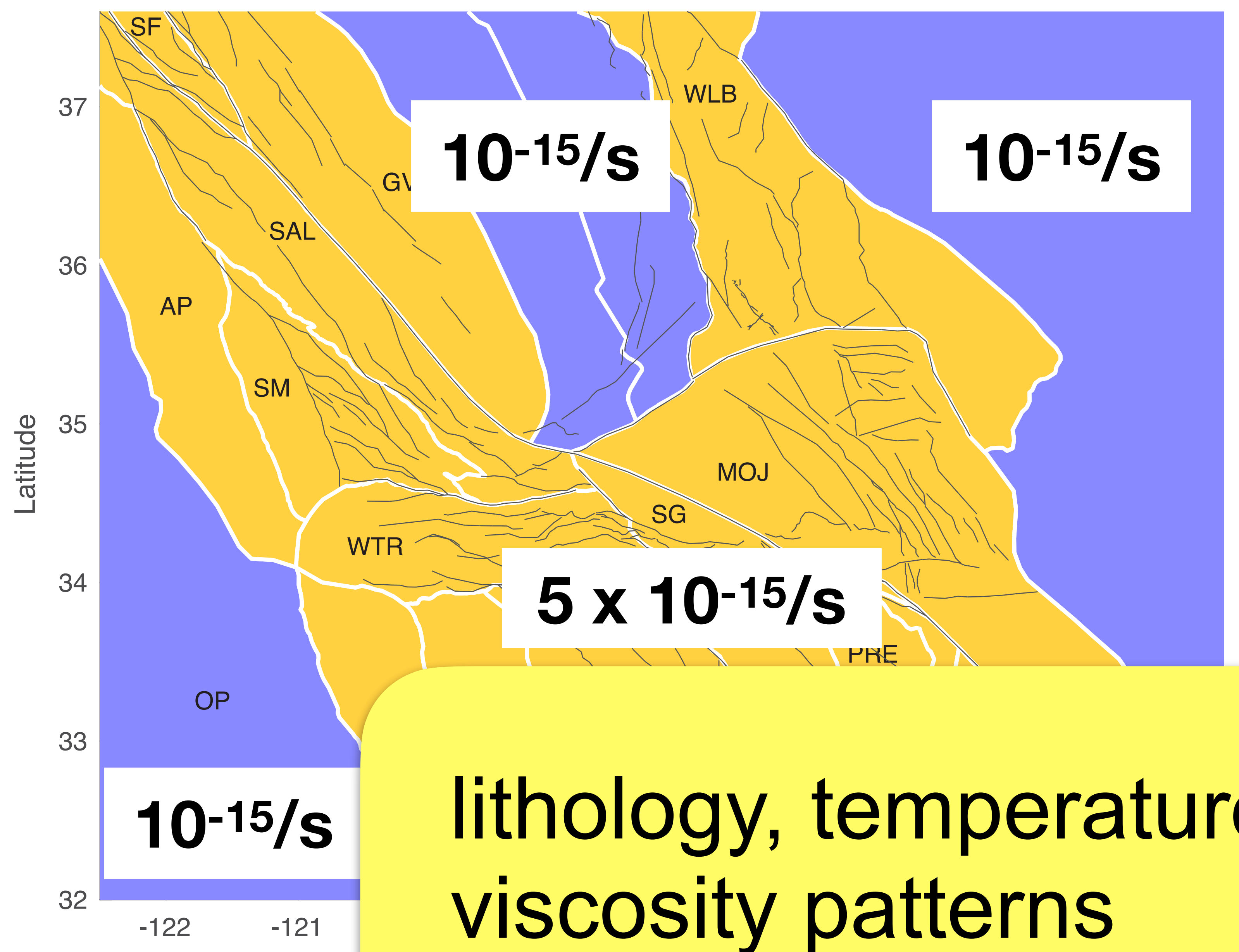
Su et al.,
Poster #020

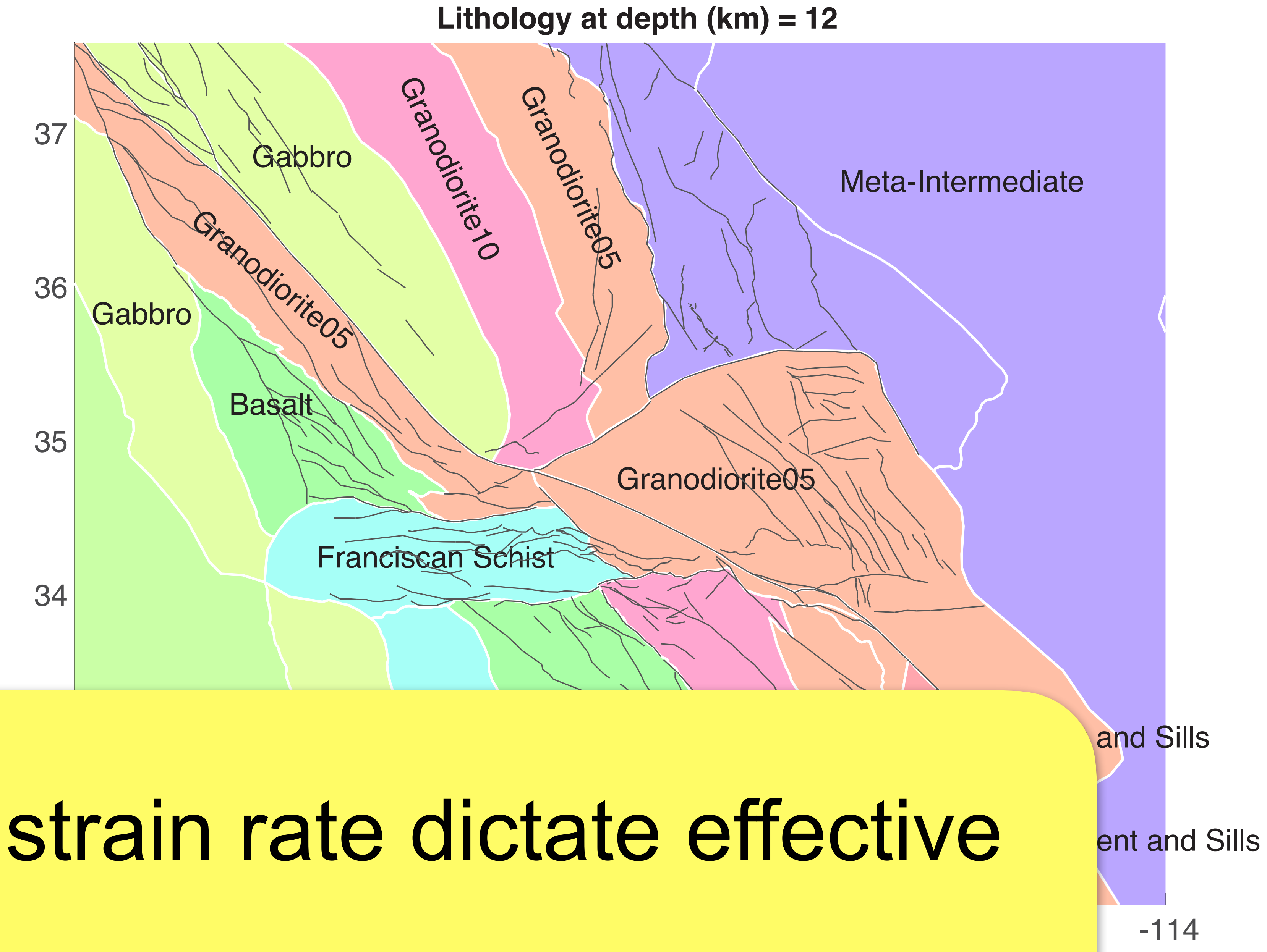
Provisional website is http://moho.scec.org/GFM_web/web/viewer.php

Upper crust effective viscosity (12 km)



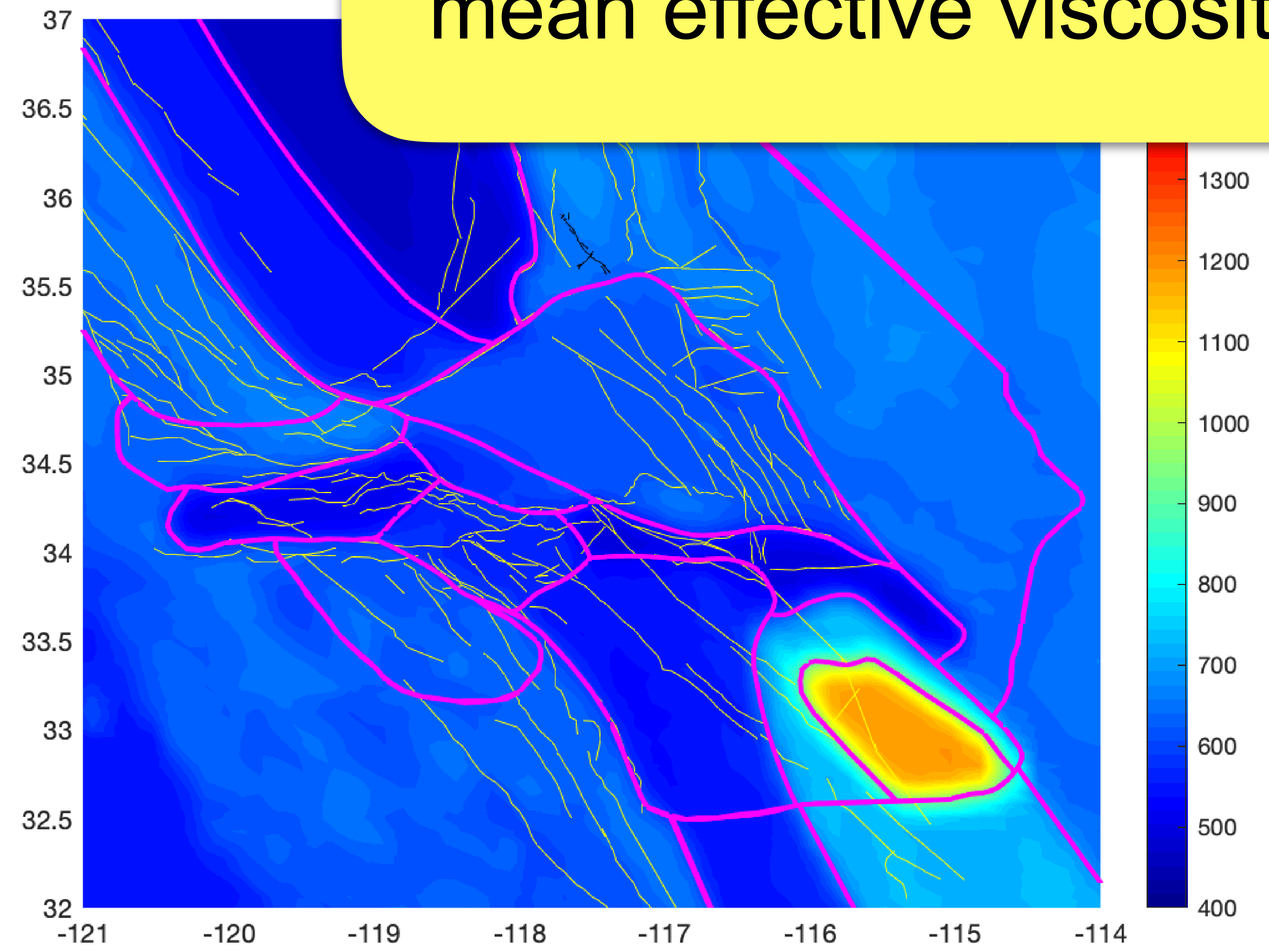
Upper crust effective viscosity (12 km)

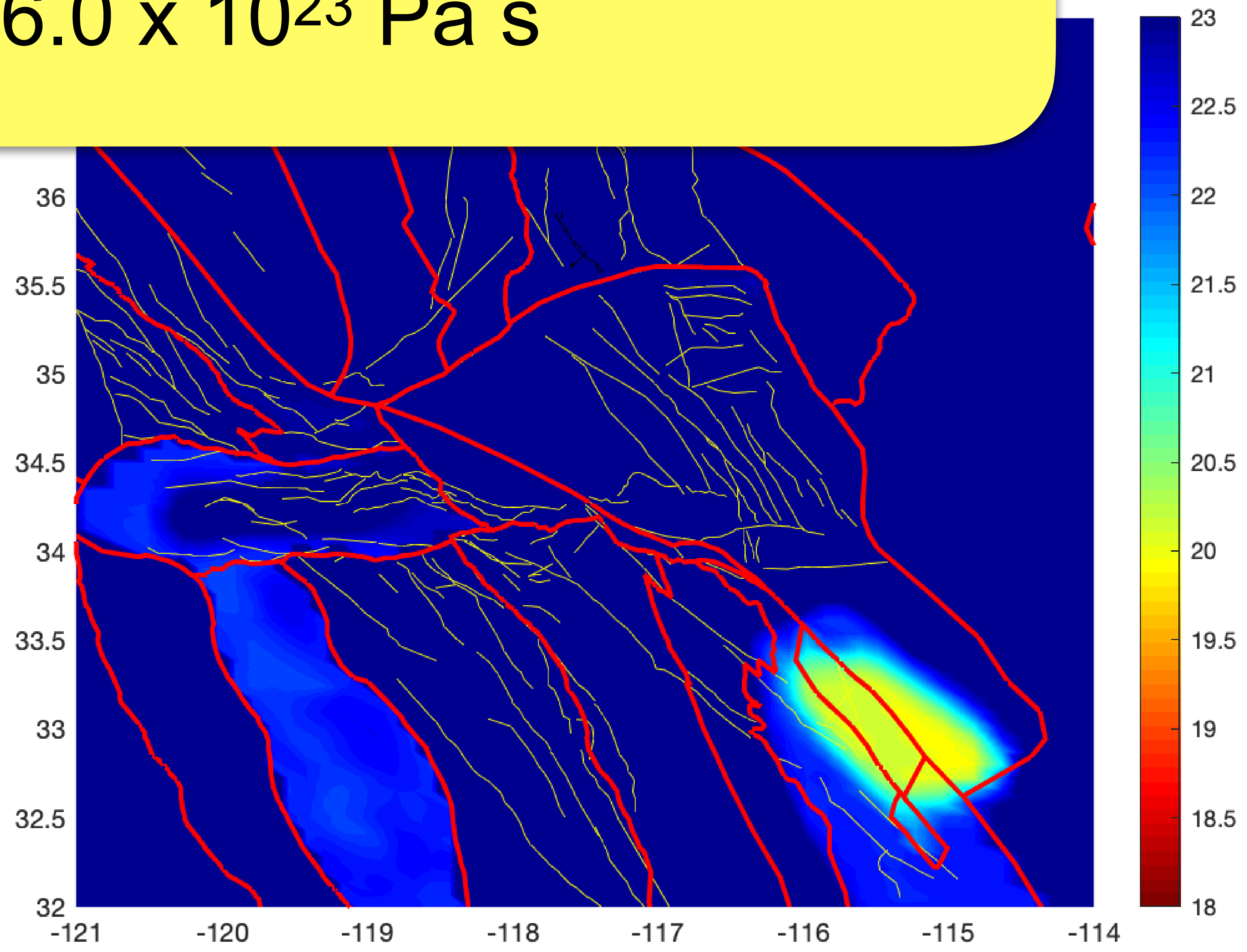




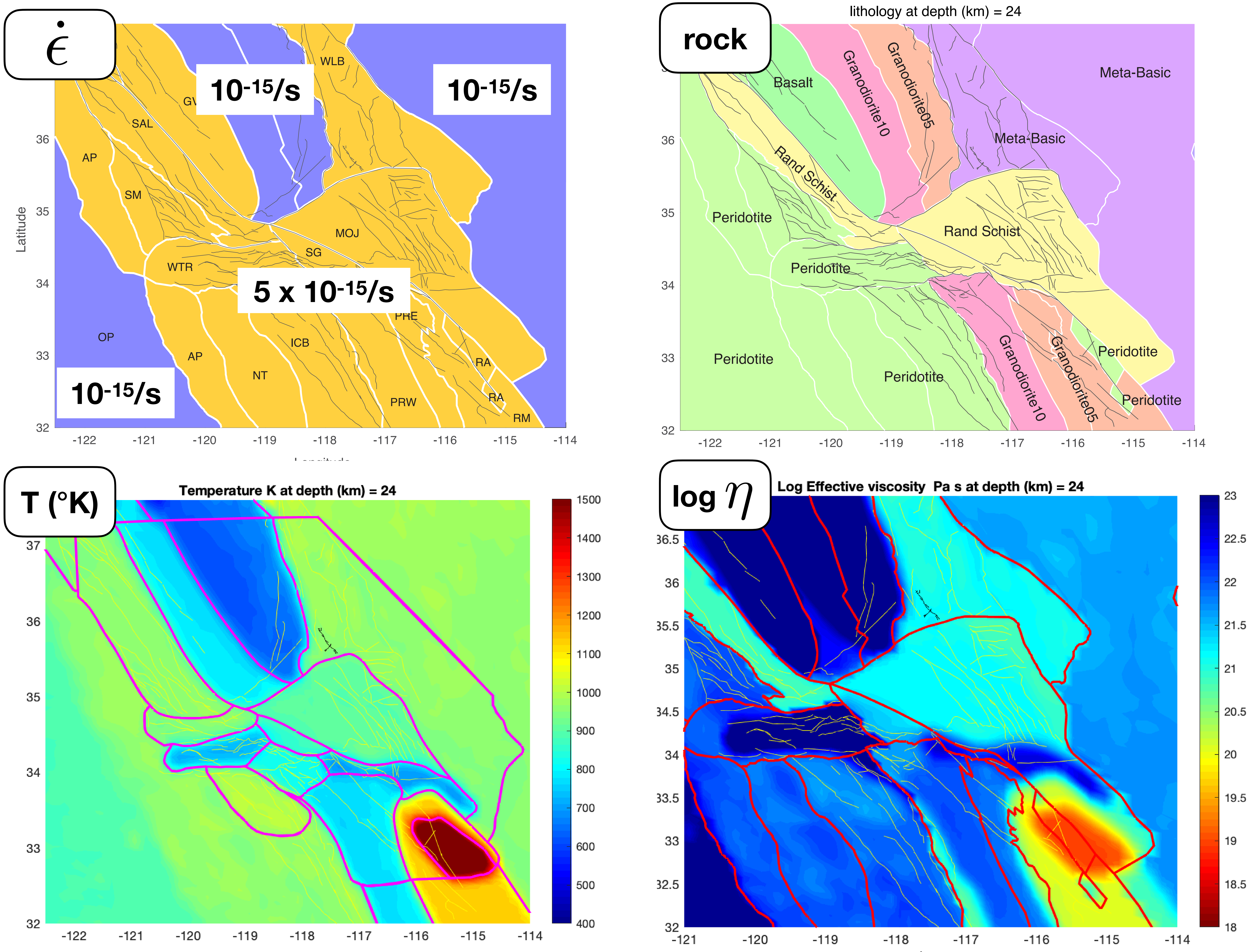
lithology, temperature and strain rate dictate effective viscosity patterns

mean effective viscosity = 6.0×10^{23} Pa s

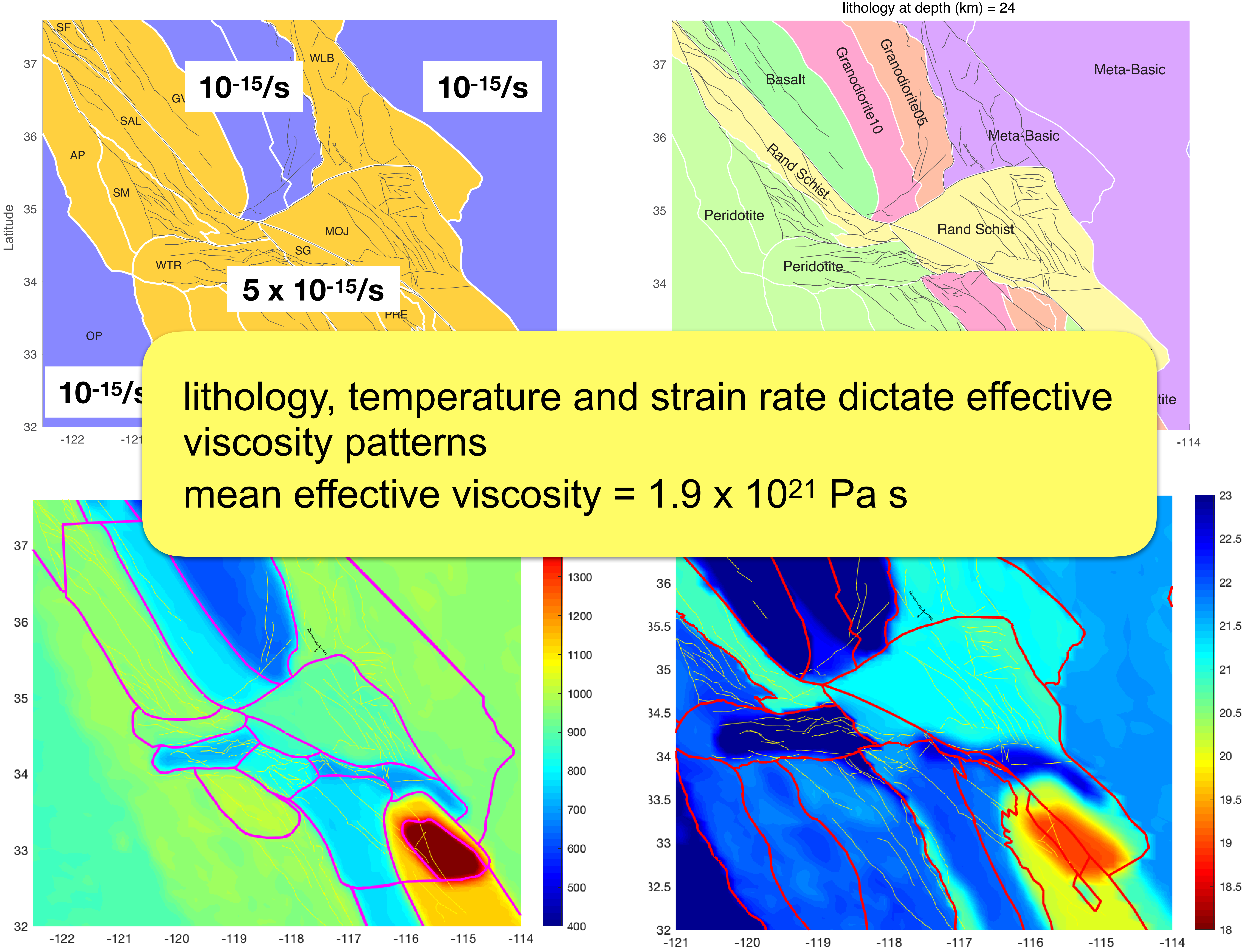




Lower crust effective viscosity (24 km)



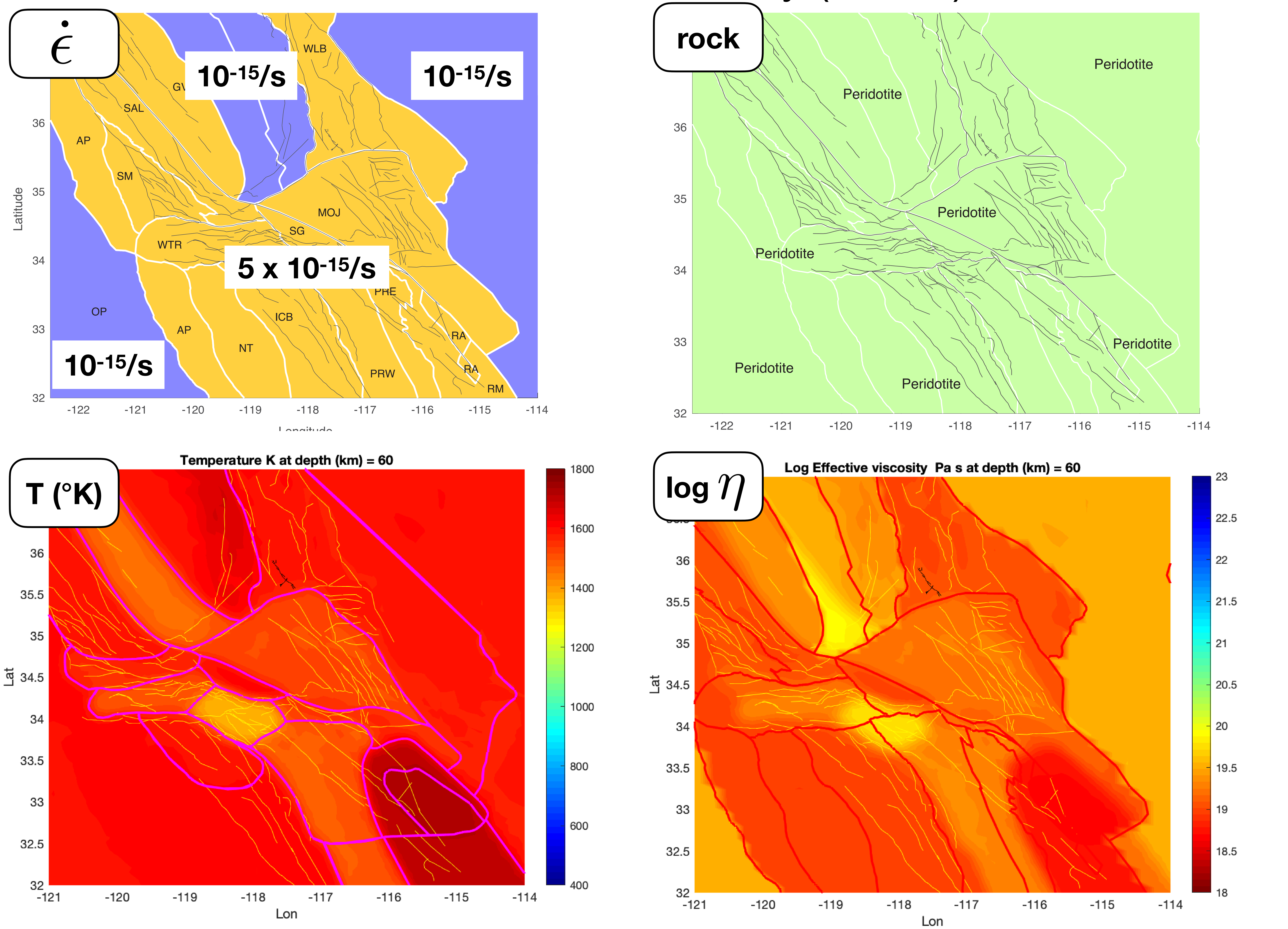
Lower crust effective viscosity (24 km)



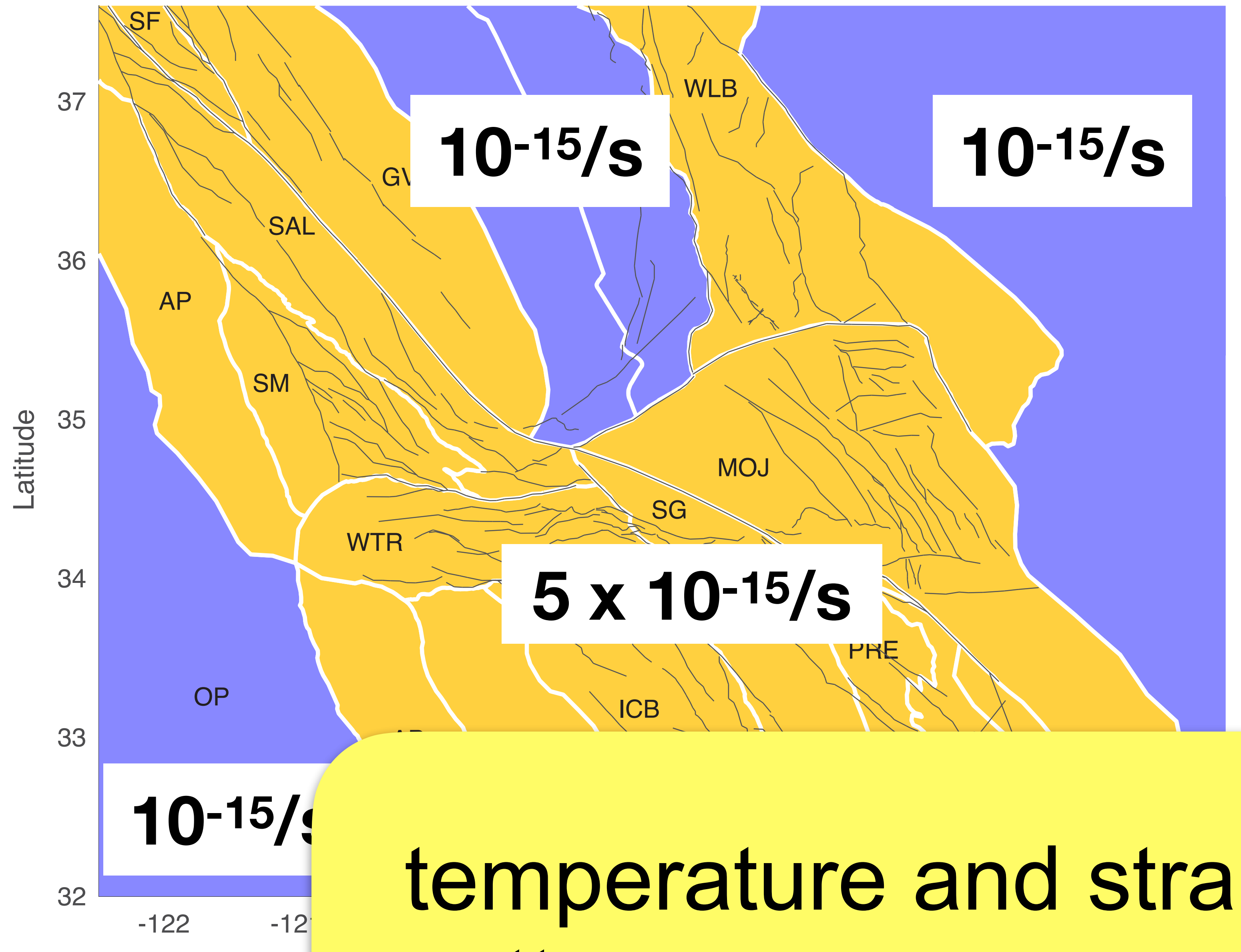
lithology, temperature and strain rate dictate effective viscosity patterns

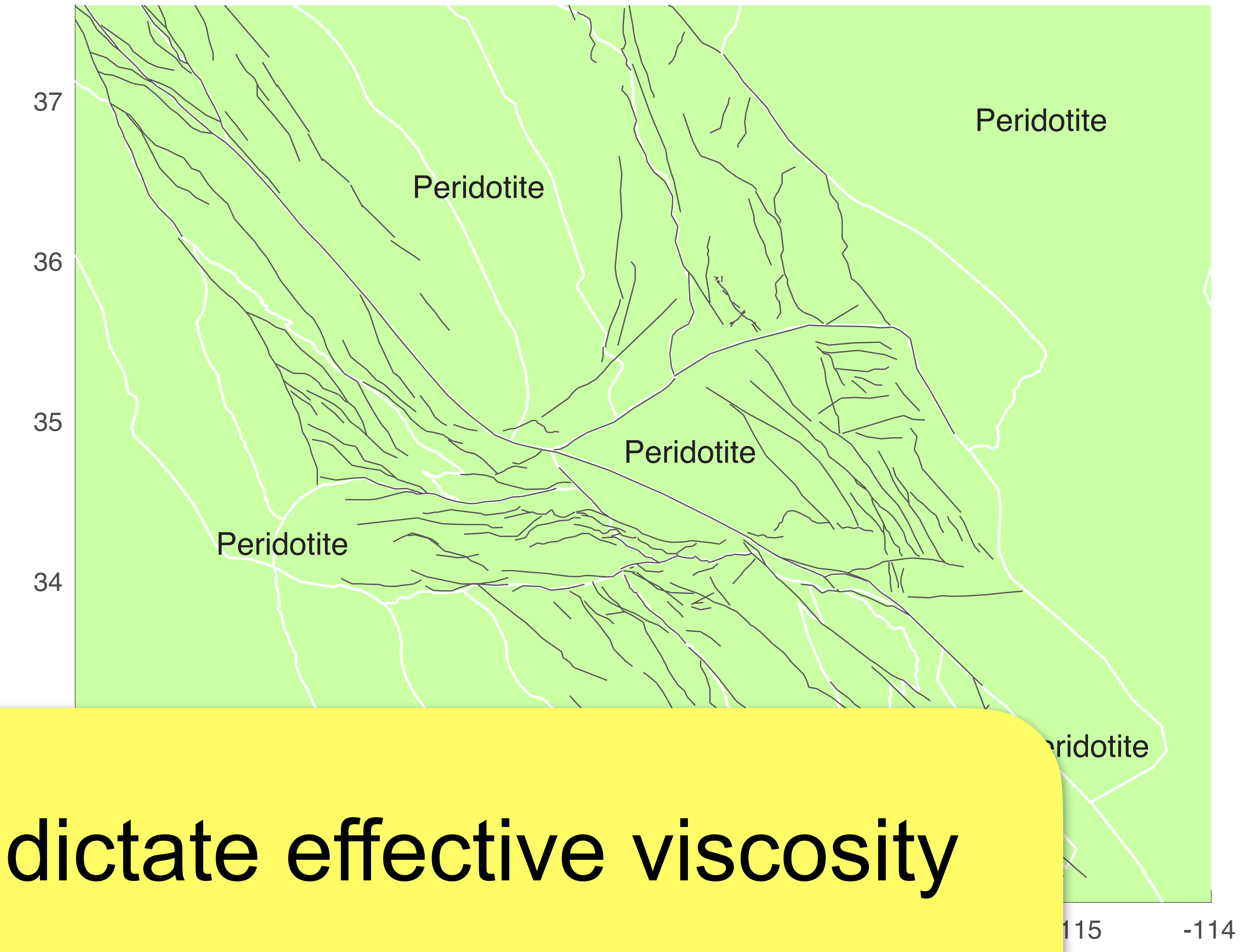
mean effective viscosity = 1.9×10^{21} Pa s

Mantle effective viscosity (60 km)



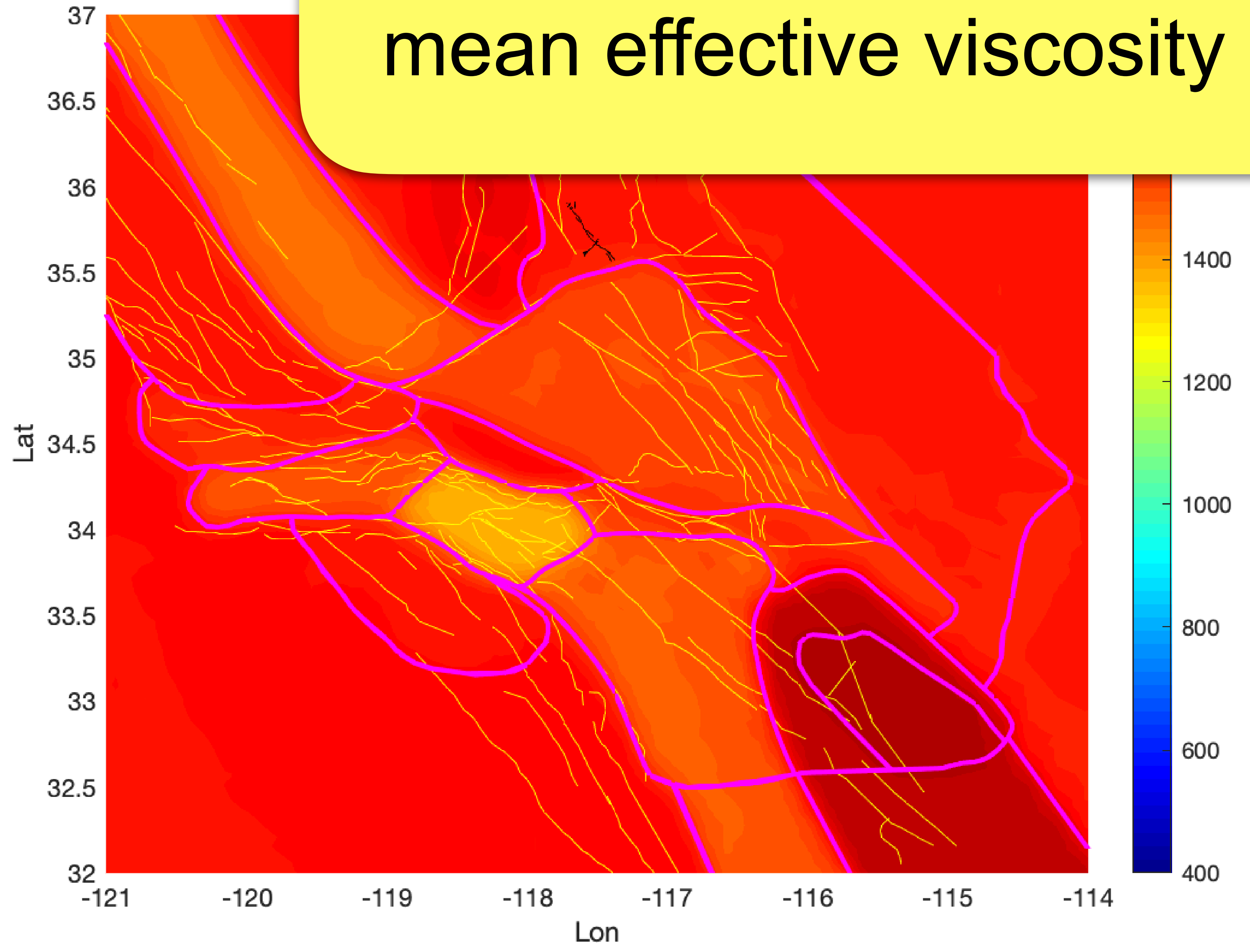
Mantle effective viscosity (60 km)

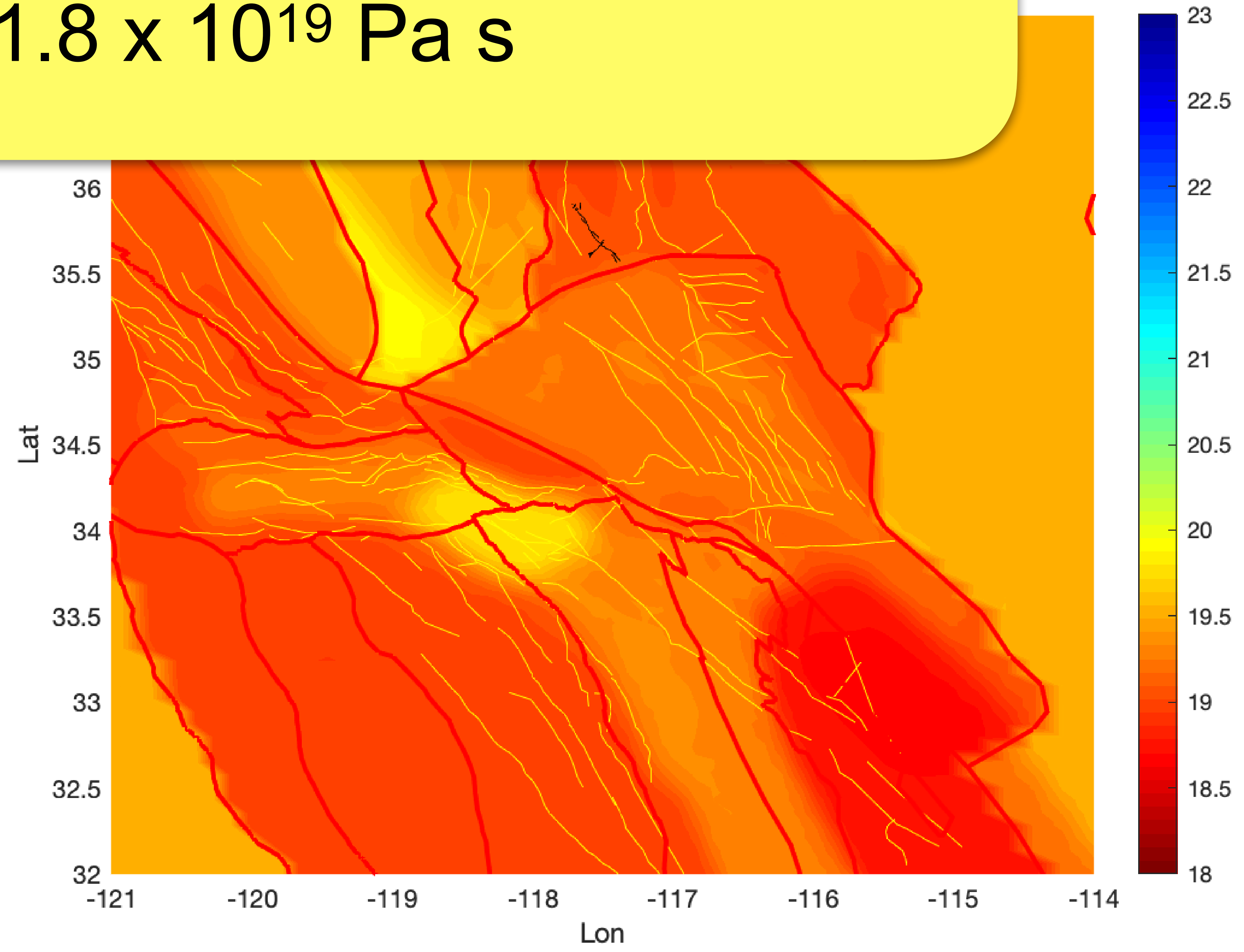




temperature and strain rate dictate effective viscosity patterns

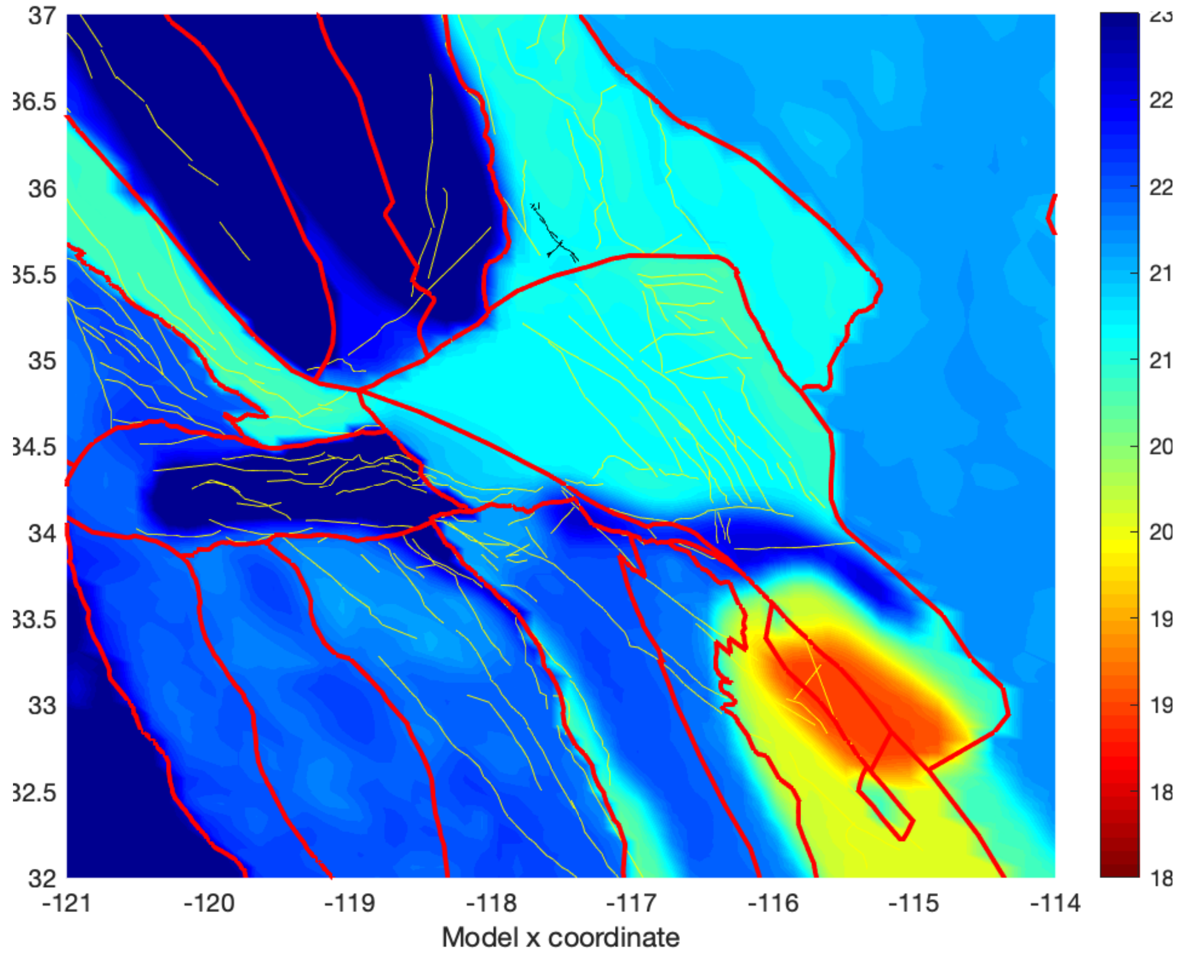
mean effective viscosity = 1.8×10^{19} Pa s



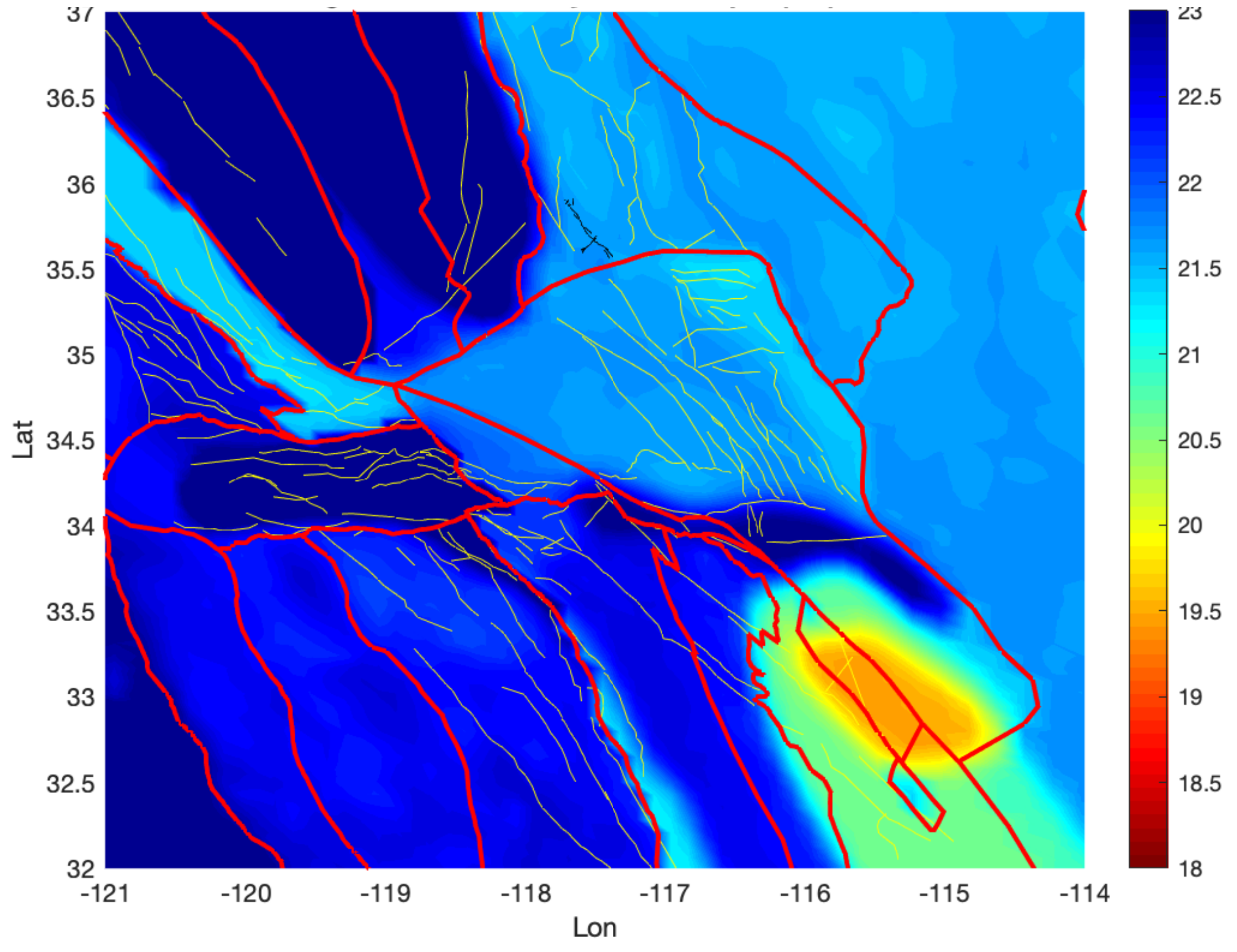


Viscosity at 24 km depth for various assumptions

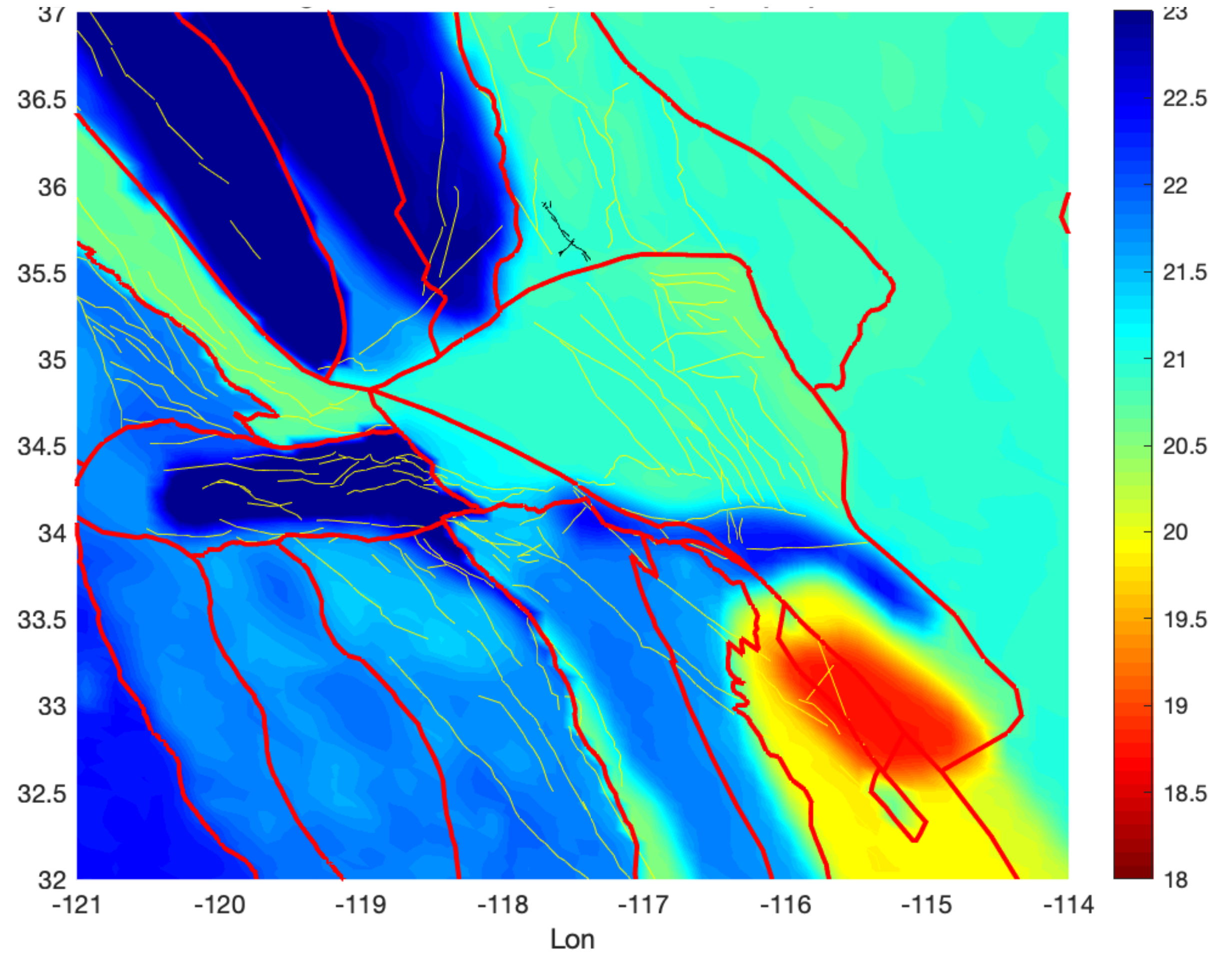
$\dot{\epsilon}$ = 10^{-15}/s and 5 x 10^{-15} /s



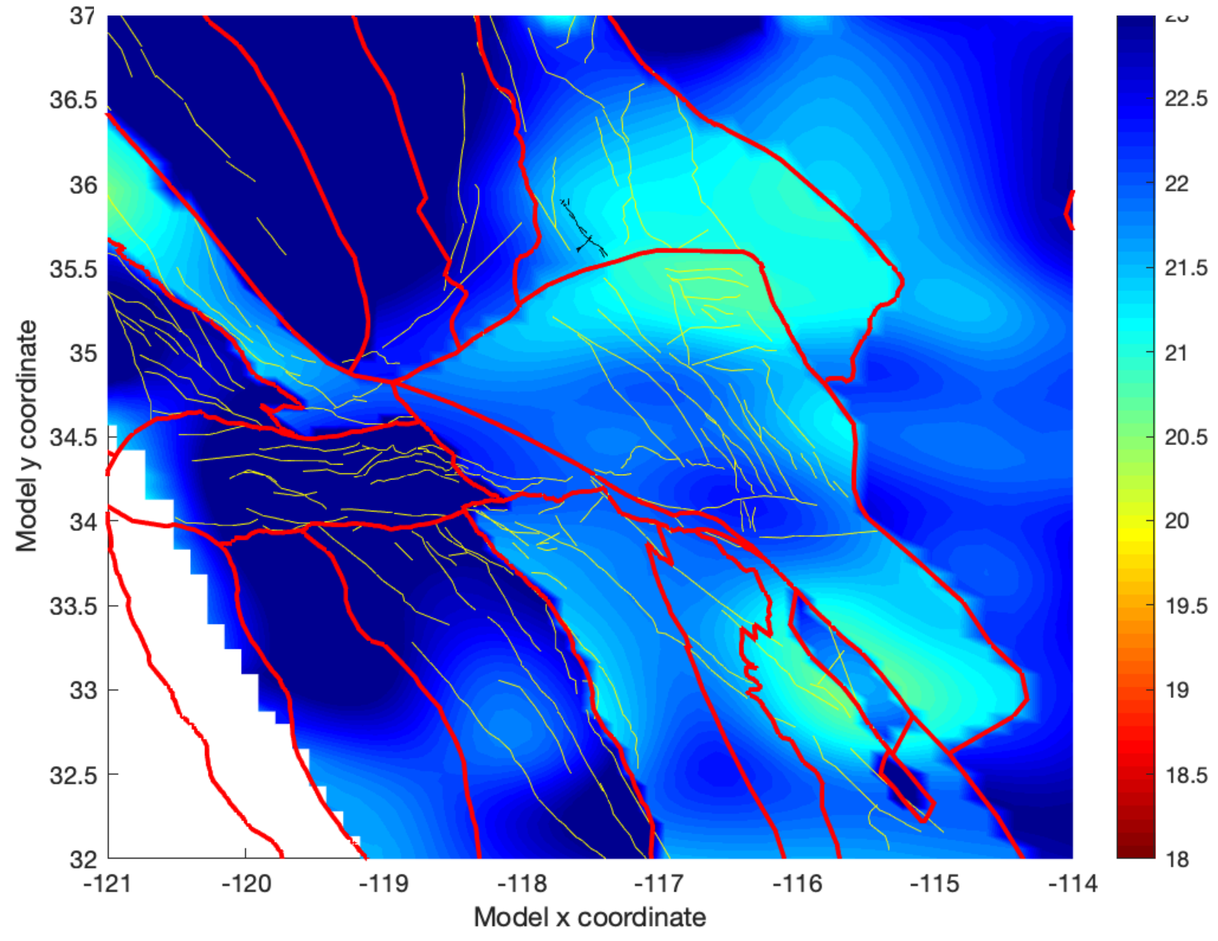
$\dot{\epsilon}$ = 10^{-15}/s



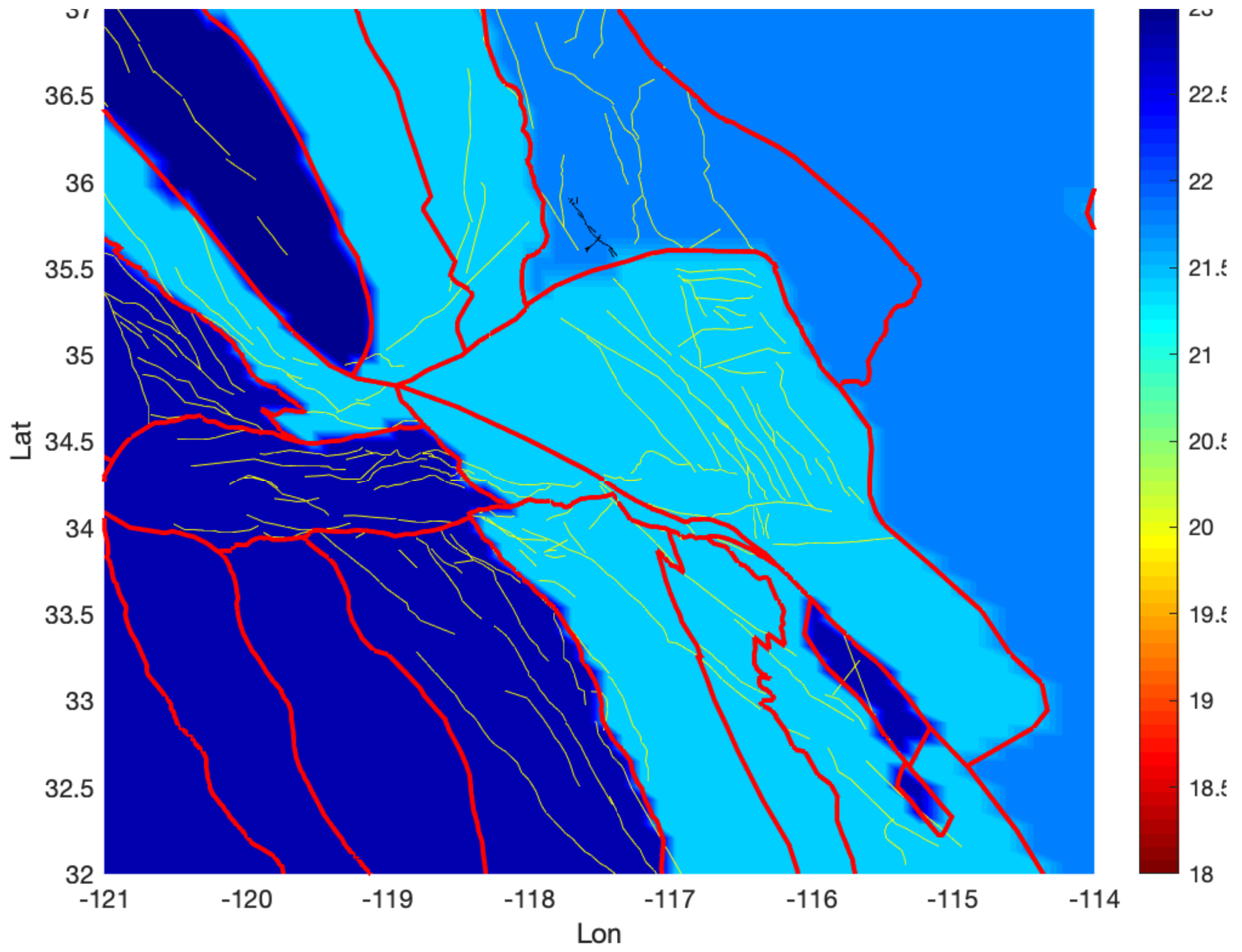
$\dot{\epsilon}$ = 10^{-14}/s



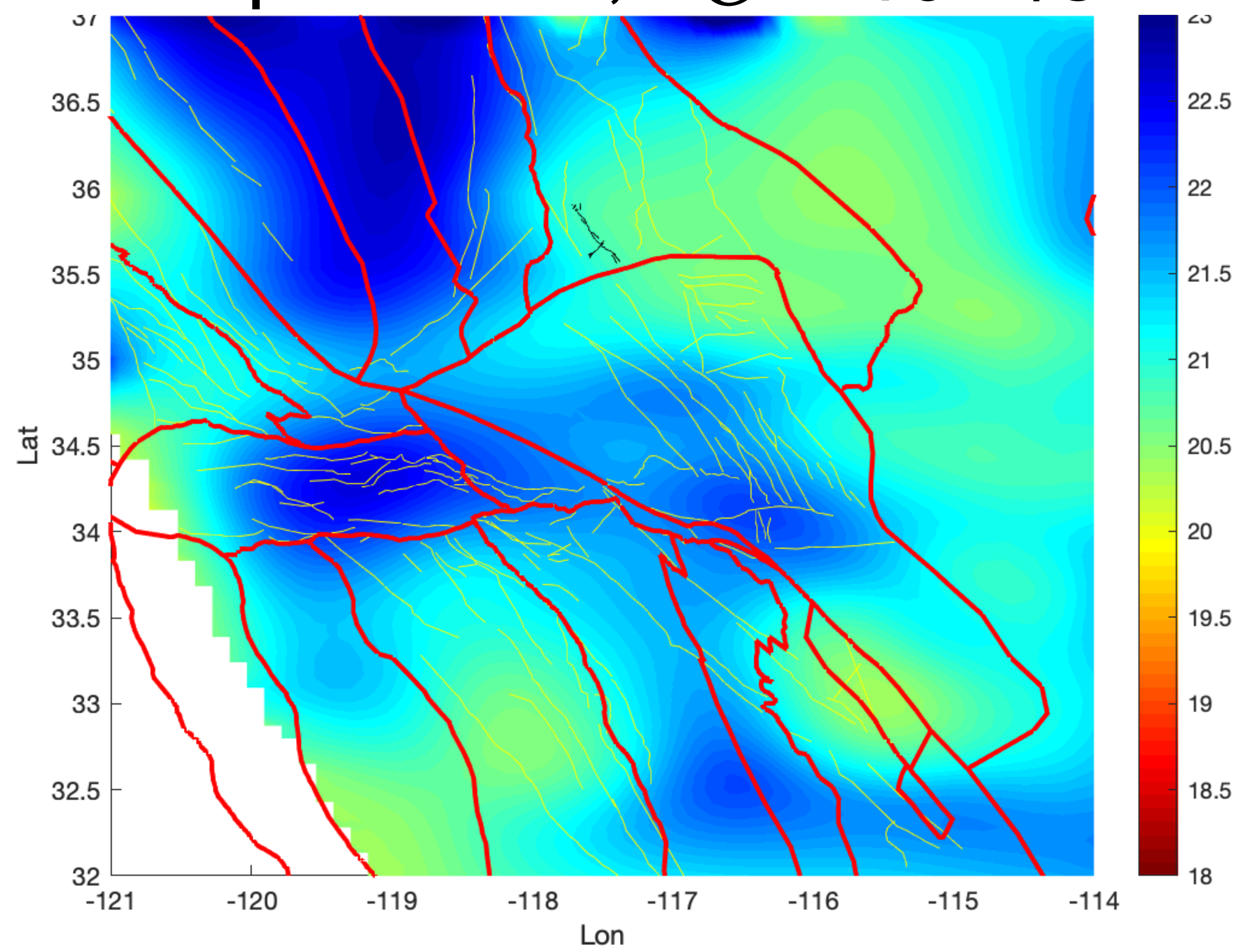
temperatures from Shinevar et al. 2018



Mojave CTM geotherm
$\dot{\epsilon}$ = 3 x 10^{-15} /s

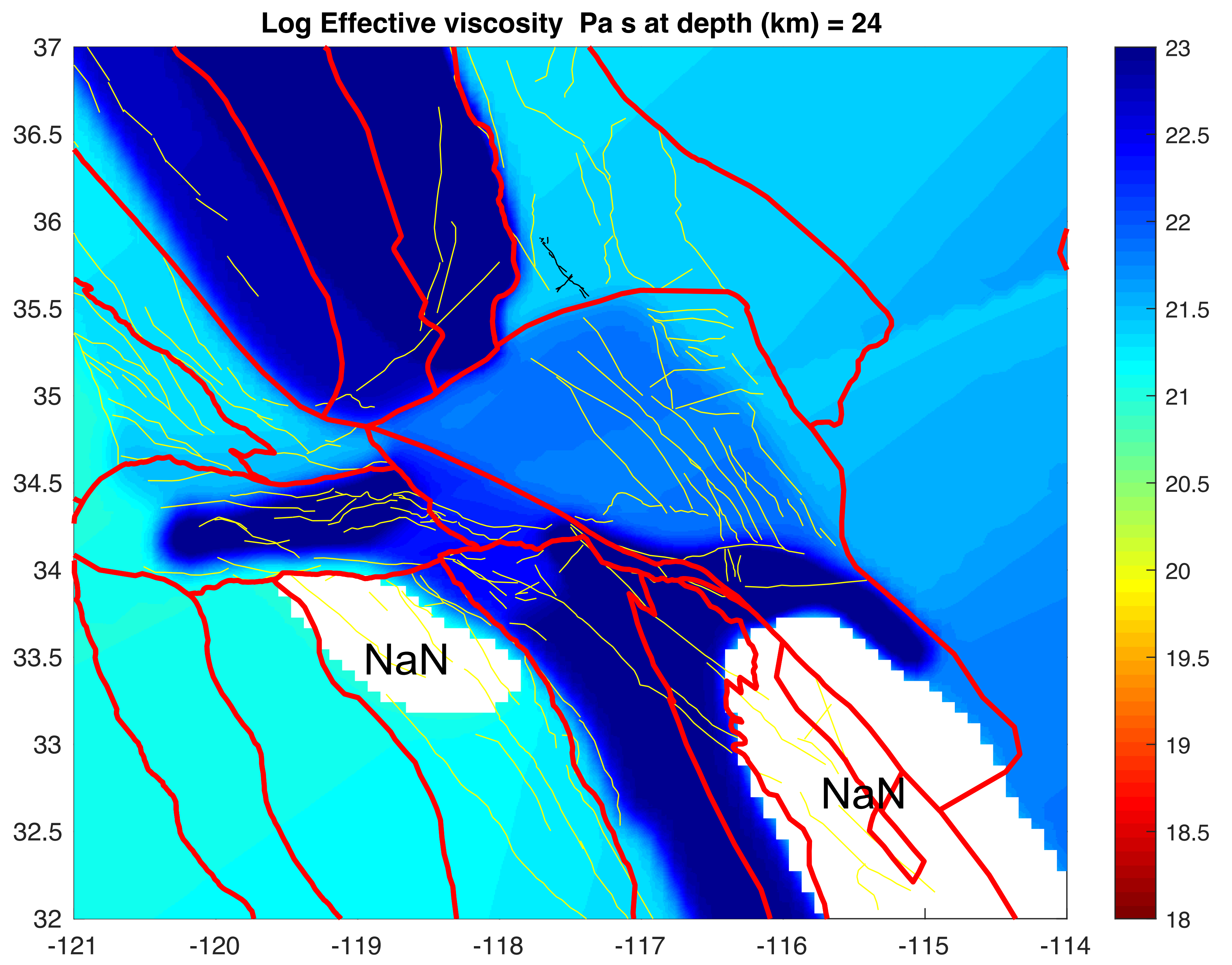


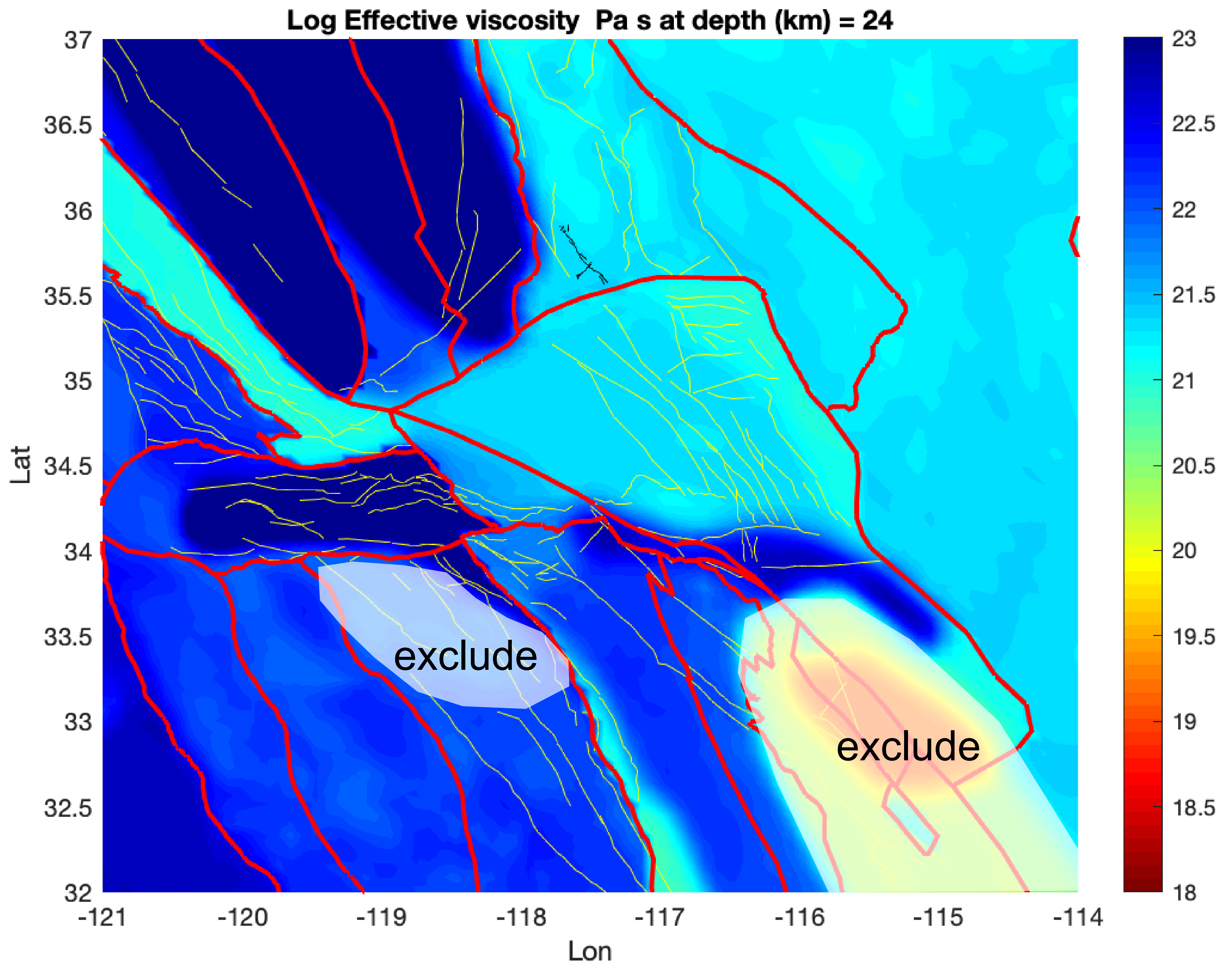
Mojave lithology, Shinevar temperatures, $\dot{\epsilon}$ = 10^{-14}/s



Comparison with viscosities inferred from seismic velocities

24 km depth, CTM temperatures, uniform strain rate of 3 x 10^{-15} /s





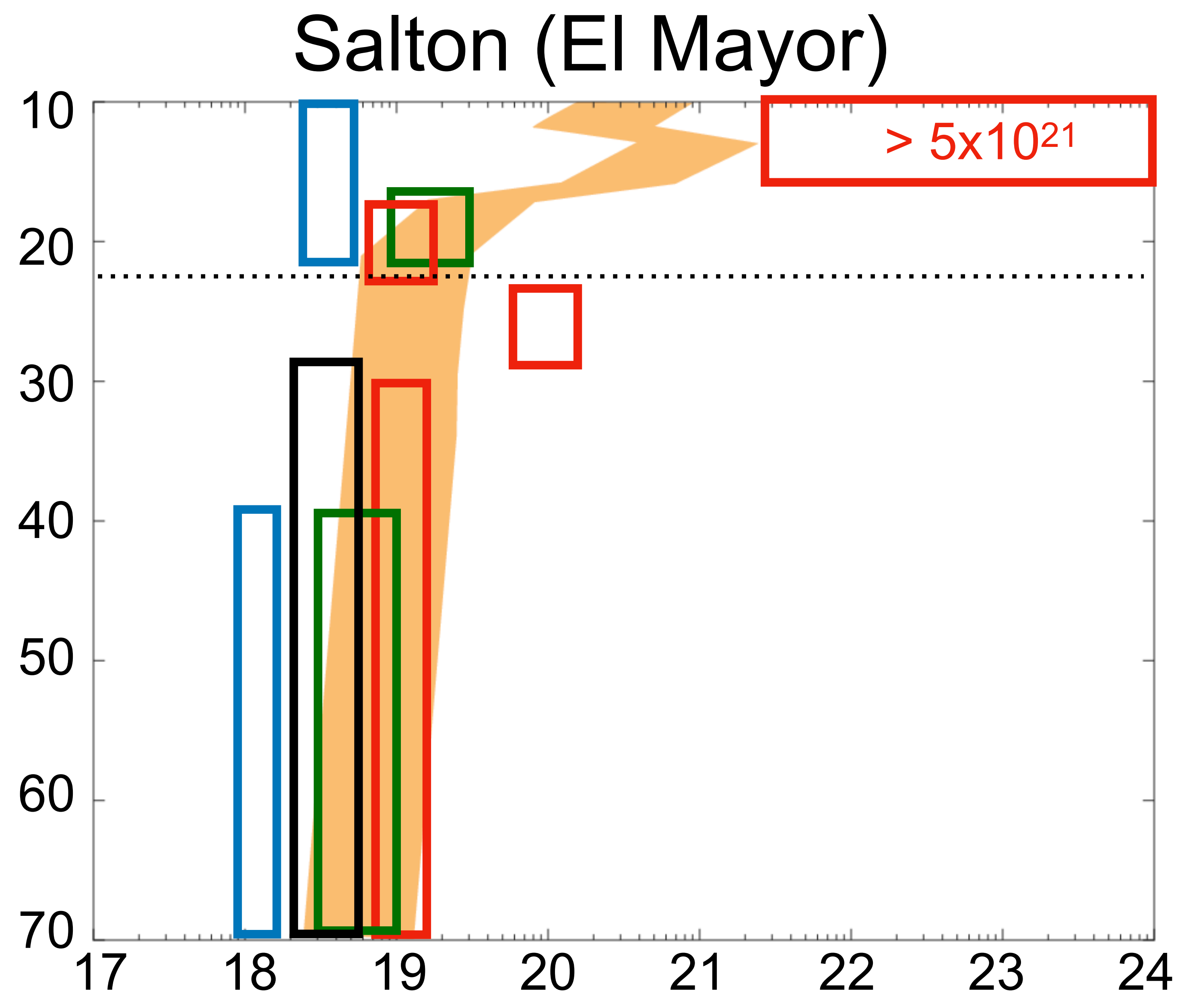
Shinevar et al. (2018)
viscosity from CVM at grid points

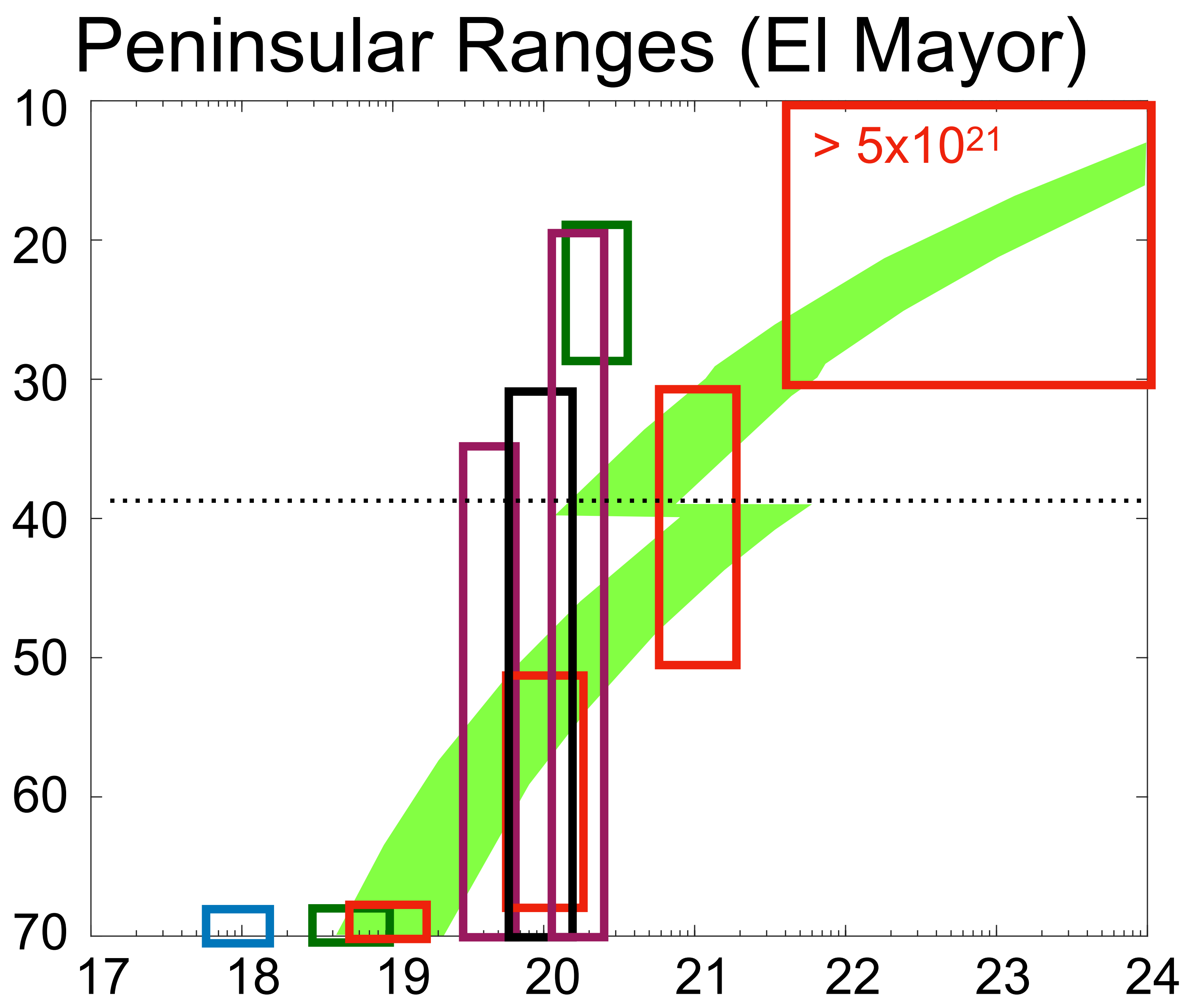
mean η = 7.31x 10^{21} Pa s
log η = 21.86 +- 0.88

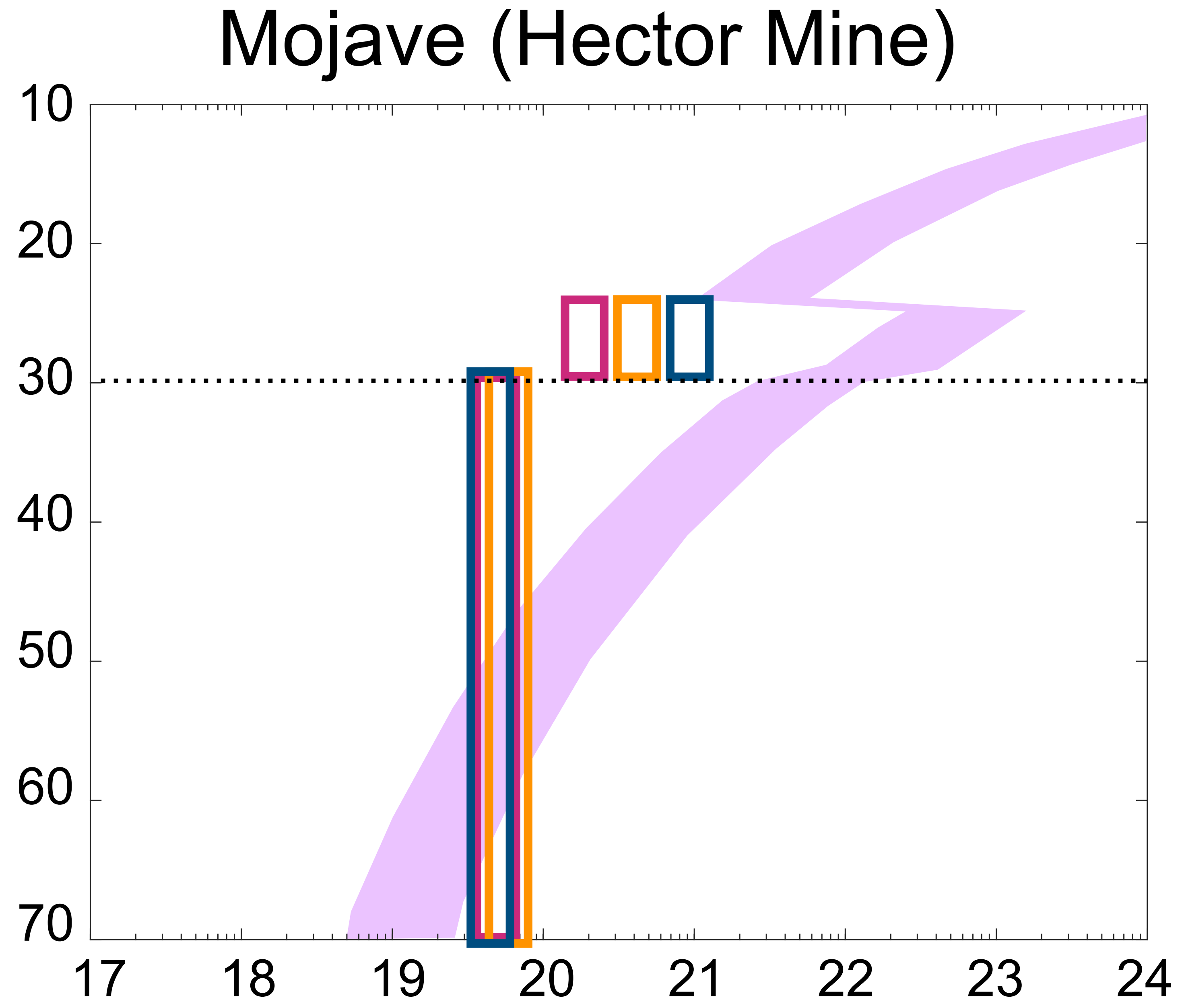
CRM, default parameters

mean η = 7.11 x 10^{21} Pa s
log η = 21.85 +- 0.92
(excluding NaN regions)

Comparison with postseismic deformation and surface unloading models







Liu et al., 2021

Tang et al., 2020 (Burgers case)

Freed et al., 2012

Pollitz et al., 2012

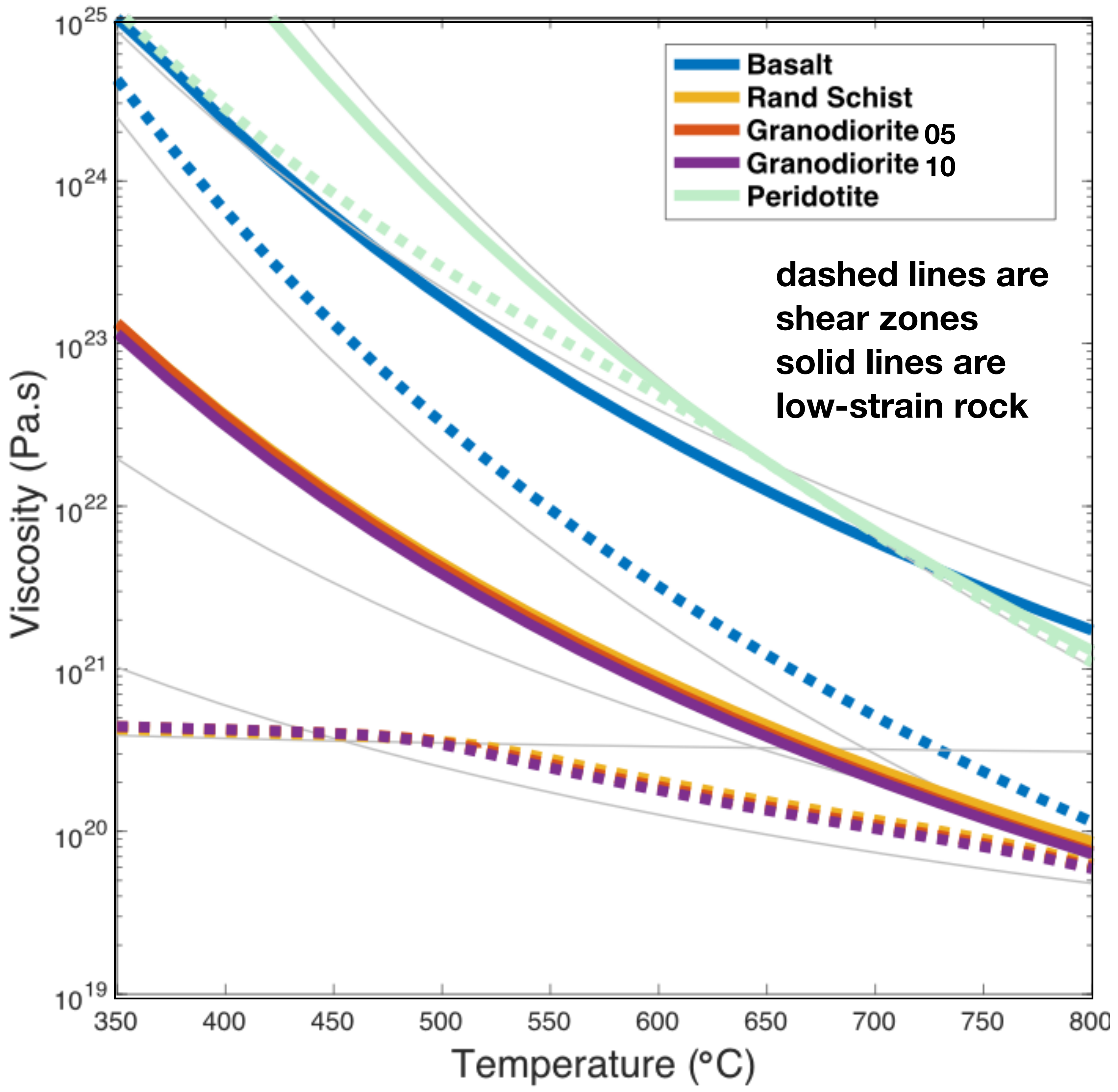
Pollitz, 2015

Rollins et al., 2015 (combo models 1 and 2)

Dickinson-Lovell et al., 2018, preferred model (6)

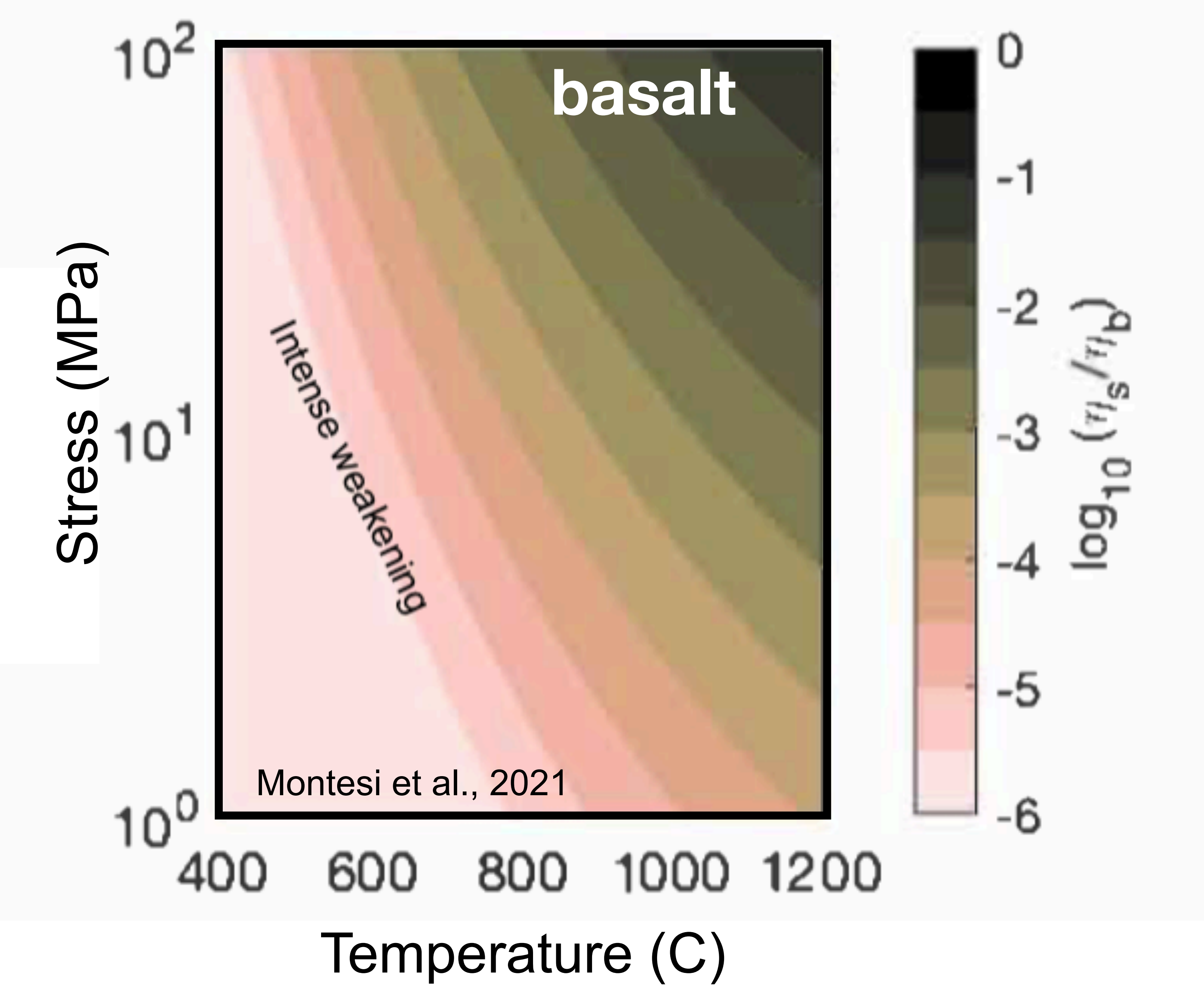
Luttrell et al., 2007 (two best)

CRM plans for the bridge period: implement viscous shear zones



Shear zone can be much weaker than low-strain rocks with same mineral content . One cause: foliation.

See **poster #018 (Montesi et al.)** for more info!



From the 2022 RFP:

"Develop strategy and workflow for implementing strain-dependent viscosity, shear zone grain size evolution, and shear zone width evolution in the CRM"

"Add representations of shear zones to the CRM based on simulations and constraints from natural examples"

More on shear zones: **poster #118, Robles et al.**

CRM plans for the bridge period

Refine and add to the CRM based on current gaps

- Improve representation of the mantle in the CRM (heterogeneity)
- Propose provisional bulk rock and fault zone rheologies for the upper crust.
- Provide guidance on transient rheology for ductile flow laws

Test the CRM and assess uncertainties and sensitivity to parameters

- Compare predicted seismic velocities for GF rocks with the SCEC CVM, and utilize velocity structure to extend the GF to a fully three-dimensional representation of crustal composition and infer the depth of the BPT throughout southern California.
- Characterize sensitivity of rock rheology to composition, water content, strain rate and temperature, in the context of the CTM and GF, to assess relative importance of these factors.
- Use deformation models to evaluate CRM effective viscosities against postseismic deformation CGM surface velocities, and the CSM.

https://www.scec.org/research/crm