Estimating lithospheric stress tensors in southern California by 2.5-D Shells F-E modeling

Peter Bird
UCLA

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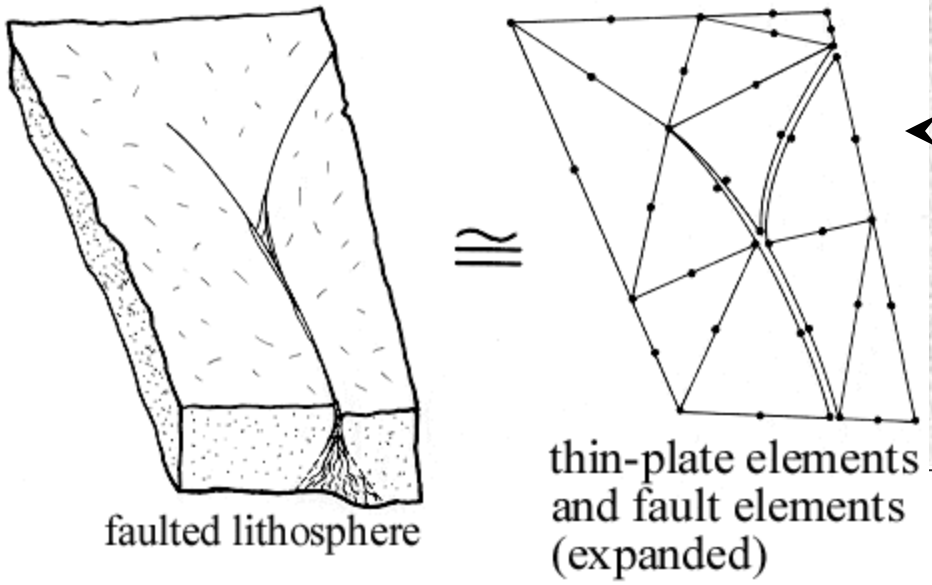
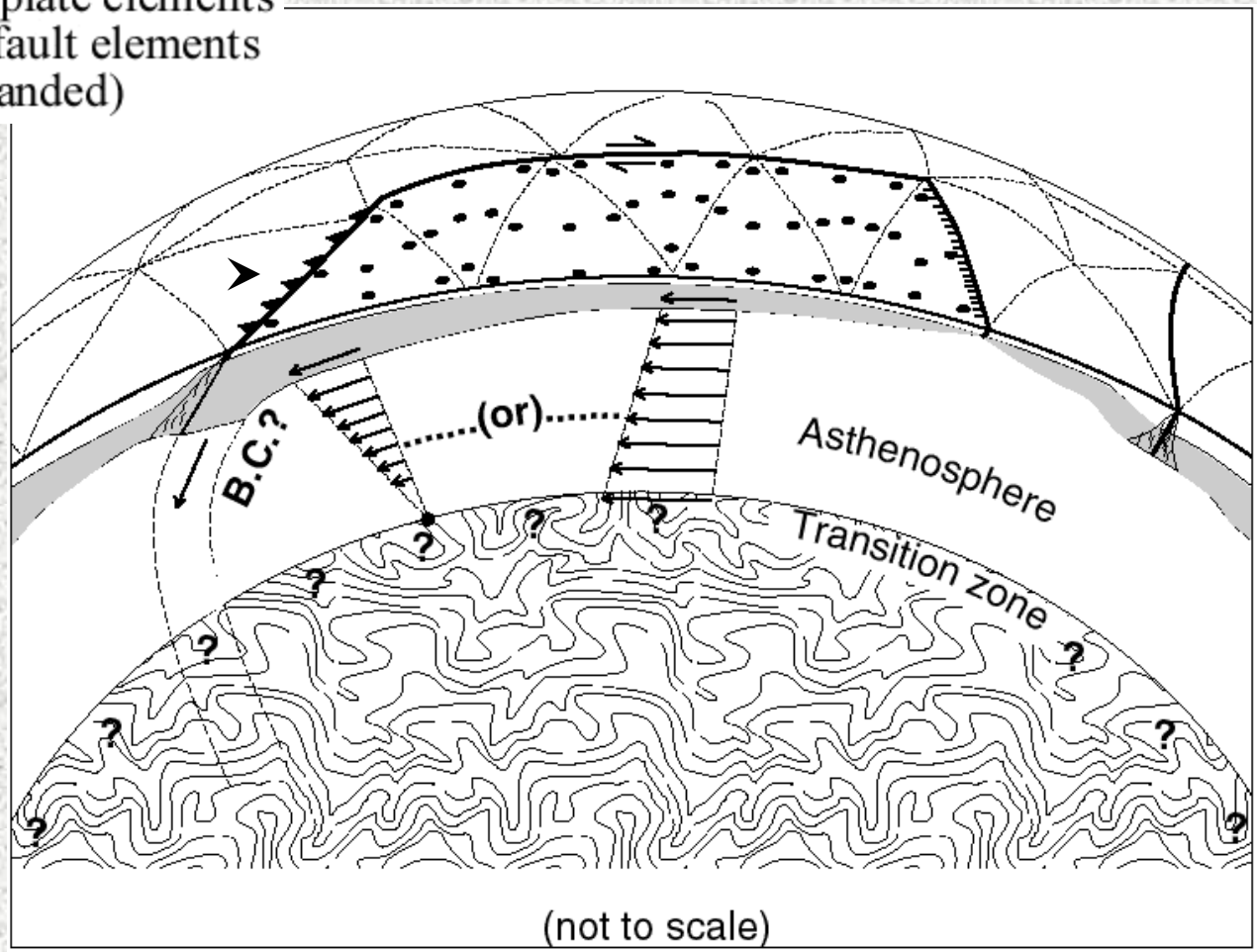
CSM workshop at SCEC, Los Angeles, CA

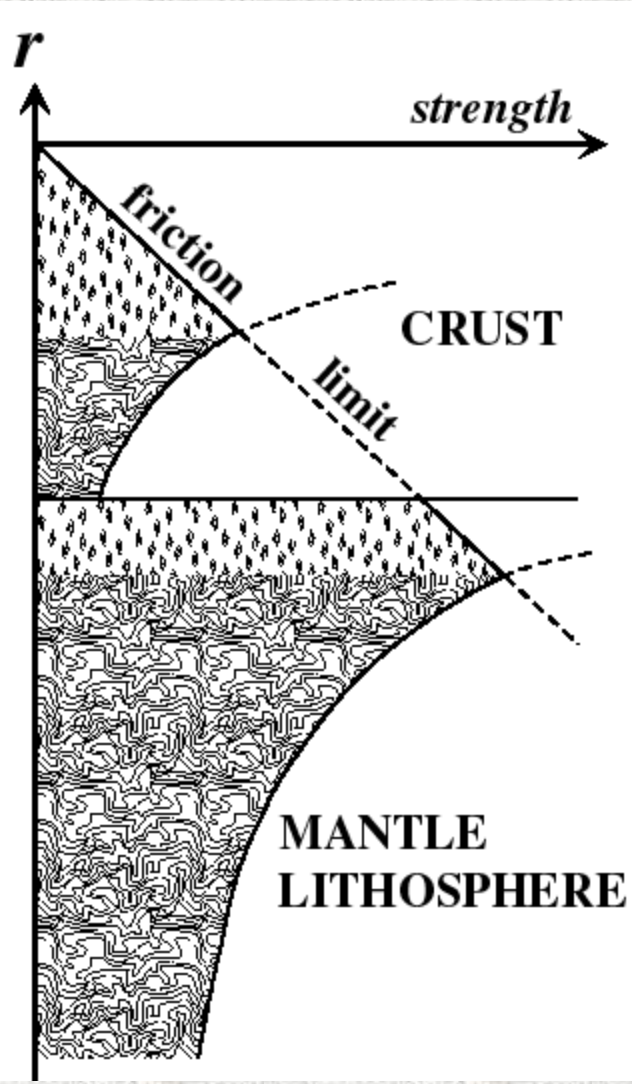


· "Thin-plate" or

"thin-shell" ·
F-E modeling:

Review paper:
Bird [1999, *Computers & Geosciences*]





Long-term rheology of lithosphere (ignoring any transient elastic strain):

Two layers, each homogeneous & isotropic:

- ❑feldspar-rich crust
- ❑olivine-rich mantle

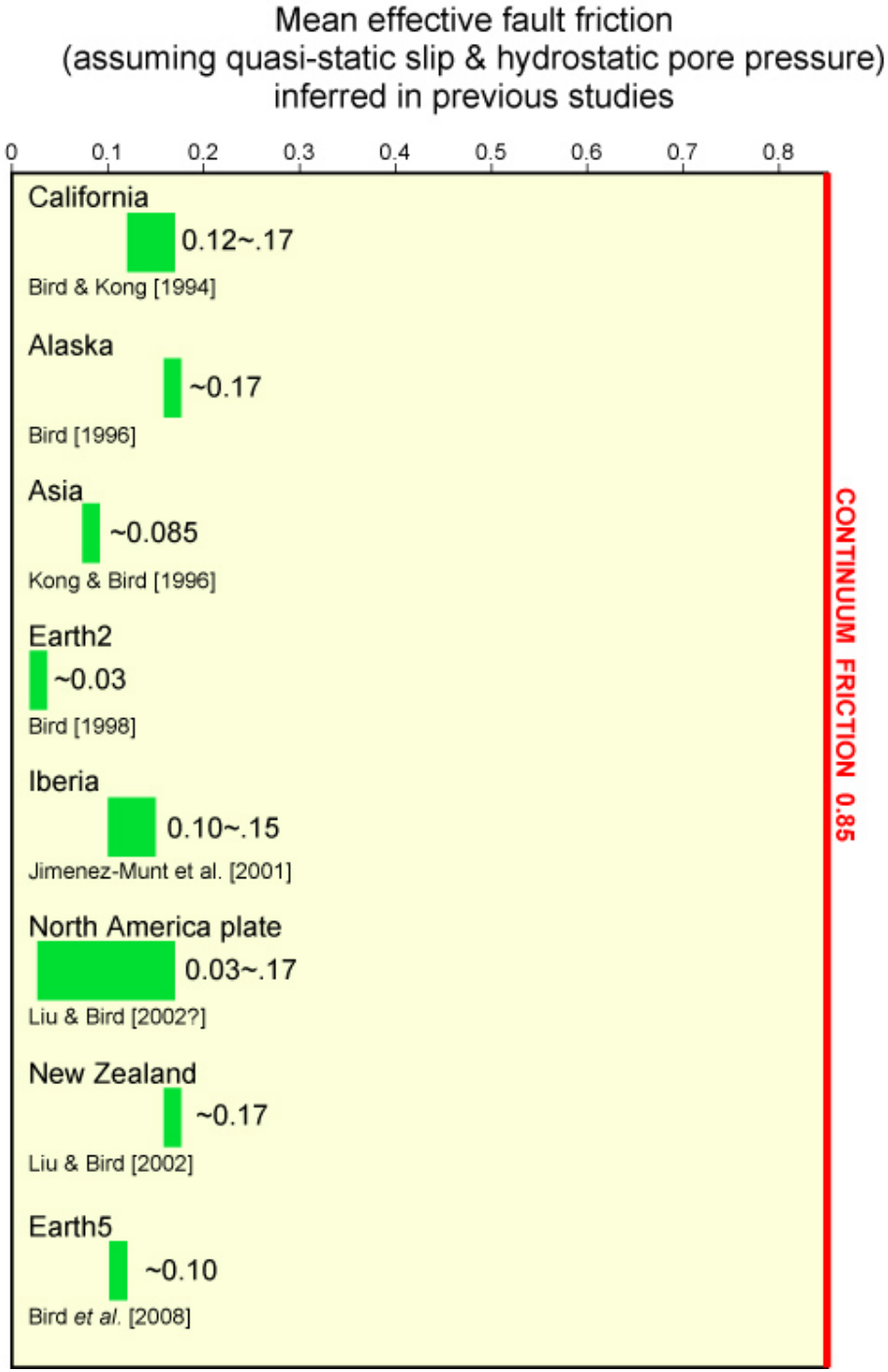
Two deformation mechanisms:

- ✓frictional plasticity (Coulomb-Anderson-Navier, both on & off designated faults)
- ✓thermally-activated dislocation-creep (with power-law exponent n = 3).

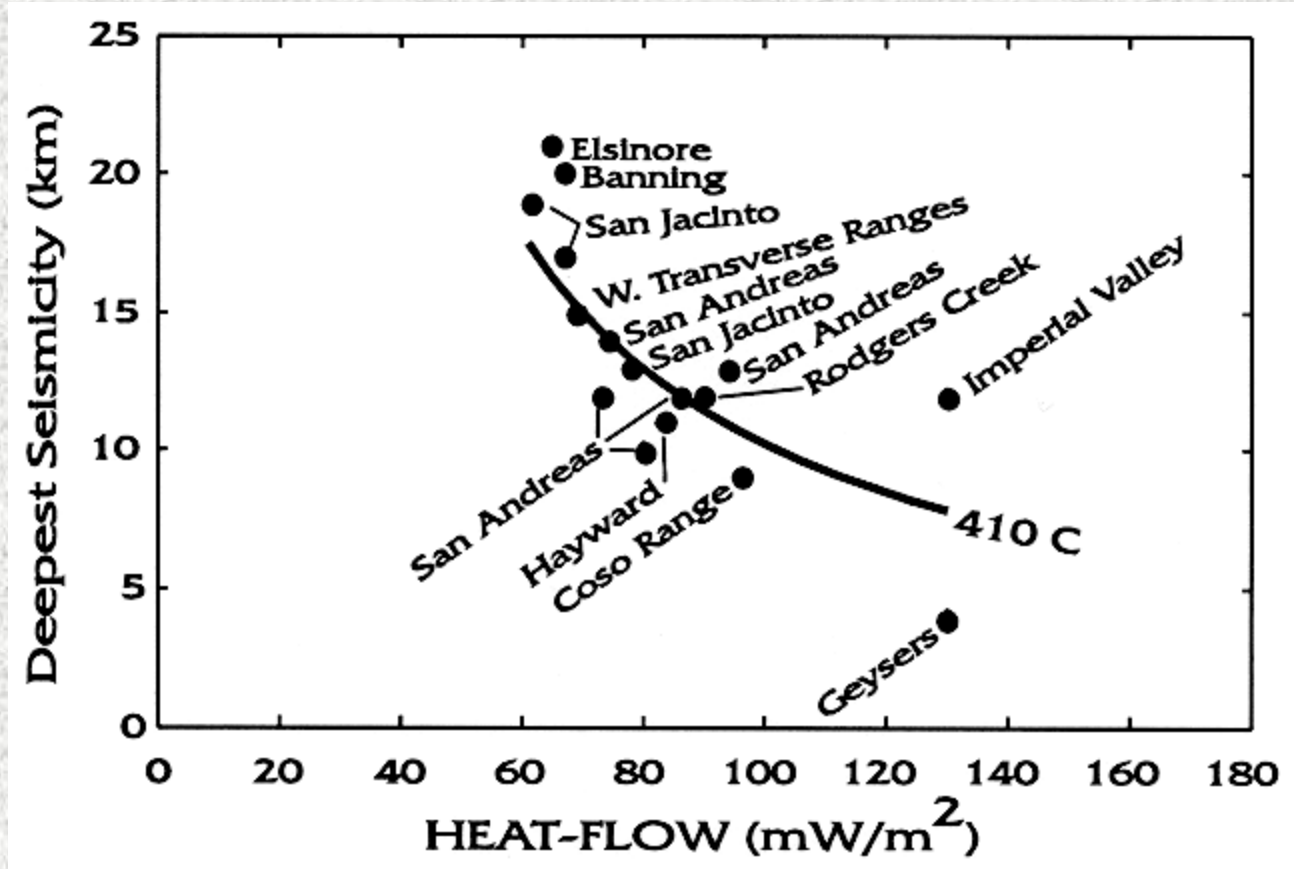
[Note: In my programs *Shells, Plates, & Faults,* the crust and mantle-lithosphere layers always move together; only *Laramy* allow independent tectonics. Hence, "2.5-D" modeling.]

The effective friction coefficient of the continuum (microplates) between the modeled faults is always 0.85, per "Byerlee's Law" [*Byerlee*, 1978, *Pageoph*].

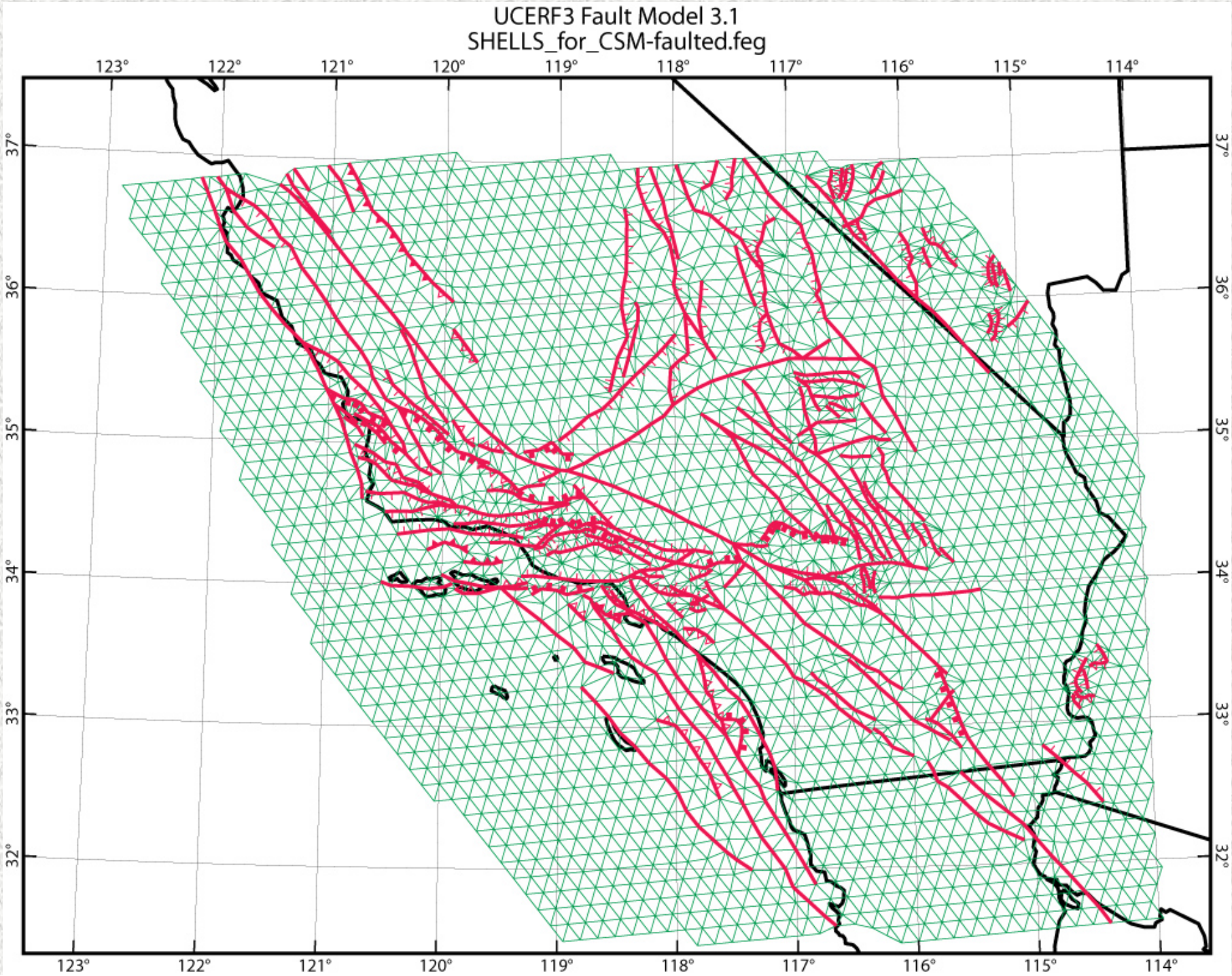
Effective friction of modeled master faults always needs to be lower for a good simulation; today I will show a model using effective friction of 0.15 on faults.

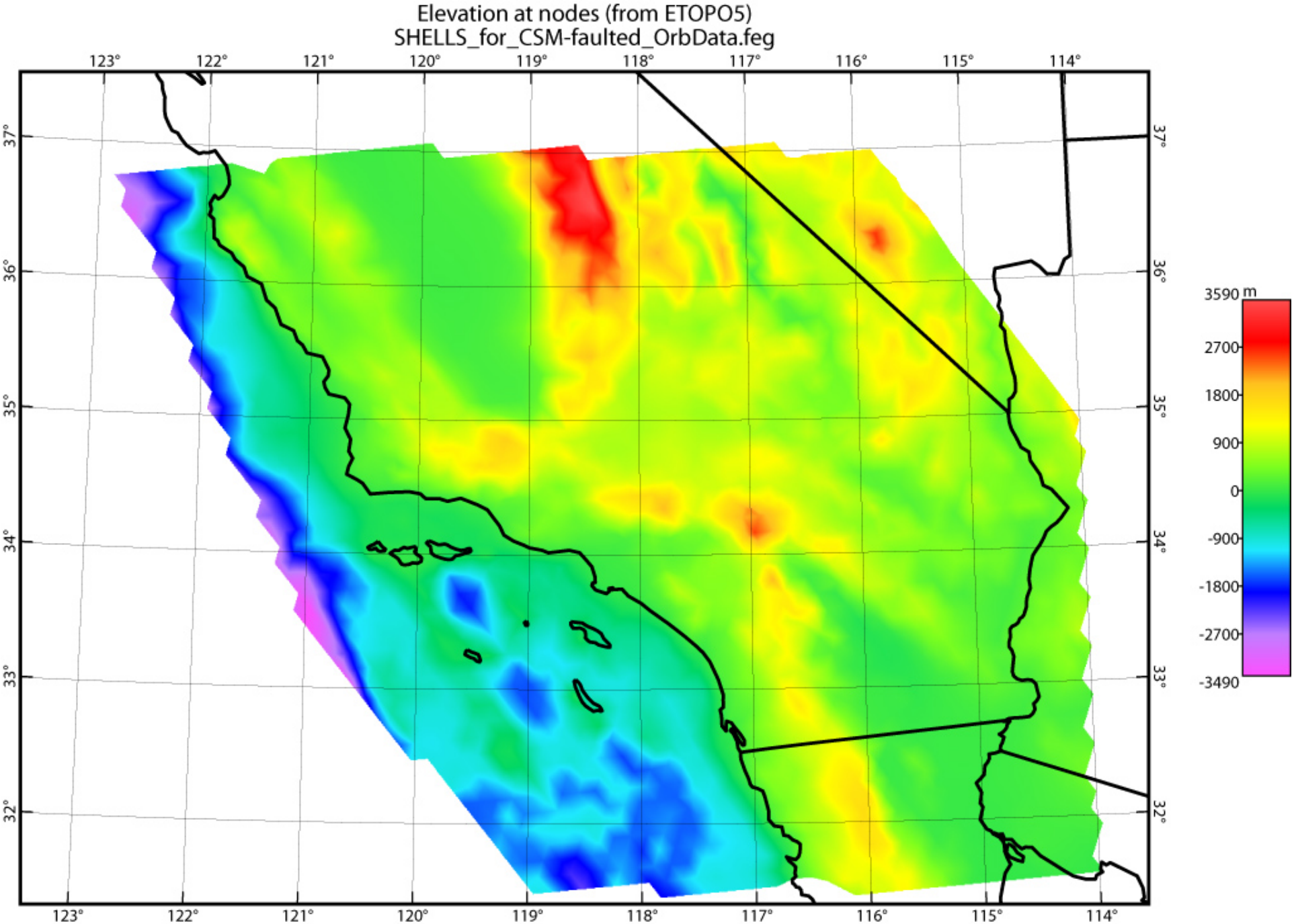


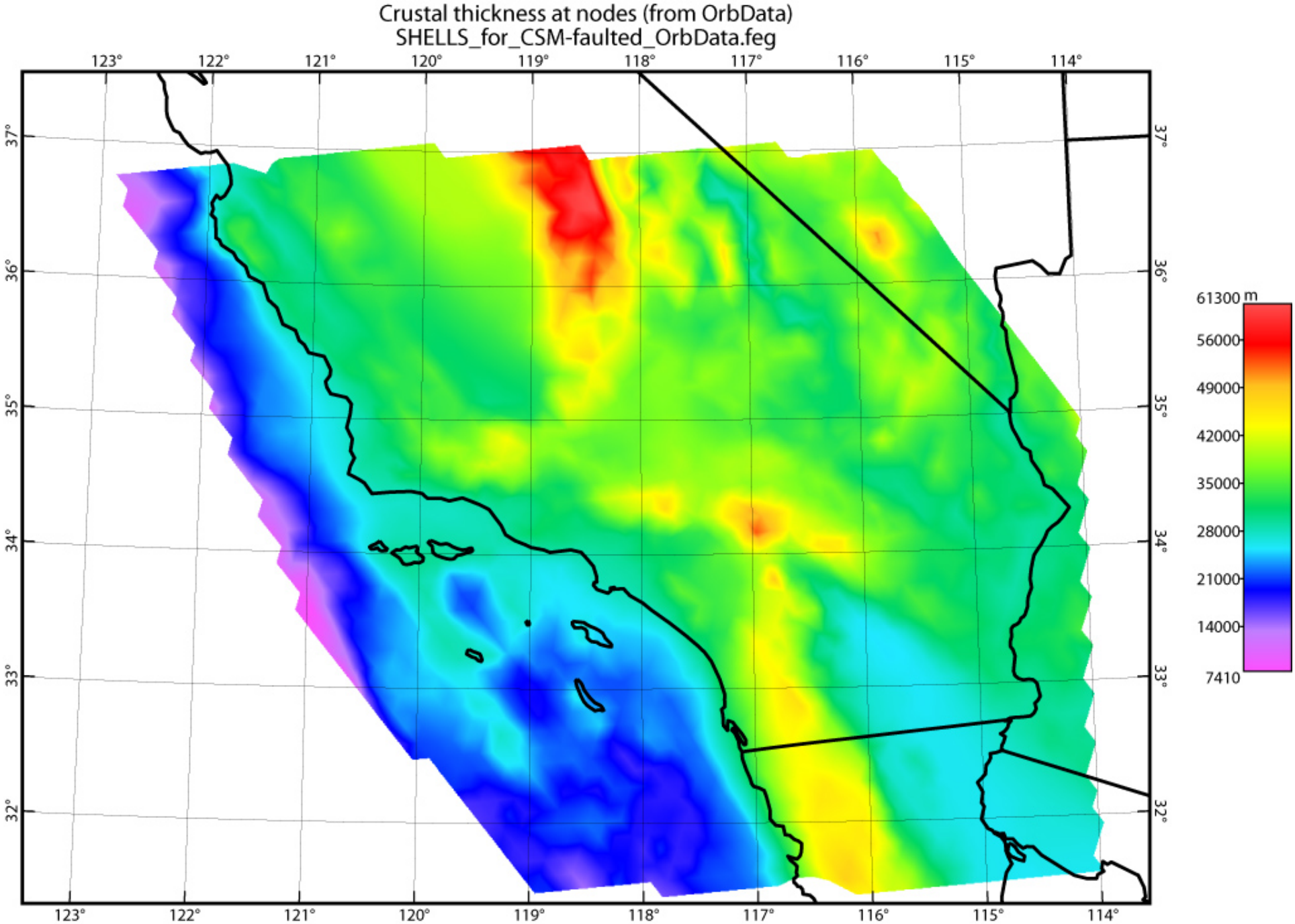
In *Bird & Baumgardner* [1984, *GSAB*] we calibrated the crustal creep strength by matching observed depths of seismicity in California, as a function of heat-flow:

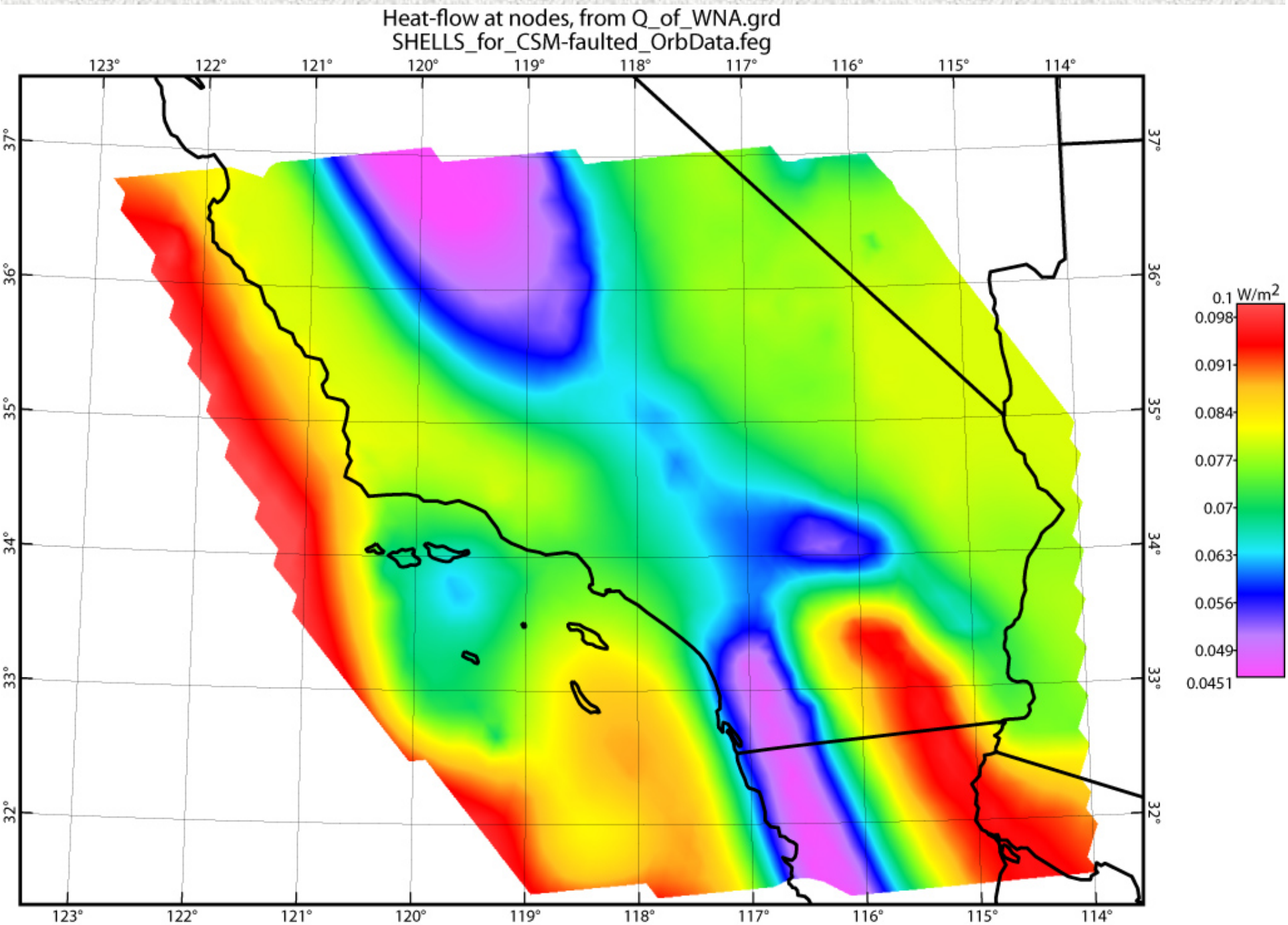


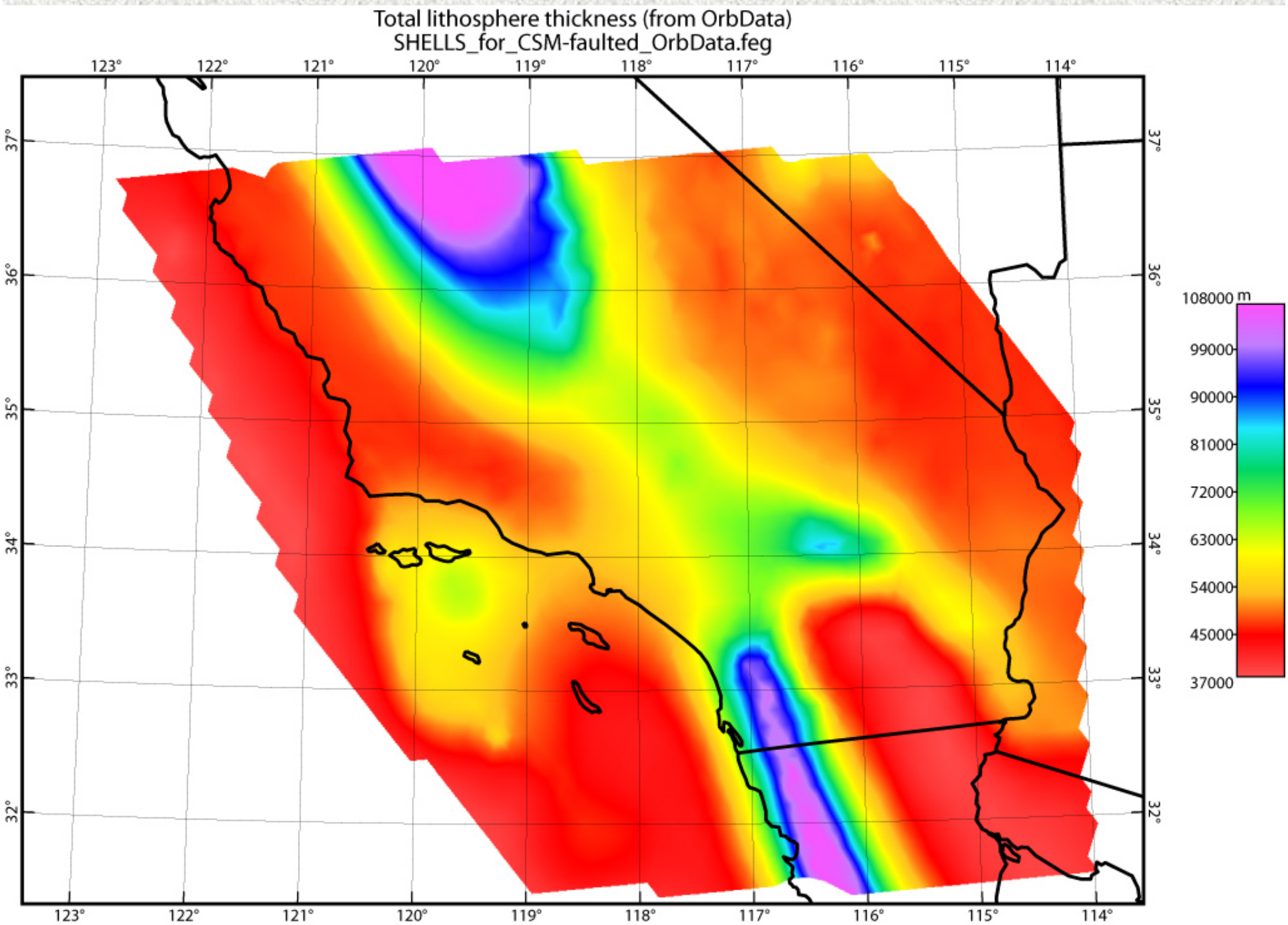
Creep strength of the mantle-lithosphere is from olivine lab studies [*Kirby*, 1983, *Rev. GSP*; *Kirby*, 1985; *Tectonophysics*].

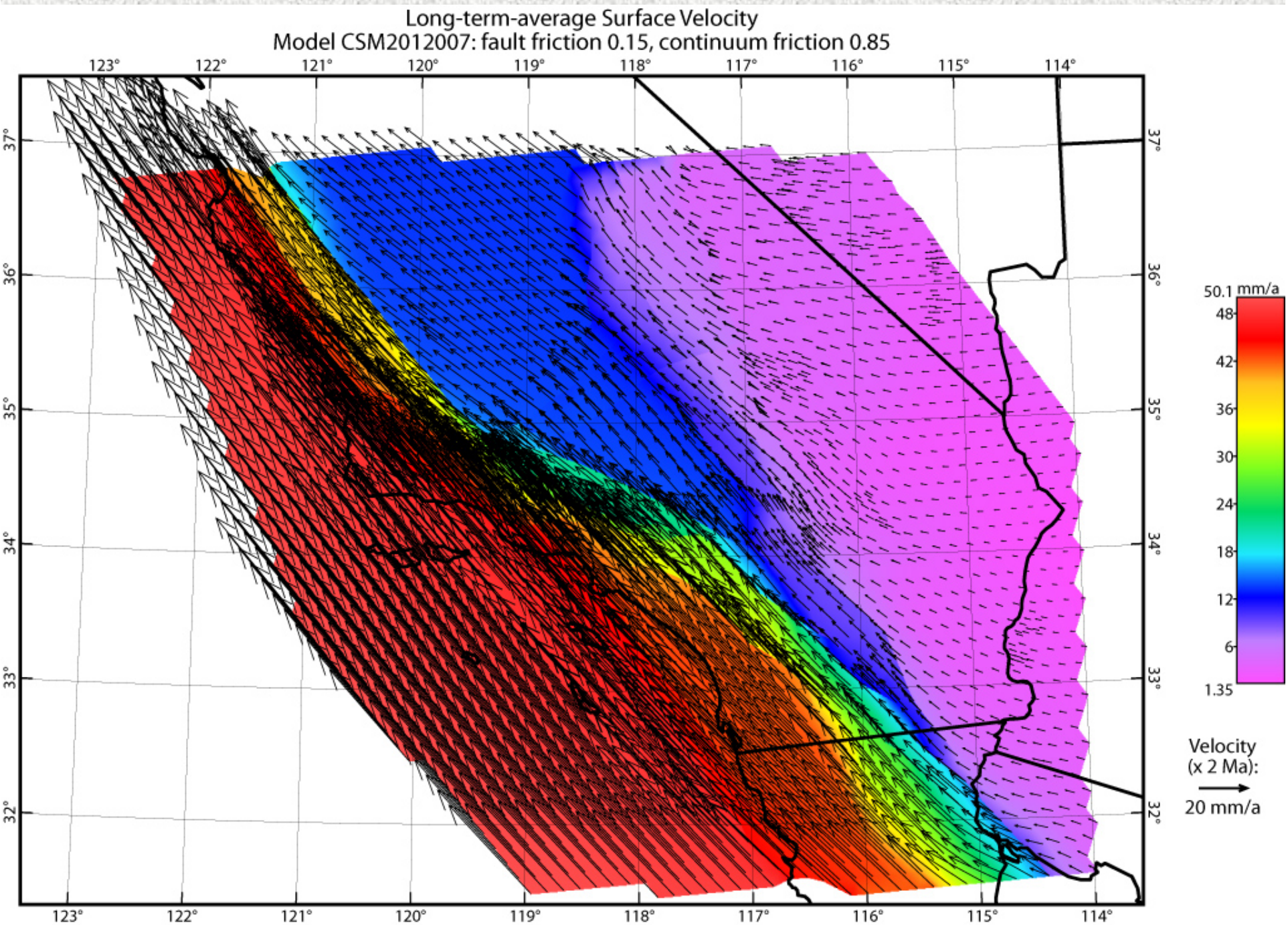

UCERF3 Fault Model 3.1
SHELLS_for_CSM-faulted.feg
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
37°
36°
35°
34°
33°
32°

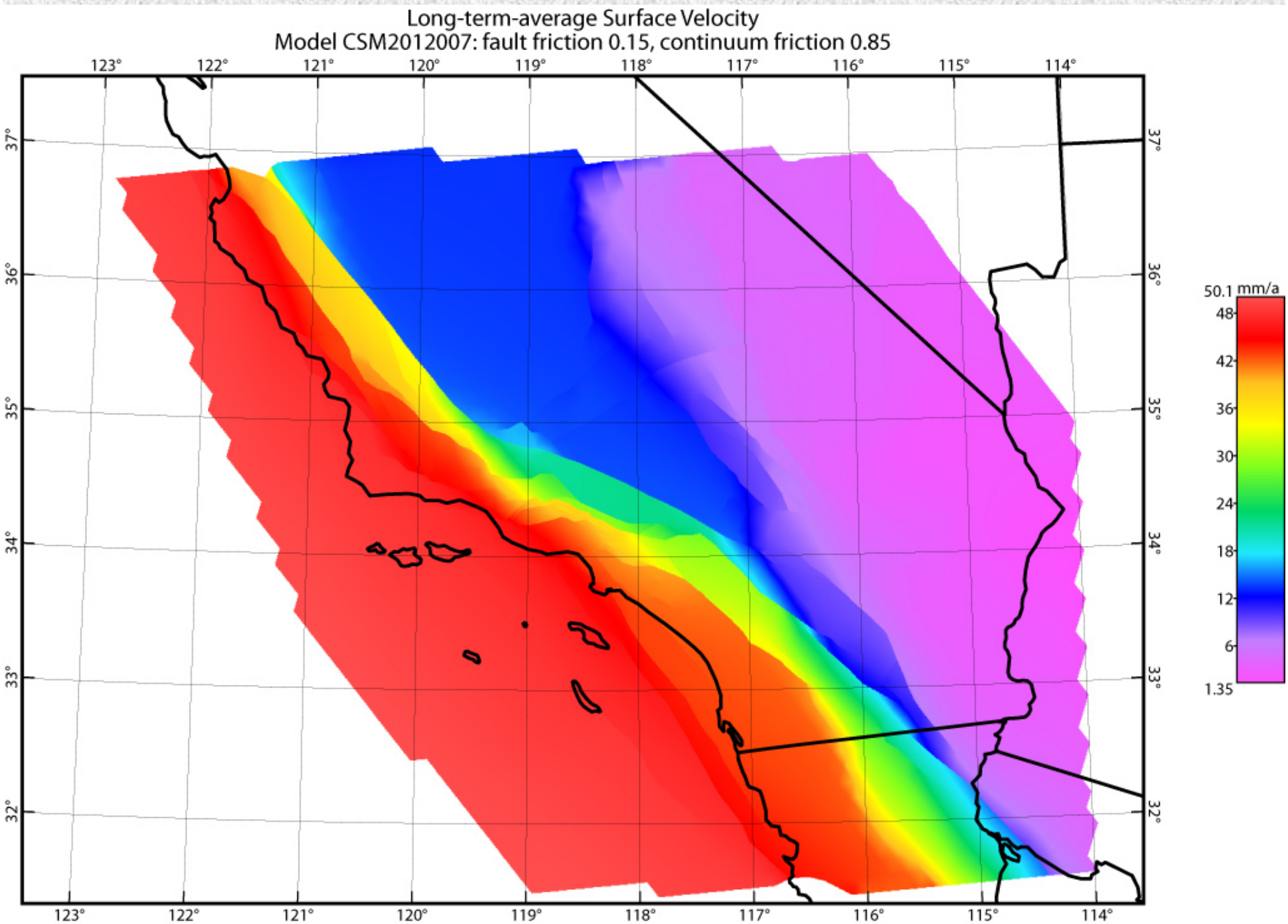

Elevation at nodes (from ETOPO5)
SHELLS_for_CSM-faulted_OrbData.feg
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
37°
36°
35°
34°
33°
32°
3590 m
2700
1800
900
0
-900
-1800
-2700
-3490

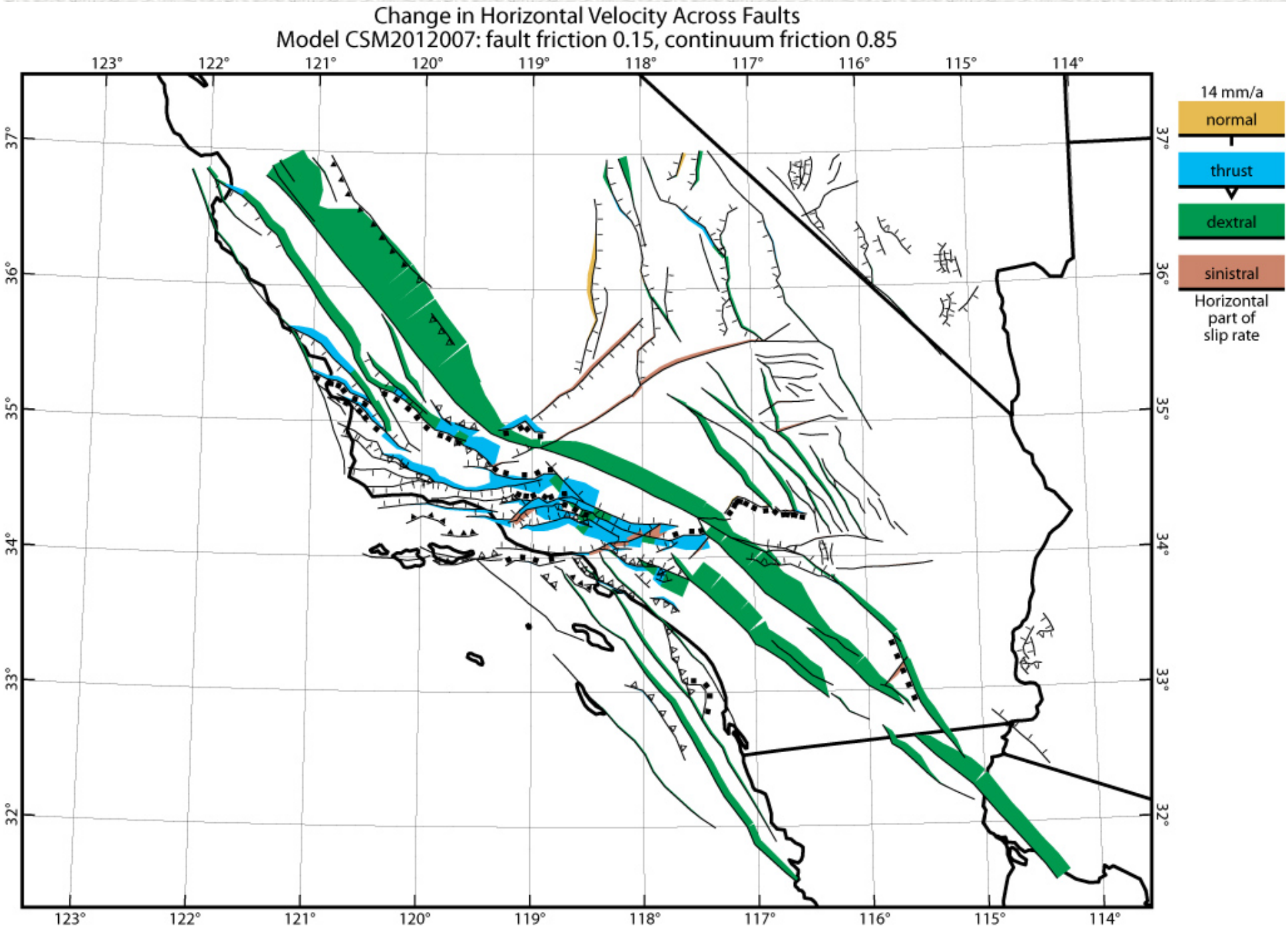

Crustal thickness at nodes (from OrbData)
SHELLS_for_CSM-faulted_OrbData.feg
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
37°
36°
35°
34°
33°
32°
61300 m
56000
49000
42000
35000
28000
21000
14000
7410


Heat-flow at nodes, from Q_of_WNA.grd
SHELLS_for_CSM-faulted_OrbData.feg
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
37°
36°
35°
34°
33°
32°
W/m2
0.1
0.098
0.091
0.084
0.077
0.07
0.063
0.056
0.049
0.0451

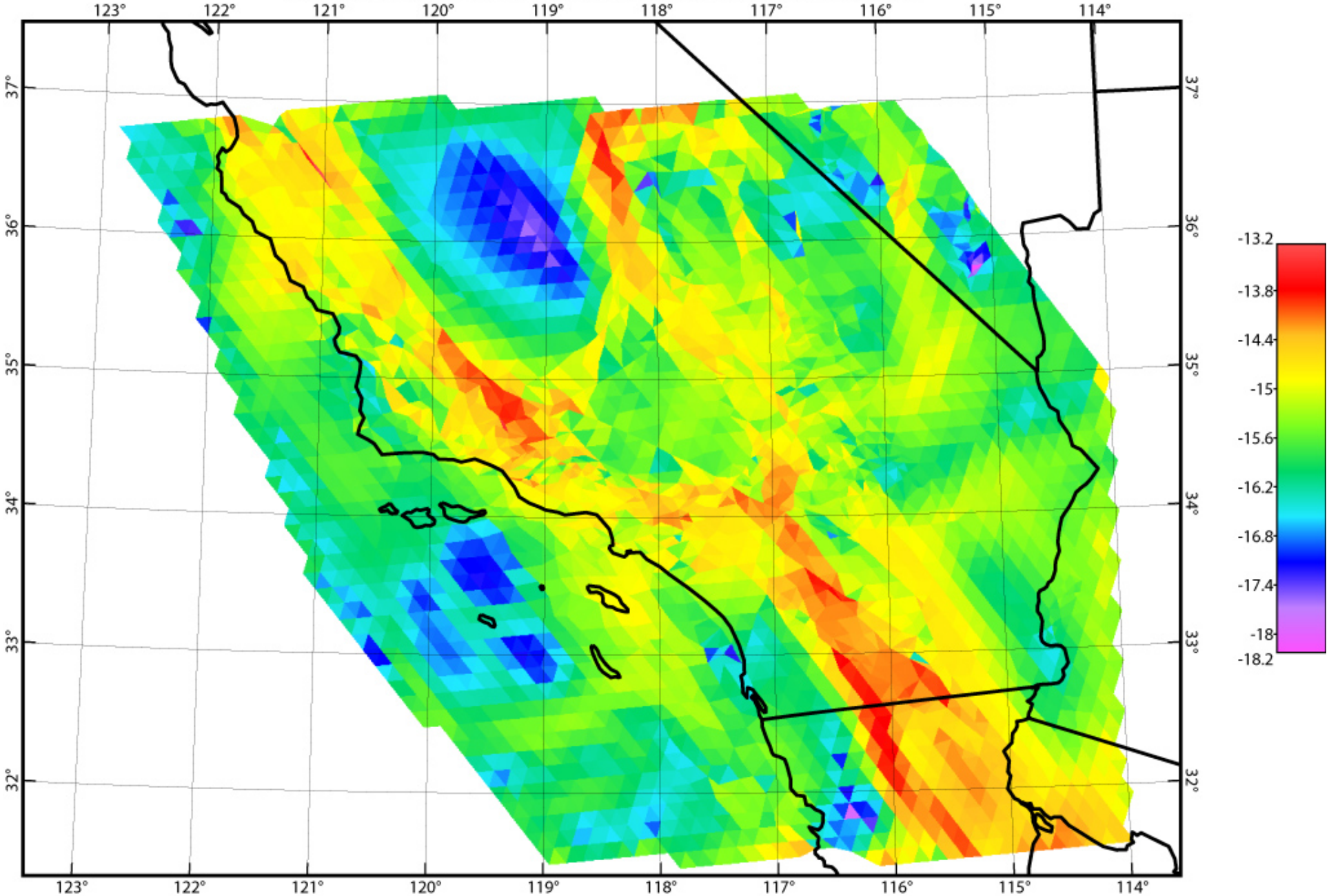

Total lithosphere thickness (from OrbData)
SHELLS_for_CSM-faulted_OrbData.feg
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
37°
36°
35°
34°
33°
32°
108000 m
99000
90000
81000
72000
63000
54000
45000
37000

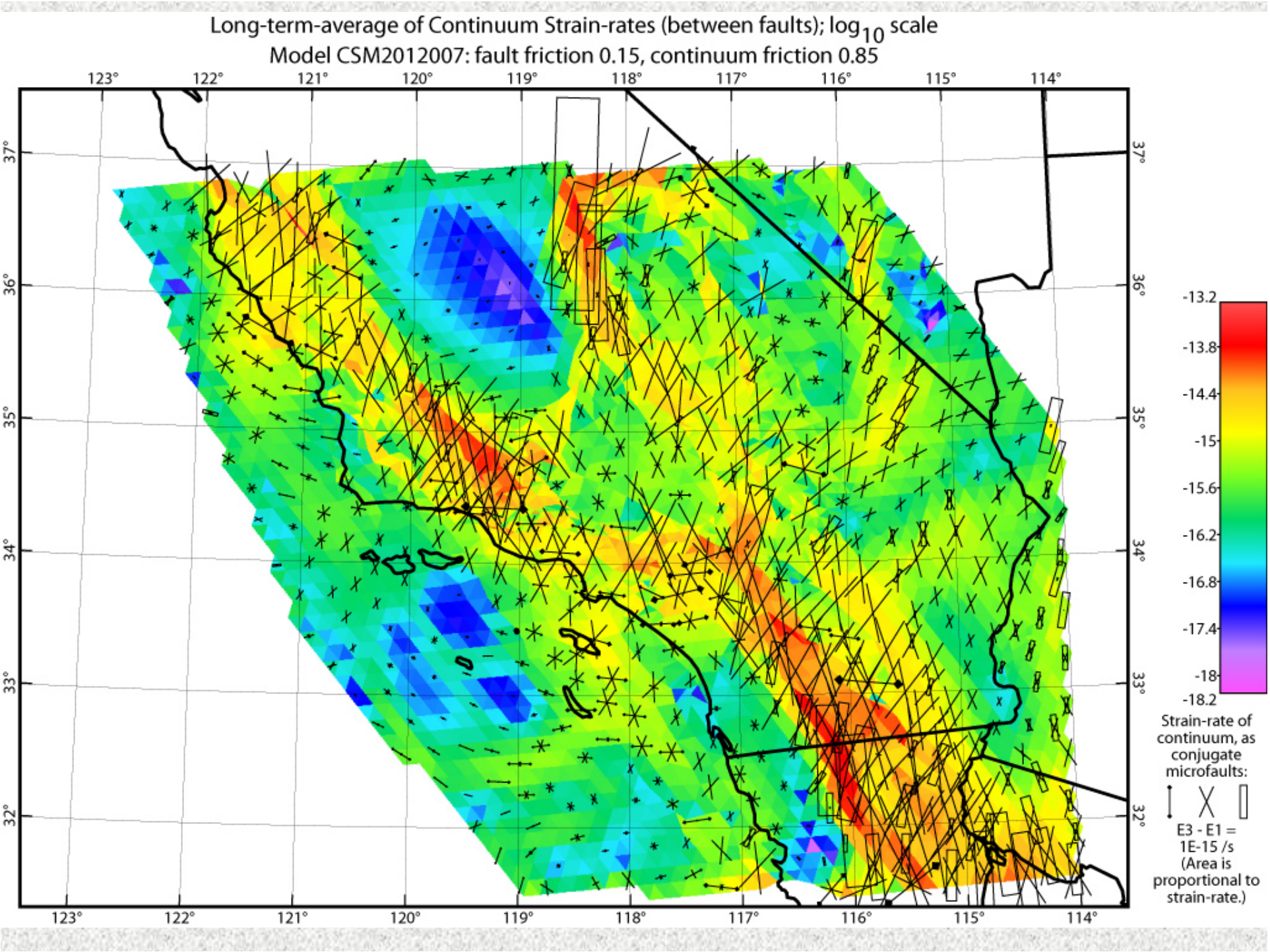

Long-term-average Surface Velocity
Model CSM2012007: fault friction 0.15, continuum friction 0.85
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
37°
36°
35°
34°
33°
32°
50.1 mm/a
48
42
36
30
24
18
12
6
1.35
Velocity
(x 2 Ma):
20 mm/a

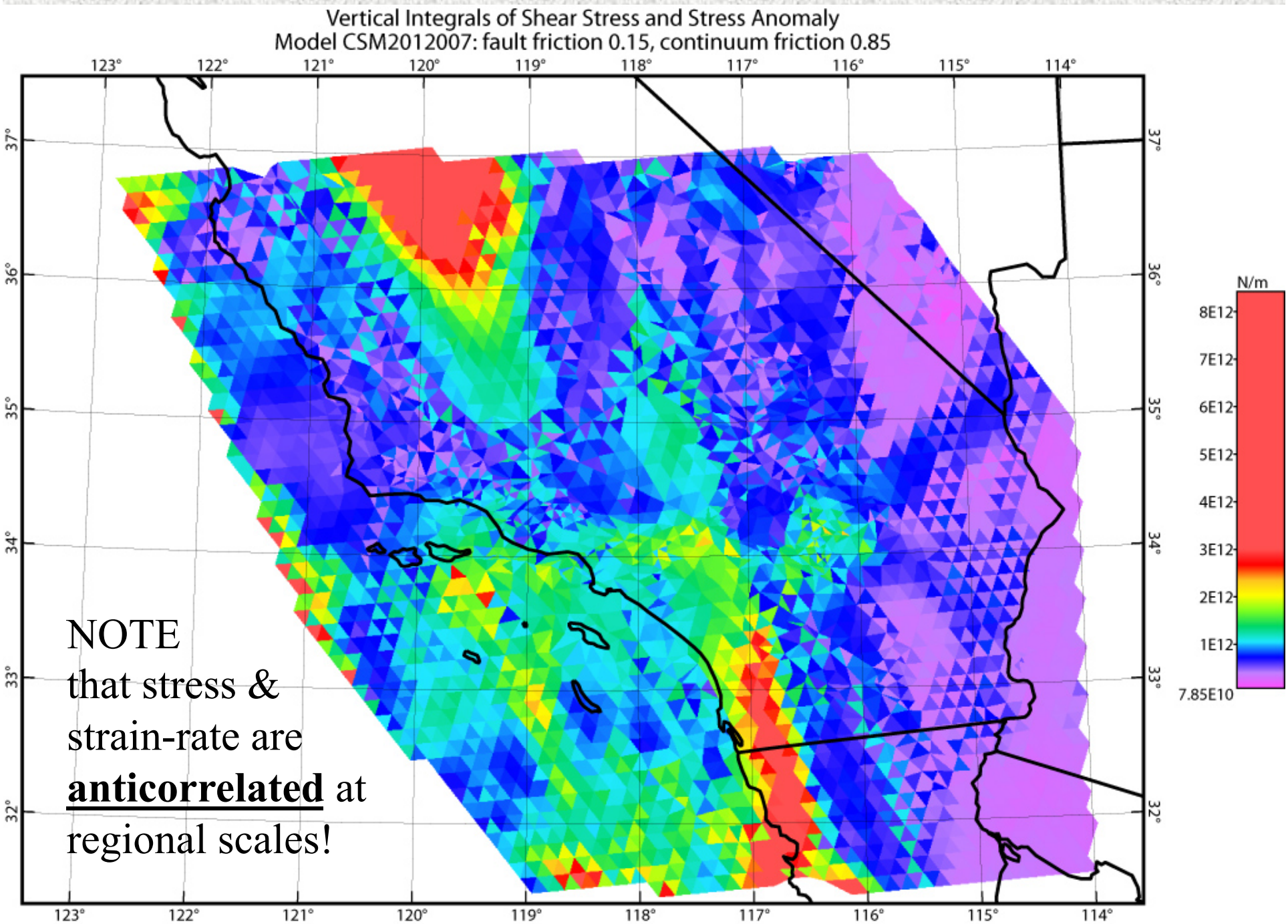

Long-term-average Surface Velocity
Model CSM2012007: fault friction 0.15, continuum friction 0.85
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
37°
36°
35°
34°
33°
32°
50.1 mm/a
48
42
36
30
24
18
12
6
1.35

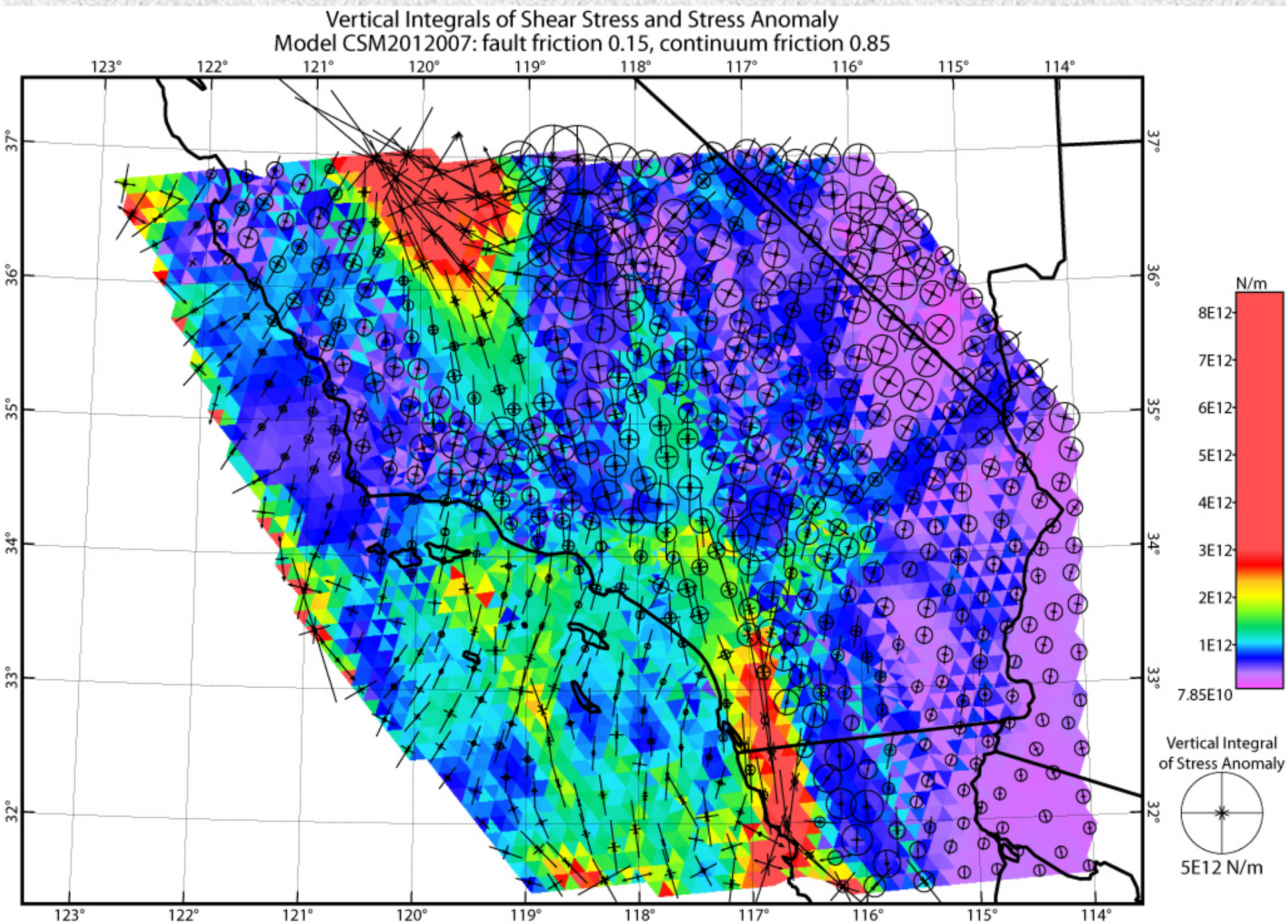

Change in Horizontal Velocity Across Faults
Model CSM2012007: fault friction 0.15, continuum friction 0.85
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
37°
36°
35°
34°
33°
32°
14 mm/a
normal
thrust
dextral
sinistral
Horizontal part of slip rate

Long-term-average of Continuum Strain-rates (between faults); $\log_{10}$ scale
Model CSM2012007: fault friction 0.15, continuum friction 0.85




Long-term-average of Continuum Strain-rates (between faults); log10 scale
Model CSM2012007: fault friction 0.15, continuum friction 0.85
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
37°
36°
35°
34°
33°
32°
-13.2
-13.8
-14.4
-15
-15.6
-16.2
-16.8
-17.4
-18
-18.2
Strain-rate of continuum, as conjugate microfaults:
E3 - E1 = 1E-15 /s
(Area is proportional to strain-rate.)


Vertical Integrals of Shear Stress and Stress Anomaly
Model CSM2012007: fault friction 0.15, continuum friction 0.85
123° 122° 121° 120° 119° 118° 117° 116° 115° 114°
37° 36° 35° 34° 33° 32°
N/m
8E12
7E12
6E12
5E12
4E12
3E12
2E12
1E12
7.85E10
NOTE
that stress &
strain-rate are
anticorrelated at
regional scales!


Vertical Integrals of Shear Stress and Stress Anomaly
Model CSM2012007: fault friction 0.15, continuum friction 0.85
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
37°
36°
35°
34°
33°
32°
N/m
8E12
7E12
6E12
5E12
4E12
3E12
2E12
1E12
7.85E10
Vertical Integral
of Stress Anomaly
5E12 N/m

(1/9) of Most-Compressive Horizontal Principal Stress Directions
Model CSM2012007: fault friction 0.15, continuum friction 0.85