STANFORD UNIVERSITY

State of Stress and Crustal Strength in the New Madrid Seismic Zone and Central and Eastern U.S.

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Outline

- Update on Regional Stress Field of the CEUS
  - 10 stress inversions from (Mazzotti and Townend, 2010)
  - 52 New Well-Constrained Focal Plane Mechanisms (Hurd and Zoback, 2012)
- Strength of Crustal Faults in CEUS
  - Hurd and Zoback revisiting ML Zoback (1992)
- Stress and Fault Strength in New Madrid Region
- A Few Words About Crustal Rheology

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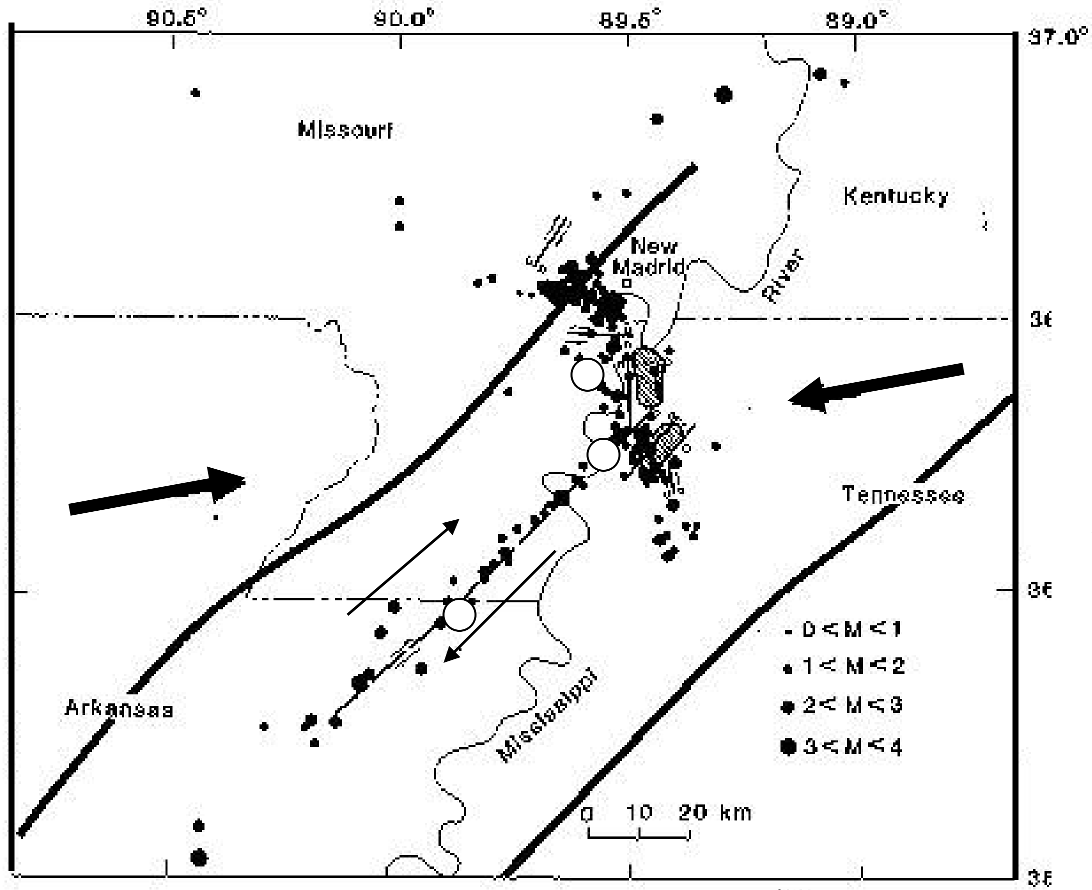
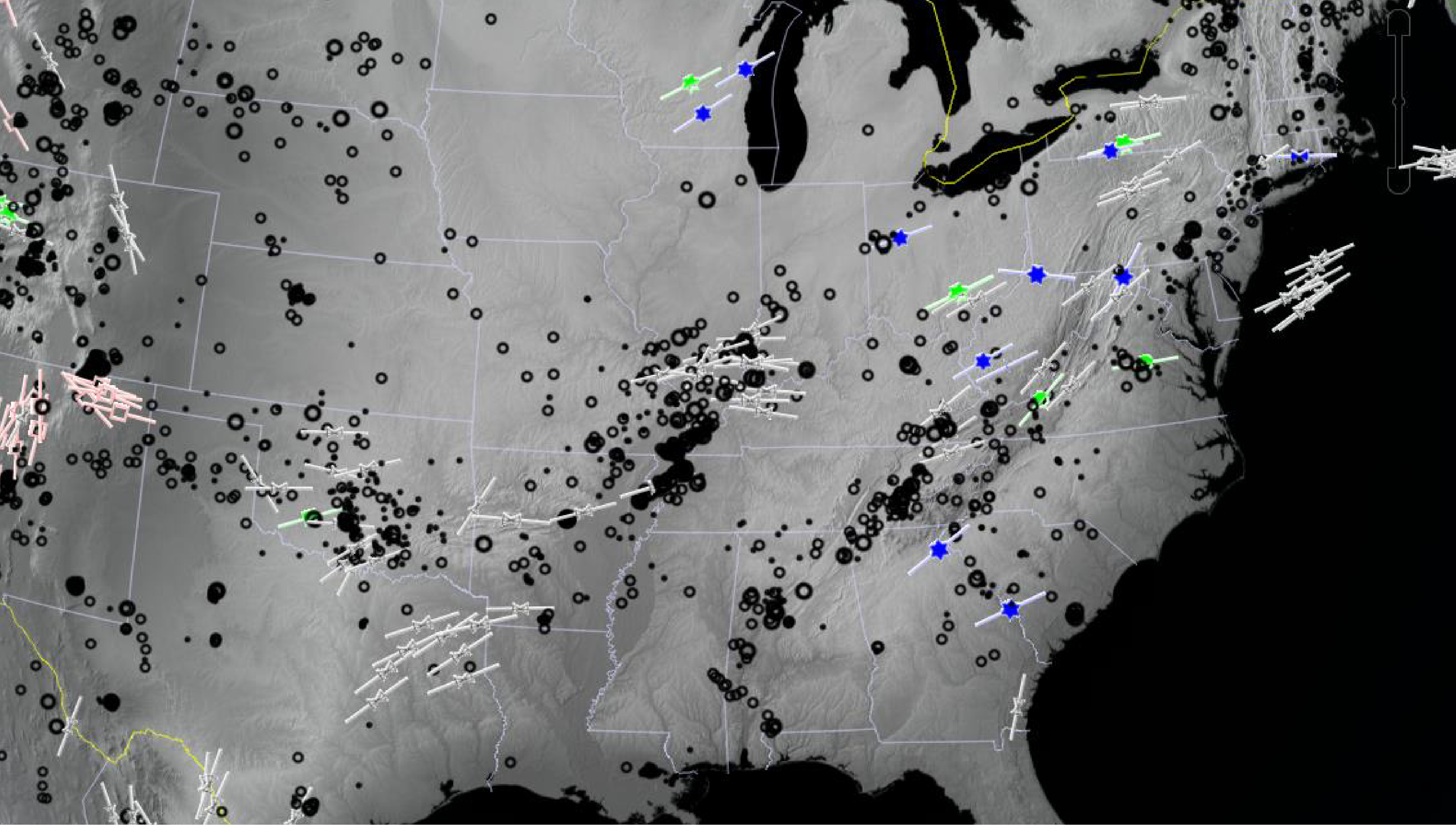
SCIENCE



Fault Slip in New Madrid Consistent with Regional ENE-WSW Compression and Coulomb Faulting Theory

State of Stress and Intraplate Earthquakes in the United States

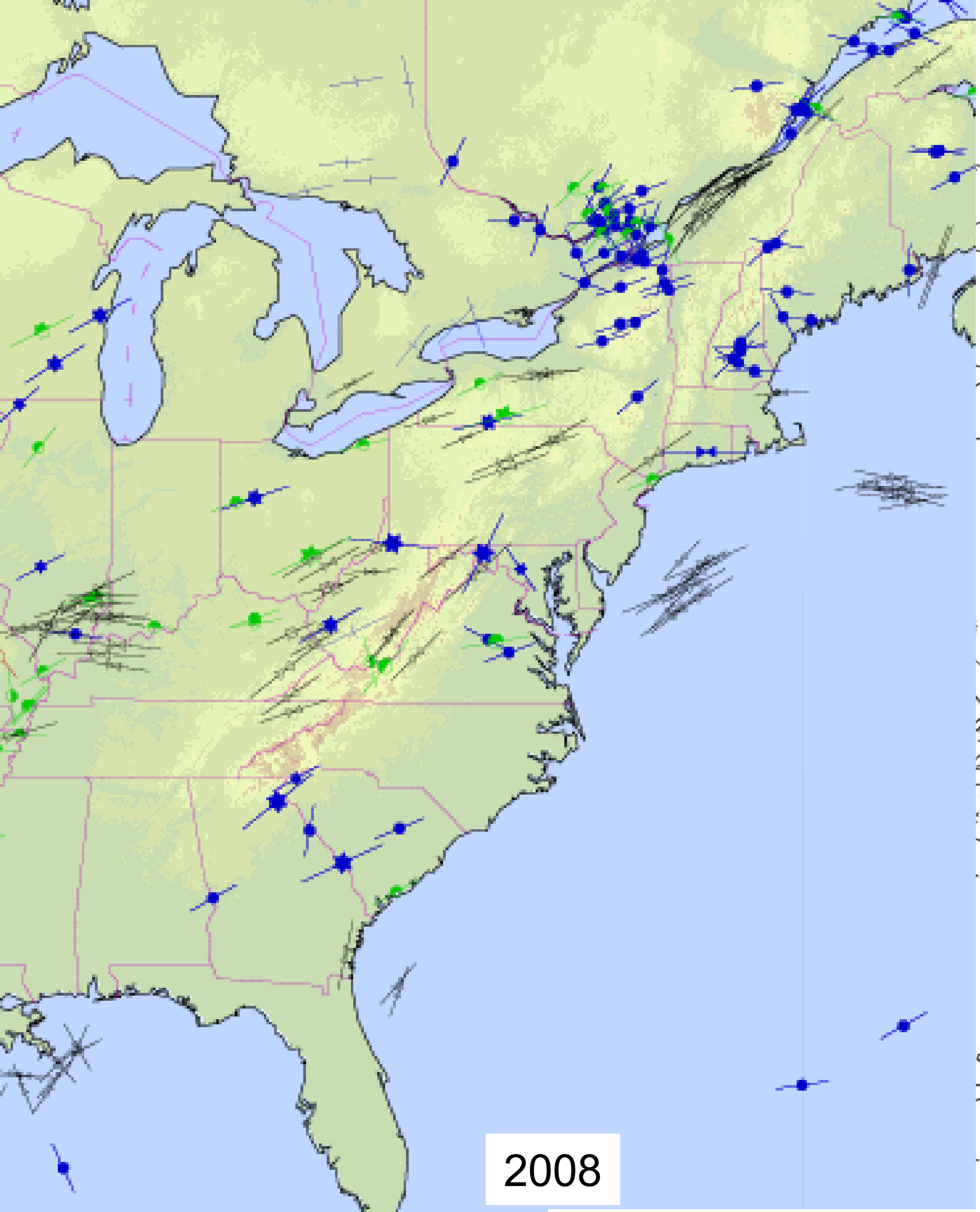
Mark D. Zoback and Mary Lou Zoback

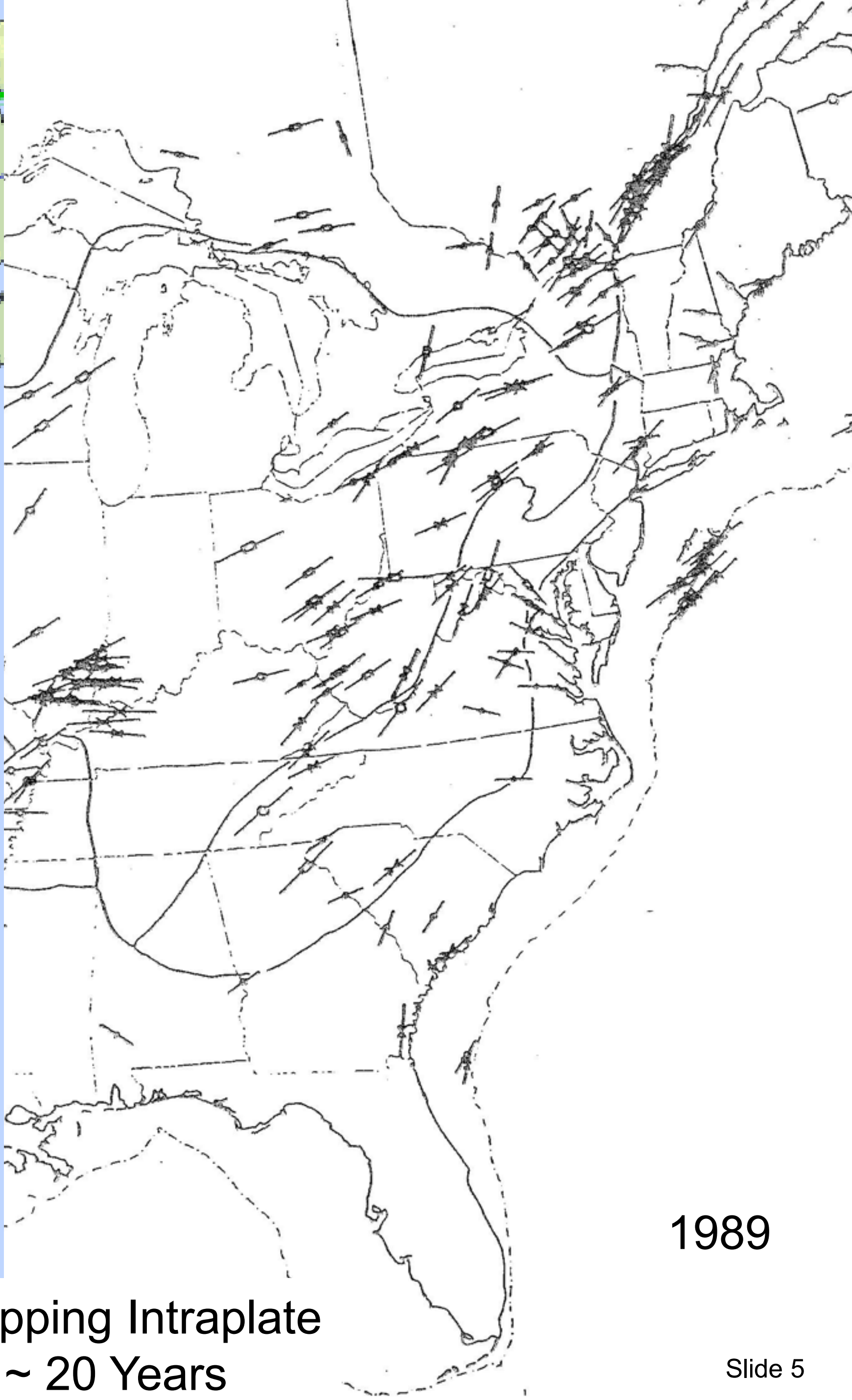


Relatively Uniform Stress Orientations Across Complex Geologic Boundaries

Intraplate Earthquakes Result from Contemporary Stress Field Acting on Pre-Existing Faults

Zoback and Zoback (1980, 1989)

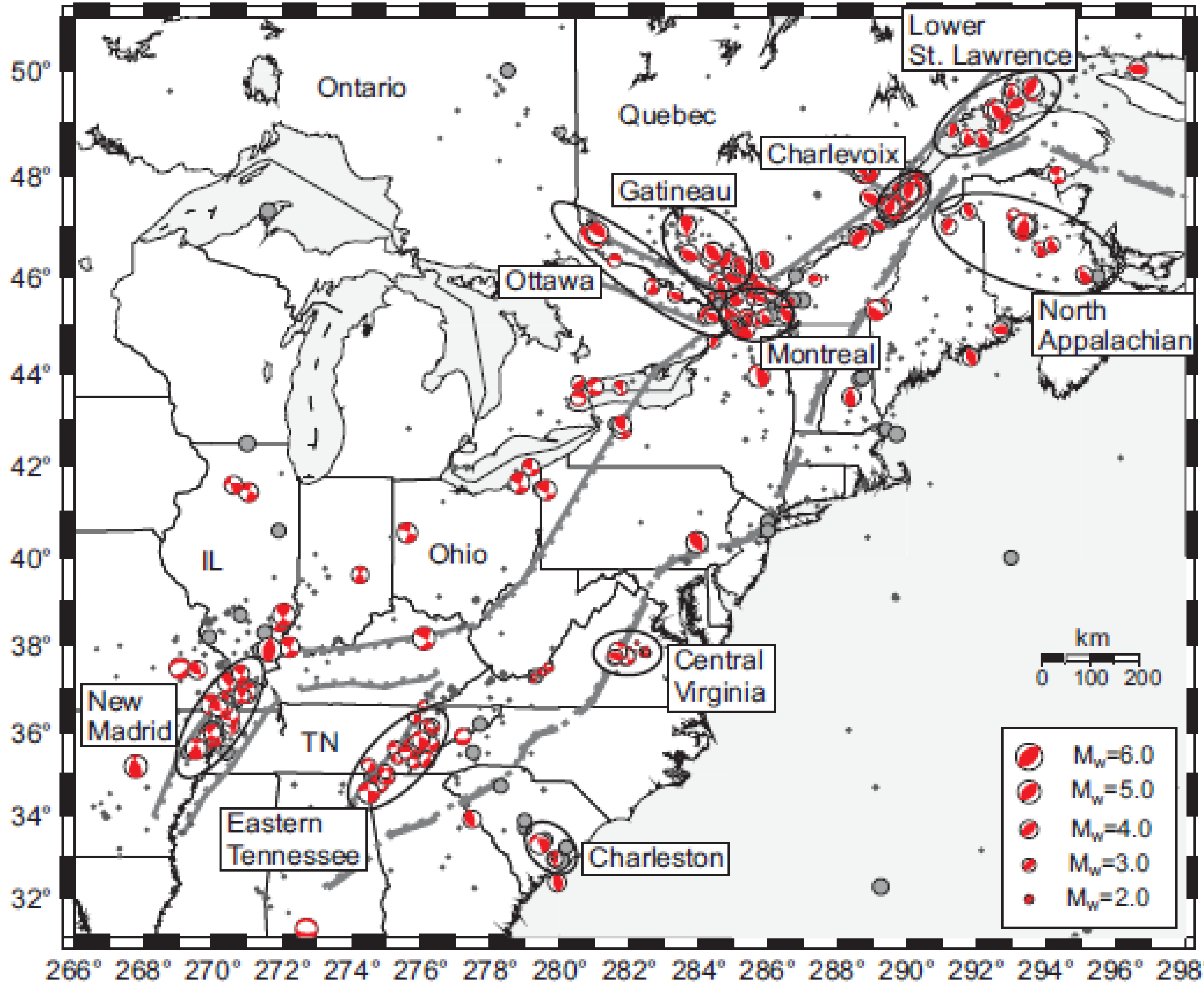




Little Progress in Mapping Intraplate Stress in CEUS ~ 20 Years

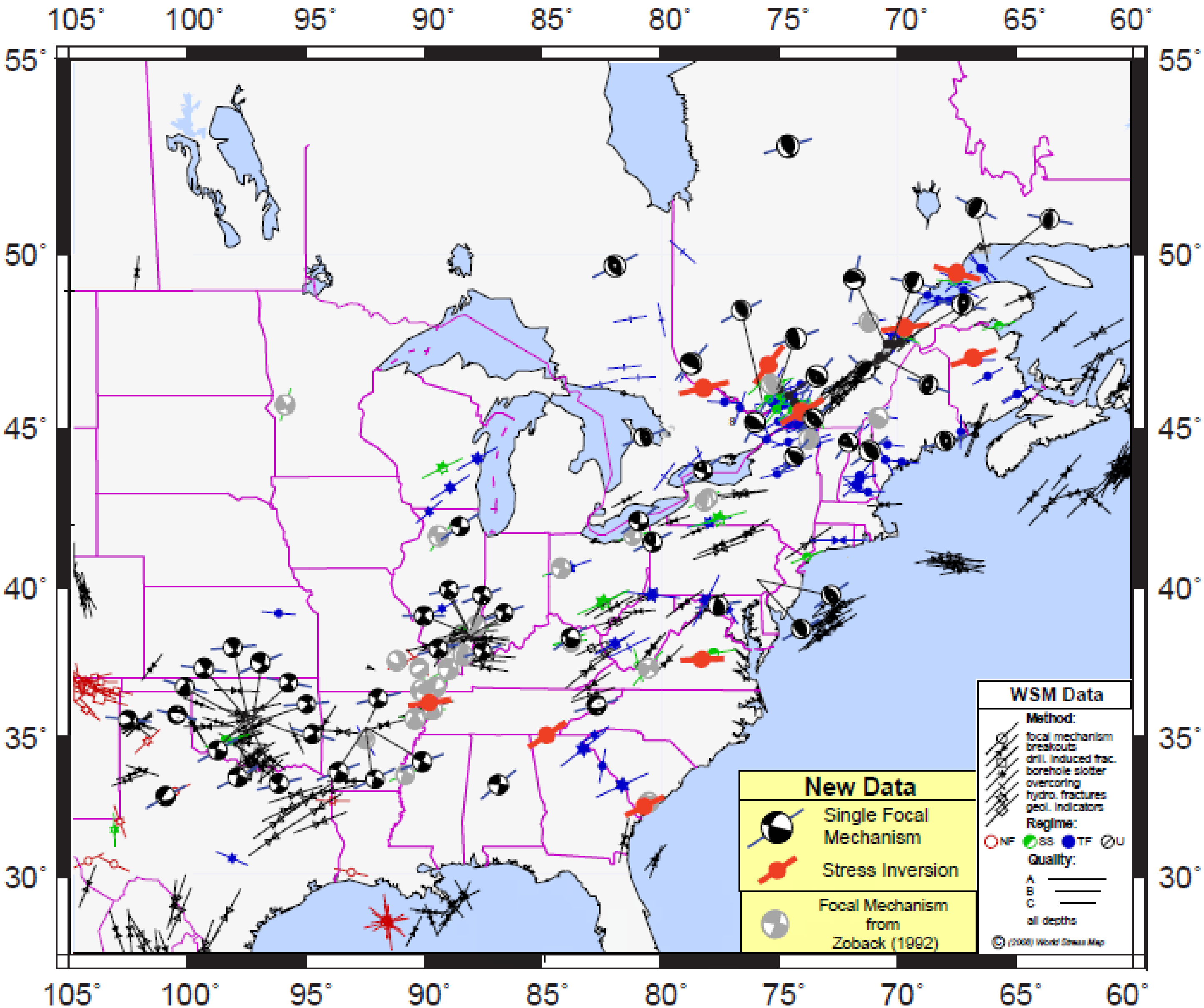
Stress Inversions in Areas of Dense Seismicity

Mazzotti and Townend (2010)



52 New Focal Plane Mechanisms

Hurd and Zoback (2012)

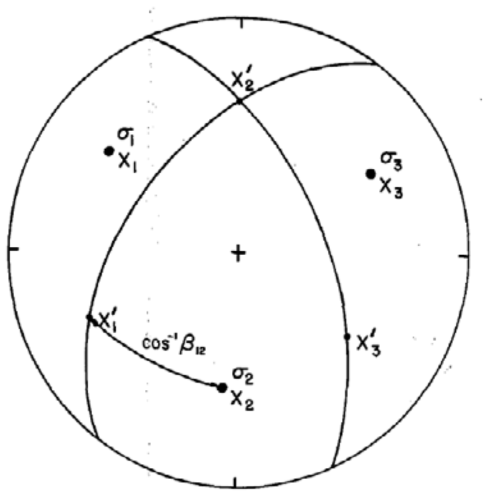


Mapping Relative Stress Magnitudes

$$\Phi = \frac{S_2 - S_3}{S_1 - S_3}$$

Angelier (1979)

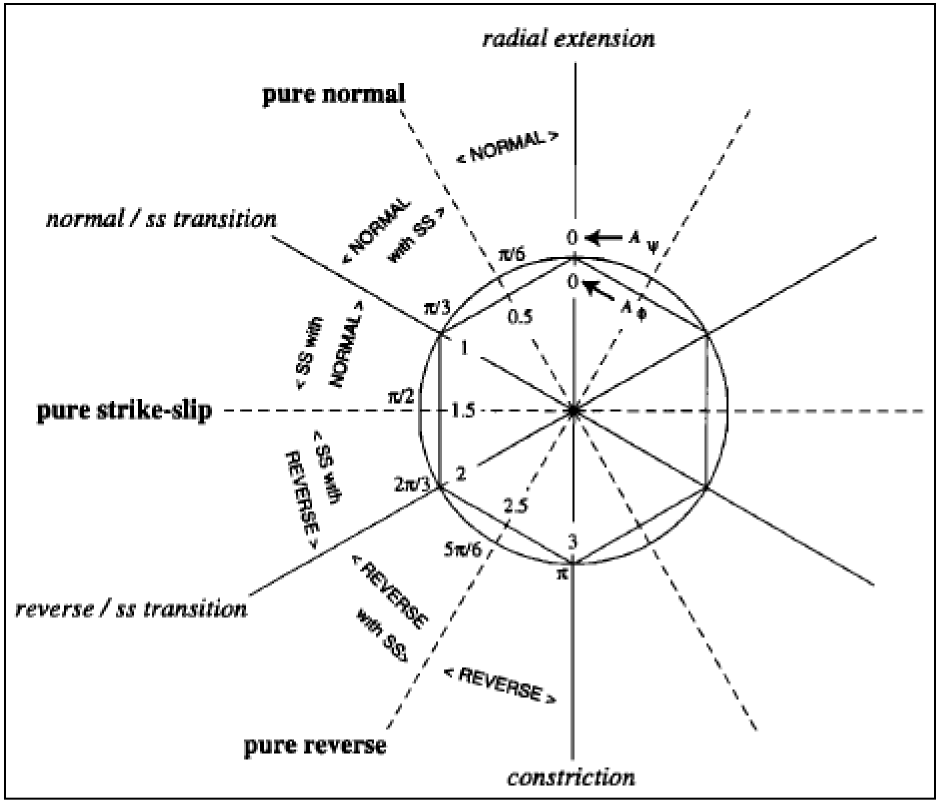
$$0 \le A\Phi \le 3$$



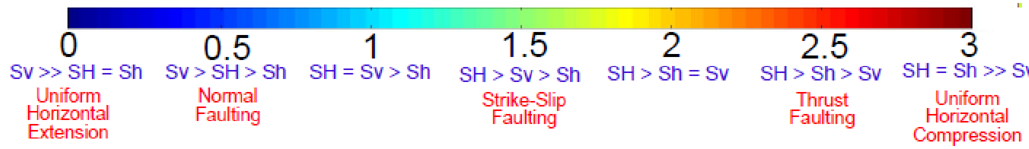
$$R = -\frac{\beta_{13}\beta_{23}}{\beta_{12}\beta_{22}} = -\frac{\beta_{33}\beta_{23}}{\beta_{32}\beta_{22}}$$

Gephart (1985)

$$\Phi = 1 - R$$

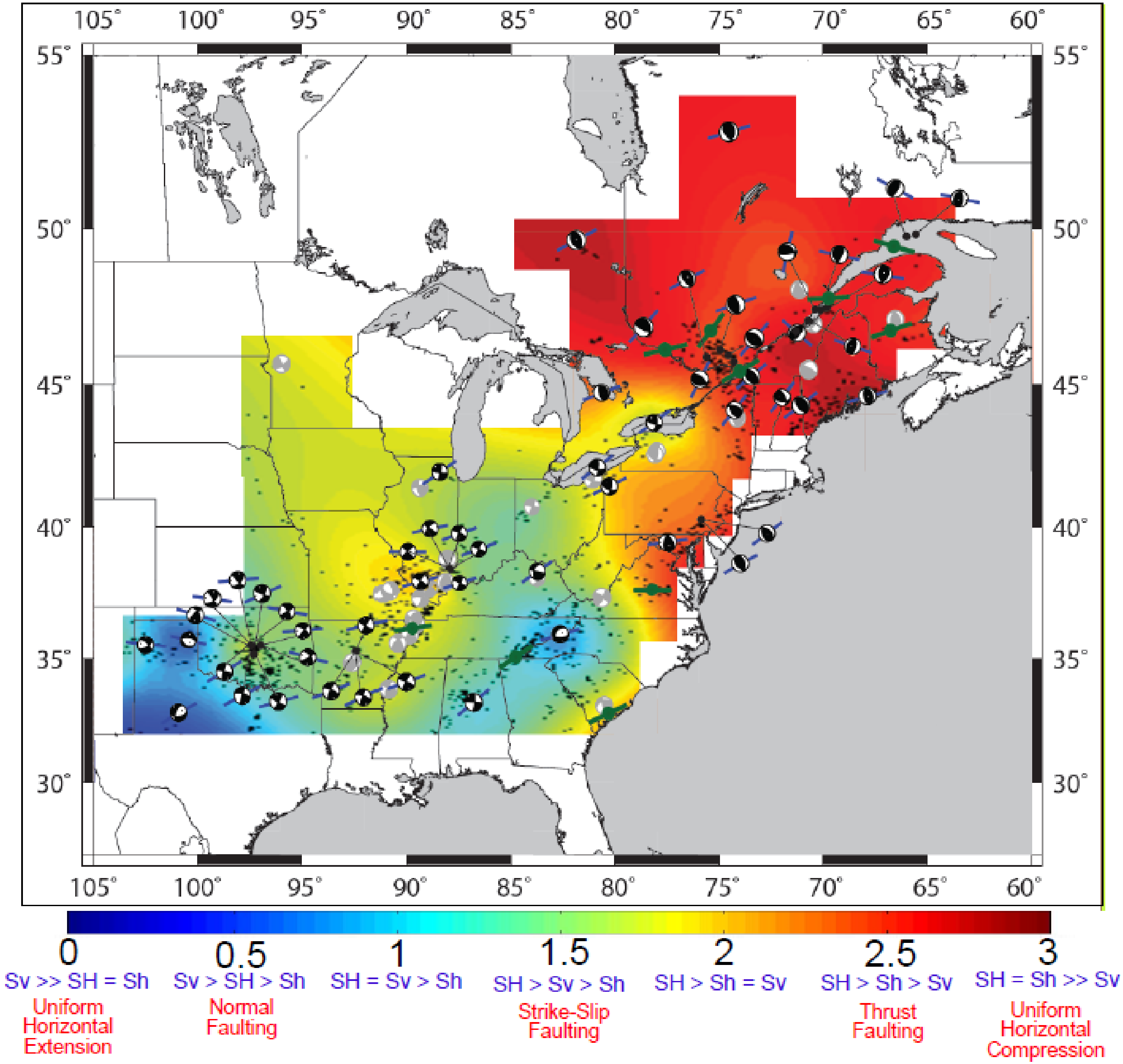


Simpson (1997)



Mapping Relative Stress Magnitudes

Hurd and Zoback (2012)



82 data points

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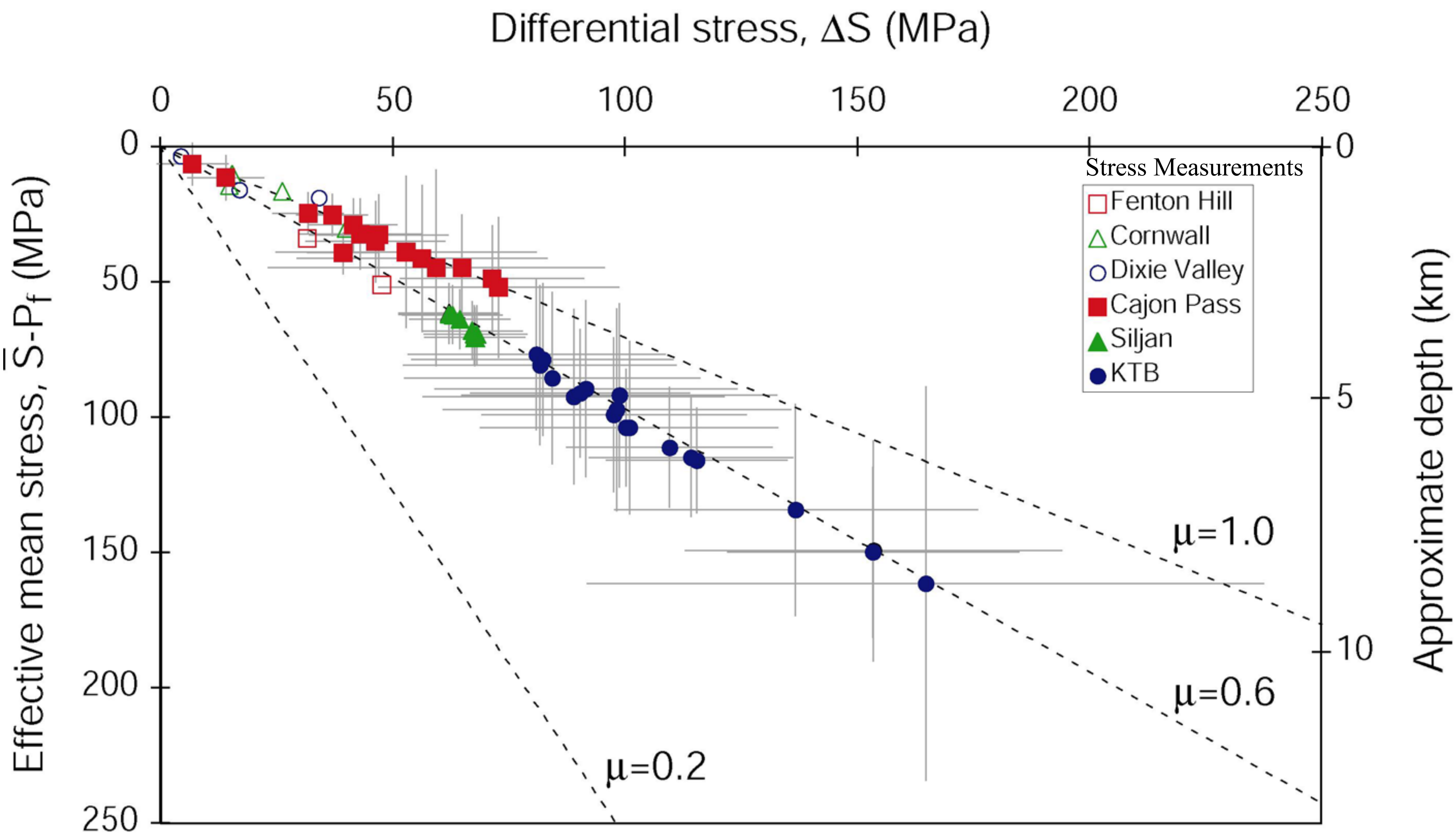
Strong Crust in Intraplate Areas
Lab Coefficients of Friction and Hydrostatic Pore Pressure



Townend and Zoback (2000)

Estimating Fault Strength From Stress/Fault Orientation

Hurd and Zoback (2012)

Friction Defines Orientation Between Stress Field and Optimally-Oriented Fault Planes

Assume Mohr-Coulomb Criterion

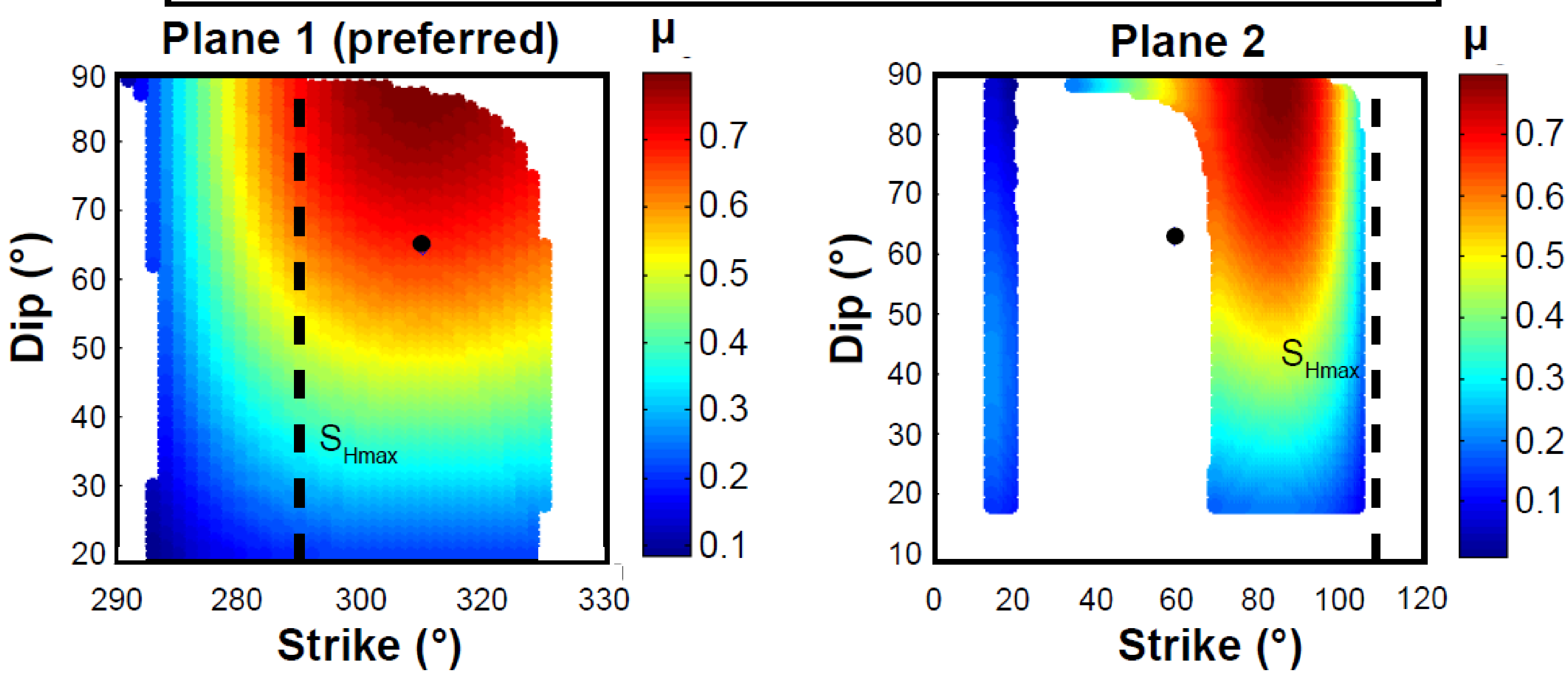
$$\tau = \mu(S_N - P_P)$$

Question – If we assume hydstrostatic P_P, is the relationship between the local stress field (derived from independent data) and slip on one of the nodal planes of each focal plane mechanism consistent with laboratory-derived coefficients of friction?

Slip Compatibility Test

1) Rotate nodal plane strike from ±45°
2) At each strike, rotate dip ± 45°
3) Calculate μ that explains slip vector on each nodal plane

Event: NW Texas **Date**: 2/10/2010 **Location**: 35.49° N, 102.65° W
Depth: 13 km **Regime** = strike-slip $\mathbf{S_{Hmax}}$ = 109°



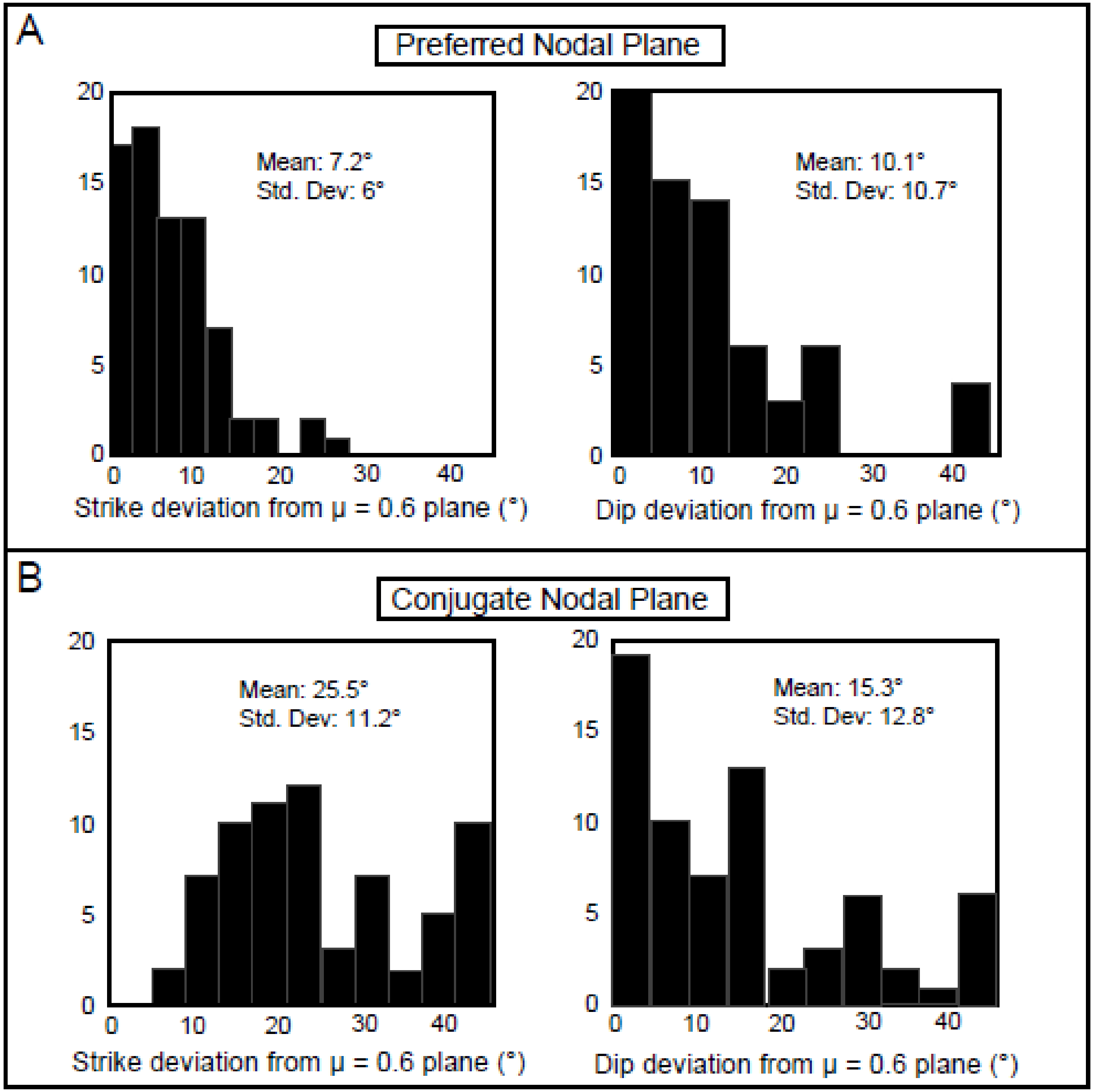
Slip Compatibility Test

Which tells us:

(1) Which nodal plane is preferred (*for example,* closer to the nearest plane that would fail if $\mu = 0.6$)

(1) How close (in terms of strike and dip deviation) this preferred plane is to an optimally-oriented plane

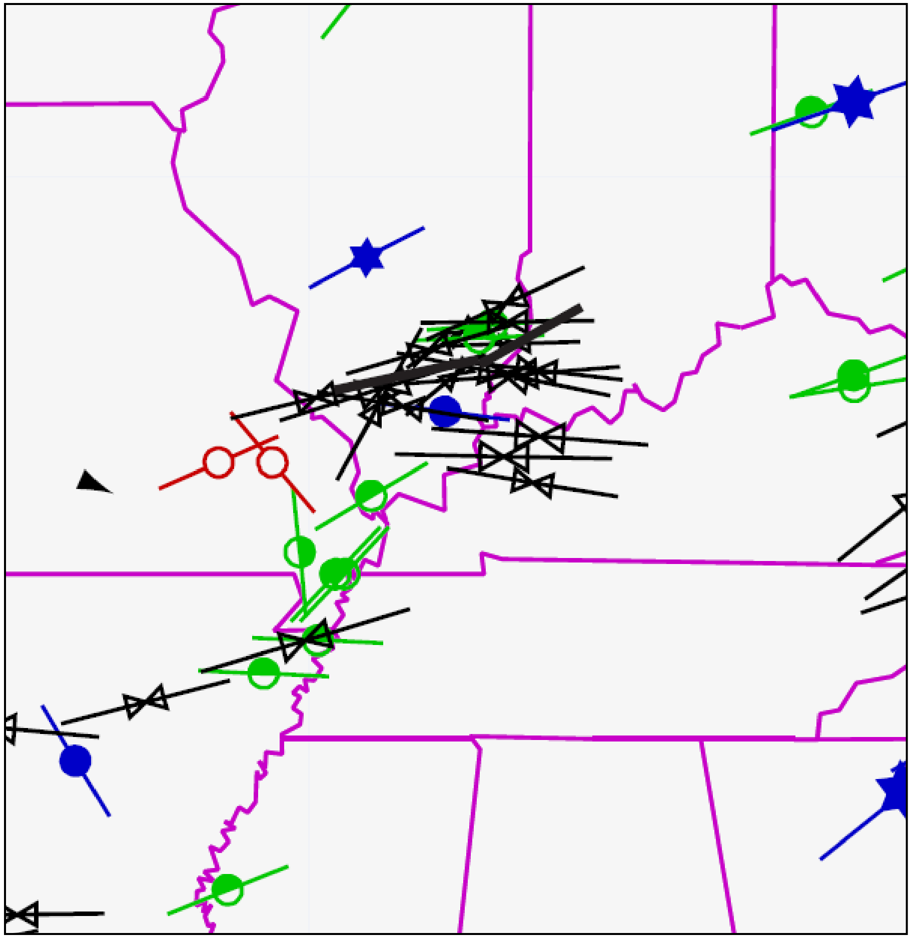
Stress Field and Slip on Preferred Nodal Plane Consistent With μ=0.6



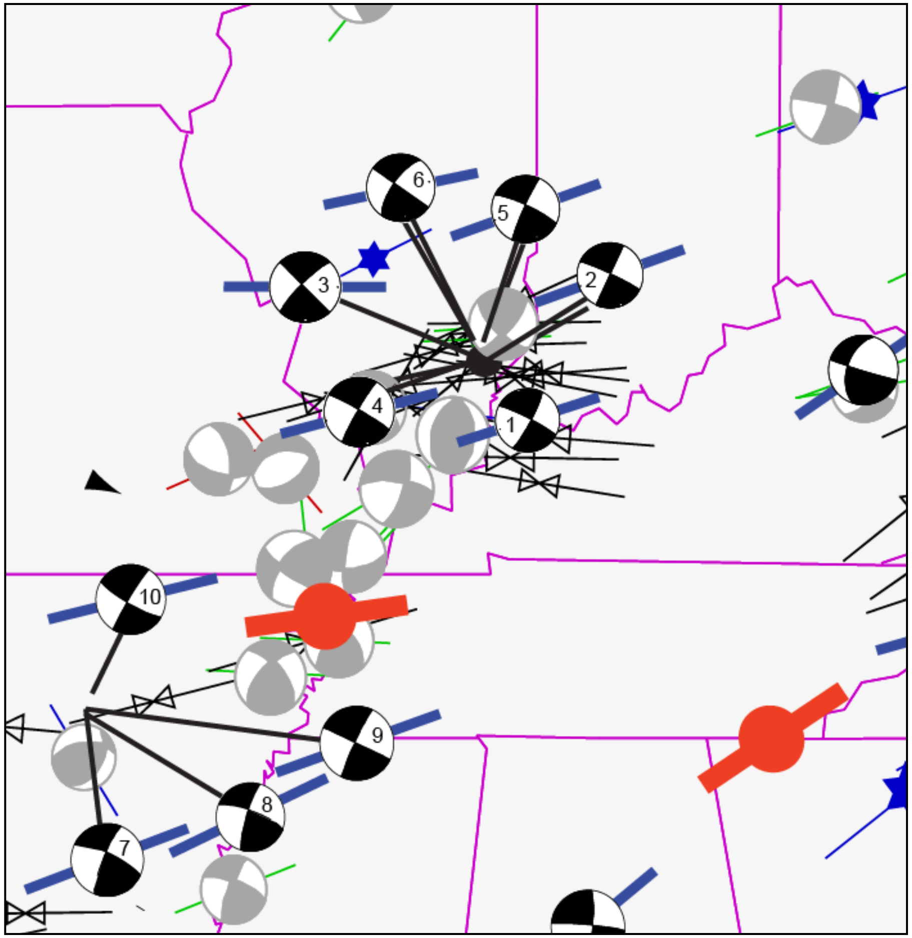
Summary

- New data points confirm consistent NE-SW S_{Hmax} in most of the CEUS (but there are exceptions)
- Horizontal stresses become increasingly compressive moving from central U.S. to northeastern U.S. and SE Canada
- Slip compatible with μ=0.6 on preferred nodal plane in the regional stress field
- So what about the New Madrid region?

New Madrid Focal Plane Mechanisms

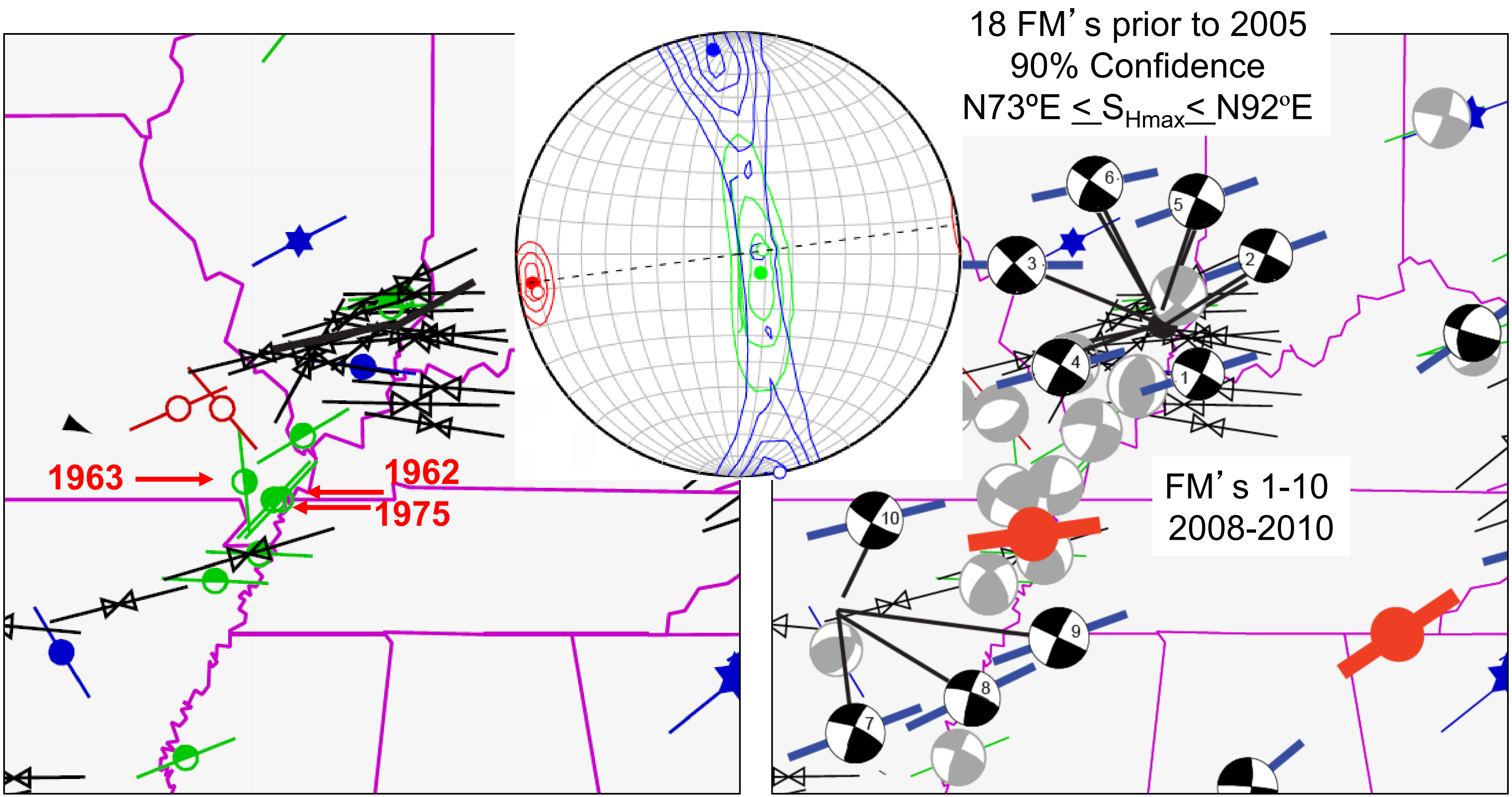


2008 WSM Data Base



New FM's and Mazzotti and Townend Inversions

New Madrid Focal Plane Mechanisms



2008 WSM Data Base

New FM's and Mazzotti and Townend Inversions

Summary

- New data points confirm consistent NE-SW S_{Hmax} in most of the CEUS (but there are exceptions)
- Horizontal stresses become increasingly compressive moving from central U.S. to northeastern U.S. and SE Canada
- Slip compatible with $\mu \approx 0.6$ on preferred nodal plane in the regional stress field
- Slip on faults in New Madrid seem consistent with regional stress field for expected values of fault friction

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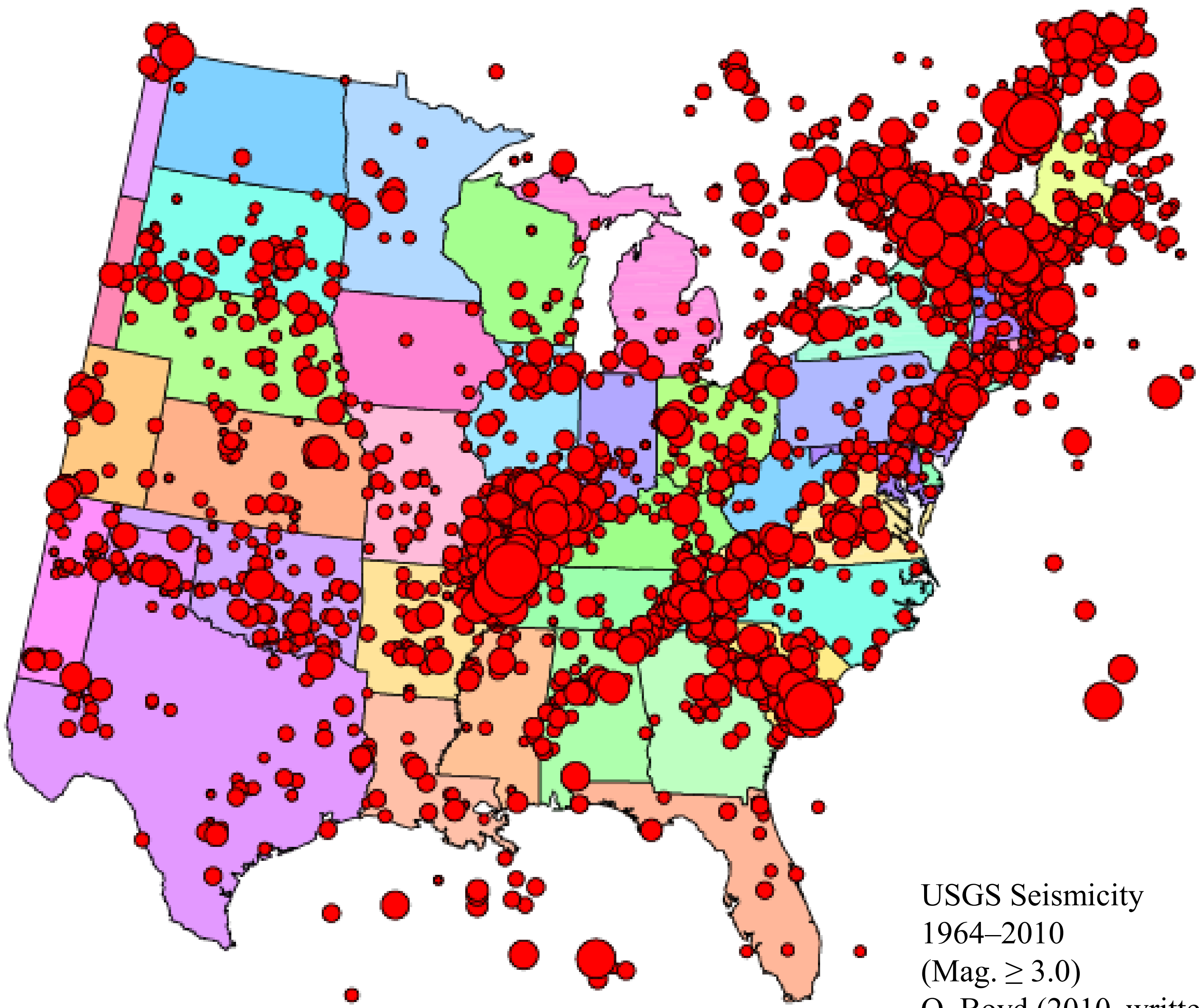
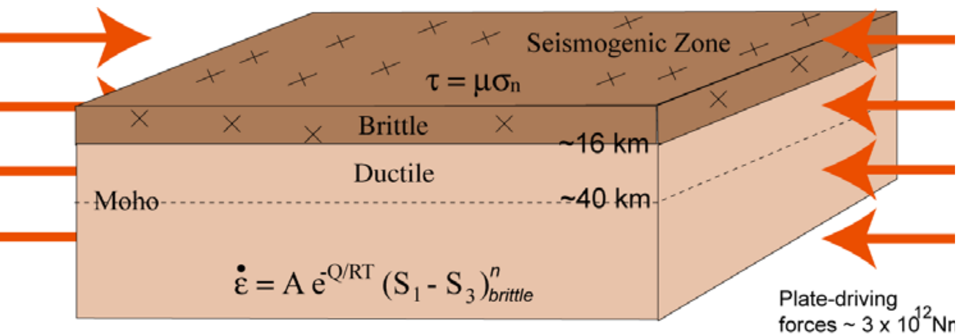
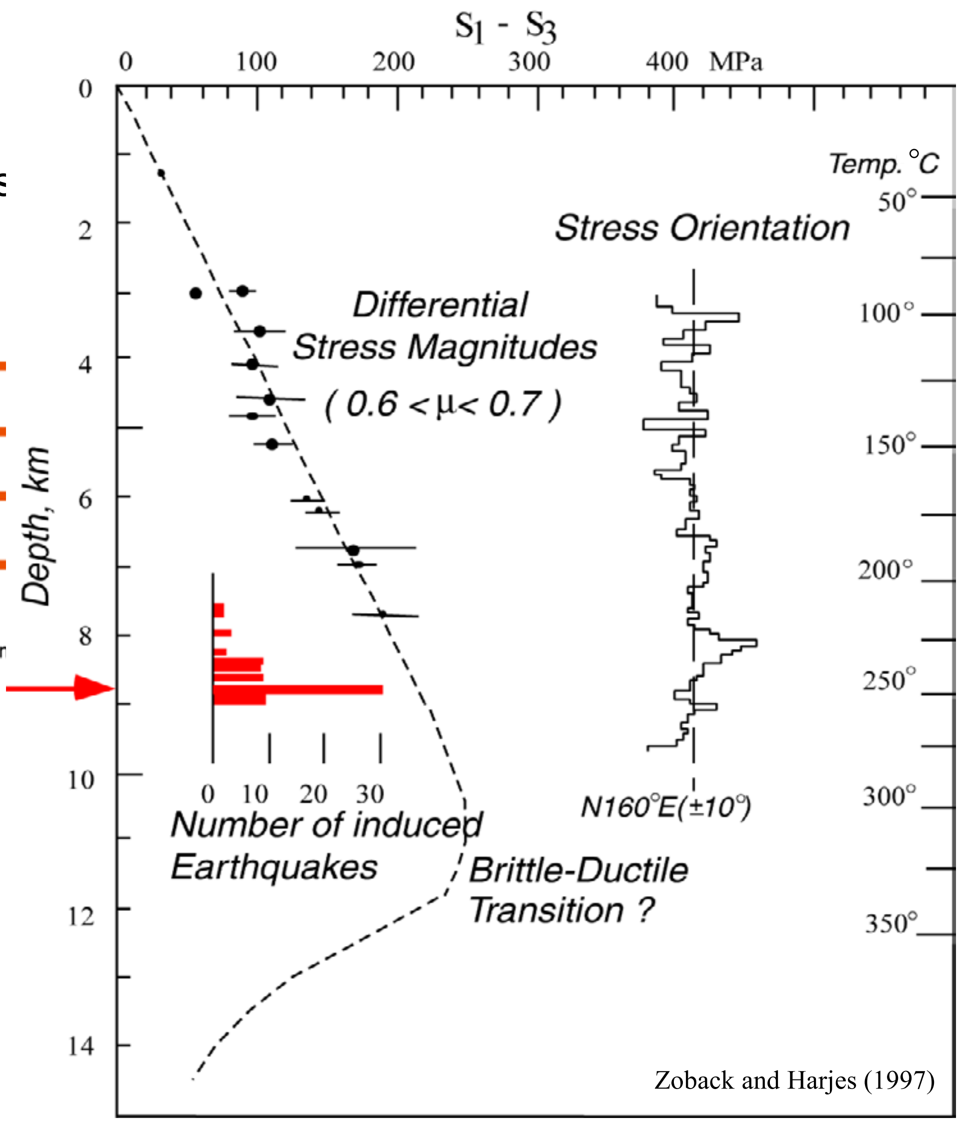


USGS Seismicity
1964–2010
(Mag. ≥ 3.0)
O. Boyd (2010, written commun.)

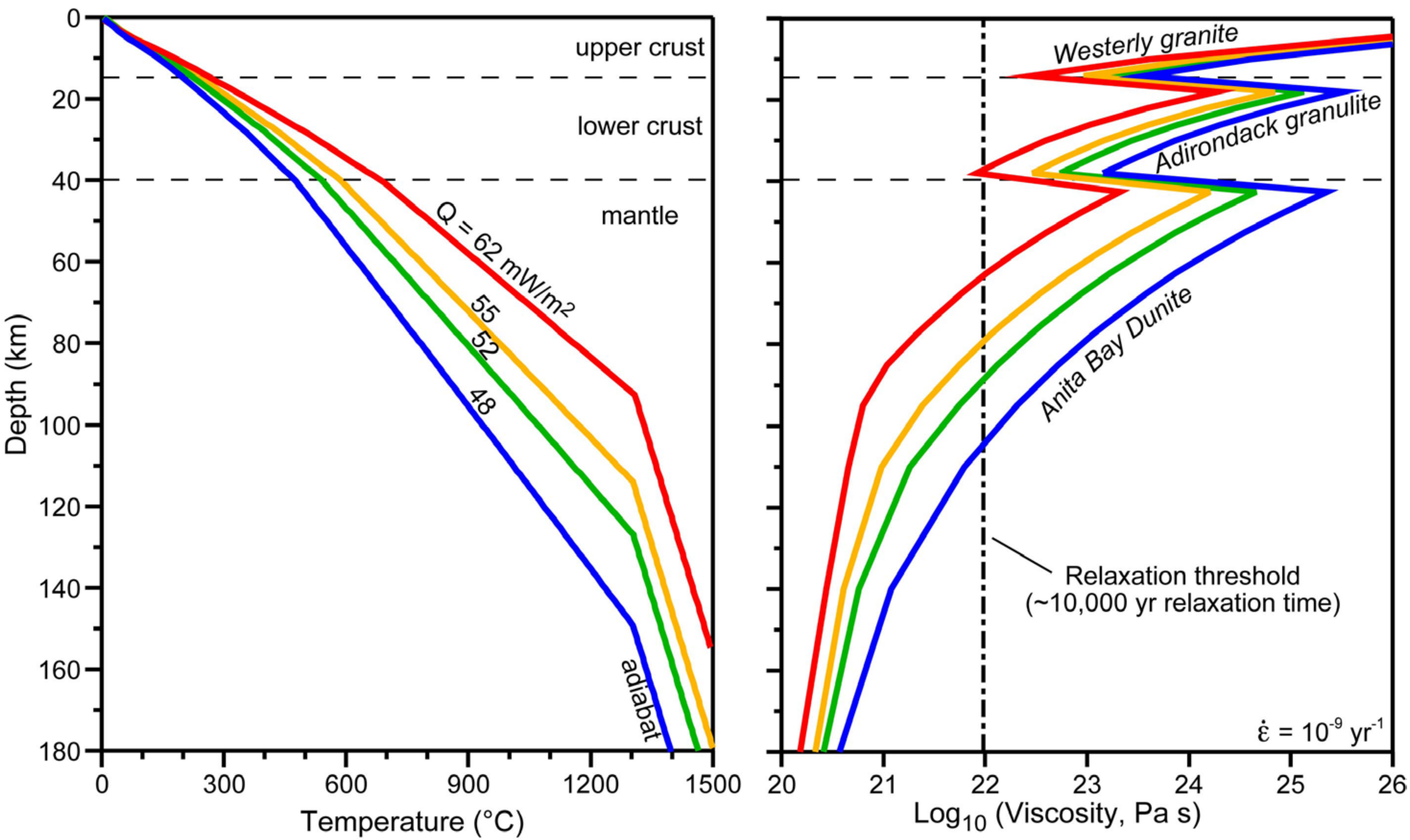
Brittle Crust in Failure Equilibrium

Brittle Failure in Critically-Stressed Crust Results From Creep in Lower Crust and Upper Mantle



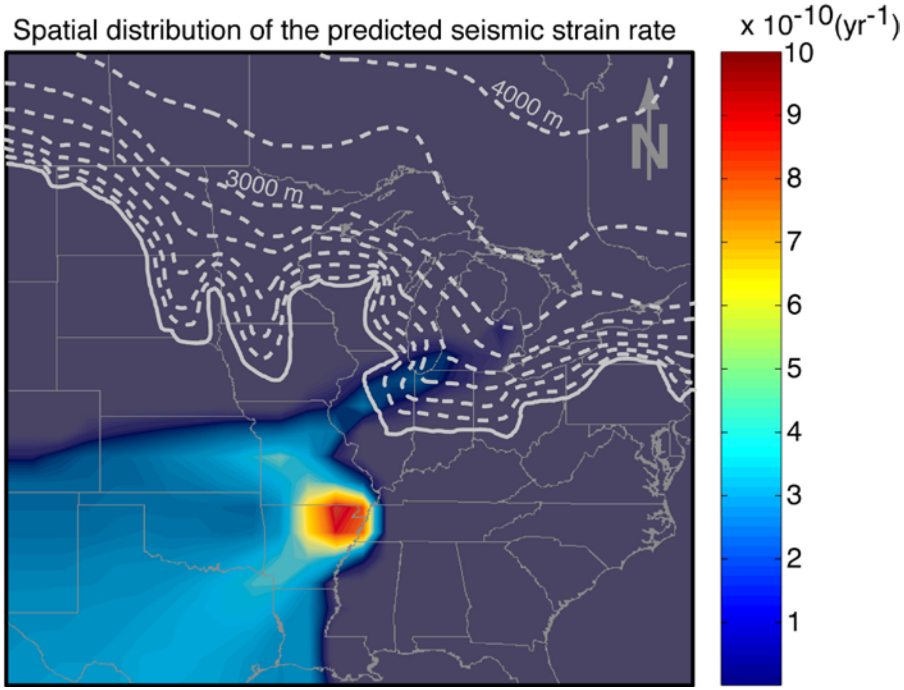


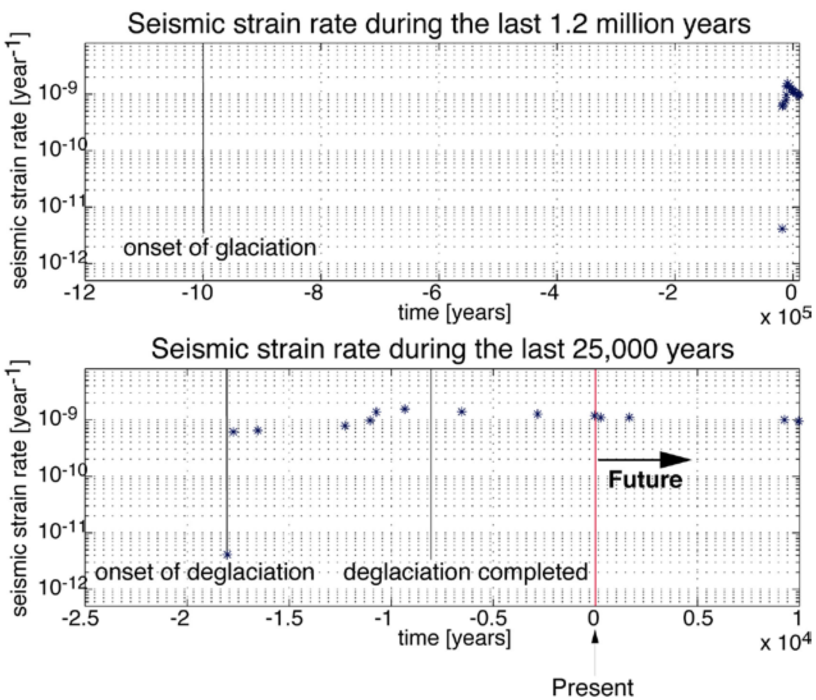
Estimated viscosity structure of the New Madrid region as a function of the assumed thermal gradient

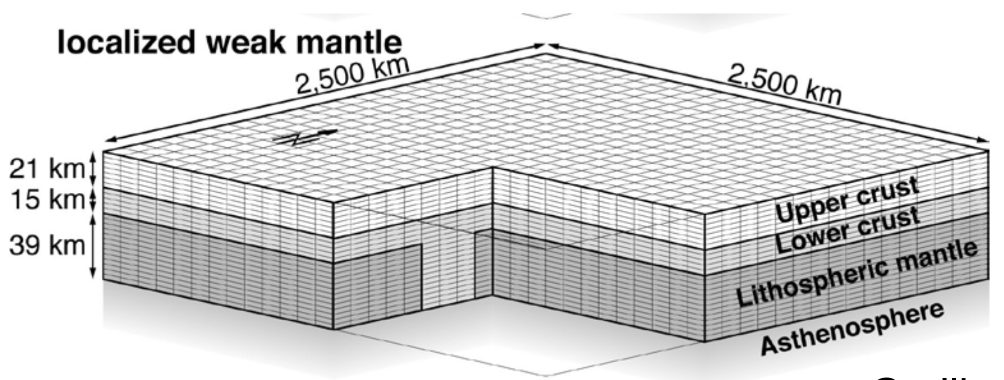


(Calais and others, 2010)

Concentrated Deformation in Area of a Localized Weak Mantle Model?

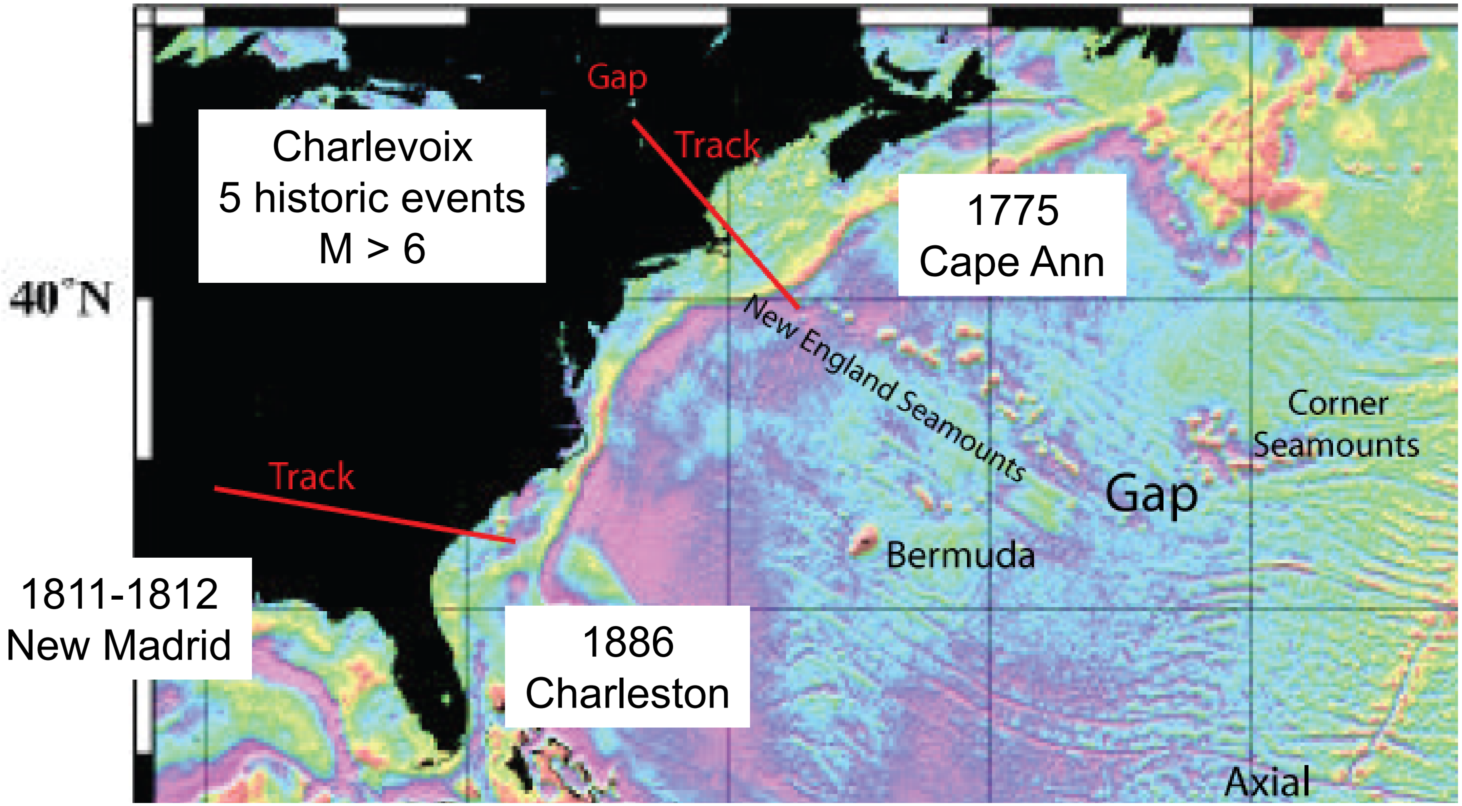






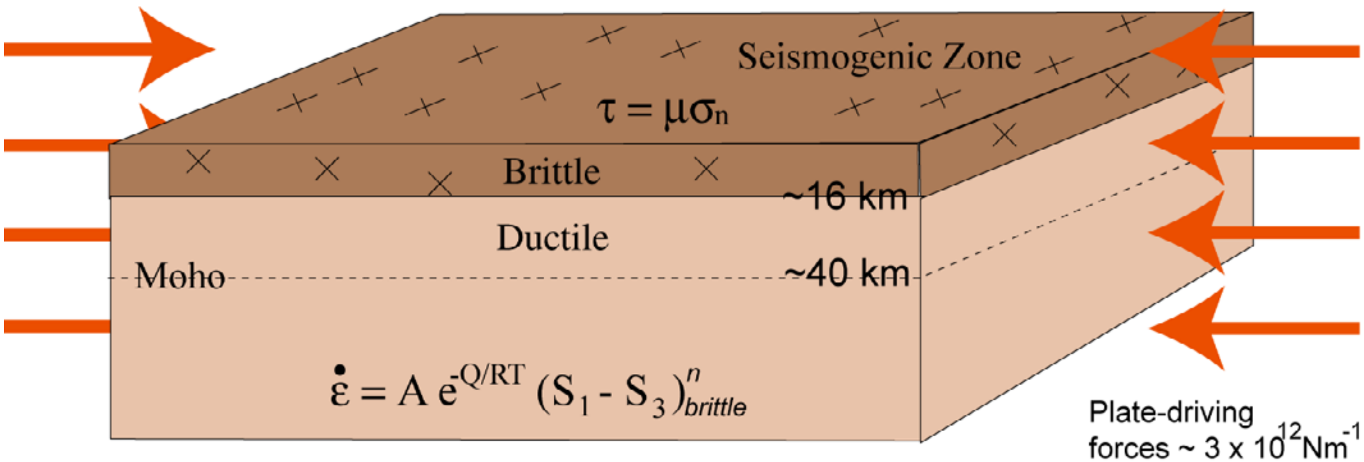
Grollimund and Zoback (2001)

Bermuda Hot Spot Track
(in New Madrid Area in Late Cretaceous Time)



Geologic History and Inheritance of Potential Seismogenic Structures is Important

Brittle Crust in Failure Equilibrium



Brittle Failure in Critically-Stressed Crust Results
From Creep in Lower Crust and Upper Mantle