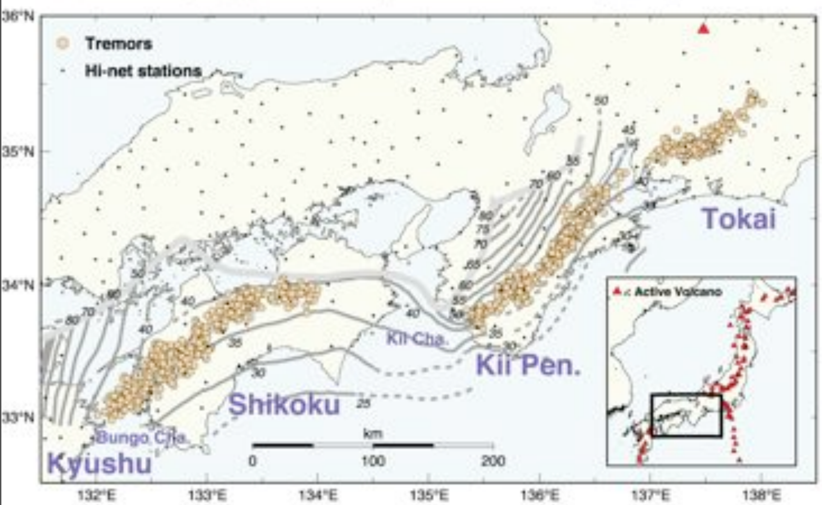
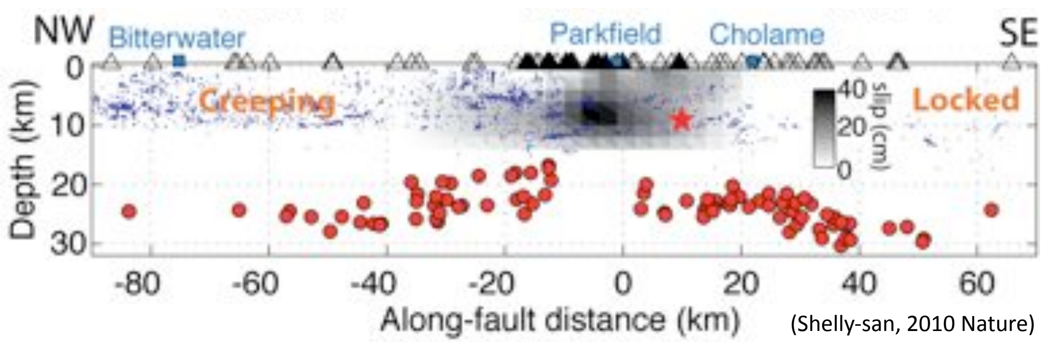
Implications of Transient Fault Slip for



(Obara-sensei, 2002 Science)



(Shelly-san, 2010 Nature)

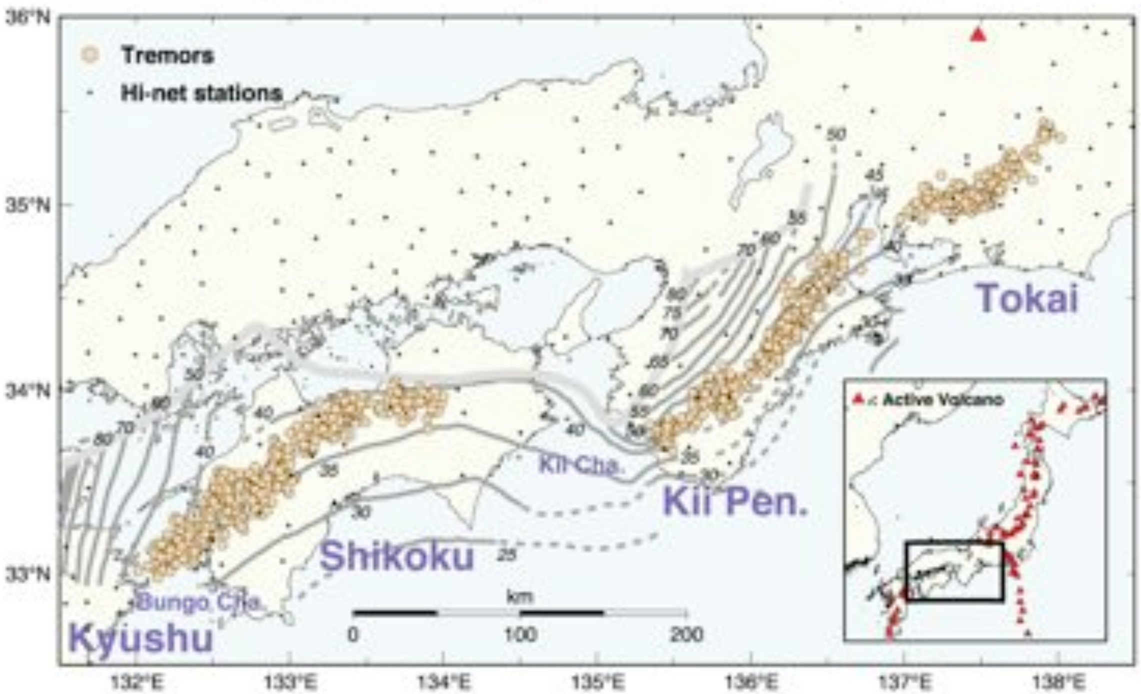
Wayne Thatcher

U. S. Geological Survey

Menlo Park, CA 94025

Thanks to : David Shelly, K. Obara, Greg Hirth, Rich Sibson, Greg Beroza
Susan Schwartz & Juliana Rokosky for Sharing Results

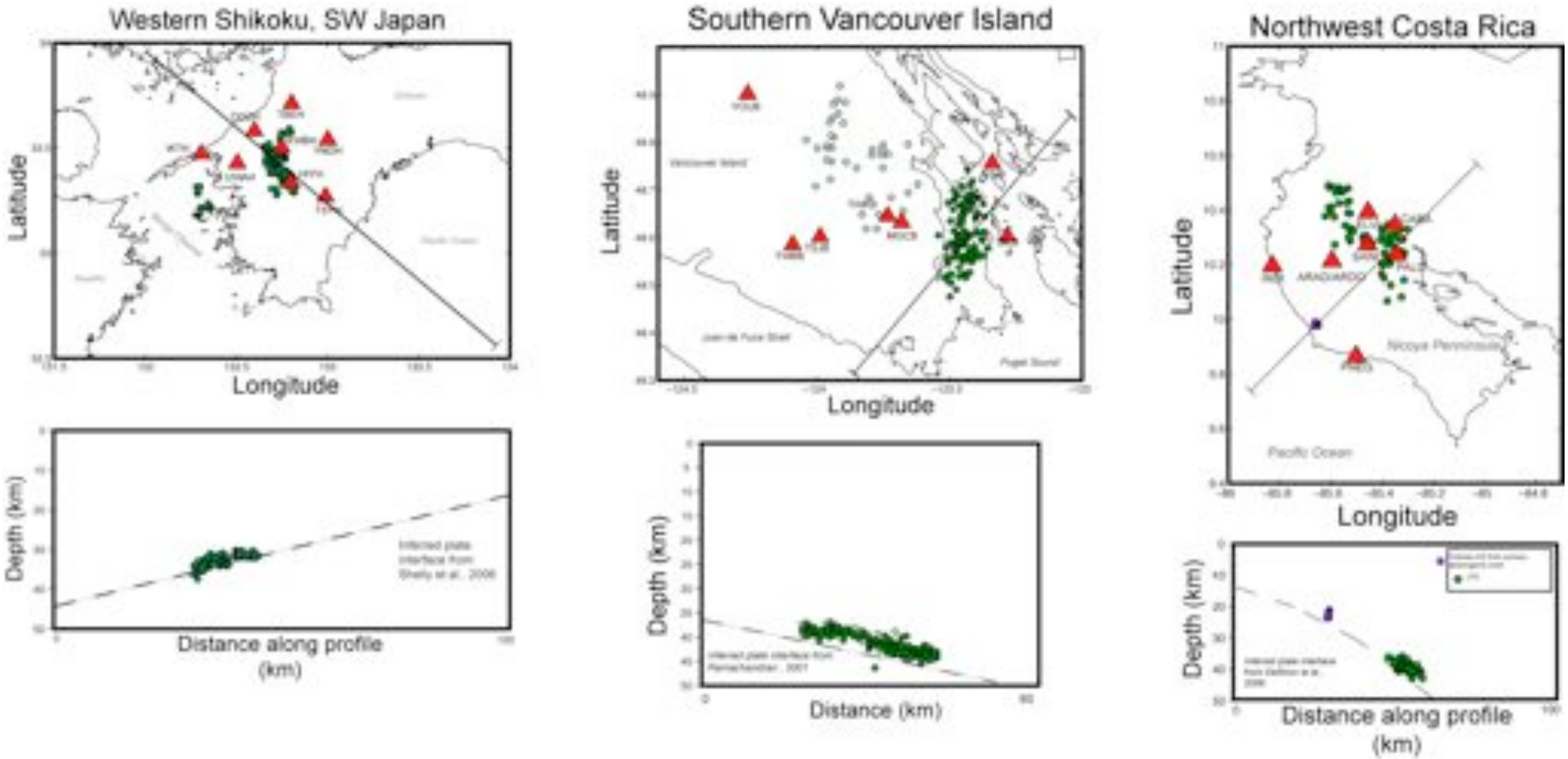
Lessons from Discovery of Deep Nonvolcanic Tremor



(Obara, 2002 Science)

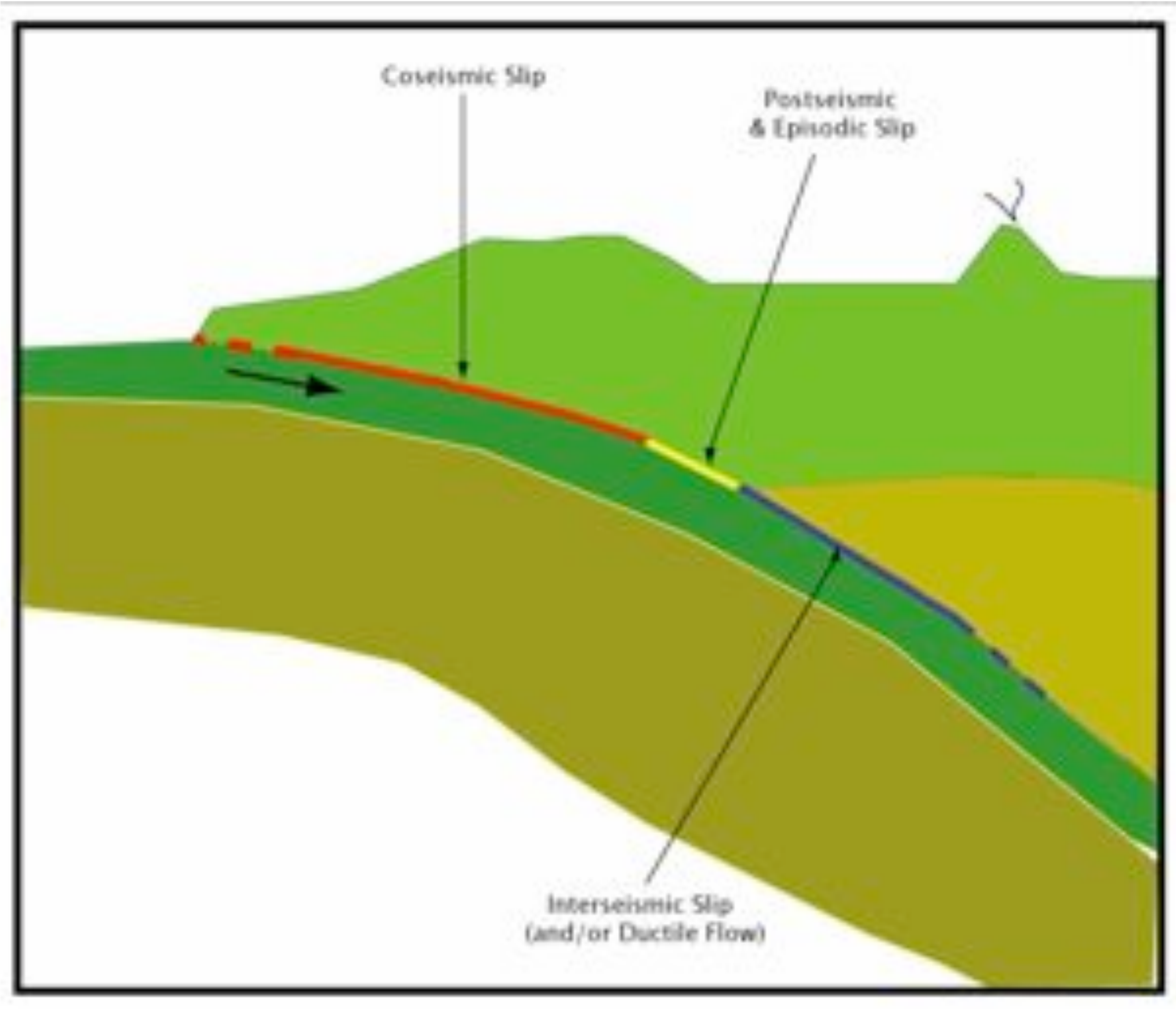
- Importance to eq science (Kei Aki's 2001 comment)
- Arguably would not have been found without Hi-net (highlighting crucial role of better observation nets)

Tremor Occurs on the Deep Extension of Faults



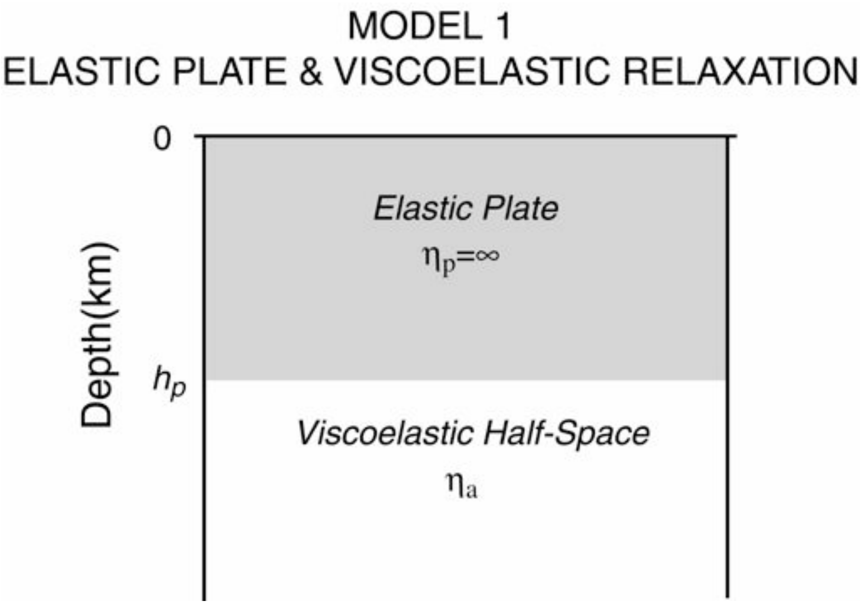
***Brown et al.* [2009]**

Generic Subduction Zone



Alternative Mechanisms of Post Earthquake

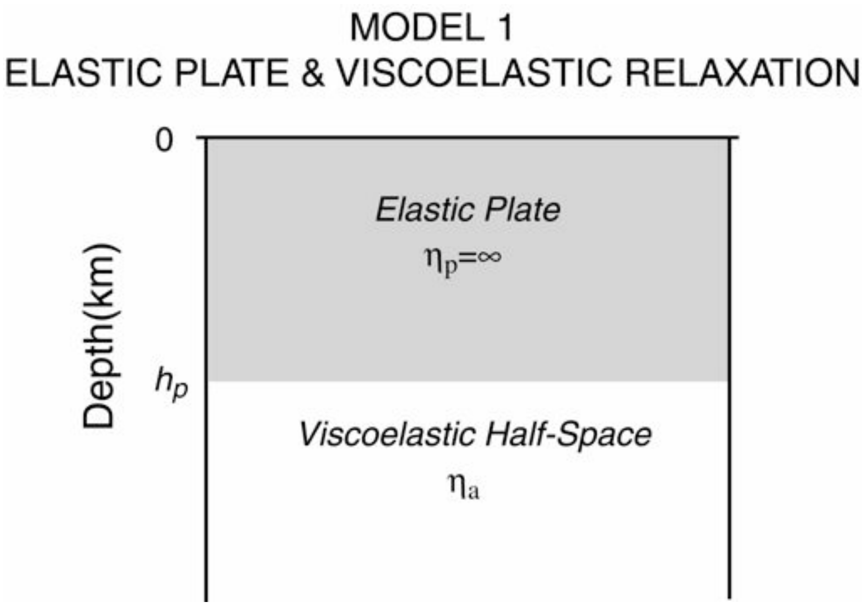
Alternative Mechanisms of Post Earthquake



- Elastic plate coupled to ductile underlying layer (or layers)
- Earthquake stresses relax

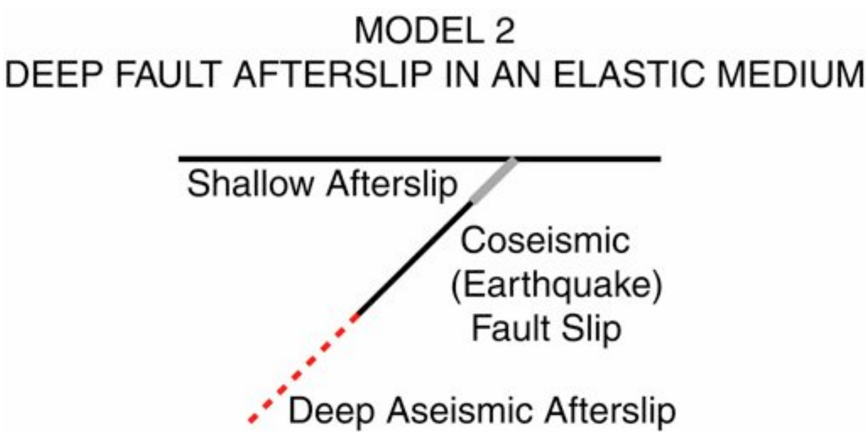
  by ductile flow
- Elastic plate thickness determines scale of surface deformation
- Effective viscosity determines time dependence

Alternative Mechanisms of Post Earthquake



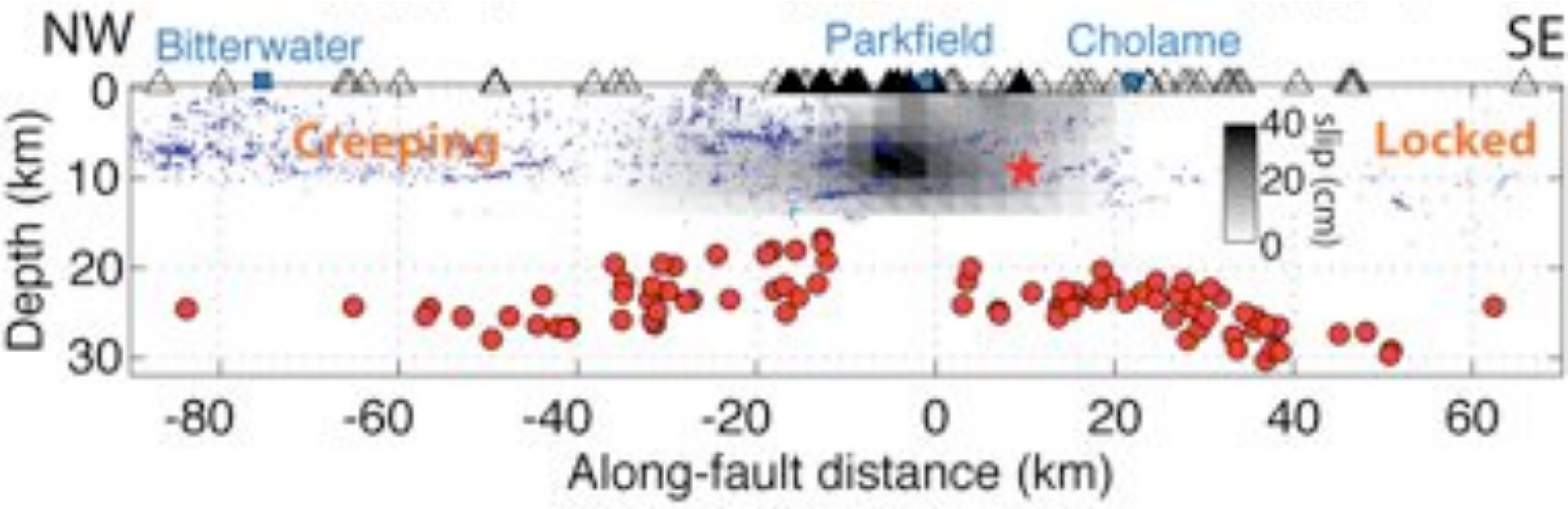
- Elastic plate coupled to ductile underlying layer (or layers)
- Earthquake stresses relax

  by ductile flow
- Elastic plate thickness determines scale of surface deformation
- Effective viscosity determines time dependence



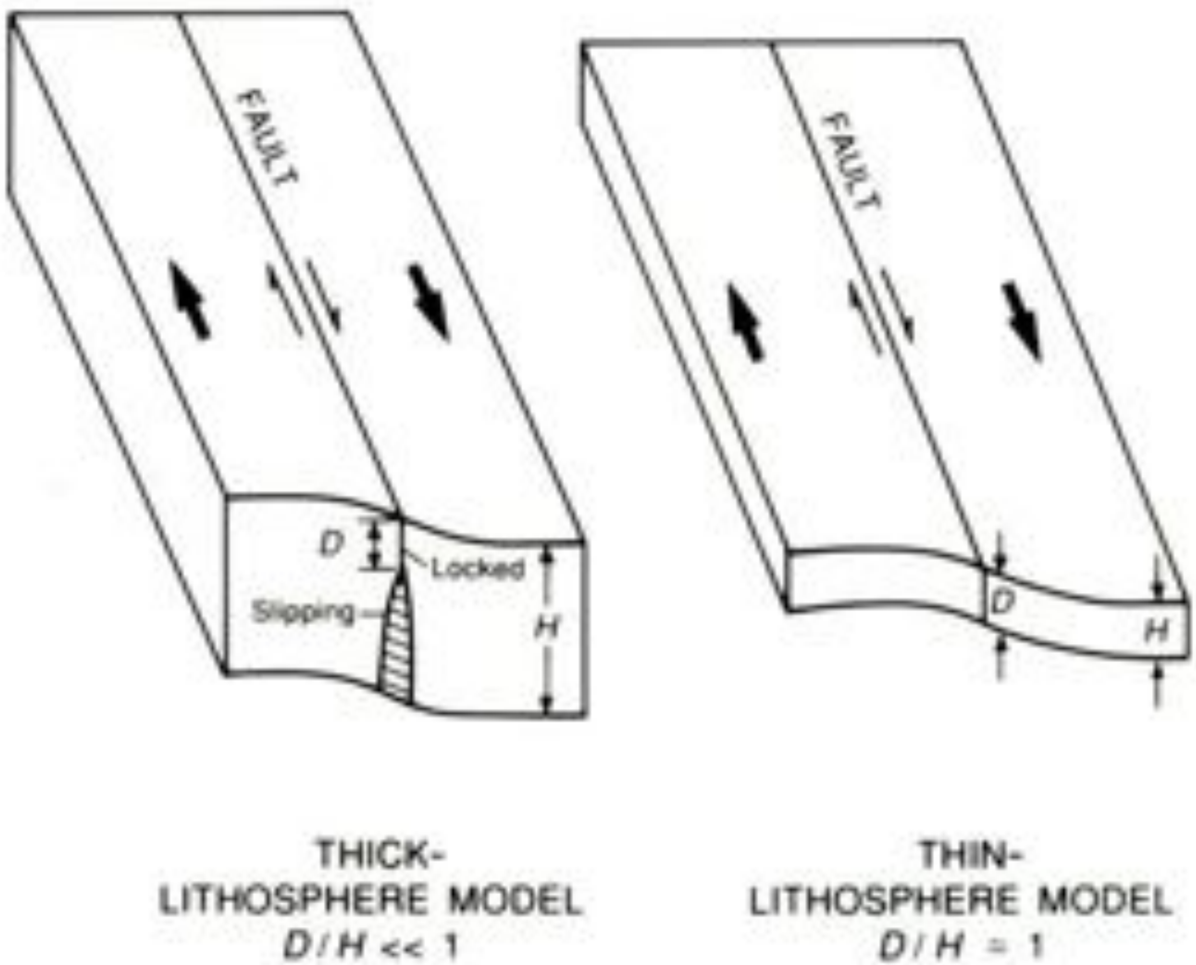
- On down-dip extension (or low slip parts) of earthquake fault plane
- More important process at major, high slip rate, plate boundaries?
- Fault geometry and depth determine scale of surface motions
- Aseismic fault slip history determines time dependence

Tremor Hypocenters Show Seismogenic Zone SAF Continues As Localized Shear Zone to Base of Crust



(Shelly & Hardebeck, 2010 GRL)

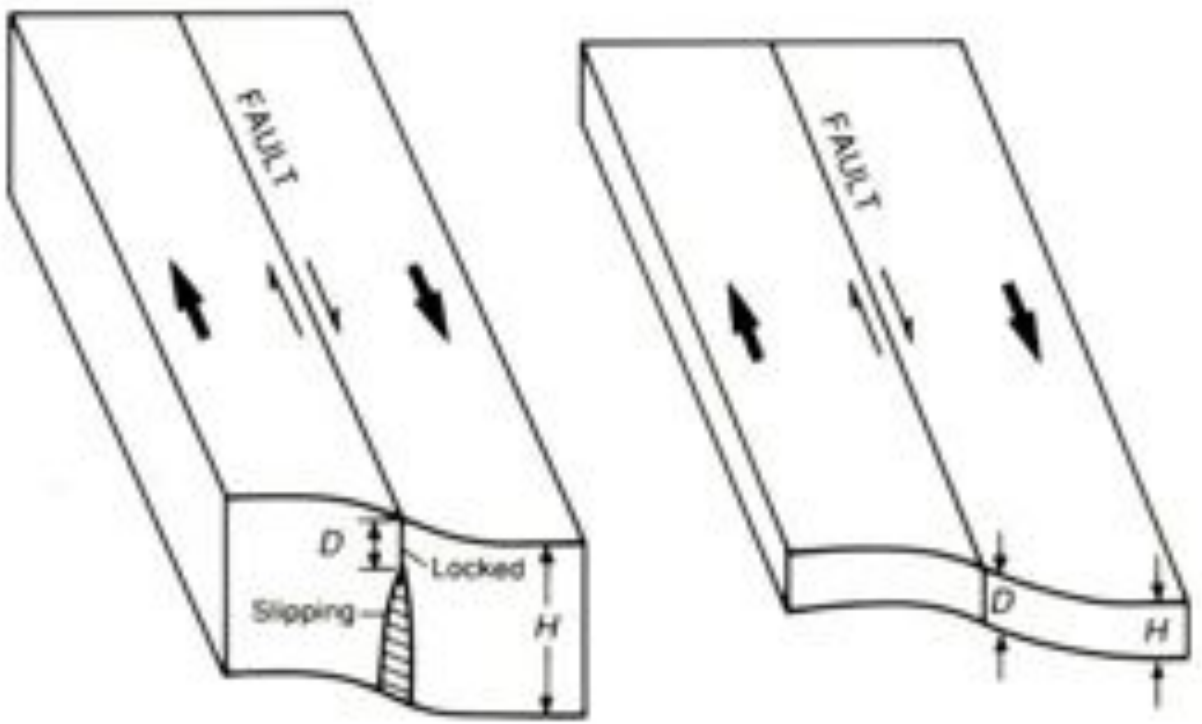
Thick & Thin Lithosphere Models of Earthquake Deformation Cycle



"Savage-Burford"

"Savage-Prescott"

Thick & Thin Lithosphere Models of Earthquake Deformation Cycle



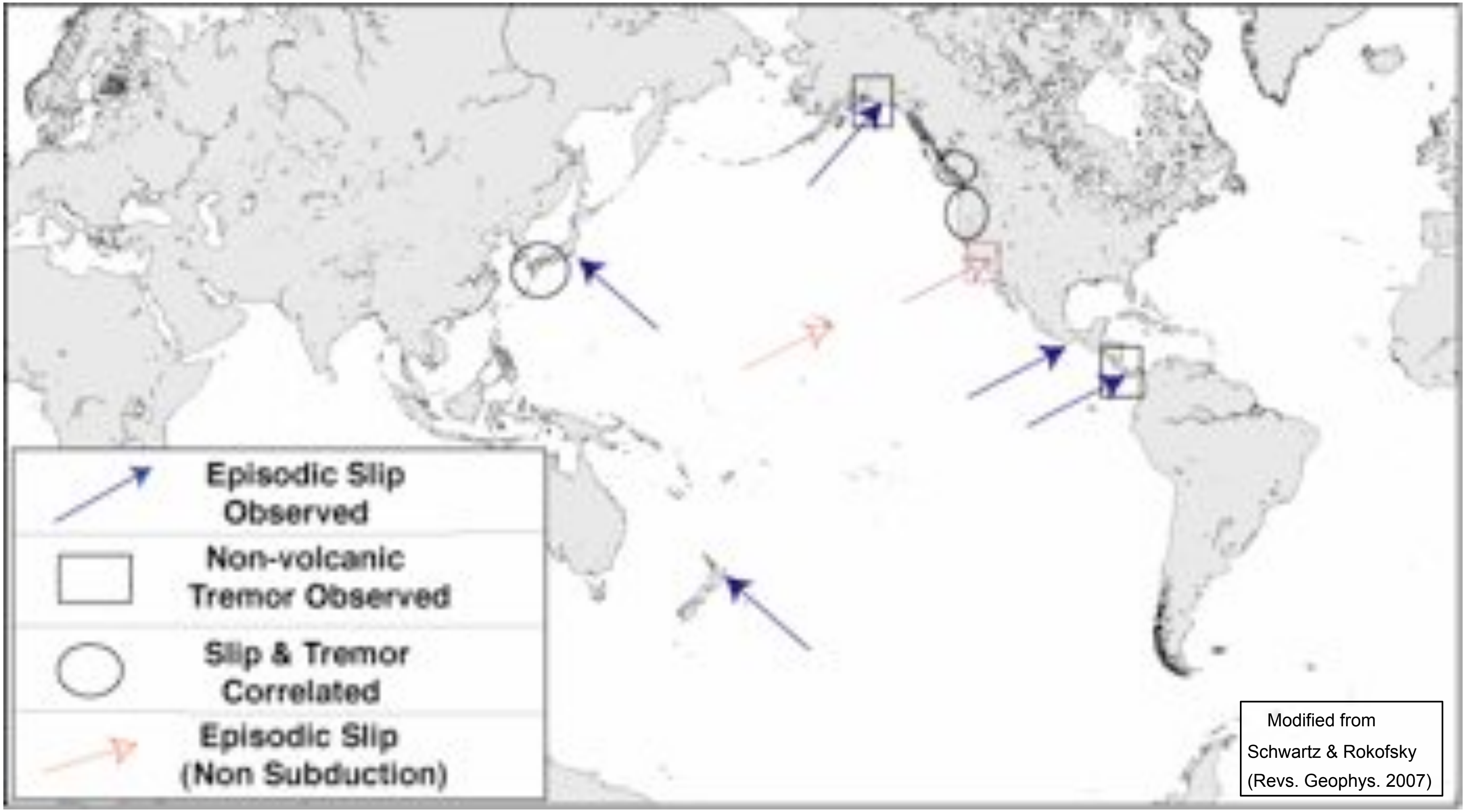
THICK-
LITHOSPHERE MODEL
D / H << 1

"Savage-Burford"

THIN-
LITHOSPHERE MODEL
D / H = 1

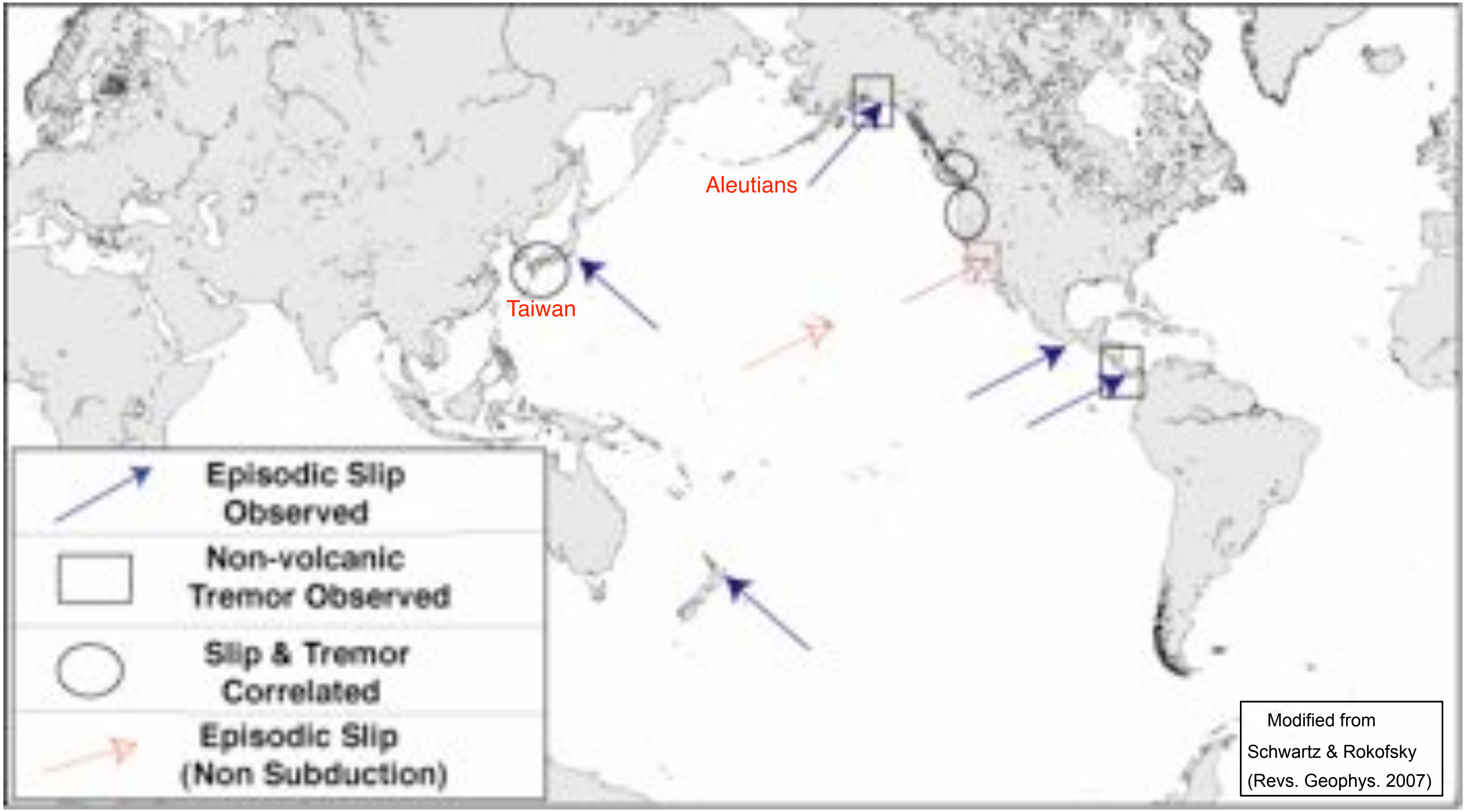
"Savage-Prescott"

Current Observations of Episodic Slip & Non-Volcanic Tremor--Where Else?



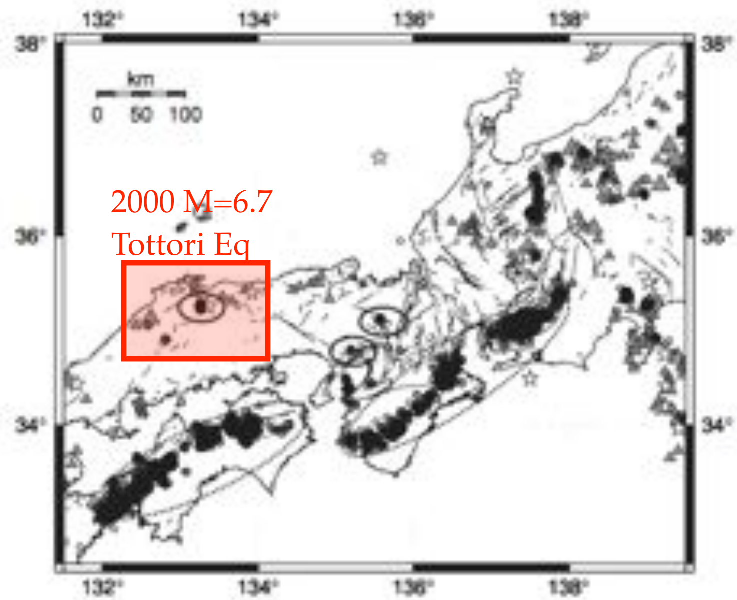
- Observed Mainly in Subduction of Young Oceanic Lithosphere
  - Where else does it occur in subduction zones?
  - What about tremor detection on continental faults?

Current Observations of Episodic Slip & Non-Volcanic Tremor--Where Else?



- Observed Mainly in Subduction of Young Oceanic Lithosphere
  - Where else does it occur in subduction zones?
  - What about tremor detection on continental faults?

Does Tremor Occur at Ductile Roots of "Minor" Low Cumulative Offset Faults?



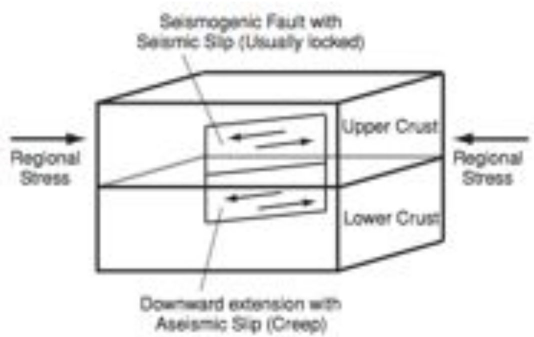
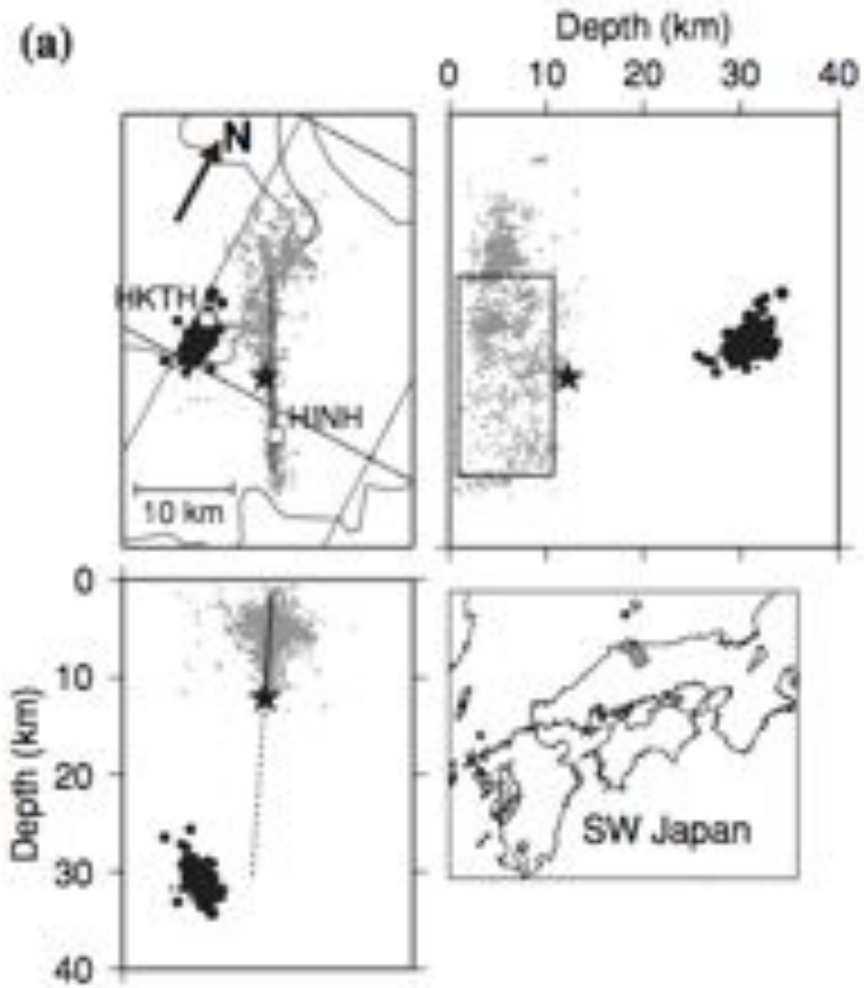
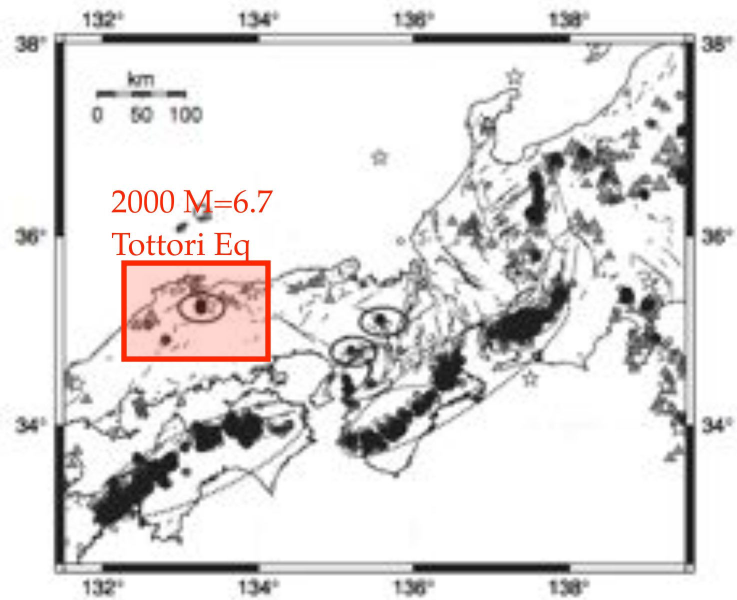


Fig. 6. Schematic cartoon of the downward extension of the seismogenic fault proposed by Iio and Kobayashi (2002). Downward extension of the fault in the lower crust plays an important role to accumulate stress on the seismogenic fault in the upper crust.



Ohmi et al, 2004 EPS

Does Tremor Occur at Ductile Roots of "Minor" Low Cumulative Offset Faults?



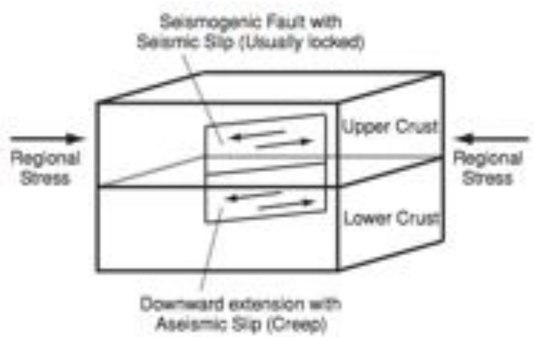
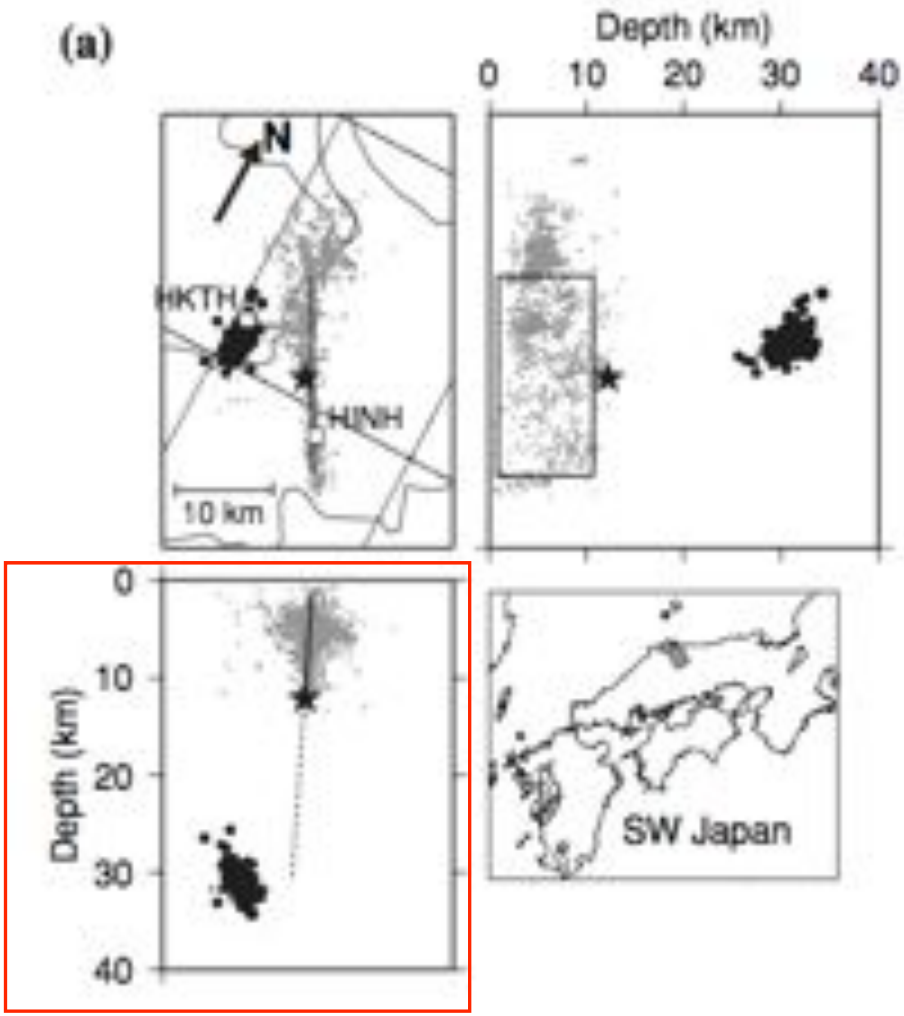
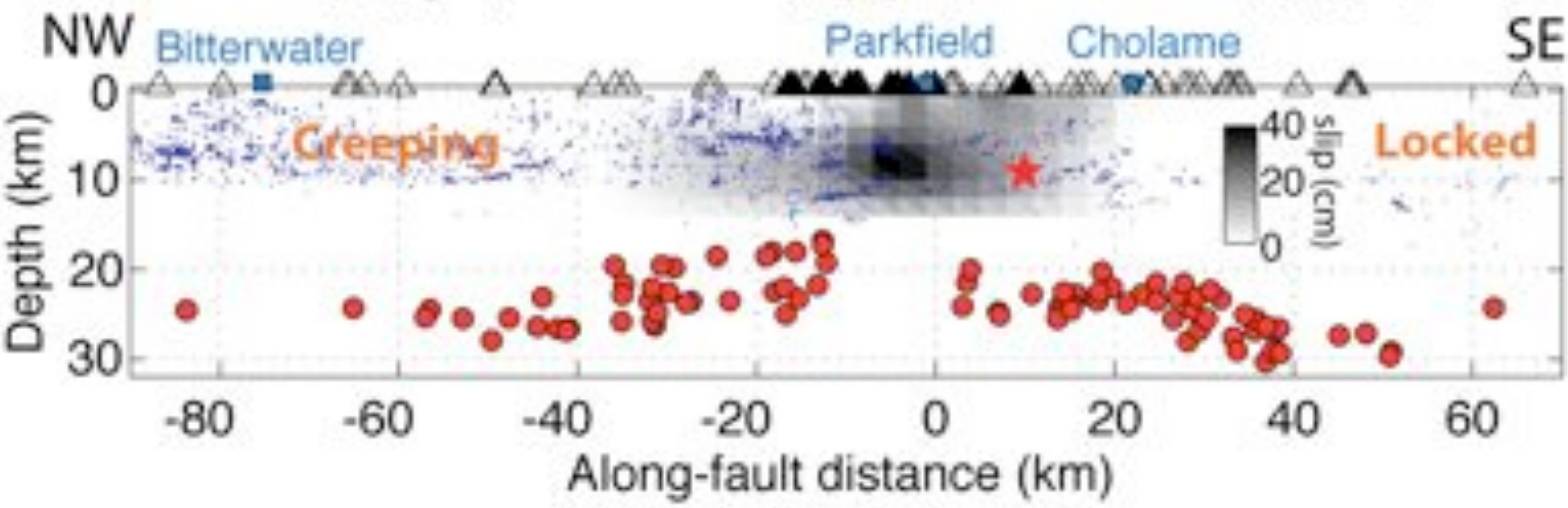


Fig. 6. Schematic cartoon of the downward extension of the seismogenic fault proposed by Iio and Kobayashi (2002). Downward extension of the fault in the lower crust plays an important role to accumulate stress on the seismogenic fault in the upper crust.



Ohmi et al, 2004 EPS

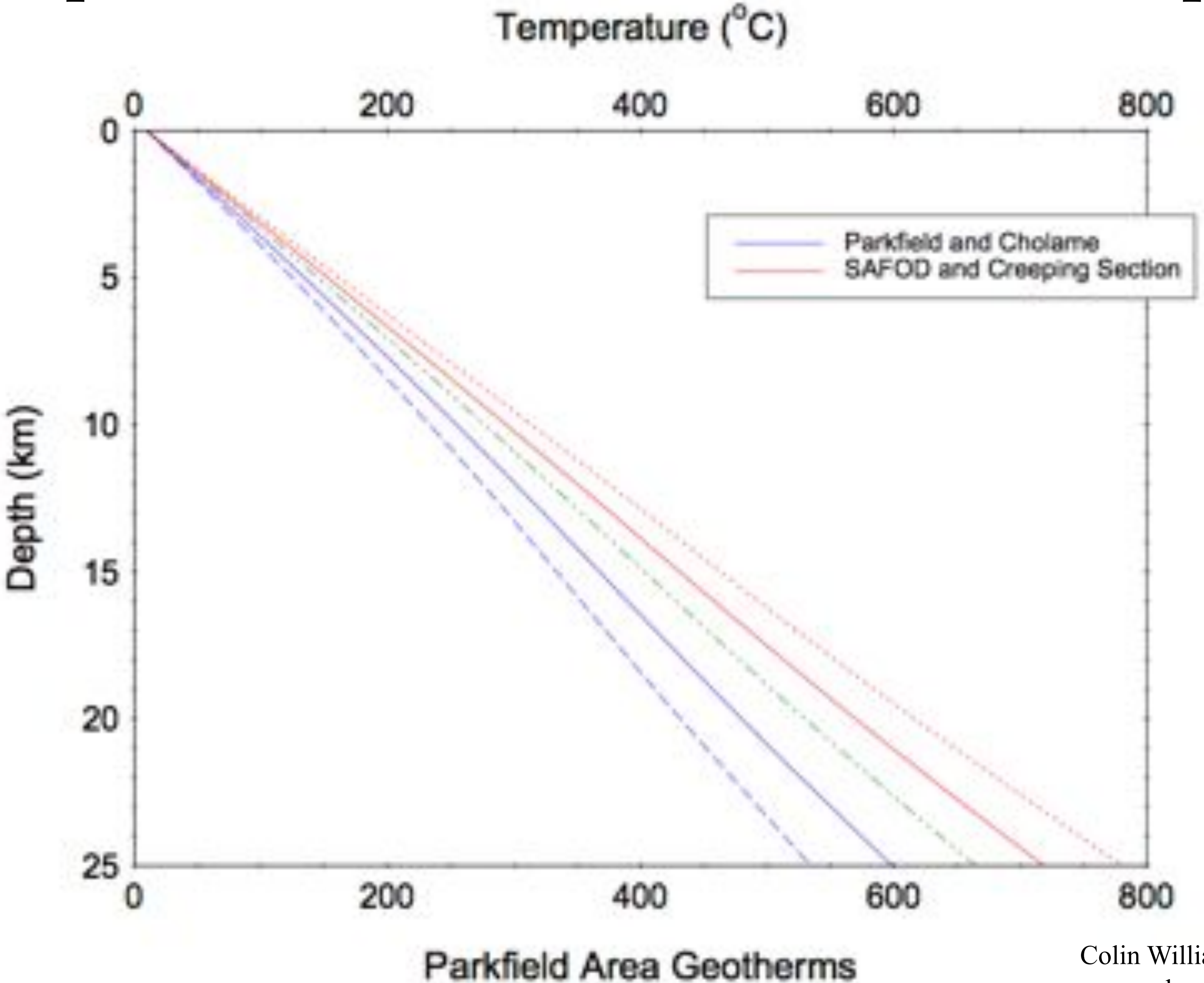
SAF Tremor Hypocenters Show Brittle-like Deformation Occurring at Temperatures Where Ductile Shear Expected



(Shelly & Hardebeck, 2010 GRL)

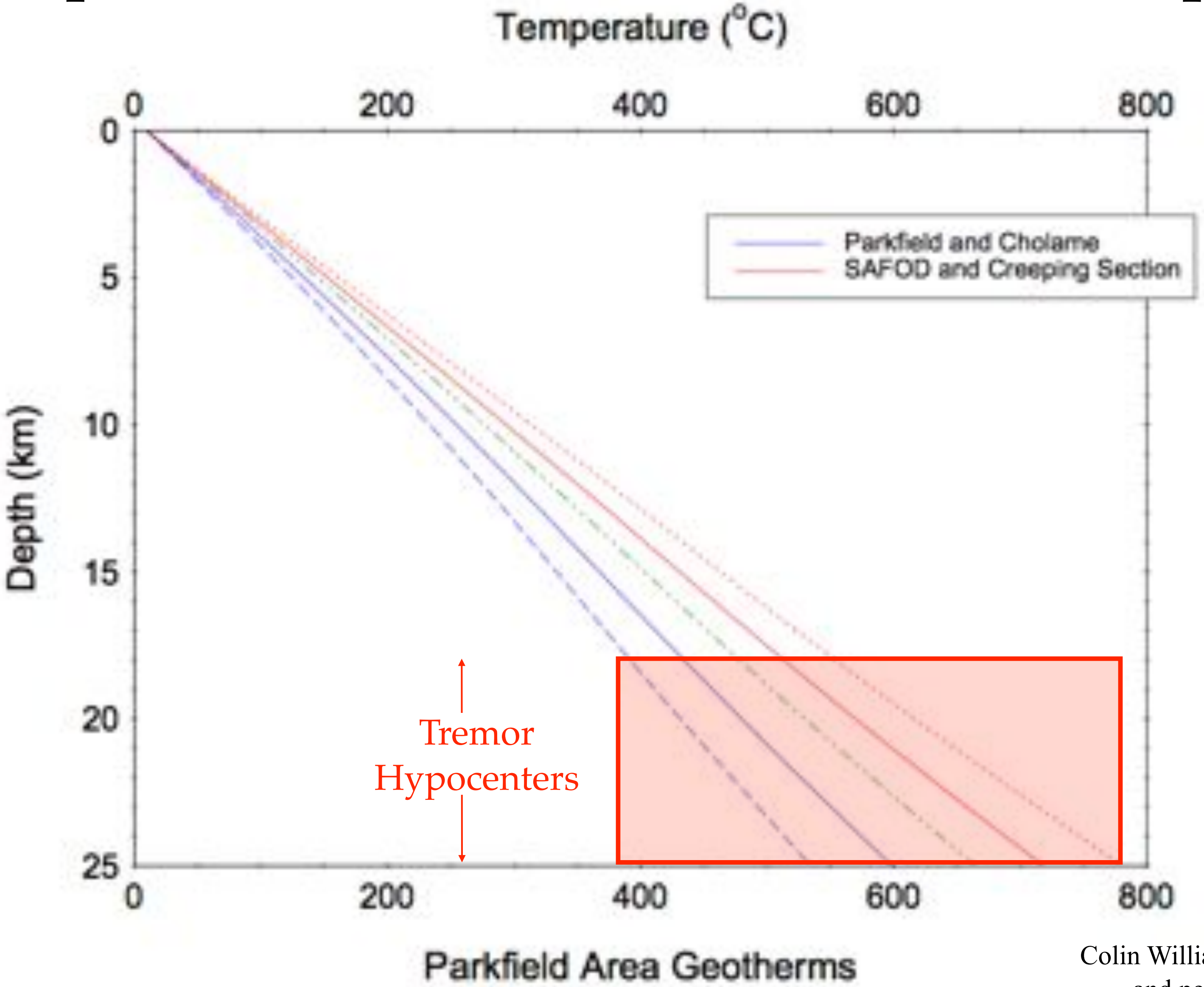
As Dave Shelly & Darrel Cowan Asked,
What's Going On??

Conductive Geotherm at Parkfield Requires Temperature of 400˚- 800˚ at Tremor Depths



Colin Williams et al. 2004 GRL
and pers. comm. 2010

Conductive Geotherm at Parkfield Requires Temperature of 400°- 800° at Tremor Depths



Colin Williams et al. 2004 GRL
and pers. comm. 2010

Transition from Discontinuous to Continuous Shearing

Surface Rupture

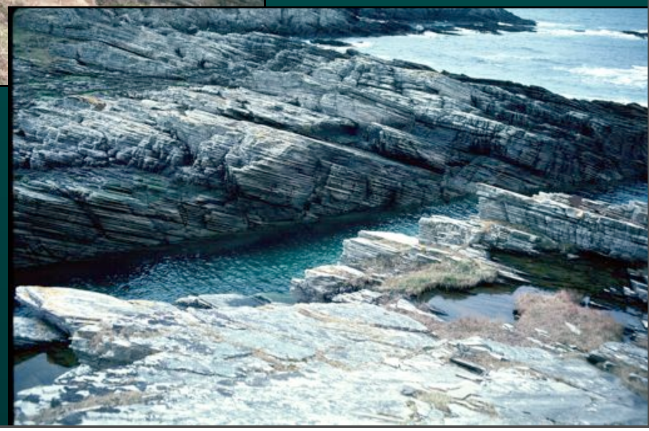
SEISMOGENIC ZONE

5-10 km

DISCONTINUOUS

c. 15 km
T ~ 350°C

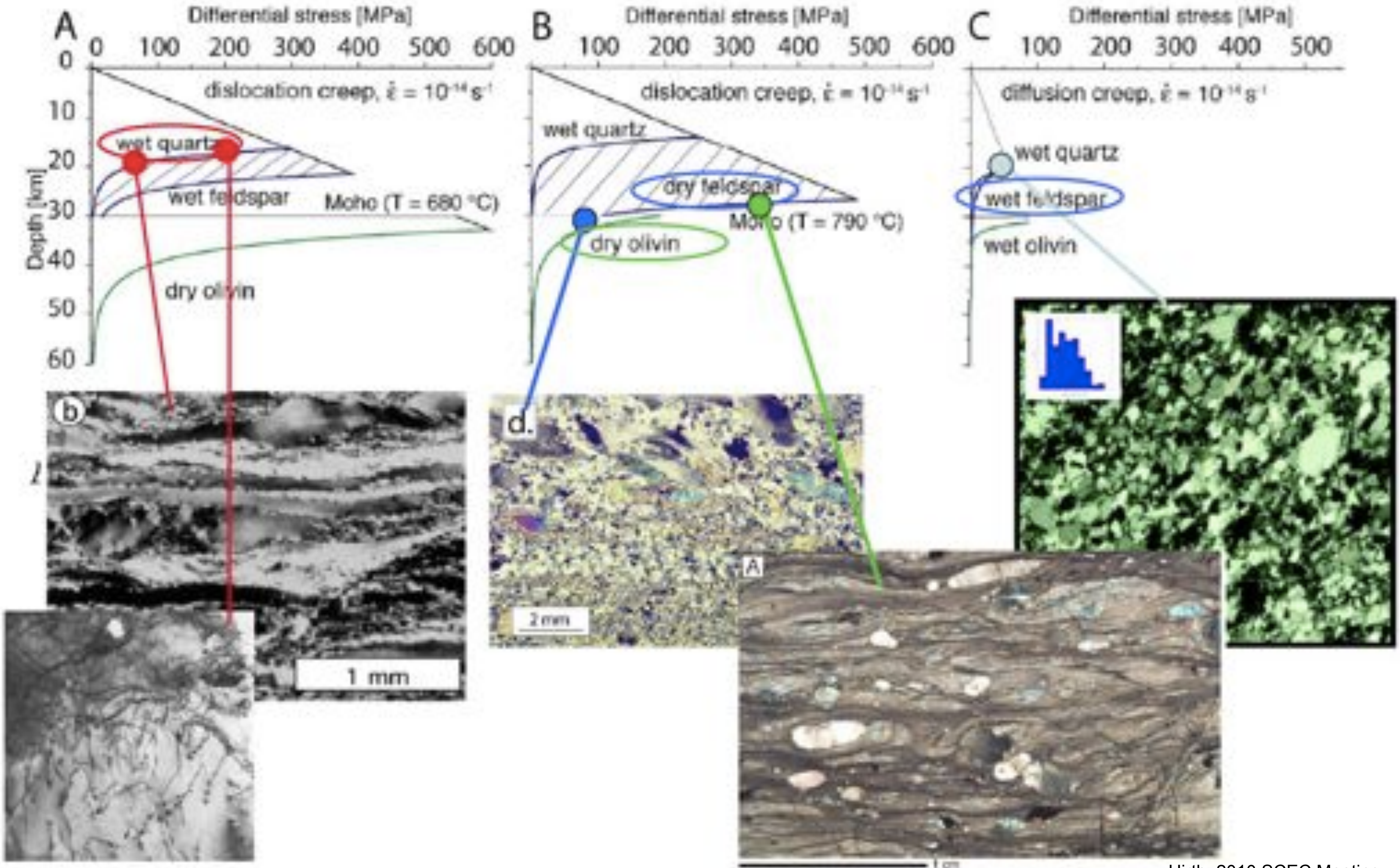
Type Mylonite
Eriboll



CONTINUOUS

c. 20-25 km

Behavior of Deep Roots of Faults
"earthquake science from the bottom up"



Hirth, 2010 SCEC Meeting

New Science Directions 1

New Science Directions 1

- Investigate mixed ductile/brittle deformation tremor models
  - -Could SSEs and tremor be mostly ductile processes?
  - -ductile instabilities in the lab?
  - -see Daub et al. poster

New Science Directions 1

- Investigate mixed ductile/brittle deformation tremor models
  - -Could SSEs and tremor be mostly ductile processes?
  - -ductile instabilities in the lab?
  - -see Daub et al. poster

- World-wide searches for tremor
  - -establish scale for relative activity level
  - -many networks with untapped data
  - -low slip rate continental faults
  - -negative results important!

New Science Directions 2

- Tremor monitoring in near-real time

  -suggested by Shelly (2010 GRL)

  -ETS undeniably loads shallow seismogenic fault (Mazzoti & Adams, 2004 BSSA)

  -tremor exquisitely sensitive to small stress changes

  -Why not? Technology exists & potential payoff high