The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA
International Atomic Energy Agency

2053-40

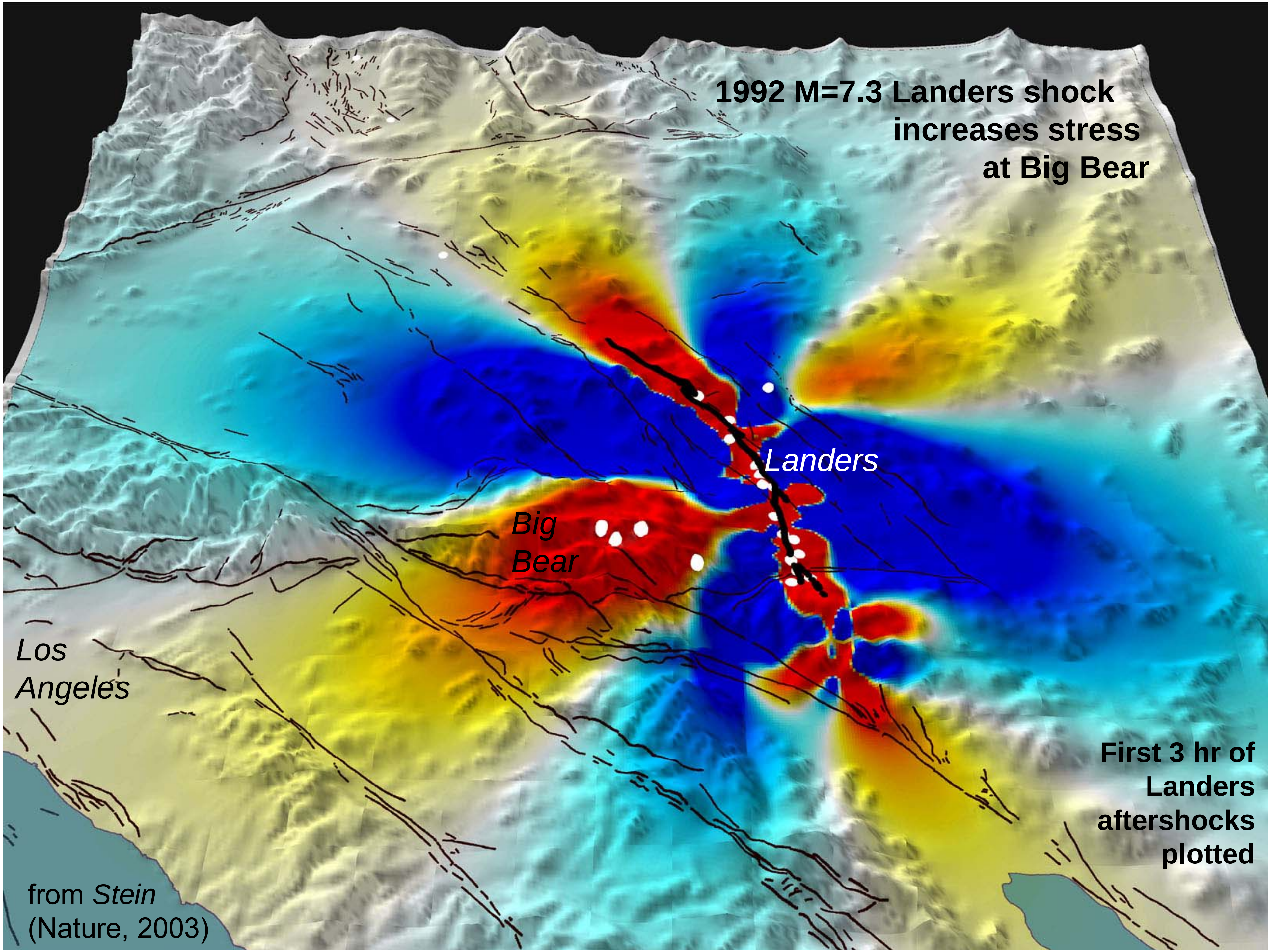
Advanced Workshop on Evaluating, Monitoring and Communicating Volcanic and Seismic Hazards in East Africa

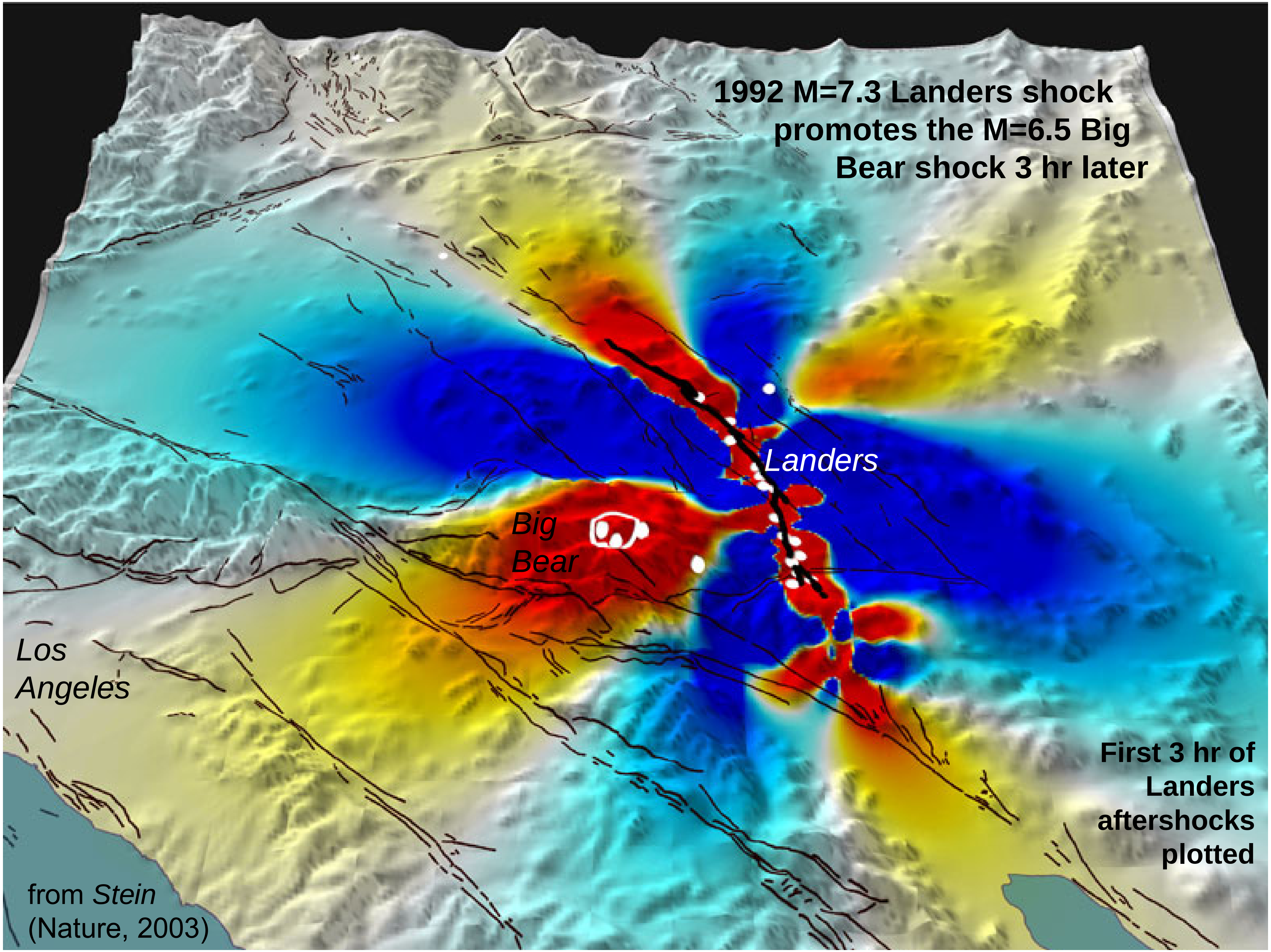
17 - 28 August 2009

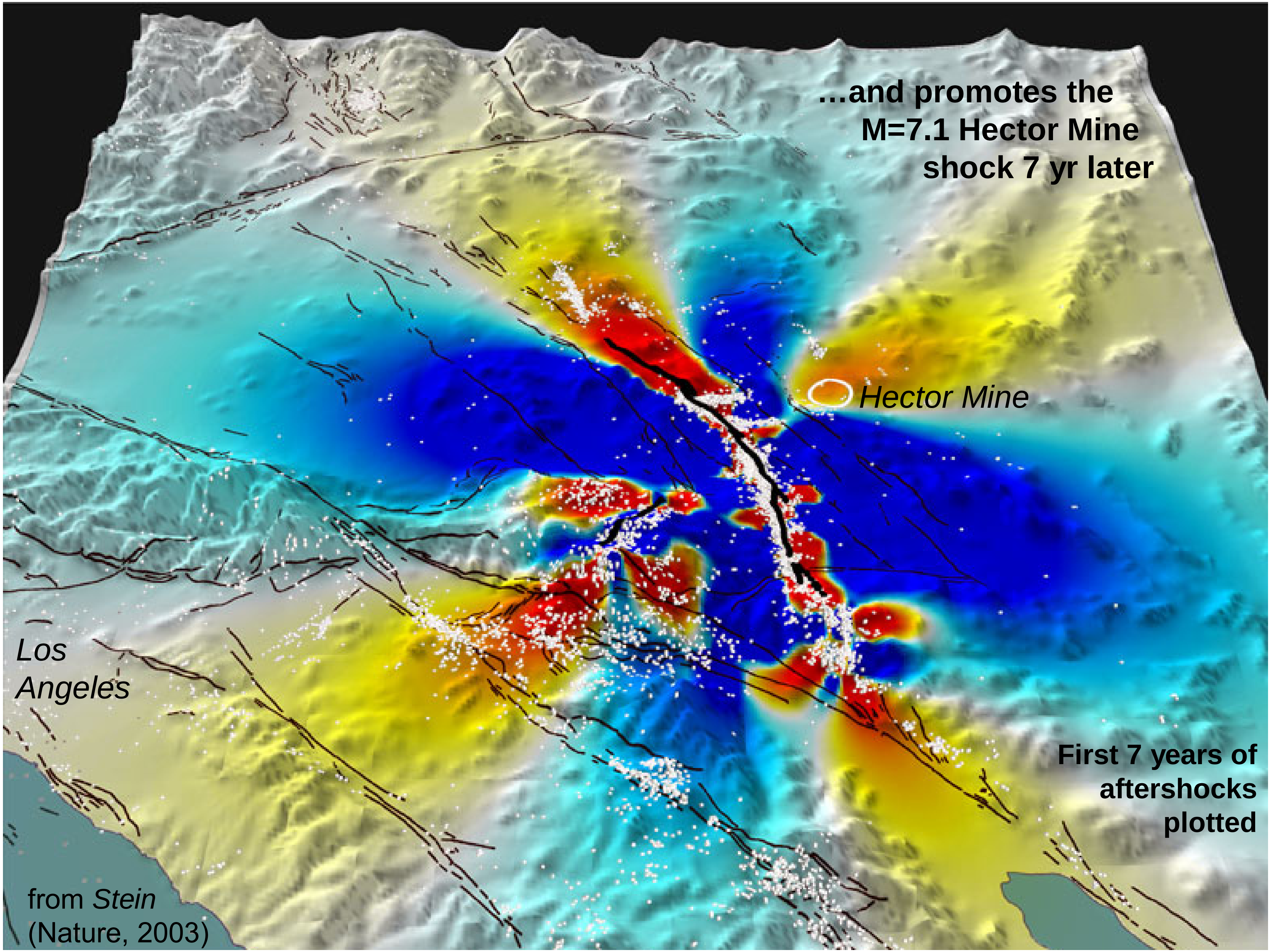
Coulomb 3.1 basics demonstration (displacement, strain, stress)

Ross Stein

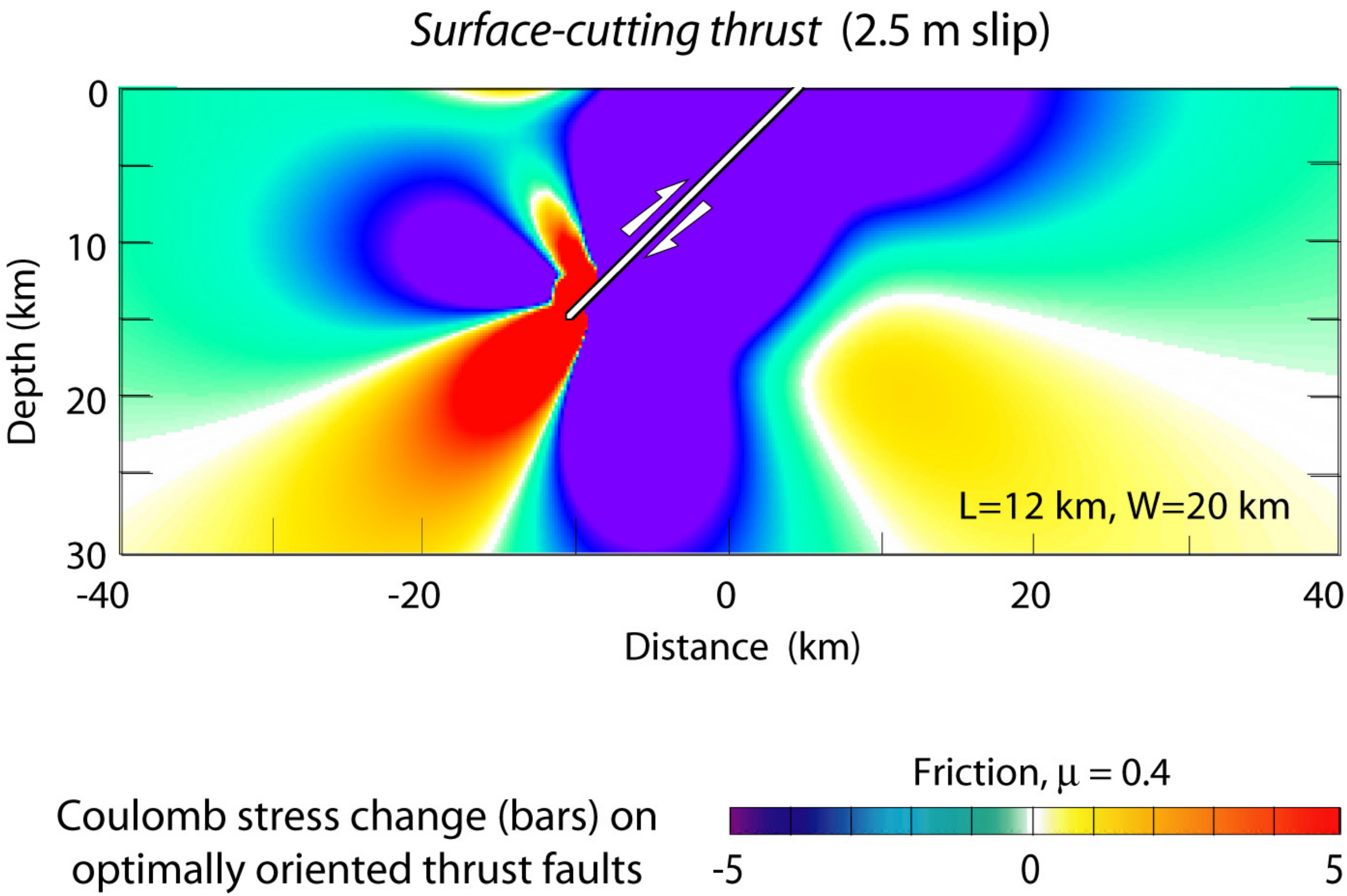
US Geological Survey, Menlo Park
USA


1992 M=7.3 Landers shock
increases stress
at Big Bear
Landers
Big
Bear
Los
Angeles
First 3 hr of
Landers
aftershocks
plotted
from Stein
(Nature, 2003)


1992 M=7.3 Landers shock promotes the M=6.5 Big Bear shock 3 hr later
Landers
Big Bear
Los Angeles
First 3 hr of Landers aftershocks plotted
from *Stein* (Nature, 2003)

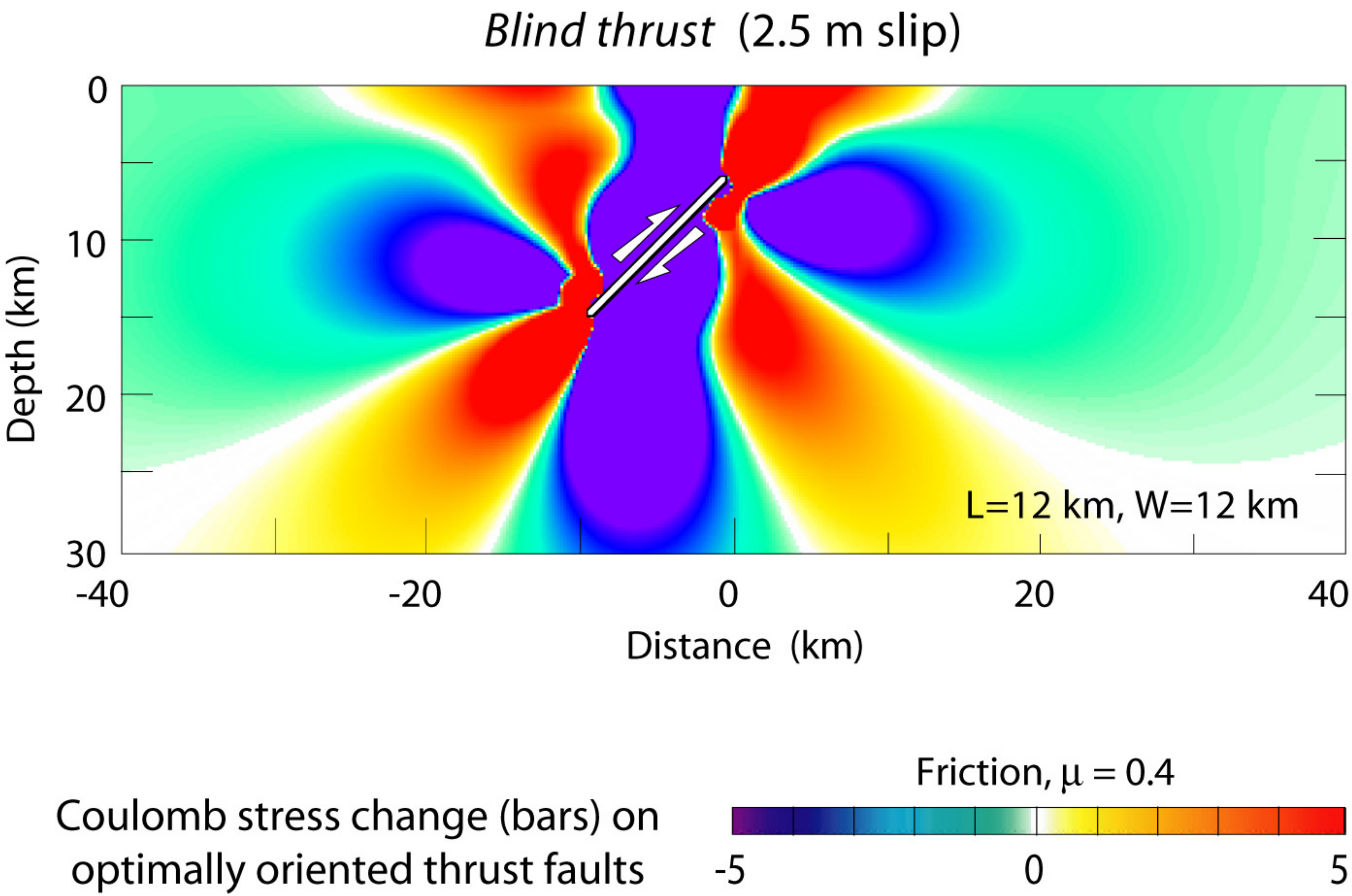

...and promotes the
M=7.1 Hector Mine
shock 7 yr later
Hector Mine
Los
Angeles
First 7 years of
aftershocks
plotted
from Stein
(Nature, 2003)

Surface-cutting thrusts drop the stress in the upper crust



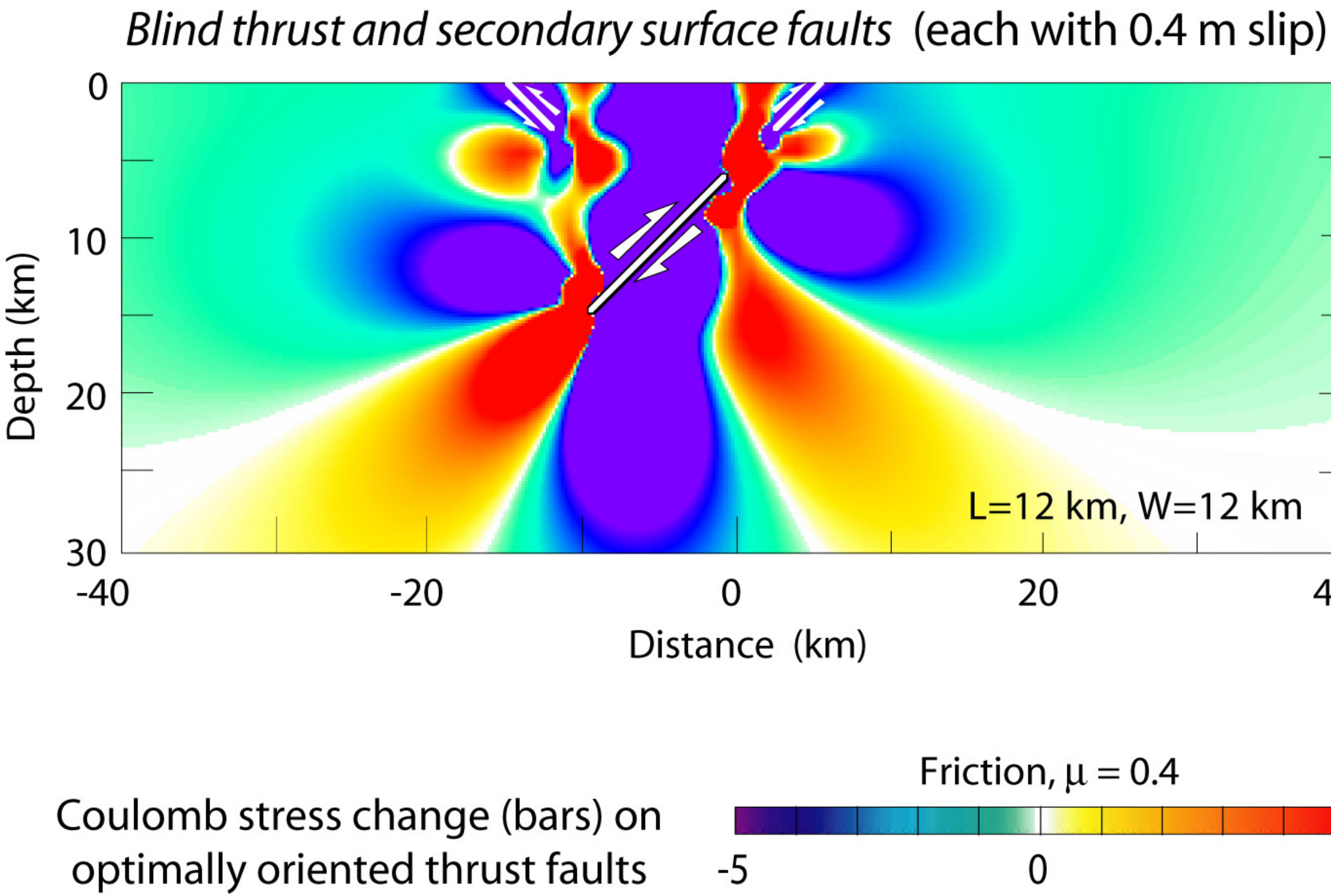
from *Lin & Stein* (JGR, 2004)

Blind thrusts raise the stress in parts of the upper crust

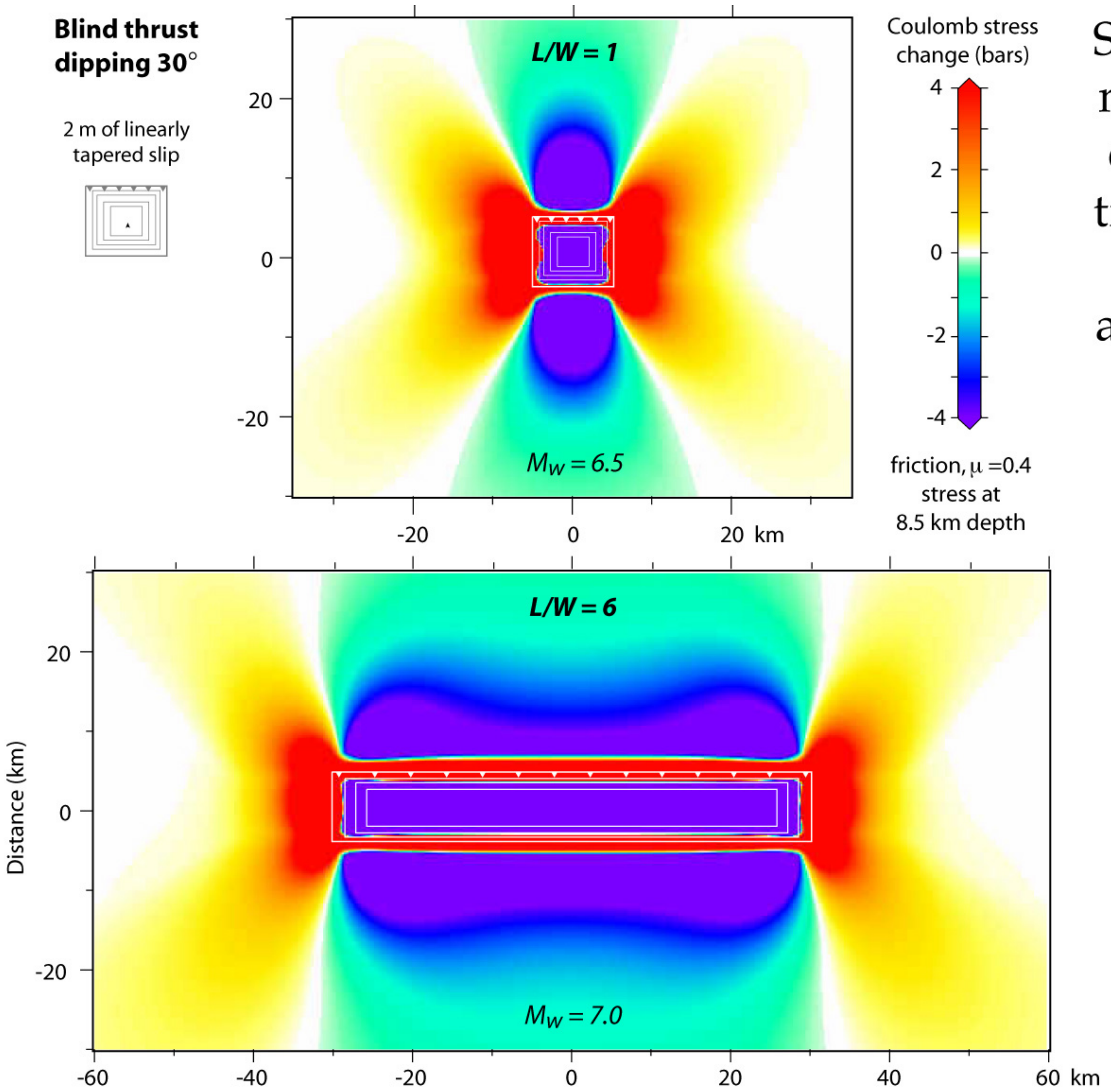


from *Lin & Stein* (JGR, 2004)

Secondary surface faults relieve the imparted stress

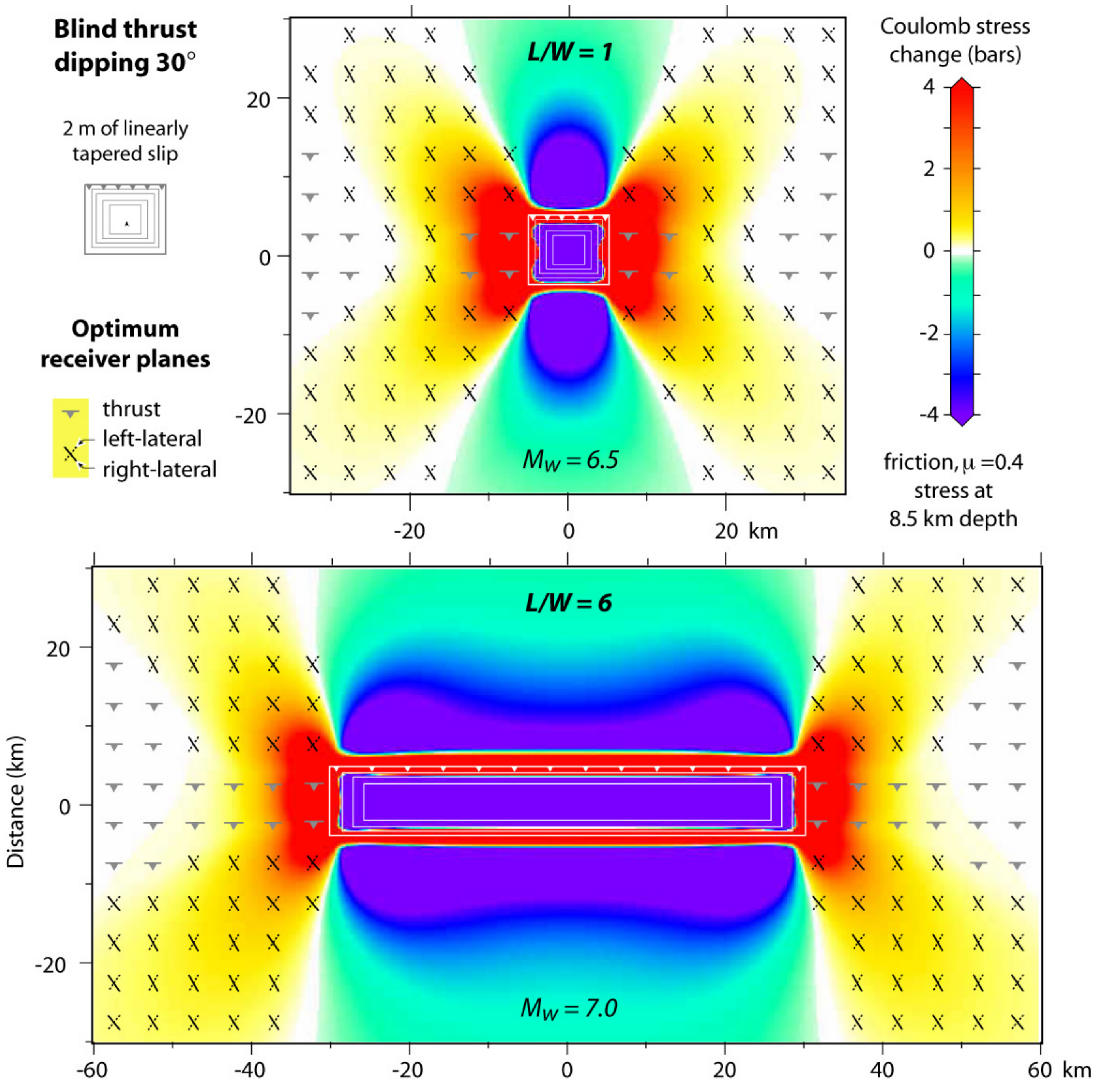


from *Lin & Stein* (JGR, 2004)



Short thrusts much more efficient at transferring stress along strike

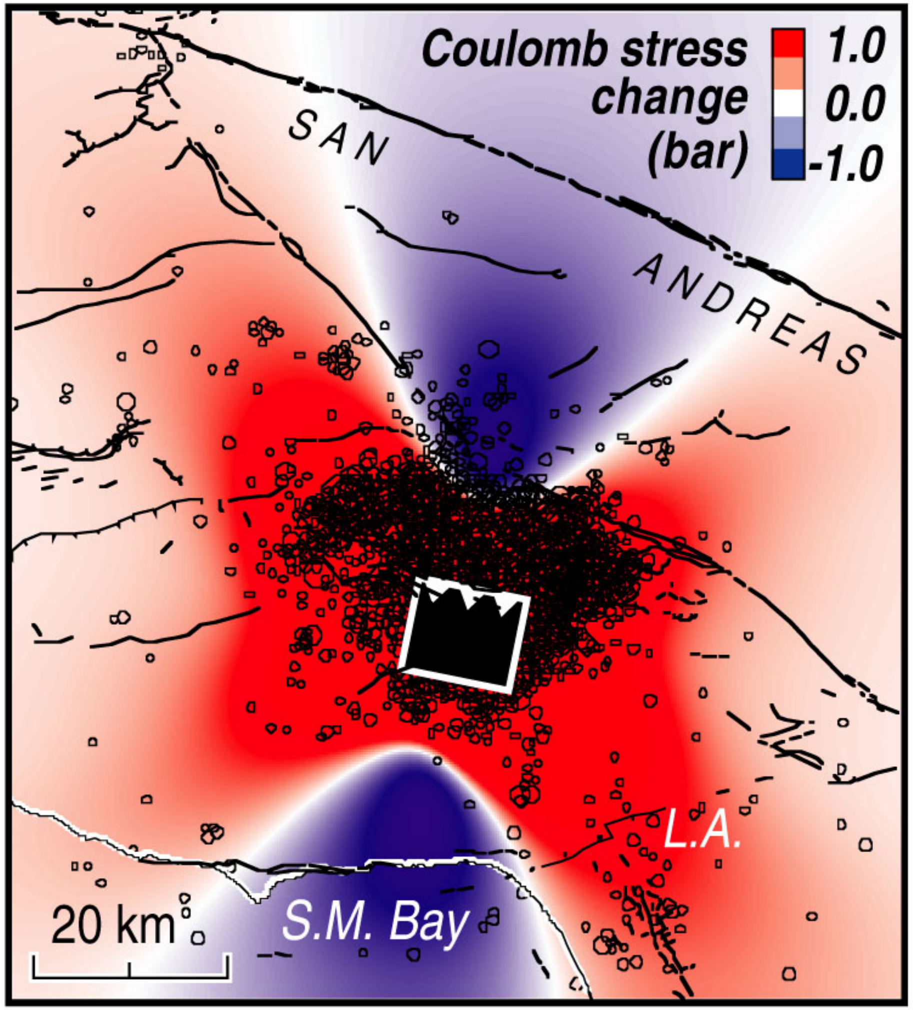
from *Lin & Stein* (JGR, 2004)



Stress imparted to wings promotes strike-slip faulting

from *Lin & Stein* (JGR, 2004)

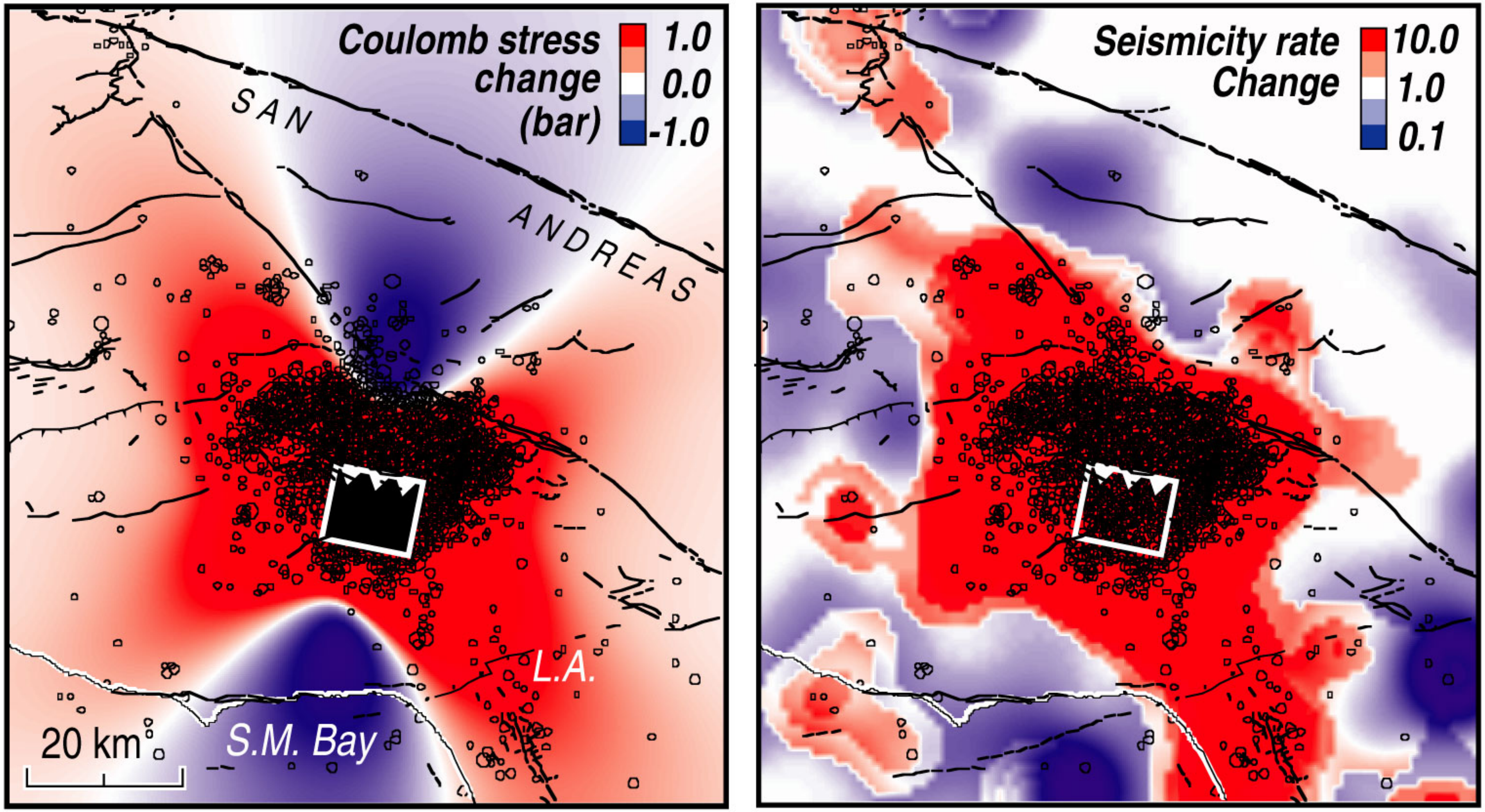
Stress change is correlated with seismicity rate change for 1994 M=6.7 Northridge shock



M≥1.5 shocks 3-6 months after mainshock plotted

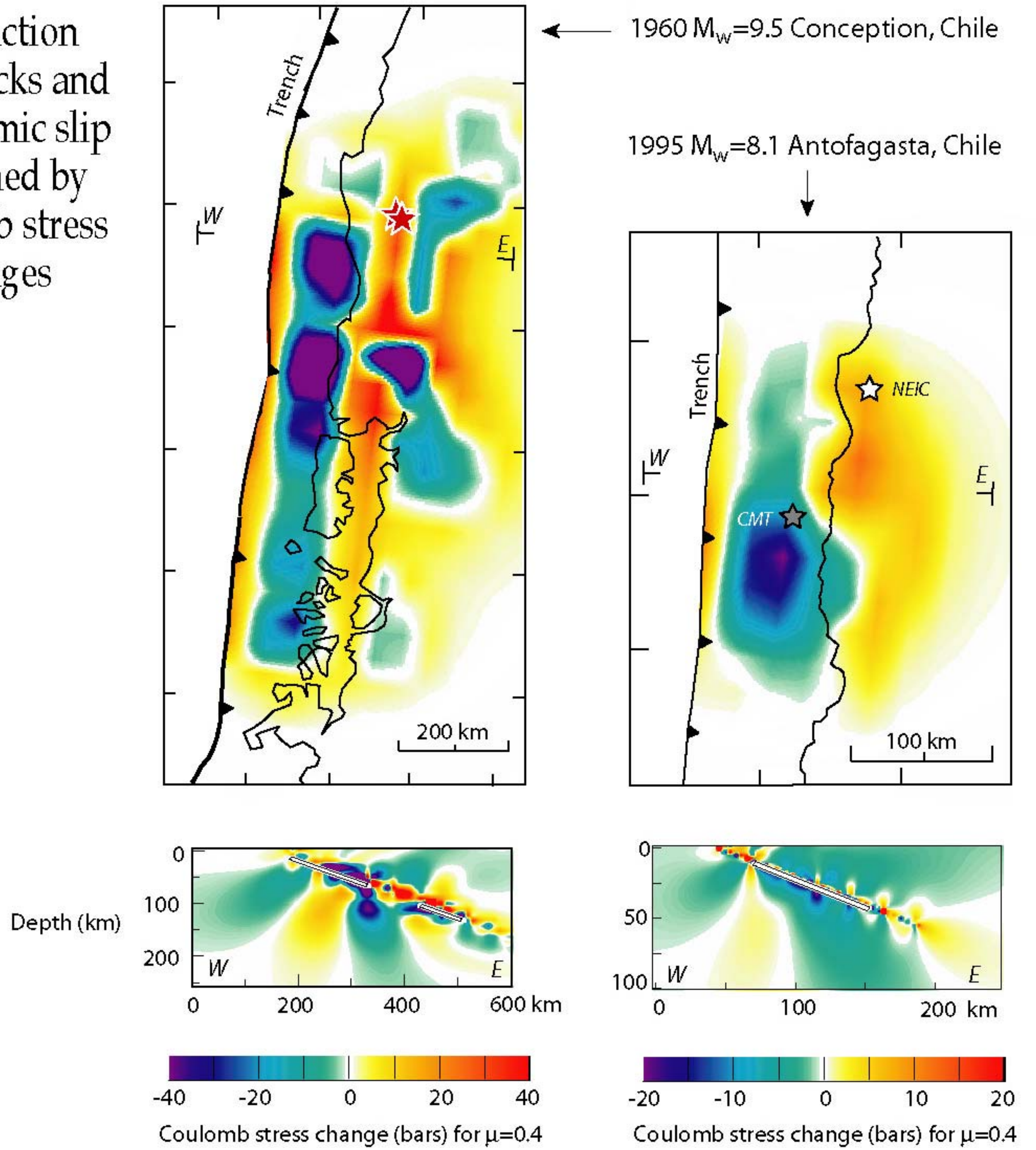
from *Stein* (***Nature***, 1999)

Stress change is correlated with seismicity rate change for 1994 M=6.7 Northridge shock



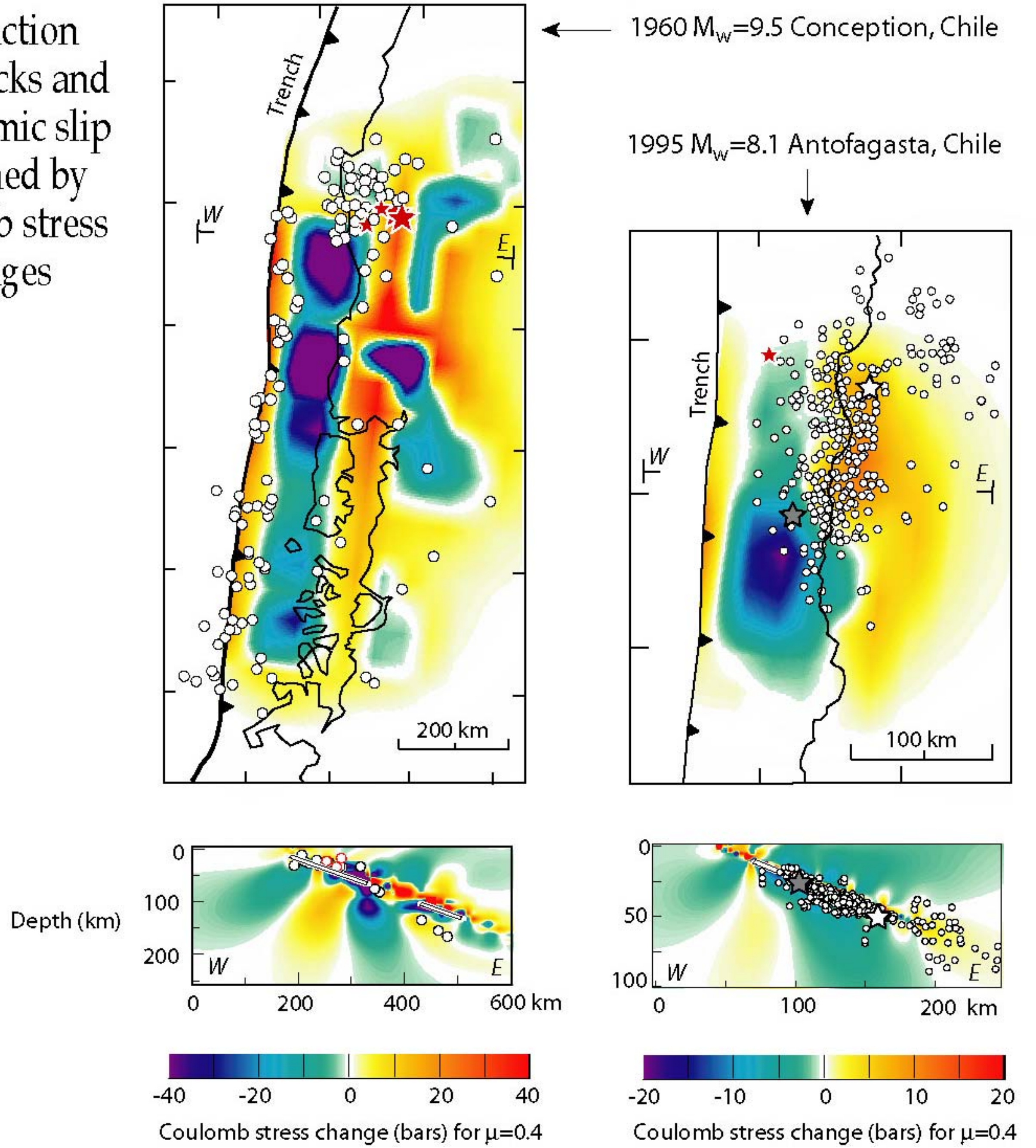
from *Stein* (***Nature***, 1999)

Subduction aftershocks and postseismic slip explained by Coulomb stress changes



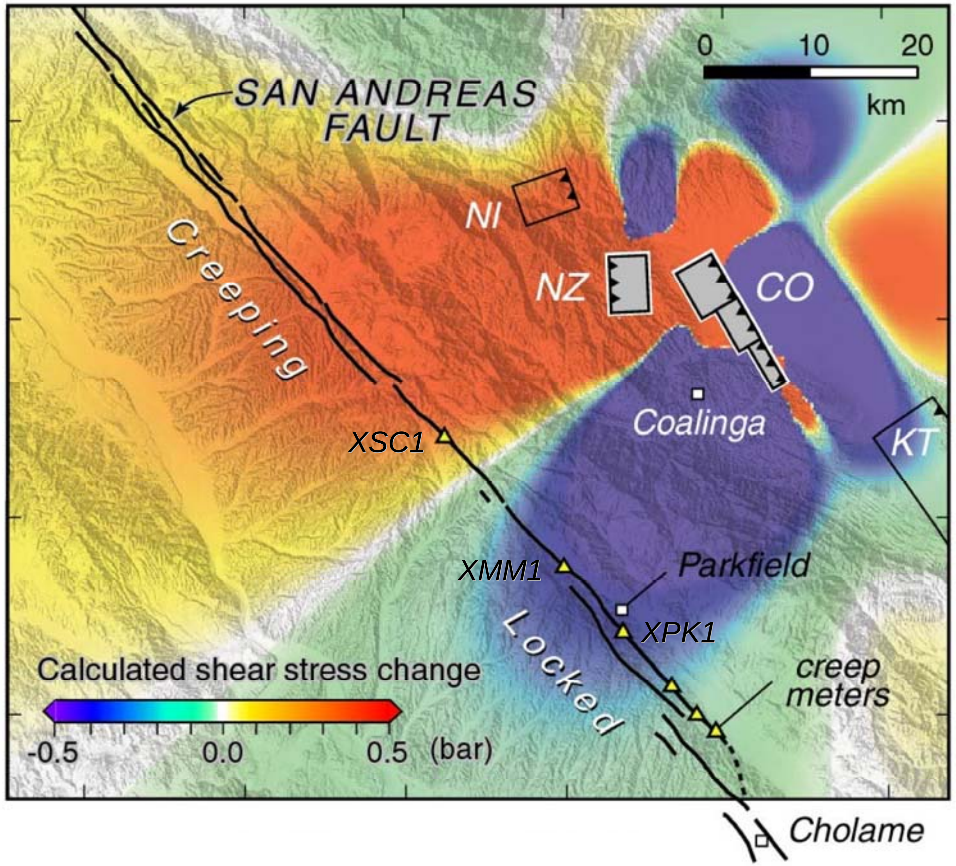
from *Lin & Stein* (JGR, 2004)

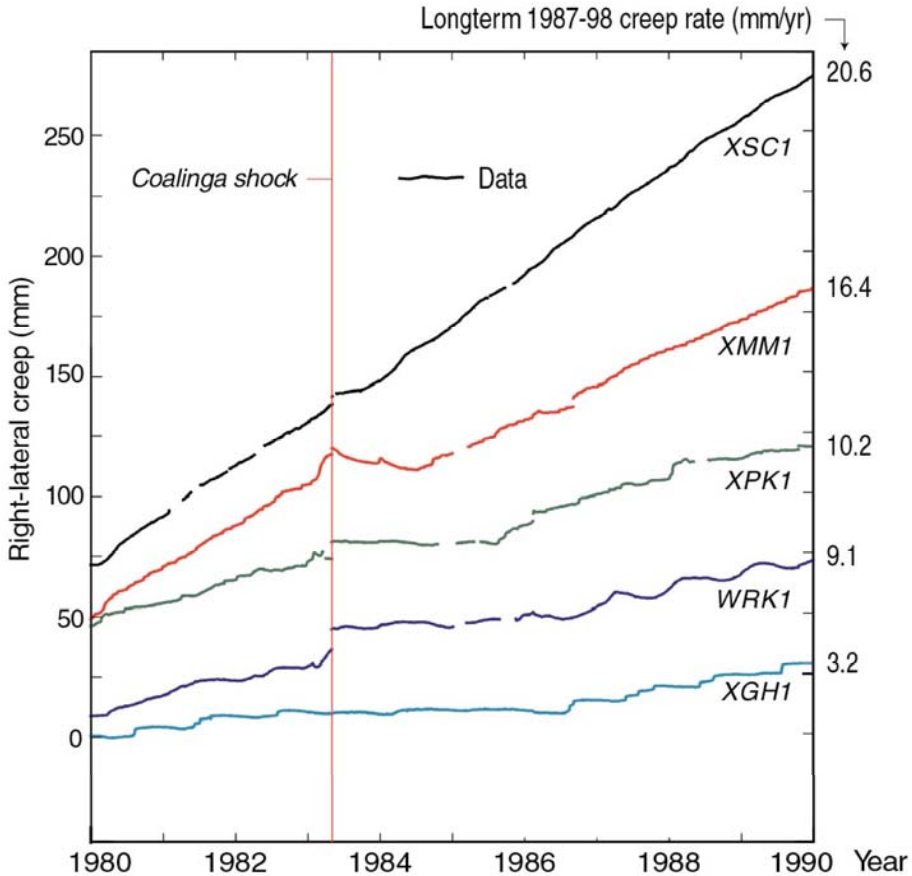
Subduction aftershocks and postseismic slip explained by Coulomb stress changes



from *Lin & Stein* (JGR, 2004)

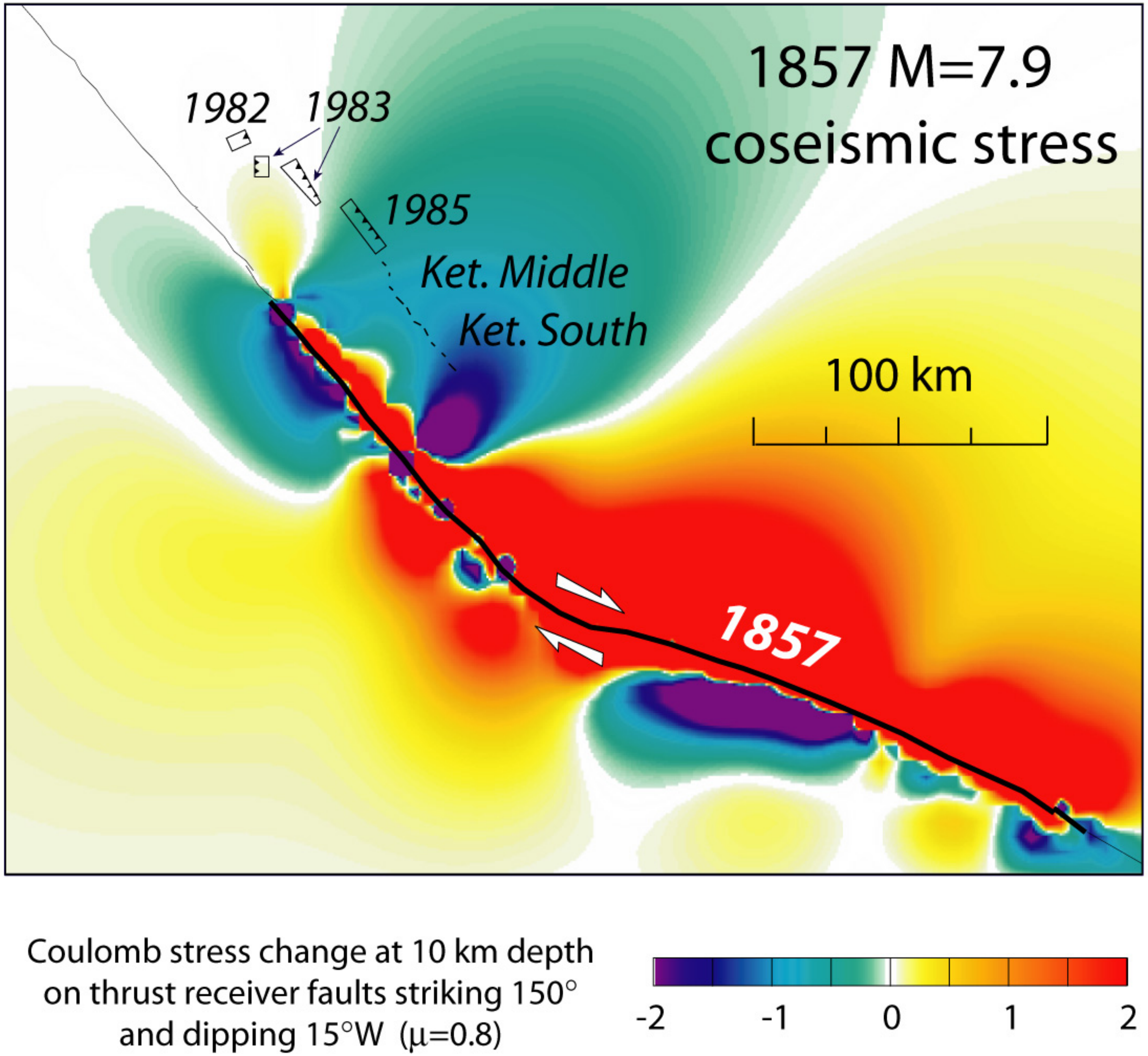
San Andreas responds to shear stress imparted by 1983 M=6.7 Coalinga shock





from *Toda & Stein* (JGR, 2003)

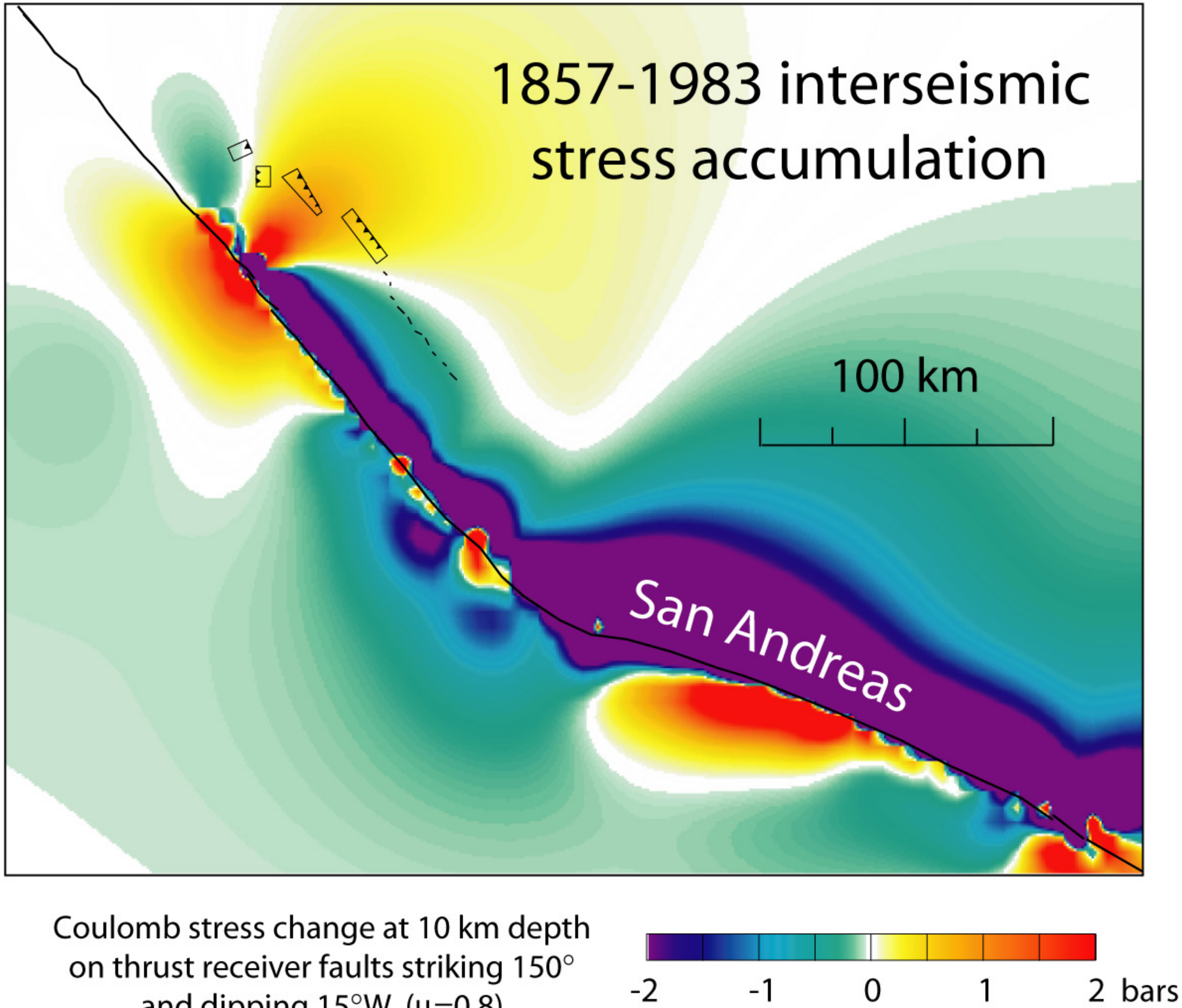
Great 1857 shock stresses northern end of fold belt



Coulomb stress change at 10 km depth on thrust receiver faults striking 150° and dipping 15°W (μ=0.8)

from *Lin & Stein* (JGR, 2004)

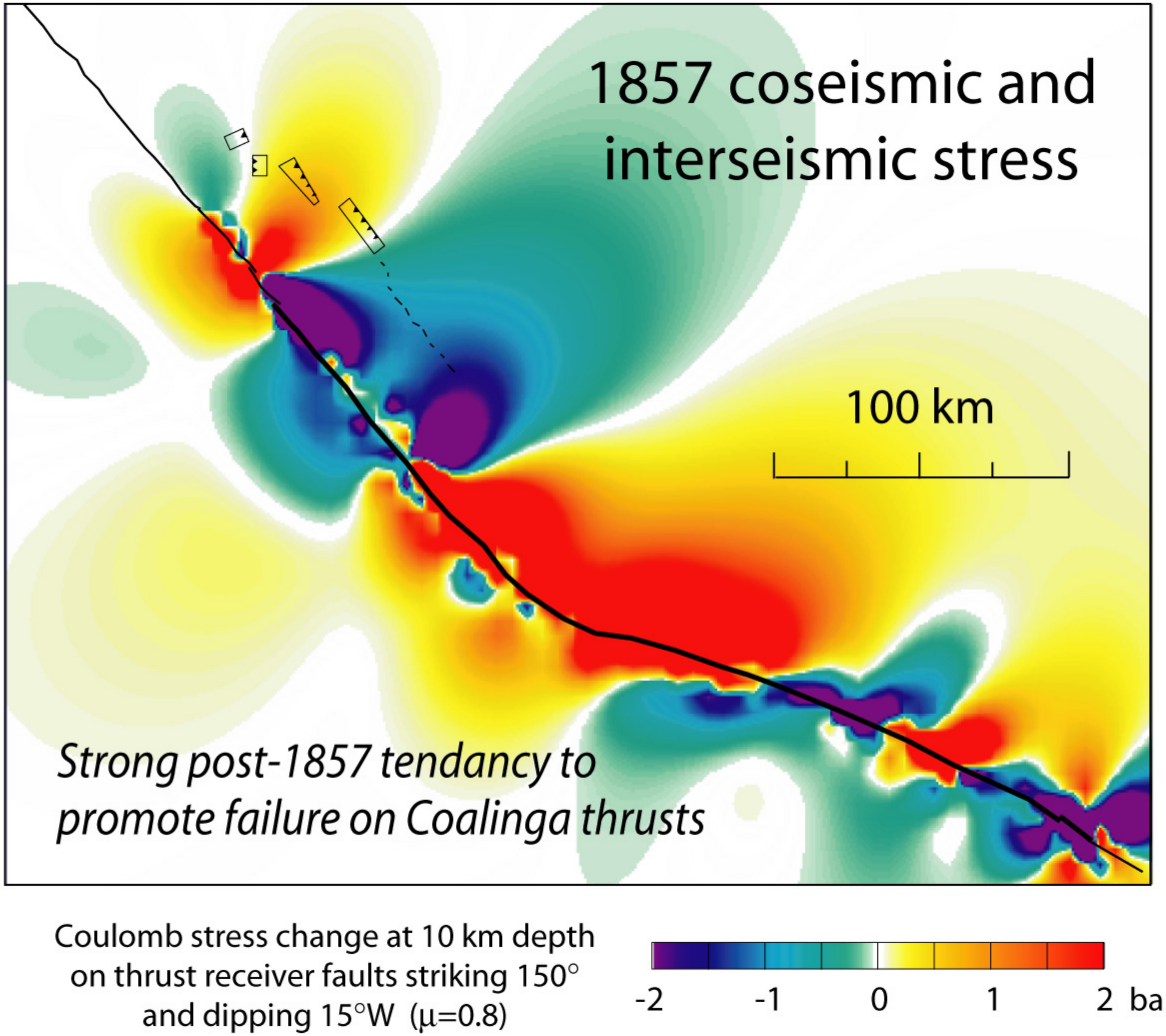
Interseismic stress brings Coalinga thrusts close to failure



Coulomb stress change at 10 km depth on thrust receiver faults striking 150° and dipping 15°W (μ=0.8)

from *Lin & Stein* (JGR, 2004)

Combined stresses promote—and restrict—Coalinga sequence



Coulomb stress change at 10 km depth on thrust receiver faults striking 150° and dipping 15°W (μ=0.8)

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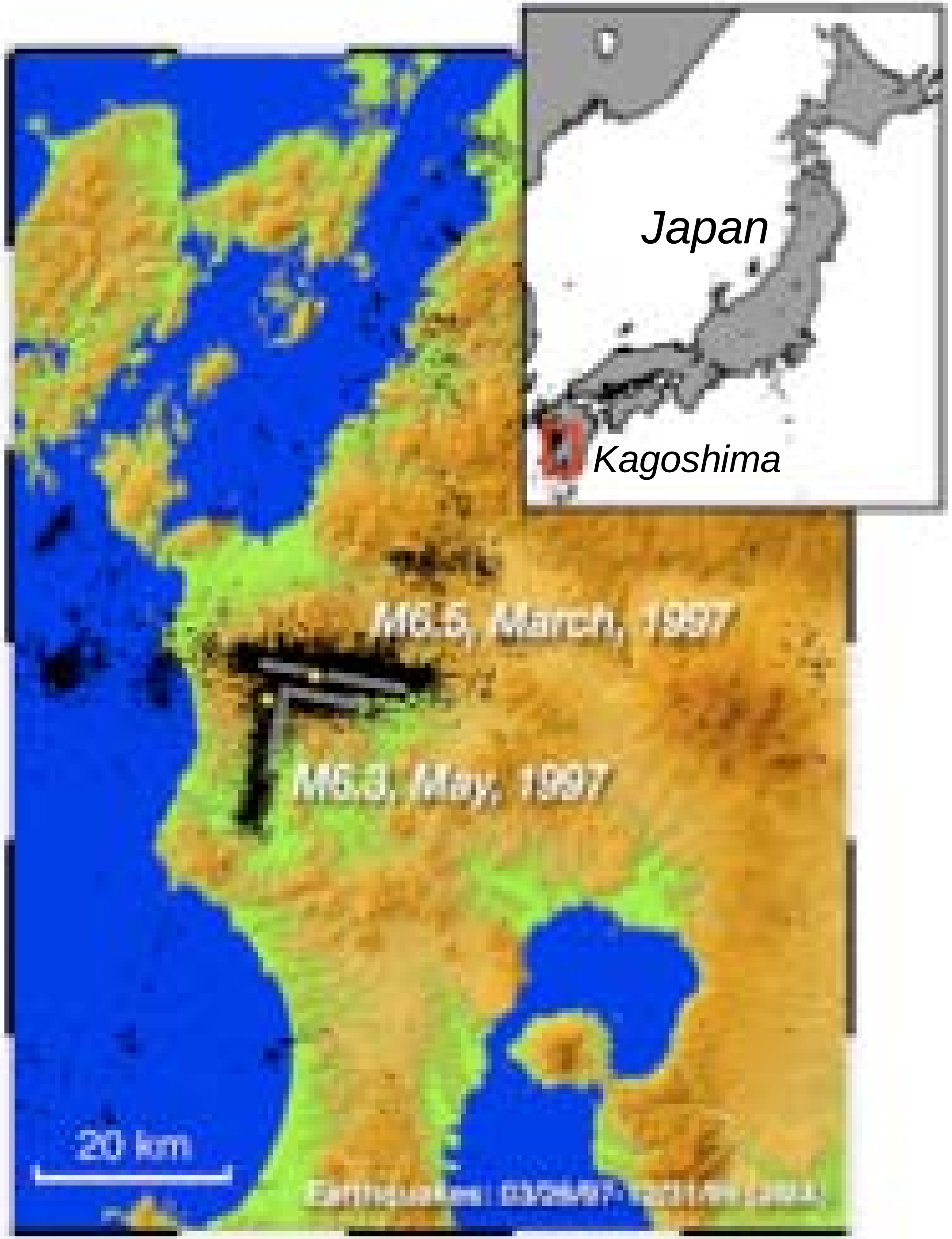
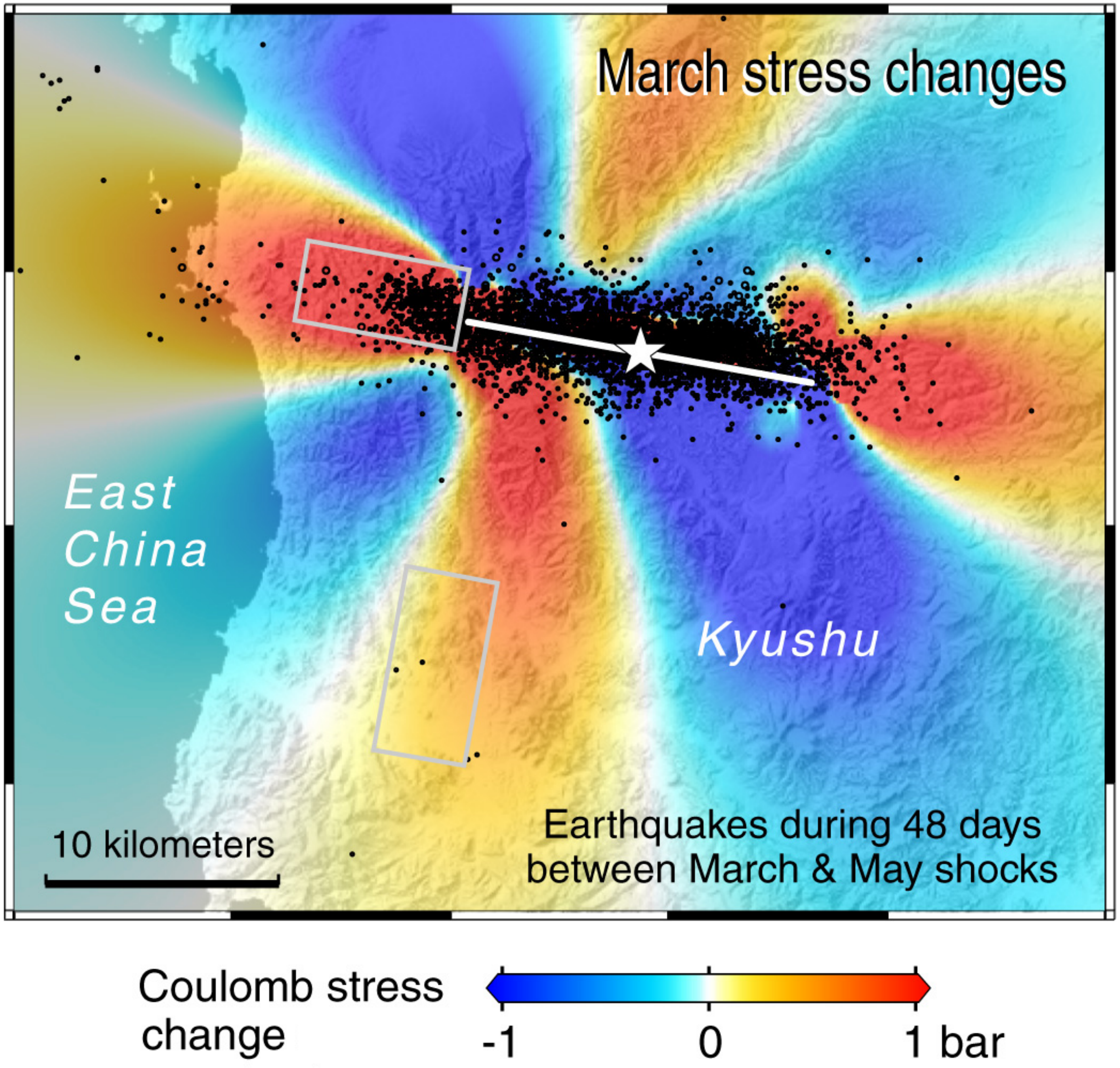


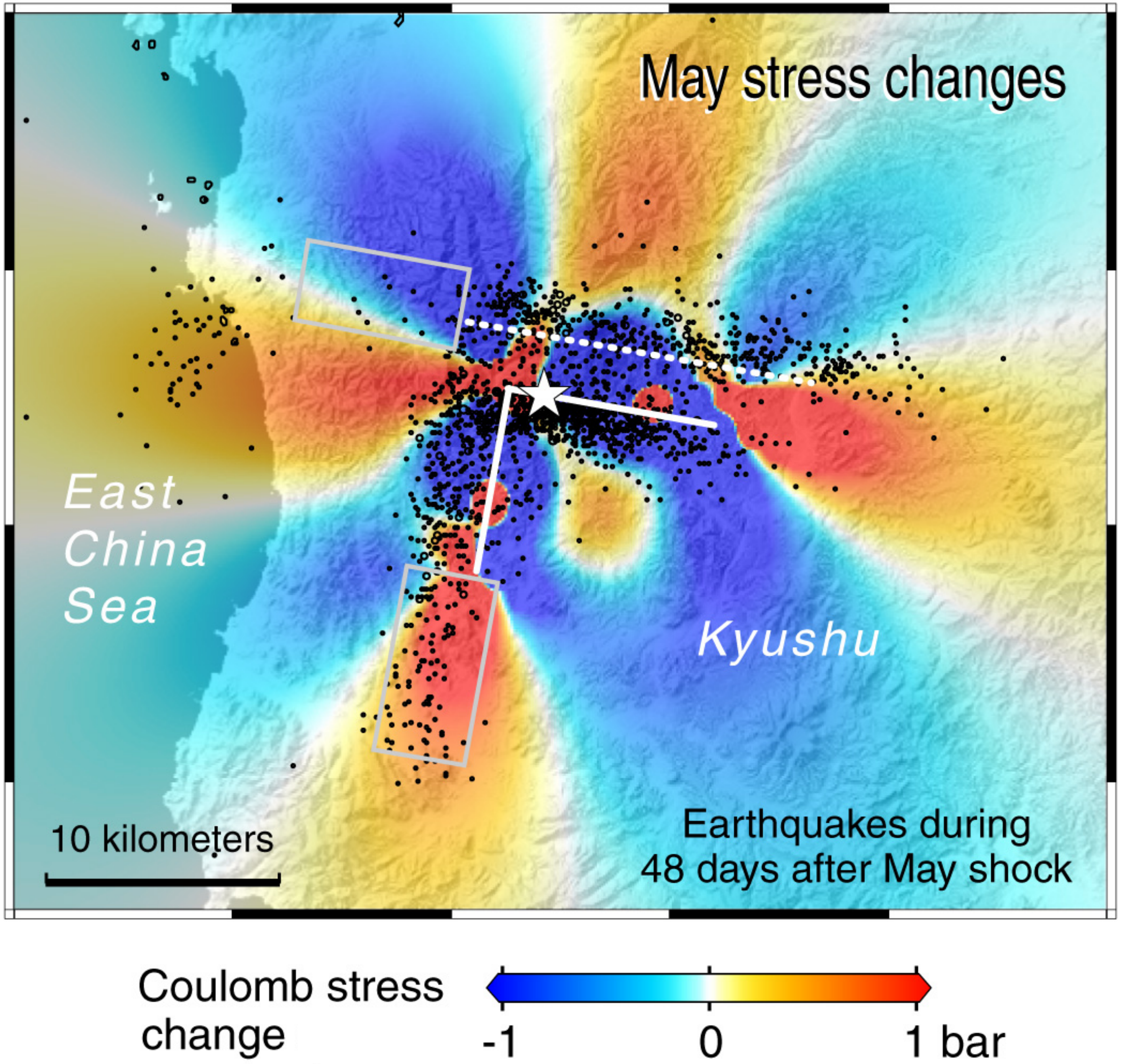
Not only do stress increases promote shocks, but stress shadows inhibit shocks

Toda & Stein (2004)

Off-fault aftershocks controlled by Coulomb stress changes

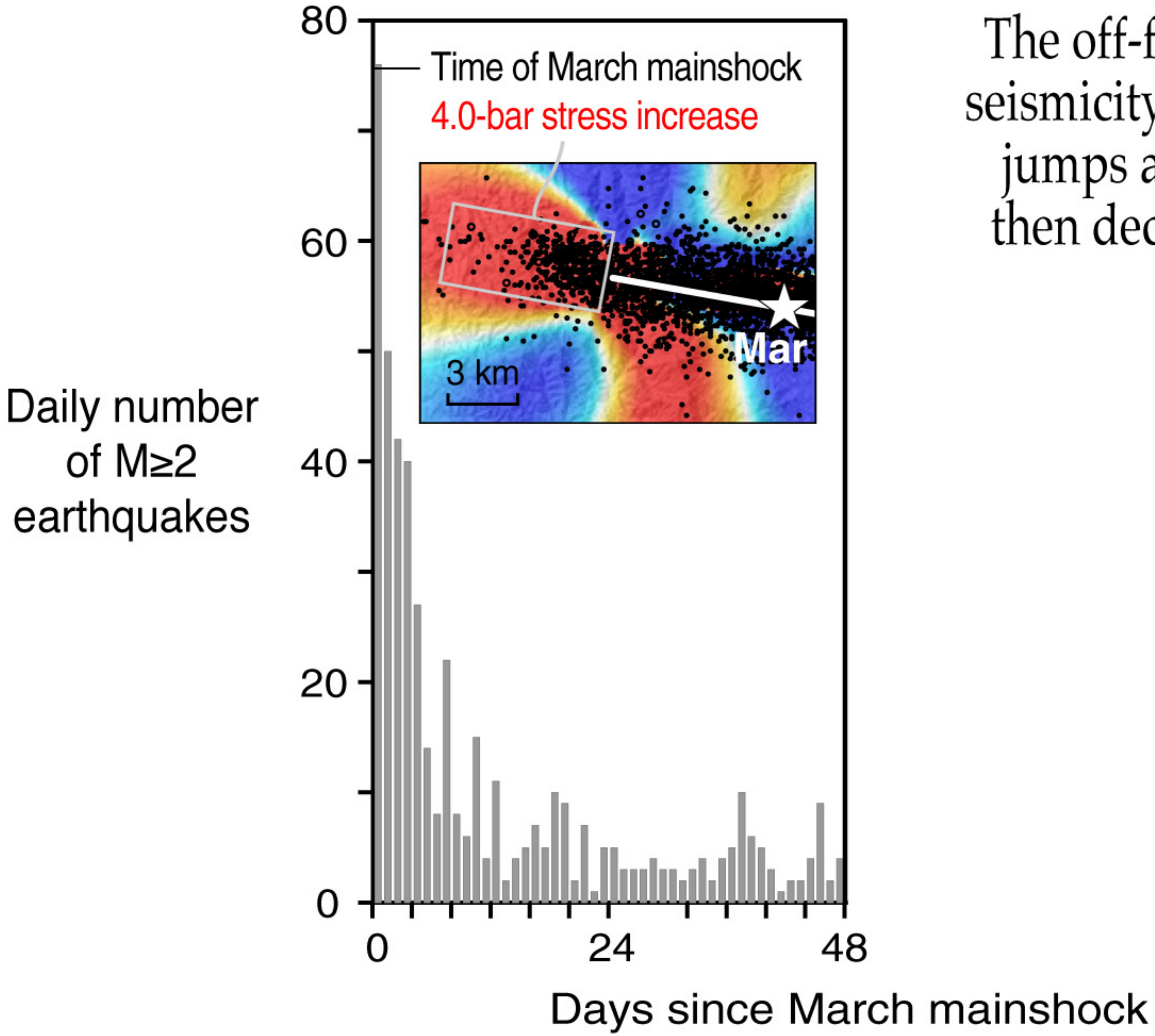


Toda & Stein (2004)



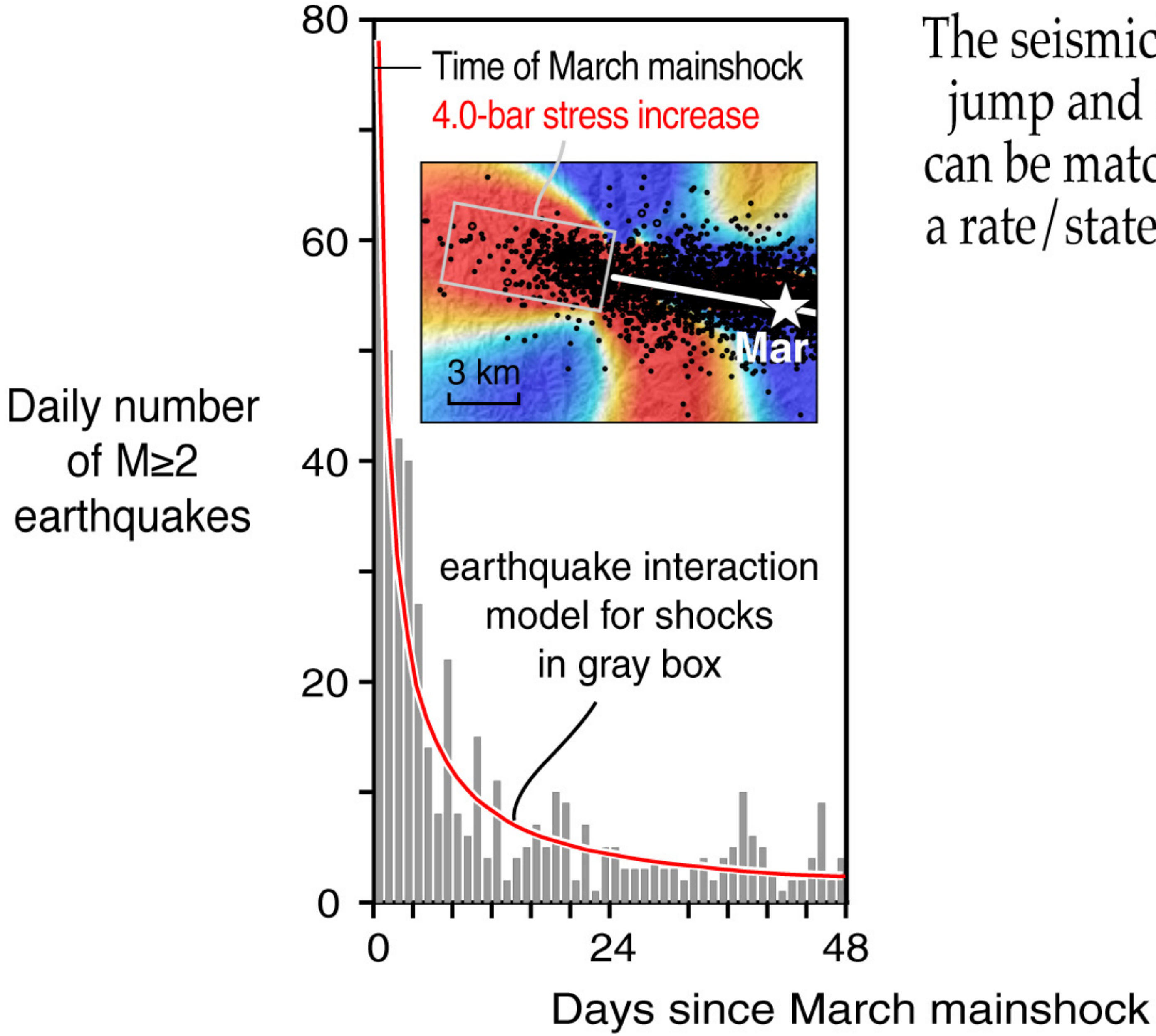
Off-fault aftershocks controlled by Coulomb stress changes

Toda & Stein (2004)



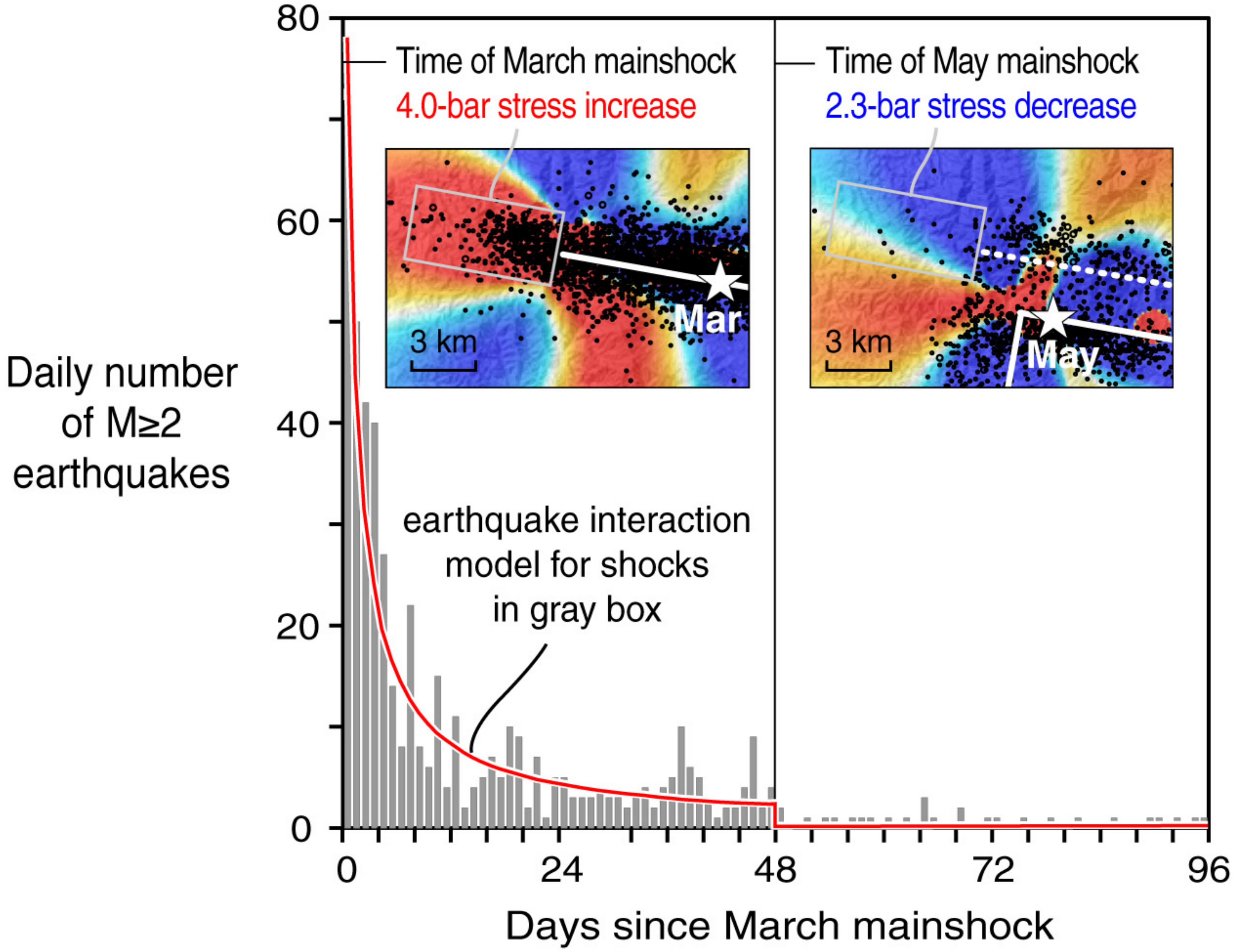
The off-fault seismicity rate jumps and then decays

Toda & Stein (2004)



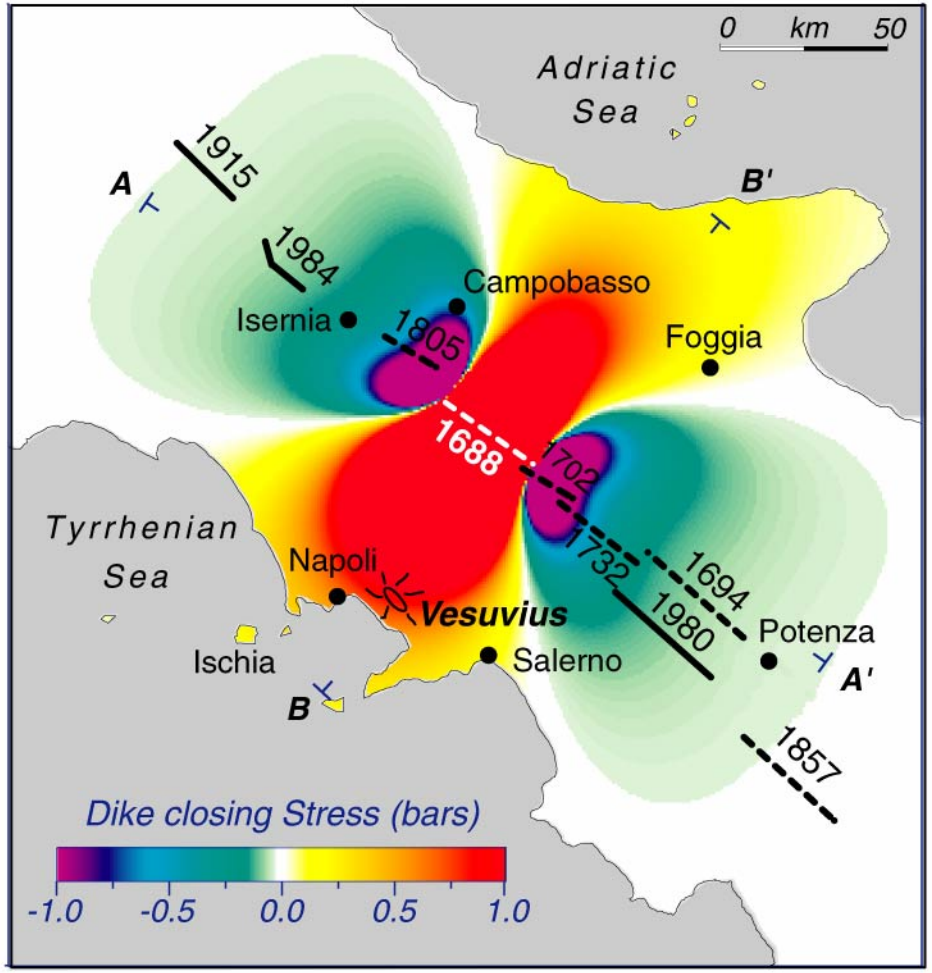
The seismicity rate jump and decay can be matched by a rate/state model

Toda & Stein (2004)



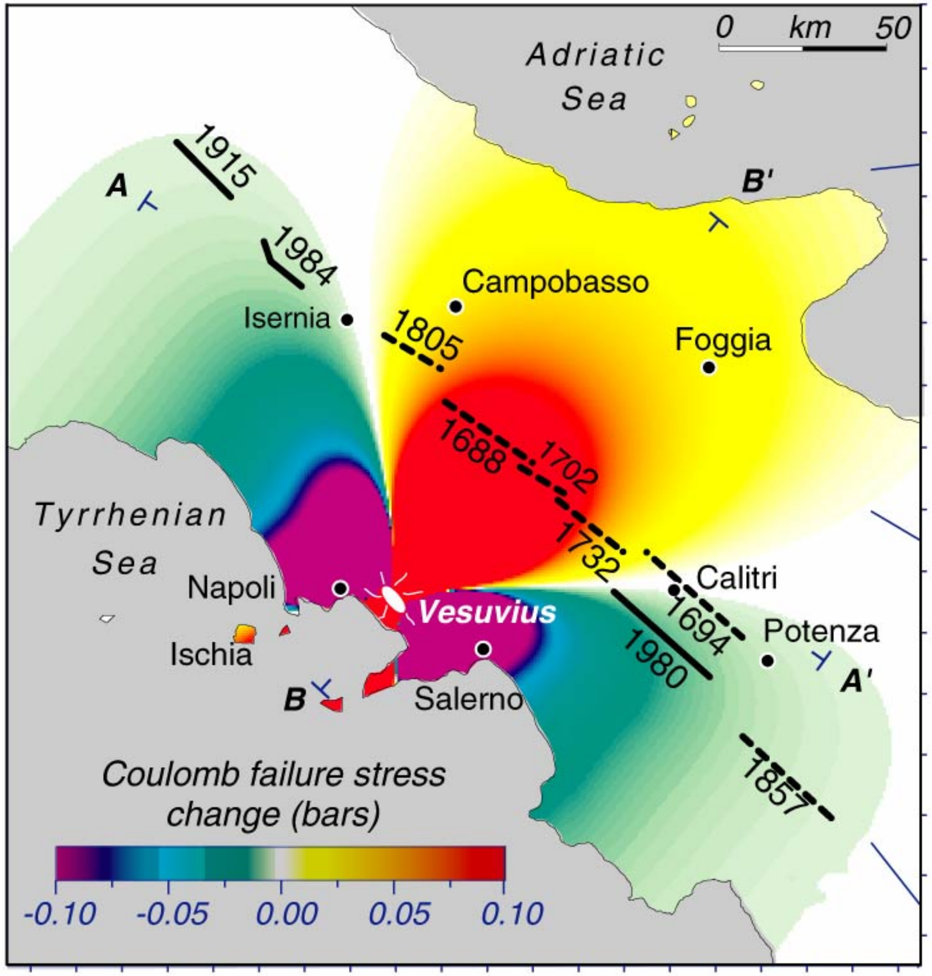
Toda & Stein (2004)

A large earthquake along the Apennine chain acts to compress a NW-striking dike beneath Vesuvius, potentially driving magma and volatiles to the surface



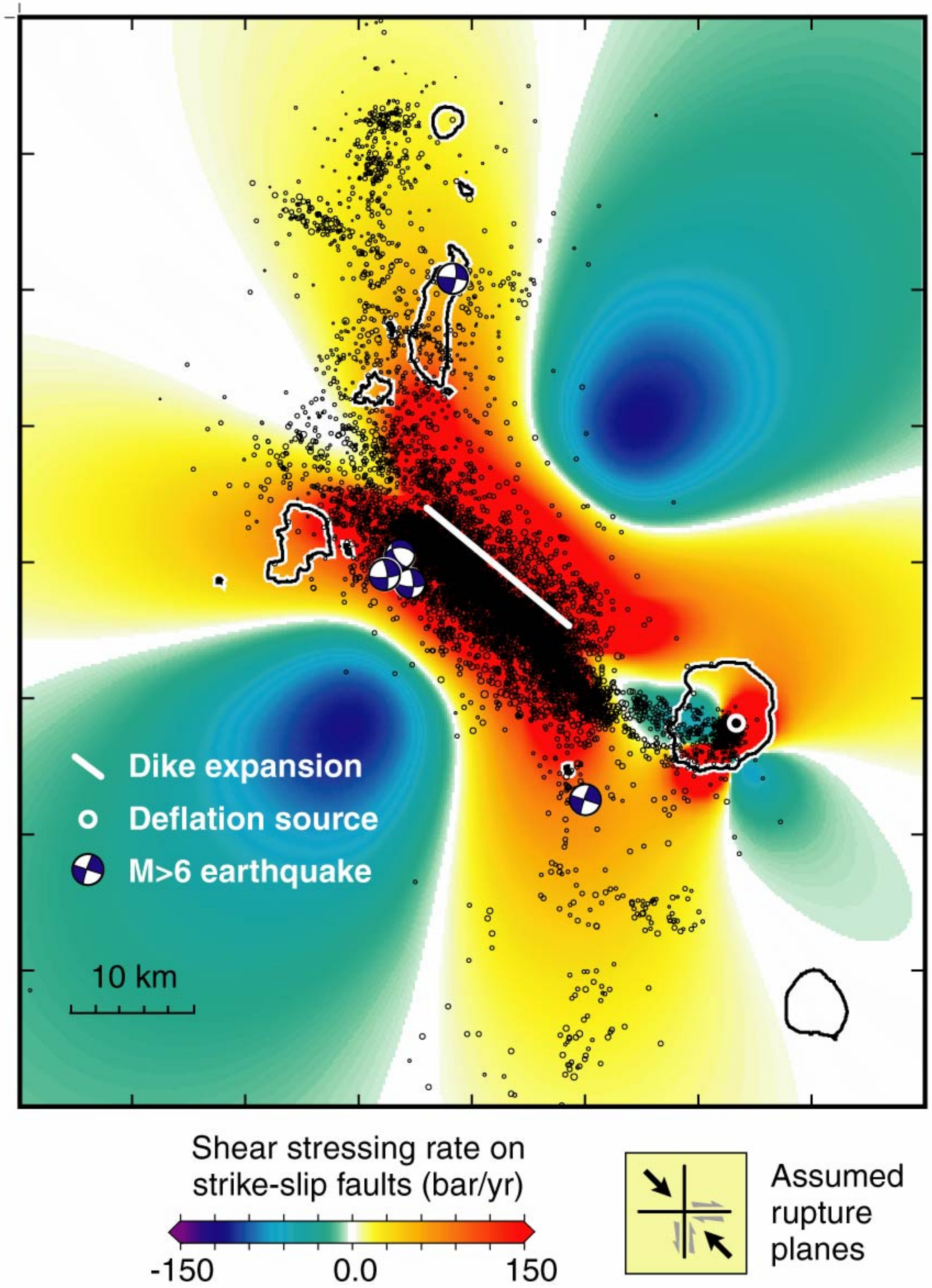
from *Nostro et al.* (JGR, 1998)

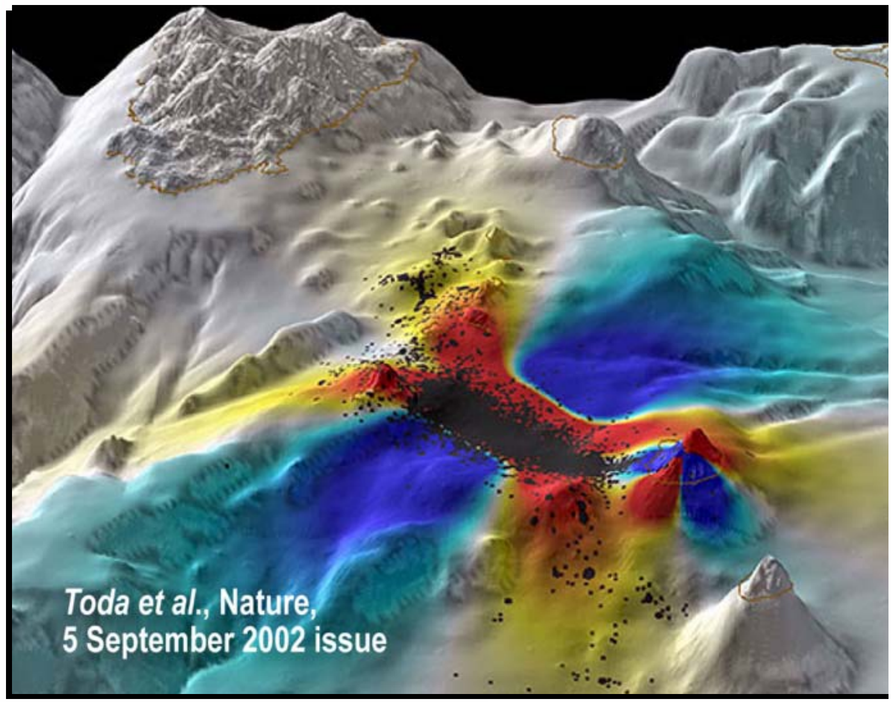
Voiding 0.1 km^3 of magma from a NW-striking dike beneath Vesuvius, in turn, brings normal faults along the Apennine chain closer to failure



from *Nostro et al* (JGR, 1998)

Stress transfer explanation for the 'dog bone' distribution of seismicity



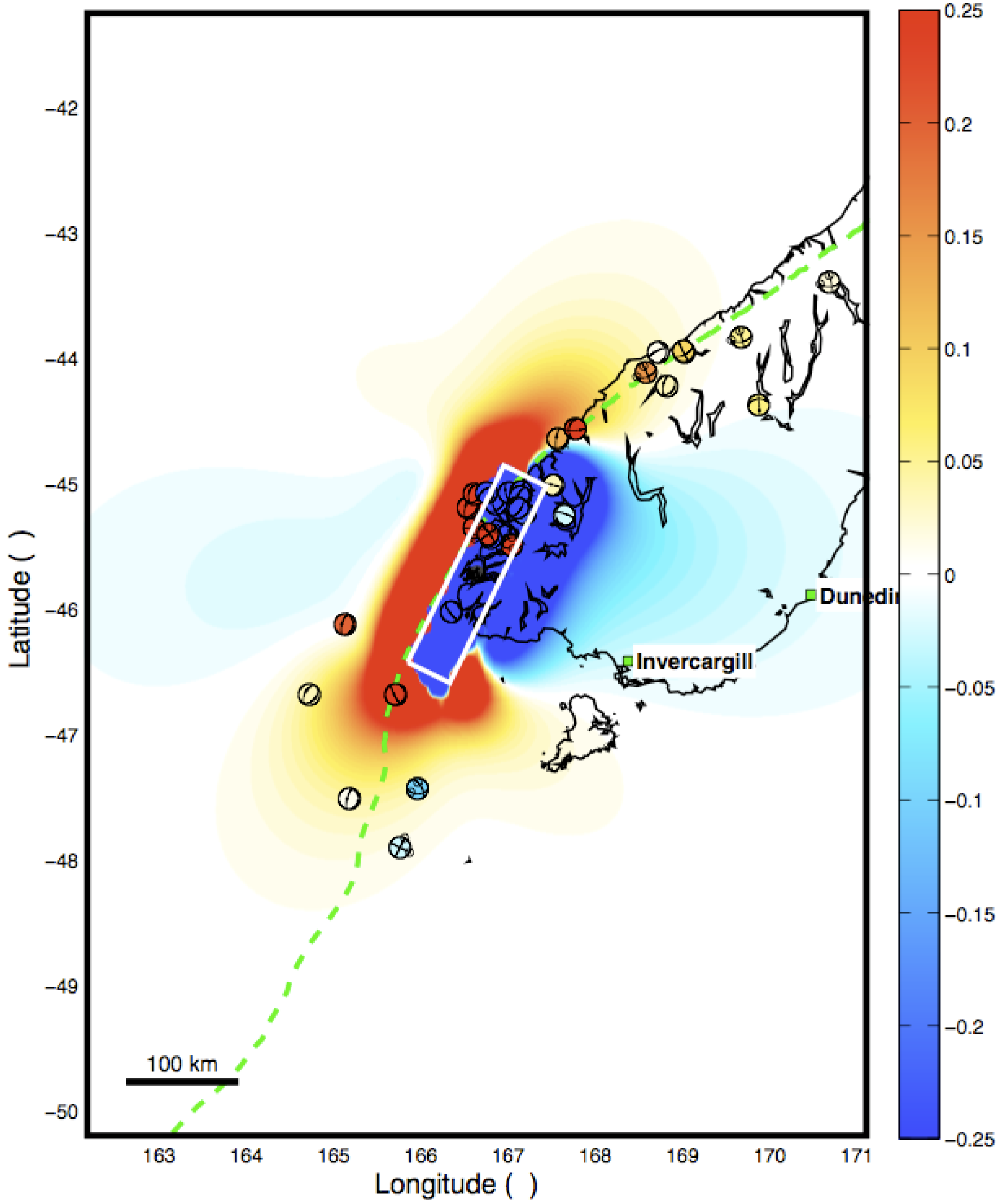


The Izu, Japan, 2000 seismic swarm
Six M≥6 and 3000 M>4 in 3 months!

Mw=7.8 OFF W. COAST OF S. ISLAND OF NEW ZEALAND

July 15, 2009 at 9:22 UTC, Location: 45.7 S 166.6 E, Depth: 35 km

Nodal Plane 1 solution: strike /dip /rake = 26/24/140



Stress Scale Bar
Max. Coulomb stress change (bars)

Color Gradient Map
Source and receivers: strike/dip/rake
of NEIC Rapid focal mechanism
Maximum Coulomb stress change
at depths within ±20 km of hypocenter

Focal Mechanism Color
Max. Coulomb stess shown as disk color
Stress change resolved on both nodal planes
of 1976-2004 Global CMT quakes; largest
of two stress change shown if ≥ 0.01 bars.
Lower hemisphere compress. lobes lie
between nodal plane dots; exten. lobes lie
between nodal plane circles.

Map Features
Source: white rectangle centered on
hypocenter (point source for Mw<6;
otherwise Wells-Coppersmith 1994 scaling)
Active volcanoes: purple triangles
Cities: green squares propotional to pop.
Active faults: blue lines
Coastlines: black lines
National boundaries: black dot-dash lines
Plate boundaries: solid green (trenches),
long-dash green (transforms or oblique
subduction), short-dash green (ridges)

CoulombExpress DPRI-KU USGS science for a changing world


The Coulomb team
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Toda
Jian
Lin
Volkan
Sevilgen

http://quake.usgs.gov/~ross

for Coulomb, animations, and papers in this talk

Animators

Serkan Bozkurt

U.S. Geological Survey (2002-2005)

Thomas Dewez

USGS & Brunel University (2001)

Rachel Margrett

USGS & Brunel University (2000)

Shinji Toda

遠田晋次